National Aeronautics and
Space Administration

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CONSTELLATION ARCHITECTURE REQUIREMENTS DOCUMENT (CARD)

REVISION AND HISTORY PAGE

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		001	Change 001 (Reference CxCBD 000166/3-1, dated 10/2/07 and CAR C000166, dated 11/2/07) *(Per Book Manager's request, the document was re-released replacing the 11/1/07 release.)*	11/02/07
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NOTE: Updates to this document, as released by numbered changes (Change XXX), are identified by a black bar on the right margin.

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1.0 INTRODUCTION

1.1 PURPOSE

In January 2004, President George W. Bush announced the new Vision for Space Exploration for NASA. The fundamental goal of this vision is to advance U.S. scientific, security and economic interests through a robust space exploration program. In support of this goal, the United States will:

a. Implement a sustained and affordable human and robotic program to explore the solar system and beyond.

b. Extend human presence across the solar system, starting with a human return to the Moon by the year 2020, in preparation for human exploration of Mars and other destinations.

c. Develop the innovative technologies, knowledge, and infrastructures both to explore and to support decisions about future destinations for human exploration.

d. Promote international and commercial participation in exploration to further U.S. scientific, security, and economic interests.

The requirements in this document can be traced back to CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), which is traced from the Vision for Space Exploration, the NASA Authorization Act of 2005 and the NASA Strategic Plan.

1.2 SCOPE

The Constellation Architecture Requirements Document (CARD) defines requirements controlled by the Constellation Program for the hardware, software, facilities, personnel and services needed to perform the Design Reference Missions (DRMs). The Constellation Architecture (CA) is comprised of a human-rated Orion and Lunar Surface Access Module (LSAM), the Mars Transfer Vehicle (MTV), the Descent Ascent Vehicle (DAV), a human-rated Ares I, an Ares V which includes the Earth Departure Stage (EDS), Ground Systems (GS), Missions Systems (MS), and future Destination Surface Systems (DSS), such as the habitats, power systems, rovers, science equipment, robotic systems and resource utilization systems that enable the crewmembers to live, work and explore the surface of other worlds. The architecture also includes necessary interfaces to external entities including International Space Station (ISS), international partners, and communications and tracking infrastructure.

1.3 CHANGE AUTHORITY / RESPONSIBILITY

Proposed changes to this document shall be submitted by a Constellation Program (CxP) Change Request (CR) to the appropriate Constellation Control Board (CxCB) for consideration and disposition.

All such requests will adhere to the Constellation Program Configuration Management Change Process. The appropriate NASA Office of Primary Responsibility (OPR) identified for this document is Constellation Systems Engineering and Integration (SE&I).

1.4 DOCUMENT STRUCTURE

1.4.1 Convention and Notation

The convention used in this document which indicates requirements, goals, and statements of facts is as follows: Shall -- Used to indicate a requirement which must be implemented and its implementation verified; Should -- Used to indicate a goal which must be addressed by the design but is not formally verified; Will -- Used to indicate a statement of fact and is not verified. In some cases the values of quantities included in this document have not been determined and are designated as To Be Resolved (TBR), To Be Determined (TBD) or To Be Supplied (TBS). Where approximate values of such quantities are known and provide useful guides for development, these are shown along with the TBR notation. Where no value is yet known, a TBD is included. Where a value is known, but has not been supplied to the CARD book manager, a TBS is included. Each requirement in this document is uniquely numbered and identified by the presence of a tag of the form [CAnnnn-xx] at the beginning of the requirement statement in blue-gray text. The "nnnn" portion of the identifier is a unique four-digit number. The -xx portion signifies the controlling authority by which changes to the requirement must be approved. Requirements controlled by NASA Headquarters are indicated by -HQ. Requirements controlled by the Constellation Program Office are indicated by -PO. Objective stretch requirements are denoted with [CAnnnn-xx-Objective]. The Objective requirements represent future goals that, in time, may replace the existing threshold requirements. Verification requirements are not required for the stretch Objective requirements in this document.

1.4.2 How to Use this Document

The CARD is structured to provide top-level design guidance, architecture-wide requirements and allocations to the systems. The CARD contains the following major sections: Section 1: Introduction - This section includes the purpose, scope, conventions used within the CARD and a description on how to use the CARD. Section 2: Documents - This section contains the list of applicable documents called out in requirements and the reference documents mentioned within the CARD. Section 3: Constellation Requirements - This section contains the functional, performance, and constraint requirements. Section 3 is further structured as follows: Section 3.1: Constellation Architecture Description - This section contains the top level description of the architecture, the internal and external interfaces, and the program's Design Policy being used to drive the development process. Section 3.2: Constellation Architecture Requirements - This section contains the functional and performance requirements at the architecture level. These requirements apply to more than one system with the allocations to the systems being captured in Appendix D. Section 3.3: Design and Construction Standards - This section contains the technical standards being invoked on the Constellation Program. Each technical standard was reviewed by the program for inclusion in full or in part. The applicable documents within these documents are not applicable unless approved by the program as documented in the program's Applicable Document List. These requirements apply to more than one system with the allocations to the systems being captured in Appendix D. Section 3.4: External Interfaces - This section contains the interface requirements for entities external to the Constellation Architecture. Section 3.5: Physical Characteristics - This section contains physical constraint requirements for the architecture. Section 3.6: Currently Reserved. Section 3.7: Systems - This section contains a brief description of each system along with the unique requirements allocated to the systems of the architecture. Each system will have a subsection within Section 3.7 at the next level of indenture. Requirements that are direct flow downs from the 3.2 architecture level are documented in the allocation matrix in Appendix D. The requirements for each system in section 3.7 represent the sub-allocations to the systems. The internal architecture interfaces or system-to-system interfaces are also documented within this section. Section 4: Verification - Section 4 mirrors Section 3 but provides the detailed verification requirements that define the verification method, approach, and success criteria. Appendix A: Glossary and Acronyms – List of glossary terms and acronyms used within this document. Note that these definitions are from the single common glossary and acronym list developed and approved by the Constellation Program. Appendix B: Open Work - Includes TBD and TBR Resolution Plans and any other open CARD issues. Appendix C: Verification Cross Reference Matrix - Provides a mapping of the Section 3 requirement to the verification method and associated verification requirement. Appendix D: Allocation Matrix - Provides the allocations of the architecture level requirements to each system. Appendix E: Requirements Traceability Matrix (RTM) - Provides the parent-to-child and child-to-parent requirement traceability.

1.5 "DRAFT" REQUIREMENTS NOTATION

Requirements marked with the word “Draft” prior to a “shall” statement are considered to be draft and not part of the Constellation Program (CxP) approved Configuration Management (CM) baseline. These requirements describe future mission capabilities beyond what the Constellation Program has currently developed and are shown in this document to enhance the vision for future missions and clarify the extent of full mission capabilities. Draft requirements will be matured through the Systems Engineering (SE) process and will be baselined through either a Program System Requirements Review (SRR) or the Program CM Change Request (CR) process.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

Only documents that are specifically referenced in "shall statements" herein will be listed in the Applicable Documents table. These documents are available on the CxP Library of the Integrated Collaborative Environment (ICE) System. The list of program approved applicable documents with the revision level accepted by the program for implementation will be maintained in the Constellation Applicable Documents List located in CxP 70013, Constellation Program System Engineering Management Plan.

CxP 70007	Constellation Design Reference Missions and Operational Concepts
CxP 70012	Constellation Program Reference Architecture Document (RAD)
CxP 70013	Constellation Program System Engineering Management Plan
CxP 70017	Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document
CxP 70022-01	Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification
CxP 70022-04	Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 4: Information Representation Specification
CxP 70023	Constellation Program Design Specification for Natural Environments
CxP 70024	Constellation Program Human-Systems Integration Requirements
CxP 70026	Constellation Program Orion -to- Ares I Interface Requirements Document
CxP 70028	Constellation Program Orion -to- Ground Systems Interface Requirements Document
CxP 70029	Constellation Program Orion -to- Mission Systems Interface Requirements Document
CxP 70031	Constellation Program Orion -to- International Space Station Interface Requirements Document
CxP 70033	Constellation Program Orion -to- EVA Systems Interface Requirements Document

CxP 70034 (Baseline Pending) (TBD-ADL-0001)	Constellation Program Orion -to- LSAM Interface Requirements Document
CxP 70036	Constellation Program Environmental Qualification and Acceptance Testing Requirements (CEQATR)
CxP 70038	Constellation Program Hazard Analyses Methodology
CxP 70050-01	Constellation Program Electrical Power System Specification, Volume 1: Electrical Power Quality Performance for 28Vdc
CxP 70050-02	Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28Vdc
CxP 70052-02	Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD)
CxP 70052-03	Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD)
CxP 70052-04	Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD)
CxP 70053	Constellation Program Ares I -to- Mission Systems Interface Requirements Document
CxP 70054 (Baseline Pending) (TBD-ADL-0002)	Constellation Program Mission Systems (MS) -to- Ground Systems Interface Requirements Document (IRD)
CxP 70064	Constellation Program Supportability Plan
CxP 70072	Constellation Program Management System Plan (MSP)
CxP 70076	Constellation Program Modeling and Simulation Management Requirements - Level II

CxP 70080	Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document
CxP 70084 (Baseline Pending) (TBD-ADL-0003)	Constellation Program Integrated Test Plan
CxP 70086	Constellation Program Software Verification and Validation Plan
CxP 70087	Constellation Program Reliability, Availability, and Maintainability Plan
CxP 70104 (Baseline Pending) (TBD-ADL-0004)	Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD)
CxP 70105 (Baseline Pending) (TBD-ADL-0005)	Constellation Program Cargo Launch Vehicle (CaLV) -to- Ground Systems Interface Requirements Document (IRD)
CxP 70106 (Baseline Pending) (TBD-ADL-0006)	Constellation Program Lunar Surface Access Module (LSAM) -to- Ground Systems Interface Requirements Document (IRD)
CxP 70107 (Baseline Pending) (TBD-ADL-0007)	Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD)
CxP 70109 (Baseline Pending) (TBD-ADL-0008)	Constellation Program Lunar Surface Access Module (LSAM) -to- Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD)
CxP 70112 (Baseline Pending) (TBD-ADL-0009)	Constellation Program Cargo Launch Vehicle (CaLV) -to- Mission Systems (MS) Interface Requirements Document (IRD)
CxP 70113 (Baseline Pending) (TBD-ADL-0010)	Constellation Program Lunar Surface Access Module (LSAM) -to- Mission Systems (MS) Interface Requirements Document (IRD)
CxP 70118-01	Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 1: Orion

CxP 70118-02	Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 2: Ares I
CxP 70118-03 (Baseline Pending) (TBD-ADL-0011)	Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 3: Lunar Surface Access Module (LSAM)
CxP 70118-04 (Baseline Pending) (TBD-ADL-0012)	Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 4: Cargo Launch Vehicle (CaLV)
CxP 70118-05 (Baseline Pending) (TBD-ADL-0013)	Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 5: Ground Systems (GS)
CxP 70118-06 (Baseline Pending) (TBD-ADL-0014)	Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 6: Mission Systems (MS)
CxP 70119 (Baseline Pending) (TBD-ADL-0015)	Constellation Program Crew Exploration Vehicle (CEV) -to- Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD)
CxP 70130	Constellation Program Extravehicular Activity Design and Construction Specification
CxP 70135	Constellation Program Structural Design and Verification Requirements
CxP 70142 (Baseline Pending) (TBD-ADL-0016)	Constellation Program Navigation Standards Specification Document
CxP 70143 (Baseline Pending) (TBD-ADL-0017)	Constellation Program Induced Environment Design Specification
CxP 70151	Constellation Program Mass Properties Control Plan
CxP 70155-02 (Baseline Pending) (TBD-ADL-0018)	Constellation Program Tailored Range Safety Requirements, Volume 2: Ares I

CxP 70155-03 (Baseline Pending) (TBD-ADL-0019)	Constellation Program Tailored Range Safety Requirements, Volume 3: Ares V
CxP 70159 (Baseline Pending) (TBD-ADL-0020)	Constellation Program Support Requirements Document
CxP 70169 (Baseline Pending) (TBD-ADL-0021)	Constellation -to- CTN Architecture & Services Requirements Document
CxP 70170	Constellation Program Information Technology (IT) Functional Security Requirements
CxP 72000 Rev. A	Constellation Program System Requirements for the Orion System
CxP 72001 (Baseline Pending) (TBD-ADL-0022)	Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD)
CxP 72002 (Baseline Pending) (TBD-ADL-0023)	EVA Systems Project System Requirements Document (SRD)
CxP 72004 (Baseline Pending) (TBD-ADL-0024)	Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD)
CxP 72006 (Baseline Pending) (TBD-ADL-0025)	Ground Systems, Systems Requirements Document (SRD)
CxP 72034 (Baseline Pending) (TBD-ADL-0026)	Crew Launch Vehicle (CLV) Systems Requirements Document (SRD)
CxP 72085 (Baseline Pending) (TBD-ADL-0027)	Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line
CxP 72120	Ground Operations Project Plan

CxP 72136 (Baseline Pending) (TBD-ADL-0028)	Mission Systems System Requirements Document
IS-GPS-200 Rev. D	Navstar Global Positioning System Interface Specification
ICD-GPS-705	Navstar GPS Space Segment/User Segment L5 Interfaces
JPR 8080.5	JSC Design and Procedural Standards
JSC 62550 (Draft)	Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications
JSC 62809 Rev. C	Constellation Spacecraft Pyrotechnic Specification
NASA-STD-(I)-5019	Fracture Control Requirements for Spaceflight Hardware
NASA-STD-(I)-6016 (Baseline)	Standard Manned Spacecraft Requirements for Materials and Processes
NASA-STD-4003 Rev. 9/8/03	Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment
NASA-STD-5005 Rev. B	Ground Support Equipment
NASA-STD-5017 (Baseline)	Design and Development Requirements for Mechanisms
NPR 8715.5	Range Safety Program
NPR 8715.6	NASA Procedural Requirements for Limiting Orbital Debris
NSS-1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris

2.2 REFERENCE DOCUMENTS

Only documents that are specifically referenced in rationale or other non-requirement text herein will be listed in the Reference Documents table.

CxP 70003-ANX01	Constellation Program Plan, Annex 1: Need, Goals, and Objectives
CxP 70043	Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology
CxP 70044	Constellation Program Natural Environment Definition for Design
CxP 70052-01	Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 1: Introduction to Ares I -to- Ground Systems Interface Requirements Document (IRD)
CxP 70070-ANX01	Constellation Program, Program Management Plan, Annex 1: Boards and Panels Structure
CxP 70073-02	Constellation Program Management Systems Requirements, Volume 2: Data Management Requirements
CxP 70132	Constellation Program Commonality Plan
CxP 70136 (Baseline Pending) (TBD-ADL-0029)	Constellation Program Loads Data Book: Overview, Criteria, and Methodologies
CxP 70136-ANX01 (Baseline Pending) (TBD-ADL-0030)	Constellation Program Loads Data Book, Annex 1: System -to- System Interface Loads Data
AFSPCMAN-91-710	Eastern and Western Range Safety User Requirements, Volumes 2, 3 and 4
NASA-TM-2005-214062 (Baseline)	NASA's Exploration Systems Architecture Study
NIST SP 811	Guide for the Use of the International System of Units (SI)
NPR 2810.1 Rev. A	Security of Information Technology
NPR 8705.2	Human Rating Requirements for Space Systems

3.0 CONSTELLATION REQUIREMENTS

3.1 CONSTELLATION ARCHITECTURE DESCRIPTION

The Constellation Architecture is comprised of Spacecraft, Launch Vehicles, Support Systems, and Destination systems as reflected in the Constellation Architecture Hierarchy. Systems that are external to the Constellation Architecture include the Communications and Tracking Network (formerly Exploration Communication and Navigation Systems [ECANS]) and the International Space Station (ISS).

The Constellation spacecraft include Orion and the Lunar Surface Access Module (LSAM). Orion consists of a Crew Module (CM), a Service Module (SM), Spacecraft Adapter (SA) and a Launch Abort System (LAS). Several configurations of Orion are envisioned to meet the needs of the Constellation Architecture Design Reference Missions (DRMs). The Lunar Surface Access Module (LSAM), provides the capability to insert the crew into Low Lunar Orbit (LLO), carry the crew to the lunar surface, and then return them to LLO. The LSAM also has the capability to deliver significant cargo to the surface along with the crew. While on the surface, the LSAM can serve as the crew's home for up to seven days. In an uncrewed mode, the LSAM can be used to deliver large, monolithic cargo to the lunar surface. In addition to the spacecraft, the Constellation Architecture also provides the Extravehicular Activity (EVA) Systems and Flight Crew Equipment. The EVA System includes the pressure suits, EVA life support systems, umbilicals, EVA tools and mobility aids, EVA-specific vehicle interfaces, EVA servicing equipment, suit avionics, individual crew survival equipment (i.e. integral to the pressure suit), and ground support systems. Flight Crew Equipment includes the items that are interior to the spacecraft for use by the crewmembers (i.e. restraint and mobility aids, tools, stowage items).

The Constellation launch vehicles deliver crew and cargo to Earth orbit as well as trans-lunar trajectories. Orion is launched atop a human-rated Ares I, which provides safe, reliable transportation of Orion to Low Earth Orbit (LEO). The Ares V is the heavy-lift companion to the Ares and will provide over 250,000 lb cargo to LEO. Integral to the Ares V is an Earth Departure Stage (EDS), a restartable stage that performs a portion of the Earth ascent and provides the propulsion to accelerate large cargo from LEO to trans-lunar trajectories.

The Constellation Architecture Ground Systems (GS) and Mission Systems (MS) provide support to vehicle processing, mission planning, crew training, launch, flight control, and crew and return vehicle recovery.

Additionally, the Constellation Architecture destination systems include the habitats, power systems, surface mobility (i.e. rovers), payloads, robotic systems and resource utilization systems that enable the crewmembers to live, work and explore the surface of other worlds. The Mars Transfer Vehicle (MTV) and Descent Ascent Vehicle (DAV) support the Mars missions and will be added to the Architecture in the future. The MTV is used to transport crew from Low Earth Orbit to Low Mars Orbit. The DAV function is similar to that of LSAM; it provides transportation to and from the Martian surface and crew habitat for up to 30 days while habitation is activated. These systems will be addressed in future versions of the CARD.

Standard coordinate systems have been established for the Constellation Program and are documented in CxP 70138, Constellation Program Level 2 Coordinate Systems.

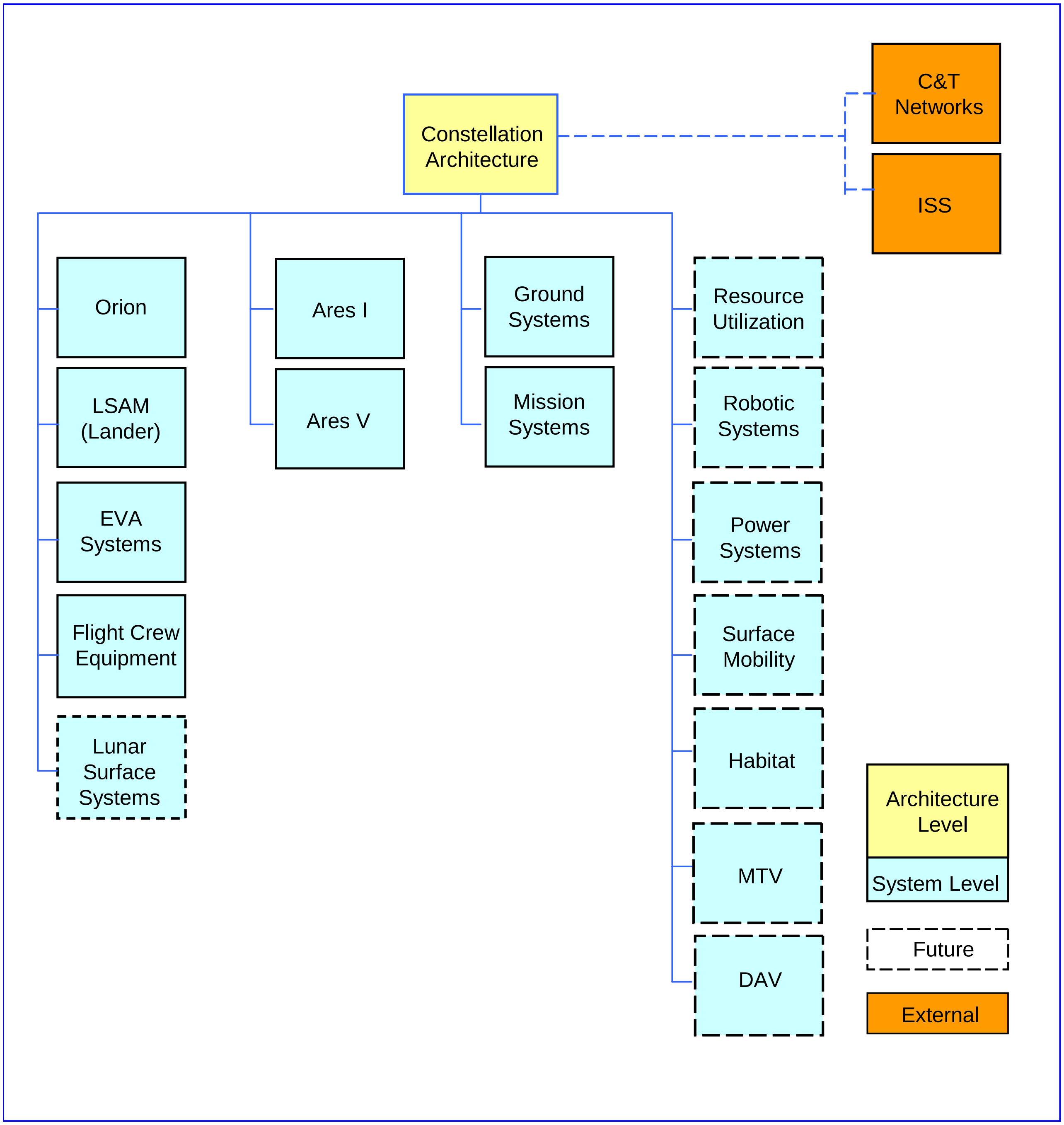

FIGURE 3.1-1 CONSTELLATION ARCHITECTURE HIERARCHY

3.1.1 Interfaces

3.1.1.1 External Interfaces

Based on the complexity of the Constellation Architecture, there are several external interfaces with Programs, Facilities, and other Government Agencies. These interfaces include the International Space Station (ISS), Communications and Tracking Network (C&TN), Robotic Lunar Exploration Program (RLEP), the Eastern and Western Ranges, and several others. The requirements to the Constellation Architecture associated with these external interfaces are located in CARD Section 3.4, and a placeholder for functionality required from these external systems is Section 3.8.

3.1.1.2 Internal Interfaces

Similarly, the internal interfaces associated with the Constellation Architecture are defined in the IRDs. The Constellation Architecture Interface Chart provides a high-level overview of the internal interfaces required to meet the Program needs.

TABLE 3.1.1.2-1 CONSTELLATION ARCHITECTURE INTERFACE CHART

Functional Interfaces between Constellation Systems								
System in top row has an interface (in left column) with the System(s) identified in the intersecting cell.	**Orion**	**Ares I**	**Ares V**	**LSAM**	**EVA**	**GS**	**MS**	**FCE**
Loads, Structures, and Mechanisms								
Loads	Ares I, EVA, GS, LSAM, Ares V	Orion, GS	Orion, LSAM, GS	Ares V, Orion, EVA	Orion, LSAM, GS	Ares V, Orion, Ares I, EVA	NONE	NONE
Structures	Ares I, EVA, GS, LSAM, FCE	Orion, GS	LSAM, GS	Orion, FCE, EVA, Ares V	Orion, GS, LSAM	Ares V, Orion, Ares I, EVA	NONE	Orion, LSAM
Mechanisms	Ares I, LSAM	Orion, GS	LSAM, GS	Orion, Ares V		Ares V, Ares I	NONE	NONE
Umbilicals	GS	GS	GS	NONE	NONE	Orion, Ares I, Ares V	NONE	NONE
Power Requirements								

Functional Interfaces between Constellation Systems								
System in top row has an interface (in left column) with the System(s) identified in the intersecting cell.	**Orion**	**Ares I**	**Ares V**	**LSAM**	**EVA**	**GS**	**MS**	**FCE**
Power Characteristics	EVA, GS, LSAM, FCE	GS	GS	Orion, FCE, EVA, GS	Orion, GS, LSAM	Ares V, Orion, Ares I, LSAM	NONE	Orion, LSAM
Isolation	EVA, GS, LSAM	GS	GS	Orion, EVA, GS	Orion, LSAM	Ares V, Orion, Ares I, LSAM	NONE	NONE
Circuit Protection	Ares I, LSAM	Orion, GS	GS	Orion, GS	NONE	Ares I, Ares V, LSAM	NONE	NONE
Electromagnetic Environmental Effects	Ares I, EVA, GS, LSAM	Orion, GS	GS, LSAM	Ares V, Orion, EVA, GS	Orion, LSAM	Ares V, Orion, Ares I, LSAM	NONE	NONE
Bonding and Grounding	Ares I, EVA, GS, LSAM	Orion, GS	GS, LSAM	Ares V, Orion, EVA, GS	Orion, GS, LSAM	Ares V, Orion, Ares I, EVA, LSAM	NONE	NONE
Unique Power Interfaces	NONE	GS	GS	NONE	NONE	Ares V, Ares I	NONE	NONE
Environmental Control and Life Support								
Atmosphere	EVA, LSAM, FCE	NONE	NONE	Orion, EVA	Orion, GS, LSAM	EVA	NONE	Orion
Thermal	LSAM	NONE	NONE	Orion, EVA	LSAM	NONE	NONE	NONE

Functional Interfaces between Constellation Systems								
System in top row has an interface (in left column) with the System(s) identified in the intersecting cell.	**Orion**	**Ares I**	**Ares V**	**LSAM**	**EVA**	**GS**	**MS**	**FCE**
Potable Water	EVA, FCE	NONE	NONE	EVA	Orion, LSAM	NONE	NONE	FCE
Gasses and Fluids								
Propellant Fluids	GS	GS	GS	NONE	NONE	Ares I, Ares V, Orion	NONE	NONE
Thermal Gasses and Fluids	Ares I, EVA, GS	Orion	LSAM	Ares V, EVA	Orion, GS, LSAM	Orion, EVA	NONE	NONE
Communication Requirements								
RF Communications	Ares V, GS, LSAM	GS	Orion, GS	EVA(1)	LSAM(1), MS	Ares V, Orion, Ares I	EVA	NONE
Hardline Communications	Ares I, EVA, GS, LSAM	Orion, GS	GS, LSAM	Ares V, Orion, EVA	Orion, LSAM	Ares V, Orion, Ares I, MS	GS	NONE
Internet Protocol	Ares V, Ares I, GS, MS, LSAM	Orion, GS, MS	Orion, GS, LSAM	Ares V, Orion	NONE	Ares V, Orion, Ares I, MS	Orion, Ares I, GS,	NONE
Security	Ares V, GS, LSAM, MS	MS, GS	Orion, GS	Orion	NONE	Ares V, Orion, Ares I, MS	Orion, Ares I, GS	NONE
Data and Information Requirements								
Data	Ares V, Ares I, EVA, GS, MS, LSAM, FCE	Orion, GS, MS	Orion, GS, LSAM	Ares V, Orion, EVA	Orion, LSAM, MS	Ares V, Orion, Ares I, MS	Orion, Ares I, GS, EVA	Orion

Functional Interfaces between Constellation Systems								
System in top row has an interface (in left column) with the System(s) identified in the intersecting cell.	**Orion**	**Ares I**	**Ares V**	**LSAM**	**EVA**	**GS**	**MS**	**FCE**
Information	Ares I, EVA, GS, MS, LSAM, FCE	Orion, GS, MS	GS	Orion, EVA	Orion, LSAM, MS	Ares V, Orion, Ares I, MS	Orion, Ares I, GS, EVA	Orion
Flight Performance								
Guidance, Navigation, and Control	LSAM, Ares I	Orion	GS	Orion	NONE	Ares V	NONE	NONE
Mass Properties	Ares I, LSAM	Orion	LSAM	Ares V, Orion	NONE	NONE	NONE	NONE
Proximity Operations and Docking Performance	Ares I, LSAM	Orion	LSAM	Ares V, Orion	NONE	NONE	NONE	NONE
Human Factors								
Human Factors	EVA, LSAM	NONE	NONE	Orion, EVA	Orion, GS, LSAM	EVA	NONE	NONE
Unique								
Unique	GS, LSAM, Ares I, FCE	GS, Orion	LSAM, GS	Ares V, Orion	GS	Orion, Ares I, EVA, Ares V	NONE	Orion

NOTE: EVA has RF communication with the LSAM and other destination surface systems, although these interfaces have not yet been defined in the IRDs.

3.1.2 General Program Policy

The objective of the Constellation Program is to carry out a series of human expeditions ranging from Low Earth Orbit (LEO) to the surface of Mars and beyond for the purposes of conducting human exploration of space. It is intended that the information and technology developed by this program will provide the foundation for broader exploration activities as our operational experience grows.

In the design and implementation of the Constellation Program, there are many competing characteristics that must be traded off in arriving at the final configuration. In making these evaluations, the four primary characteristics that should factor into each design decision are listed here in priority order.

Accomplishment of these objectives is bounded by the fraction of total national resources allocated to the program and the rate at which such resources can be brought to bear. If and whenever cost limitations dictate program compromises, it is program policy that trade-offs of the above objectives will be made in the stated order of priority. The application of these competing characteristics and the relative weightings given to each in the solution of any specific problem (without changing the order of priority) are matters of trade-offs and judgment. No inflexible yardstick of weightings can substitute.

3.1.2.1 Safety and Mission Success

To be sustainable, future space exploration systems, infrastructure, and missions pursued using them, must be both safe and reliable. Flight crew, ground crew, public safety and mission success should be the primary design consideration. Safety involves the execution of mission activities with the minimal risk of personnel injury. Mission success is defined as the safe return of all crewmembers after completing the primary mission objectives. Safety, reliability and quality will be designed-in to Constellation Program systems in order to ensure system robustness and mission success. Additionally, stringent ground, prelaunch and in-flight test/checkout requirements will be developed and detailed attention paid to the nominal, contingency, and emergency modes of operation and other key system factors. This will retain system design functionality and achieve mission success with the least risk of life.

3.1.2.2 Programmatic Risk

Accomplishments of human surface landing missions to the Moon and Mars at the earliest possible date and establishment of permanent human presence on the Moon are recognized national objectives. The system design should focus on minimizing programmatic risk by meeting or exceeding performance requirements and schedule milestones associated with accomplishing these missions while not exceeding the allocated budget or sacrificing safety and mission success objectives.

3.1.2.3 Extensibility and Flexibility

Constellation's program of exploration will use an evolutionary approach to expanding human presence in the solar system. Achieving increasingly aggressive goals in exploration should be the result of incremental cumulative achievements that can be leveraged in the design of the next generation systems. Designs should strive to address future requirements that have been anticipated by Constellation management, while fulfilling their primary mission needs. In addition, designs should strive to maximize operational flexibility to allow for accommodation of changing mission needs.

3.1.2.4 Life Cycle Cost

A sustainable program hinges on how effectively total life cycle costs are managed. Developmental costs are a key consideration, but total life cycle costs related to the production, processing, and operation of the entire architecture must be accounted for in design decisions sufficiently to ensure future resources are available for increasingly ambitious missions into the solar system. Historical data shows that typically life cycle costs of a program are set within the first 10% of its life and that design solutions (to problems encountered during development) often are not adequately scrutinized for their potential impacts on Ground and/or Mission Operations impacts over the remaining balance of the program. It is the intent of the Constellation Program to aggressively manage this aspect of the program using the design policies and simplicity highlighted below.

3.1.2.5 International System of Units (SI) and English Units of Measure

The Constellation Program has determined that the primary units of measure for this program will be SI units. In all Level I, II and III requirements documents SI will be shown as primary with the English unit equivalent in parenthesis. All Level I, II, and III integrated analyses, performance and verification systems will be completed in SI units. Constellation realizes the heritage of several hardware components and designs (as well as associated tooling and infrastructure) and will allow at Level IV and below the option to justify English units as primary with additional dimensional control plans in place to reduce technical risk, based on Project Manager concurrence. Where an interface between English and International System of Unit (SI) exists, specifications will be written to include both units and note where verification points can be explicitly identified. In addition, operational data should be presented in the same units as the development data except where information from multiple systems or elements must be operationally related. The Constellation Program will utilize NIST SP 811 for standardization and conversion of units of measure. For clarification of policy details, refer to CxP 70013, Constellation Program System Engineering Management Plan.

3.1.3 System Design Policy

The following discussion provides design, guidance and objectives for Constellation Systems.

3.1.3.1 Risk Management

The primary criterion governing the design of the system, including hardware testing and verification, the choice of flight components, the nature and extent of pre-flight and in-flight checkout provisions, the use of ground-based computing, tracking and command capabilities, and the nature and degree of crew participation will be that of achieving mission success with the least risk to safety.

It is desirable for the Constellation Architecture to be designed such that in-flight operations in Low Earth Orbit or lunar orbit may be accomplished without reliance on crew EVA. Allowing the program to use EVA for these types of operations would result in additional risk to the crew, higher training costs, and extended mission durations in Low Earth Orbit (LEO) prior to departure for the destination.

3.1.3.2 Crew Survival

The secondary criterion will be that of returning the crew to safety (e.g. Lunar or Mars surface, safe haven, Earth, etc.) even if catastrophic system failures are encountered during the mission. To mitigate the effects of failures requires crew survival capabilities such as abort, escape, safe haven, emergency egress, emergency medical and rescue to be available throughout the mission profile.

3.1.3.3 Common Cause Failure Mode Elimination

Although good design, adequate testing and a demonstration of reliability must be the primary means of achieving crew safety and mission success; there may be certain critical areas in the system where reliability demonstration is impractical in terms of cost and/or schedule. Every effort should be made to minimize this uncertainty, but where it cannot be removed, the system should be designed to include backup or alternate modes of operation wherever possible to enhance crew survival, rather than place sole reliance on simple parallel redundancy of systems whose reliability cannot be demonstrated. The net result should be, as a goal, to preclude any single component failure from necessitating abort or seriously degrading the probability of successful abort in the event of a second component failure in the same area.

3.1.3.4 In-Flight Maintenance

If the preceding reliability provisions cannot be met, then in-flight maintenance and/or parts replacement or alternative crew survival methods should be provided, where practicable.

3.1.3.5 Risk Reduction

In those areas where requirements (performance, reliability, etc.) can be met by the existing technology, the design of the system should not be made dependent on the development of new components or techniques. In the event new technologies or components offer significant benefits and are promising, the existing technology will be kept as baseline and management approval may be granted to pursue new technologies, as an option to the baseline. However, “reuse” of existing technologies, hardware and software will be coupled with a disciplined approach for verifying the total performance, safety and reliability of these previously used systems in their new and unique applications. Where a new development is required to accomplish design of the system, and is considered to involve high risk, the development should be identified to the program management together with a statement of steps being taken to ensure a suitable backup capability in the event the new development effort is unsuccessful.

3.1.3.6 Design Guidance

The design of all flight equipment and associated ground/mission equipment and procedures should be such as to accommodate the various flight tests and vehicle configurations that are planned with minimum variation of the equipment from flight to flight. For the Constellation Program, the feedback loop and linkages between operational performance and system design are particularly important if we are to maximize learning during the long-term development process that will be required. Achieving our ambitious space exploration goals will require optimal learning from each mission and the ability to apply lessons learned to future missions and system development cycles. NASA will need to create an organizational control structure for safety and mission assurance that is self-reflective, self-analytical, sustainable, adaptive and capable of compiling and applying lessons learned in a timely manner.

With this goal in mind, we address the following topics related to the overall approach to defining an effective exploration architecture:

a. Control of Hazards
b. Design for Human Operability
c. Commonality/Interchangeability
d. Maintainability
e. Reliability
f. Interoperability
g. Supportability
h. Environmental Considerations
i. Habitability
j. Open Architecture Approach
k. Software

3.1.3.6.1 Control of Hazards

3.1.3.6.1.1 Design Simplicity

Simplicity of design is a prime criterion where design trade-offs are concerned. Design simplicity involves minimization of parts and interdependence on other systems as well as minimization and simplification of interfaces, resulting in ease of operation and maintenance by the ground and flight crews. Simple systems require less operations attention, fewer operator constraints, necessitate less training, and enhance reliability for long duration missions. Balancing software and data intense designs against more simplistic/higher reliable but sometimes less obvious approaches can achieve design simplicity.

3.1.3.6.1.2 Design Robustness

A product is said to be robust when it is insensitive to the effects of sources of variability, performing consistently as intended throughout its life cycle, under a wide range of user conditions, and under a wide range of outside influences. Design for high reliability and redundancy alone is not sufficient to achieve design robustness. Reliability, by definition, is the probability that the item will perform a specified function under specified operational and environmental conditions, over a specified period of time. However, robust design deals with the device operating, or at least degrading gracefully, outside the specified operating conditions. Robust design has been shown to increase flexibility in the design of complex engineering systems involving multiple decision-makers, where uncertainty is created by having many design teams, each having control over only a portion of the total set of design variables. So application of robust design can also improve operational flexibility, cost effectiveness, and schedule.

3.1.3.6.1.3 Redundancy

All systems should allow safe execution and operation toward completion of all primary mission objectives in the presence of any single credible systems failure. Safety of the crew will be assured for any two independent credible failures sustained at any point in the mission. Where redundancy is implemented, dissimilar, full capability systems are often preferred. Minimum requirement and minimum performance backup systems are less preferable than full capability systems. Redundant paths such as fluid lines, electrical wiring, connectors, and explosive trains should be located to ensure that an event which damages one path is least likely to damage another. All systems that incorporate an automated switchover capability must be designed so as to provide operator notification of the component malfunction and to confirm that proper switchover has occurred and that the desired system is on line and functioning properly.

3.1.3.6.2 Design for Human Operability

Systems should be designed around maximizing human performance capabilities. Ground processing efficiency, mission success and crew safety will be significantly enhanced by a design of the human-to-system environment that maximizes the effectiveness of the operations personnel.

All sensing components associated with enabling operations personnel to recognize, isolate, and correct critical system malfunctions for a given vehicle should be located onboard that vehicle and be functionally independent of ground support and external interfaces. Two independent instrumented cues are required for any major change in the nominal mission plan. The source of these cues can be from space vehicle mechanical or data displays and alerts and downlink telemetry. Cues are not independent if space vehicle and ground indications are from the same sensor. Redundant sensors are required if two independent cues of a failure cannot be obtained.

Crewed vehicles will provide the flight crew with insight, intervention capability, control over vehicle automation, authority to enable irreversible actions, and critical autonomy from the ground. Display and control interfaces will be simple and intuitive. Presentation of onboard systems status information to the crew needs to be done in a consistent manner across all flight systems, and based on common well-documented practices of measure, iconography, and graphical standards. System design must preclude any failure mode requiring unreasonably swift human action to prevent a catastrophe. Unattended systems should not have catastrophic failure modes requiring immediate human intervention.

Operations personnel should have the ability to intervene and override any onboard decision regardless of sensor indications. A central objective of the sensor systems is to facilitate the situational awareness of both the crew and of remote operators (be they on the Earth or another vehicle). The design should allow the operator to make a rapid assessment of the current situation, including the exposure and investigation of off-nominal states. The design of the crewed vehicles should allow for the crew to provide functional redundancy to the automated and Earth-in-the-loop systems where practical. Examples would include orbit determination, maneuver design and execution, and rendezvous and docking operations without the aid of ground control. Crewed vehicles should require crew consent for irreversible actions where practical with respect to human reaction and decision times. Examples include commit to injection, de-orbit, and trajectory correction maneuvers. The ground should be able to control all crewed vehicle critical functionality in the event the need for uncrewed operation arises due to crew incapacitation, or maximizing effective use of crew time.

3.1.3.6.3 Commonality/Interchangeability

Commonality/Interchangeability at the component and sub-system level should be applied to and across all systems and all missions of the exploration Architecture where possible with the exception of those redundancy applications noted in the Redundancy section where unlike redundancy and use of dissimilar systems is necessary to maximize safety. Strict adherence to commonality/interchangeability will minimize training requirements, optimize maintainability (particularly on long duration missions), and increase operational flexibility. Design for commonality at the box-level and interchangeability standardization of hardware and hardware interfaces will simplify provisioning of spares, minimize the number of unique tools and amount of unique test equipment, and enable substitution between systems. This applies to hardware at all levels, among all architecture systems, including power buses and data buses, avionics circuit card assemblies, electronic components, and other assemblies such as pumps, power supplies, fans, fasteners, and connectors. Commonality applies not only to hardware components and operations, but also to similar software functions across the systems. Vehicle subsystems should be designed so that consumable items in common with other subsystems on the overall vehicle and other vehicles can be interchanged. Unattended systems should not have catastrophic failure modes requiring immediate human intervention.

3.1.3.6.4 Maintainability

Systems and hardware must be designed to simplify maintenance operations and optimize the effective use of maintenance resources. The mass and volume of spares and other materials required for maintenance and the overall effect on system availability must also be considered. Standard design approaches to simplifying maintenance operations should be employed. These include reduction of the need for EVA maintenance to the greatest degree possible, ensuring easy access to all items that may require maintenance, unambiguous marking of lines and connectors, and implementation of the minimum number of standard interfaces for transfer of power, liquids, gases, and data. System design should ensure that pre-maintenance hazard isolation is restricted to the item being maintained. Impacts by maintenance to other operations should be minimized. Hardware should be designed from the initial design phase for ease of access, repair and maintenance, due to the time and distance effects on the logistics of re-supply and the effects of hardware failure on long duration mission risk. Constellation Systems should enable and facilitate maintenance at the lowest practical hardware level by repair of failed items or, if necessitated by operational constraints, replacement with a spare at the lowest possible hardware level.

3.1.3.6.5 Reliability

The design of all flight equipment and associated ground/mission equipment should focus on reliability engineering such that the critical hardware/software subsystems receive high reliability consideration as much as possible, for example, use of class Second (S) Electrical, Electronic, and Electromechanical (EEE) parts for critical circuits in Avionics. The heritage hardware items should be reviewed to address areas that need improvement as indicated by problem history with either hardware/software or processing issues. The new designs should consider high reliability standards for mission critical/safety items particularly those that will experience long mission operating life requirements and may contain some measure of difficulty for replacement/servicing while in space, Lunar surface or Mars environments.

3.1.3.6.6 Interoperability

Where possible, systems (or components of systems) should be interoperable with similar elements or components in other systems of the architecture. Common standards should be established for power systems, operating environment envelopes, consumable or replaceable components, displays and controls, software, communication capabilities and protocols, and other systems attributes. This approach will minimize training requirements, enhance the usability of portable or transferable equipment, and reduce logistics requirements.

3.1.3.6.7 Supportability

The logistics footprint required to support exploration missions must be minimized. Strategies to achieve this objective include broad implementation of commonality and standardization at all hardware levels and across all systems, repair of failed hardware at the lowest possible hardware level (as determined on a case-by-case basis by detailed analyses), manufacture of structural and mechanical replacement components as needed. Pre-positioning of logistics resources (spares and consumables) should be used to distribute logistics mass across the architecture systems and reduce mission risk by staging critical assets at the destination prior to committing human crew. Utilization of in-situ surface resources for production of propellants, breathing gases, and possibly consumable water could significantly reduce the mass that must be delivered to planetary surfaces. A comprehensive Inventory Management System (IMS) should be implemented that monitors and records the locations and quantity of logistics items as well as cross reference for common component applications, i.e. systems and element use. The system should accommodate interaction by the crew but should perform routine audits and item tracking without active crew involvement. In addition, the Mission Integration Production template to produce products for each mission should be managed within a shorter period over legacy systems.

The length of the mission integration production template drives life cycle costs. Each template driver should identify a set of attributes, constraints, and guidelines that allow process reductions (e.g. reduced flight specific training, standard mass and center of gravity envelopes, design to limited margins based on acceptable, reliability, and safety considerations, and standard cargo interfaces). Driving requirements and processes should be designed to insure that top level components of the template are efficient and lead to shorter mission integration production templates without increasing manpower over legacy programs. While the initial template is developed for ISS missions, the template and processes should evolve as Constellation missions become more complex. While flexibility to optimize each mission is reduced over legacy systems, reduced template improves life cycle costs significantly.

3.1.3.6.8 Environmental Considerations

The vehicle design should minimize environmentally induced constraints on ground and flight operations; minimize sensitivity to extreme variations in both natural and induced environmental conditions. Hardware should be able to survive long periods with no power and be able to return to operation from such a frozen state. Where practical, crewed vehicles should be equipped with space weather sensors to provide radiation event alerts. Space Radiation should be accounted for in the design only to a risk level commensurate with other sources of risk to crew safety. It is program policy that no manned vehicle will attempt landing on a destination surface until certain information essential to system design confirmation has been obtained by measurement of the in-flight environment and surface environment of the destination at the proposed landing site. Such information may be obtained from robotic programs, by means of remote observations, surface tests, and meteoroid and radiation experiments, or from early flight tests conducted prior to the first human landing. Design features should ensure that opportunities for both forward and back contamination are minimized in the execution of Constellation missions. In addition to minimizing contamination risks, designs should also focus on accomplishing Constellation requirements in a way that causes the minimal change to the environment being explored. Further, impacts to terrestrial environment (including climate change) and considerations of environmental sustainability shall be incorporated in CxP design and operations.

3.1.3.6.9 Habitability

Habitability must be a prime consideration in the design of all vehicles/habitats used by a crew. Convenient engineering design solutions (functional adjacencies) must not compromise habitability. Habitable volumes will provide a pressurized, shirt sleeved, temperature and humidity controlled atmosphere for the crew for all nominal extended duration phases of flight (operationally the ascent/entry phases of flight will be flown suited). Habitable volumes will provide protection for the crew against failures that would compromise the habitable environment. During long duration missions, habitable volumes must allow for simultaneous activities such as sleeping, eating, performing hygiene functions, and exercising, and for off duty activities with separate and dedicated volumes. Privacy for hygiene is important.

3.1.3.6.10 Open Architecture Approach

Growth potential includes both the capability to support evolving mission requirements as well as the capability to support technology upgrades throughout an Architecture system's design life. As technology evolves, there will be potential both for growth in capability and for compatibility issues between newer and older systems. Design decisions in areas where technology is rapidly evolving (e.g. electronics/avionics) should minimize the complexity required to perform future upgrades. Technology upgrade decisions will, in some cases, be driven by the benefit (e.g. lower life cycle cost, increased reliability) associated with an upgrade while in other cases, upgrades will be driven by the need of existing Architecture systems to interface with new systems that are developed years later with significantly more advanced technologies.

3.1.3.6.11 Software

A high degree of emphasis should be placed on program-level controls over software development. New hazards and concerns will be identified throughout the development process and into operations, and there must be a simple and non-onerous way for software engineers and operational personnel to collaborate to raise concerns and safety issues and get questions answered at any time. In a recent study of the role of software in spaceflight mishaps, the cultural and managerial flaws manifested themselves in the form of technical deficiencies:

a. Inadequate system and software engineering

b. Inadequate review activities

c. Ineffective system safety engineering

d. Inadequate human factors engineering

e. Flaws in the test and simulation environments

Software standards (in particular Command, Control, Communication, and Information [C3I] commonality standards) are required to avoid cost of supporting dissimilar systems and architectures. Disciplined metrics and estimating tools supported by proven rationale must be applied early and often in this area of the Design, Development, Test and Evaluation (DDT&E) efforts. Similar software functions across all architectural systems, such as Fault Detection, Isolation, and Recovery (FDIR) or other vehicle management applications, should be developed to a common set of standards. Computer advancements, the emergence of highly reliable decision-making algorithms, and the emphasis on efficiency make an increased use of automated systems possible. However, for some human spaceflight applications, full automation is often not practical. The program must weigh DDT&E cost of placing functions onboard (including factors such as design flexibility, verification/validation of flight software, sustaining engineering during flight operations) against the cost of performing functions on ground for functions where reaction time is compatible with light-time communication delays. Software design and architecture should support capability for rapid changes according to changing program and operational needs. This capability should support major version level updates as well as time critical small-scale fixes and parameter changes, both prelaunch and in-flight. The software should be modular and provide a capability to turn on and off a function as needed. The design must ensure minimum total system impact from programming changes and additions. Additionally, software design should offer flexibility to allow the incorporation of upgraded and/or new Line-Replaceable Units (LRUs) with minimal impact such as use of industry standard interfaces and preserving performance margin. A balance must be found between how much human operators trust automation and how much benefit and cost savings automation provides. This balance may result in an intermediate level of automation somewhere between full computer responsibility and full human responsibility. Distributed control systems should change software states based on telemetry from lower tiered units, not just on events (e.g., commands completing). For multi-tiered systems, command validation at each tier should only include parameters controlled by that tier.

3.2 CONSTELLATION ARCHITECTURE REQUIREMENTS

[CA0001-HQ] The Constellation Architecture shall deliver crew and cargo to the lunar surface and return them safely to Earth.

Rationale: Establishes the top level Architecture requirement for lunar crewed mission to safely ferry crews between the Earth and the lunar surface as well as providing a capability to ferry cargo to/from the lunar surface.

[CA0003-HQ] The Constellation Architecture shall provide the capability to perform crewed and robotic activities to further scientific knowledge during lunar missions

Rationale: Establishes the need to provide mission resources to perform scientific research. Specific science objectives for each Lunar Sortie and Lunar Outpost *mission will be defined in a separate Exploration Systems Mission Directorate (ESMD) document.*

[CA0004-HQ] The Constellation Architecture shall provide the capability to perform engineering demonstrations and satisfy development test objectives during lunar missions.

Rationale: Establishes the need to provide mission resources to perform engineering demonstration and Developmental Test Objectives (DTOs) that are necessary as a precursor to Mars missions. Specific engineering objectives for each Lunar Sortie and Lunar Outpost mission will be defined in a separate ESMD document. Some DTOs may replace redundant units/subsystems as advance technology replacements.

[CA0005-HQ] The Constellation Architecture shall provide the capability to establish and support a permanently habitable outpost on the lunar surface.

Rationale: Required to achieve CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Constellation Program Goal CxP-G11: "Develop the capability for a sustainable and extensible permanent human presence on the Moon for commercial, national pre-eminence and scientific purposes leading to future exploration of Mars and beyond."

[CA0006-HQ] The Constellation Architecture shall provide the capability to demonstrate resource extraction and utilization from in situ materials during lunar missions.

Rationale: Establishes the priority of extraction and use of resources from the lunar environment. Extraction and utilization demonstrations can serve as a first step in utilizing lunar resources (if desirable), or in demonstrating a capability that may be further exploited during human missions to Mars.

Draft **[CA0011-HQ]** The Constellation Architecture shall provide the capability to perform activities to further scientific knowledge during Mars missions.

Rationale: Establishes the need to provide mission resources to perform scientific research throughout the cruise and surface phases of Mars missions. Specific science objectives for each crewed Mars mission will be defined in a separate ESMD document.

[CA0013-HQ] The Constellation Architecture shall perform Lunar Sortie missions to any designated location on the lunar surface.

Rationale: Designated lunar landing locations, which may be anywhere on the lunar surface, will allow Lunar Sortie missions to maximize the potential science return and provide the flexibility in selecting a lunar outpost location. This requirement is intended to indicate that a designated location on the lunar surface will be selected for a given mission, which then limits launch window and Trans-Lunar Injection (TLI) windows for that mission. This requirement also does not imply that the LSAM will *have the ability to reach any location on the lunar surface from a single designated lunar insertion/destination orbit or that operations must be performed under any lighting and thermal conditions at the landing location. For example, thermal conditions at lunar noon on the equator may necessitate excessive system requirements, which could be mitigated by planning the mission in less stringent conditions (i.e. a morning/evening mission).*

Draft [CA0074-PO] The Constellation Architecture shall transfer the crew from MTV to the Earth surface in no more than 3 days.

Rationale: The Mars DRM specifies jettisoning of the MTV before Orion Earth entry. Three days independent crew flight time in the Orion represents a trade between Orion lifetime and MTV propulsive diversion requirements.

[CA0202-HQ] The Constellation Architecture shall perform lunar surface EVA.

Rationale: Identifies the need for lunar sortie and outpost crews to have the capability to leave the lander to perform activities related to accomplishing mission objectives. The number of EVA crew-hours and the distance that the EVA crewmembers need to traverse will be established through analysis of specific mission objectives.

Draft [CA0404-HQ] The Constellation Architecture shall provide the capability to extract and utilize resources from in situ materials during Mars missions.

Rationale: Establishes the Vision for Space Exploration (VSE) guidance to first demonstrate, and then utilize products extracted from indigenous Martian materials. This also establishes the ties between lunar resource utilization defined in CA0006-HQ and continued resource utilization on Mars.

Draft [CA0889-HQ] The Constellation Architecture shall deliver crew and cargo to the surface of Mars and return them safely to Earth.

Rationale: Establishes the top level Architecture requirement for Mars crewed mission to safely ferry crews between the Earth and the Mars surface, as well as providing a capability to ferry cargo to/from the Mars surface.

[CA0892-HQ] The Constellation Architecture shall deliver crew and cargo to the ISS and return them safely to Earth.

Rationale: Establishes the top level Architecture requirement for ISS mission to safely ferry crews and cargo between the Earth and the ISS.

[CA6077-PO] The Constellation Architecture shall reserve 1047 kg (2308 lbm) in the Orion for Flight Crew Equipment, EVA System and flight crew mass for ISS missions.

Rationale: The individual control masses for Flight Crew Equipment, EVA System and flight crew with a manager's reserve and is part of the Orion control mass for ISS missions.

[CA6079-PO] The Constellation Architecture shall reserve 675 kg (1488 lbm) in the Orion for Flight Crew Equipment, EVA System hardware and flight crew mass for lunar missions.

Rationale: The individual control masses for Flight Crew Equipment, EVA System hardware and flight crew with a manager's reserve and is part of the Orion control mass for lunar missions.

3.2.1 Mission Success

[CA0033-HQ] The Constellation Architecture shall limit the risk of Loss of Mission (LOM) for a Lunar Sortie mission to no greater than 1 in 20.

Rationale: The 1 in 20 means a .05 (or 5%) probability of LOM during any Lunar Sortie mission. The baseline numbers were derived from a preliminary Probabilistic Risk Assessment (PRA) within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study (ESAS). This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA0095-HQ] The Constellation Architecture shall limit the risk of loss of mission (LOM) for an ISS Crew mission to no greater than 1 in 200.

Rationale: The 1 in 200 means a .005 (or 0.5%) probability of LOM during any ISS Crew mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA0097-HQ] The Constellation Architecture shall limit the risk of Loss of Mission (LOM) for an ISS Cargo mission to no greater than 1 in 200.

Rationale: The 1 in 200 means a 0.005 (or 0.5 %) probability of LOM during any ISS Cargo mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA0099-HQ] The Constellation Architecture shall limit the risk of Loss of Mission (LOM) for a Lunar Outpost Crew mission to no greater than 1 in (TBD-001-034).

Rationale: The 1 in (TBD-001-034) means a (TBD-001-034) (or (TBD-001-034)%) probability of LOM during any Lunar Outpost Crew mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

Draft **[CA3038-HQ]** The Constellation Architecture shall limit the risk of Loss of Mission (LOM) for a Lunar Outpost Cargo mission to no greater than 1 in (TBD-001-058).

Rationale: The 1 in (TBD-001-058) means a (TBD-001-058) (or (TBD-001-058)%) probability of LOM during any Lunar Outpost Cargo mission. This requirement is driven by CxP 70003- ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO): Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

Draft **[CA3039-HQ]** The Constellation Architecture shall limit the risk of Loss of Mission (LOM) for a Mars mission to no greater than 1 in (TBD-001-050).

Rationale: The 1 in (TBD-001-050) means a (TBD-001-050) or (TBD-001-050)% probability of LOM during any Mars mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.2.2 Crew Survival

[CA0028-PO] The Constellation Architecture shall return the crew to the Earth surface independent of communications with Mission Systems during all mission phases.

Rationale: This requirement ensures the safety of the crew by allowing the Constellation Systems to protect for the possibility of permanent or unplanned intermittent communication service outages that prevent or limit the ability of the Mission Systems to interface with the vehicles used for the given mission. Communication services include uplink and downlink services (Earth- and space-based), Earth-based navigation equipment, and Ground Operations centers. Communications (voice, command, and telemetry) and relative navigation between vehicles, Flight System sensors for each vehicle, and communications with Global Positioning System (GPS) remain operational. For communication service outages that occur while the crew is on the lunar surface or in the LSAM, the LSAM can return the crew back to the Orion using internal equipment along with communications with the Orion. The Orion can complete the orbit transfer to the Lunar Rendezvous Orbit (LRO), participate in Rendezvous-Proximity Operations-Docking-Undocking (RPODU) activities, perform the Trans-Earth Injection (TEI) and complete Earth entry. For ISS missions, the Orion can perform undocking, proximity operations and entry activities using only internal equipment.

[CA0107-HQ] The Constellation Architecture shall provide for crew survival capabilities through each mission phase.

Rationale: Crew survival capabilities are an inherent feature embedded in the mission design from pre-launch phase to recovery and rescue operations. This requirement is allocated to all the mission phases and elements, each may utilize different technique.

[CA0172-PO] The Constellation Architecture shall perform search and rescue operations following a landing outside of the designated landing sites, independent of ambient lighting conditions.

Rationale: The Constellation Architecture must be able to locate systems and crew outside the designated landing zones if an off nominal landing occurs. Search and rescue (SAR) operations may be required in all sorts of weather conditions and over different terrain. However, the SAR operations will be limited by weather and potentially other constraints. Lighting and time of day should not be part of the constraints.

[CA0312-PO] The Constellation Architecture shall provide safe haven for the crew for at least 36 hours post touchdown on Earth while awaiting rescue and retrieval.

Rationale: In the event Orion lands in an off-nominal location, the crew will need to take shelter and sustain themselves until they can be recovered by the Ground Systems search and recovery teams. Given the conditions associated with landing, safe haven within and outside of Orion need to be addressed. The 36 hours comes from CA0194-PO which requires Orion to provide safe haven post touchdown for 36 hours.

[CA6072-PO] The Constellation Architecture shall maintain the suit loop at a pressure no less than 15.4 (TBR-001-1431) kPa (2.2 psia) for at least 5 (TBR-001-1432) min with an equivalent maximum hole diameter of 6.4 (TBR-001-1433) mm (0.25 in).

Rationale: This requirement applies the JPR 8080.5A F-22 standard to the Constellation Architecture, and is interpreted to mean that protection is needed for large breaches in the umbilical or suit pressure layer. Functionally, the size of this hole is limited to the size of supply and return umbilical gas lines. The minimum suit loop pressure is the pressure below which the crew will lose consciousness and could be achieved through feeding the leak with EVA System and vehicle resources and/or isolating the leak. The minimum time is expected to be adequate for the crew to take corrective action including identification of the affected suit or umbilical and isolation of that crewmember from the rest of the suit loop. Corrective action can then be taken to stop the leak and return ventilation flow to the affected crewmember. Because of design controls in place to prevent inadvertent release or opening of EVA System components and control sharp edges within and external to the vehicle, it is assumed that the risk of developing a leak is credible only for crewmembers external to the vehicle.

[CA6073-PO] The Constellation Architecture shall isolate a leak as defined in [CA6072-PO] to a single suit or umbilical from the rest of the suit loop within 5 (TBR-001-1432) min.

Rationale: This is a decomposition of JPR 8080.5A F-22, which states that systems supplying gas to pressure suits should be designed so that an abrupt decompression of the suit of one crewmember will not result immediately in a similar rapid loss of pressure in the suits of the other members or in a sudden total *depletion of the gas supply. This requirement applies only during vehicle dependent (i.e. umbilical-based) operations of the EVA System.*

3.2.2.1 Crew Survival Probabilities

[CA0032-HQ] The Constellation Architecture shall limit the risk of Loss of Crew (LOC) for a Lunar Sortie mission to no greater than 1 in 100.

Rationale: The 1 in 100 means a .01 (or 1%) probability of LOC during any Lunar Sortie mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation, Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA0096-HQ] The Constellation Architecture shall limit the risk of Loss of Crew (LOC) for an ISS Crew mission to no greater than 1 in 1000.

Rationale: The 1 in 1000 means a .001 (or .1%) probability of LOC during any ISS Crew mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems.

[CA0474-HQ] The Constellation Architecture shall limit the risk of Loss of Crew (LOC) for a Lunar Outpost Crew mission to no greater than 1 in (TBD-001-036).

Rationale: The 1 in (TBD-001-036) means a (TBD-001-036) (or (TBD-001-036)%) probability of LOC during any Lunar Outpost Crew mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

Draft [CA3037-HQ] The Constellation Architecture shall limit the risk of Loss of Crew (LOC) for a Mars mission to no greater than 1 in (TBD-001-054).

Rationale: The 1 in (TBD-001-054) means a (TBD-001-054) or (TBD-001-054)% probability of LOC during any Mars mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA5818-HQ] The Constellation Architecture shall limit the risk of Loss of Crew (LOC) from an event requiring a pad or ascent abort to no greater than 1 in 10.

Rationale: The 1 in 10 means a .1 (or 10%) probability of LOC from an event requiring a pad or ascent abort. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO): Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems. The *ascent abort probability number is intended to drive flight system reliability and Ground System reliability is driven by the overall mission LOC and LOM allocations.*

3.2.2.2 Emergency Egress, Aborts, and Early Return for Survivability

[CA0027-PO] The Constellation Architecture shall provide abort capability throughout all mission phases from the launch pad until the mission destination is reached.

Rationale: Abort at any time is part of NPR 8705.2, Human-Rating Requirements for Space Systems, as well as the program policy on crew safety. This requirement will cover all of the flight phases from abort system arming on the launch pad through docking with the ISS or transit to the destination. Depending on the abort condition and consequence of the declared abort, the resulting abort scenario could be abort to orbit, abort to Earth, or abort to the destination surface. After reaching the destination, all other scenarios are covered by the return capabilities.

[CA0310-PO] The Constellation Architecture shall provide unassisted emergency egress for suited crew to a safe haven during pre-launch activities within 4 (TBR-001-018) minutes total starting from the initiation of the egress to arrival of the last crewmember at the safe haven.

Rationale: For contingency situations, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons. This should drive design of seat restraints, hatch mechanisms, launch suit, and egress paths in pre-launch orientations to allow the crew to egress without ground crew assistance.

[CA0311-PO] The Constellation Architecture shall provide unassisted emergency egress for 8 (TBR-001-962) ground crew from the launch pad within (TBD-001-252) minutes starting from the initiation of the egress to arrival of the last ground crewmember at the safe haven.

Rationale: For contingency situations, the ground crew will need the capability to egress the launch pad for safety reasons.

[CA0352-HQ] The Constellation Architecture shall return the crew from the surface of the Moon to the surface of the Earth within 132 hours after the decision to return has been made during a Lunar Sortie Mission.

Rationale: Early return is both a time-to-departure and time-of-flight issue, as documented by NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. For Lunar Sorties, opportunities exist to depart the surface every two hours, and the delta-V requirements envelope all the propulsive maneuvers required to perform an expedited return to an unconstrained Earth landing site within the nominal Orion DV capability. The number of hours, determined by analysis, is based on the total time required for the following activities:

a. *Crew to prepare the LLV for ascent and retask the Orion into the LLV ascent plane* *b. The LLV to perform ascent and RPODU with the Orion*

c. Crew to transfer to the Orion from the LLV and jettison the LLV

d. The crew and Orion to prepare and execute the TEI

e. The Trans-Earth Coast

f. The crew and Orion to prepare and perform the atmospheric entry. This requirement defines an Earth entry condition of flight path angle and speed only. Entry interface constraints such as SM disposal, coazimuth control for ground track corridors, and water landing may add either flight time or propellant loading.

TABLE 3.2.2.2-1 - EXPEDITED RETURN TIMELINE FOR NOMINAL ORION TANK LOADING

Activity	Time Alloc	Heritage
Orion performs plane change into LRO. Crew prepares the LLV for liftoff following confirmation of Orion navigation state in LRO.	6 HR	The expedited return scenario begins with crew suited in LLV and able to begin preparations for ascent. Orion is assumed to be in a 100 km circular orbit in LLO (resulting in an orbital period of approximately 2 hours). This 6 hours allows for 3 ascending node crossings of the Orion to retask into the LRO. Assumption is that Orion MUST be in LRO before LLV TIG. By the end of this interval Orion is in the LRO, LLV has an ascent targeting solution, and the LLV is configured to begin ascent.
LLV performs ascent, rendezvous, and docking with Orion in LRO.	6 HR	Discussions with APO on LLV ascent to dock timeline place this nominally at approximately 2-2.5 hours from ascent engine ignition to hard dock. The 6 hours in this interval allows margin for off-nominal trajectories and surface stay time to allow the Orion to reach the LRO.
Transfer crew to Orion and gear to/from Orion as appropriate. Jettison LLV. Prepare navigation solution and prep for TEI initiation.	6 HR	Allows for three lunar orbits at 100 km circular to obtain navigation solution. Two orbits minimum are required to obtain and confirm navigation solution. This interval allows for contingency third orbit to re-establish navigation solution as necessary. Vetted with Emil Schiesser per Apollo history. At the end of this period the crew will have transferred to Orion, jettisoned the LLV ascent stage, calculated a navigation solution for initiating TEI, and have configured Orion for TEI initiation. If the Orion vehicle is unpressurized, then requirements for unpressurized crew return begin their clock at the beginning of this period.
Time to perform TEI sequence.	113 HR	Assumes general 3 burn sequence. Some optimized trajectories may take longer in this phase at the expense of period for Trans-Earth Coast. This time interval does not include margin for longitude control, coazimuth control at Earth encounter, or SM disposal targeting.
Trans-Earth coast to EI.		*Taken with 24 hours for TEI allows for minimum DV and some longitude control. Backed by LM and NASA analysis tools to fit within ORION SM DV allocation*
Entry, Descent, and Landing.	1 HR	Conservative estimate based upon conversations with skip entry design/analysis team for time interval from

		entry interface to touchdown.
Total [CA0352-HQ]	132 HR	Each activity may be individually changed, but the sum should logically flow up to a reasonable number.

[CA0530-PO] The Constellation Architecture shall return the crew to Earth without permanent disability from any point in the mission in the event of a non-recoverable cabin depressurization.

Rationale: In the event that one of the Constellation vehicles/habitats loses its ability to maintain pressure, the crew needs to be protected either by seeking refuge in another vehicle/habitat or by using their spacesuits until they are safely returned to the surface of the Earth. Prolonged operations in a spacesuit with limited hydration, nutrition, and waste removal increases the risk of illness but is not considered to cause "permanent disability" as defined in the Constellation (Cx) glossary.

[CA3226-PO] The Constellation Architecture shall provide for Earth landing throughout each mission phase.

Rationale: This requirement provides for Earth landing following any event during the mission that requires an abort or early return to Earth, e.g., unanticipated circumstances put the crew at risk or prevents mission completion. The generic term "Earth landing" means landing anywhere on the Earth. This requirement is intended to cover scenarios in which the timing of the abort or early return necessitates Earth landing requirements to be relaxed. Relaxing Earth landing targets from designated water sites adds flexibility in mission planning and can decrease on-orbit loiter time or other total mission time that could be beneficial for time-critical medical or vehicle damage scenarios. Aborts or early return can occur at any time, requiring the capability to land regardless of lighting conditions.

3.2.3 Crew Size

Draft **[CA0010-HQ]** The Constellation Architecture shall transport six (TBR-001-082) crewmembers to the surface of Mars and return them to Earth

Rationale: Defines the crew size for initial crewed missions to Mars. This surface crew size is established to provide a reasonable skill mix and functional overlap for crew operations during surface stays.

[CA0020-HQ] The Constellation Architecture shall provide for at least four (TBR-001-010) crewmembers per mission at the Lunar Outpost.

Rationale: The intent of this requirement is to size the Lunar Outpost. A four-person crew is minimum number of crew required to accomplish the Exploration objectives. For example, a four-person crew allows two EVA teams (two crew per team) to operate simultaneously or in series while providing the capability for operational assistance from the non-EVA crew. Total crew size at the Lunar Outpost could be 8 during operational handover periods. This is not meant to imply that the Outpost could not be operated with less than four crewmembers.

[CA0203-HQ] The Constellation Architecture shall deliver crew sizes ranging from two to four to the lunar surface and return them to Earth.

Rationale: Establishes a baseline crew size for both Lunar Sortie and Lunar Outpost operations. A four-person crew delivered to the lunar surface is the minimum number required to demonstrate operations concepts for exploring more distant destinations such as Mars. A four-person crew allows two surface EVA teams (two crew per team) to operate simultaneously or in series while providing the capability for operational assistance from the non-EVA crew. There may be excursions from normal operations where fewer (test flights) crewmembers are flown.

[CA0388-HQ] The Constellation Architecture shall deliver/return zero through six crewmembers to/from the ISS.

Rationale: Nominal ISS crew rotation shall be performed by Orion delivering and returning four ISS crewmembers. This requirement provides additional capability to respond to contingency situations such as mission scenarios described in CxP 70007, Constellation Design Reference Missions and Operational Concepts, Section 4.2.1.5. During nominal crew rotations of 3 crewmembers, additional capability may be utilized to support the transfer of cargo to/from the ISS.

3.2.4 Cargo Delivery and Return

Draft [CA0002-HQ] The Constellation Architecture shall deliver at least 20,000 kg (44,092 lbm) of cargo to the lunar surface for Lunar Outpost missions.

Rationale: The Mass Delivered requirement is based on analysis. This requirement applies to the Lunar Outpost cargo mission where a large cargo deployment is required for meeting Lunar Outpost mission objectives.

[CA0209-HQ] The Constellation Architecture shall deliver at least 500 kg (1102 lbm) of cargo to the lunar surface during each crewed lunar mission.

Rationale: A cargo delivery capability to the lunar surface is required to deploy surface equipment and supplies to meet defined mission objectives. This requirement applies to each crewed lunar mission and is based on the crewed Apollo 17 mission cargo capability. This Mass Delivered requirement is based on NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study.

[CA0211-HQ] The Constellation Architecture shall return at least 100 kg (220 lbm) of Payload from the lunar surface to the Earth during each crewed lunar mission.

Rationale: The minimum Mass Returned requirement is based on NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. A mass return capability is required to enable lunar samples and possible scientific experiments to be returned from the lunar surface to Earth. This requirement applies to each crewed lunar mission and is based on the crewed Apollo mission cargo return capability.

Draft [CA0212-HQ] The Constellation Architecture shall deliver up to (TBD-001-041) kg of cargo to the surface of Mars in support of a Mars mission.

Rationale: Establishes a minimum cargo level for accomplishing Mars surface objectives.

[CA0822-HQ] The Constellation Architecture shall provide return payload volume of at least

0.075 (TBR-001-503) cubic meters (2.65 cubic feet) from the lunar surface to the Earth during each crewed lunar mission.

Rationale: Volume must be allocated for return of lunar samples and possible scientific equipment from the Moon to support Constellation science and engineering objectives. This requirement is tied in part to the return mass requirements. This requirement applies to each crewed lunar mission and the (TBR-001-503) value is based on the crewed Apollo mission cargo return capability.

Draft **[CA0823-HQ]** The Constellation Architecture shall provide the capability to return at least (TBD-001-091) volume of cargo from the Mars surface to the Earth during each crewed Mars mission.

Rationale: Volume must be allocated for return of Martian samples and possible scientific equipment from Mars to support Constellation science and engineering objectives. This requirement applies to each crewed mission.

3.2.5 Mission Rates and Durations

[CA0036-HQ] The Constellation Architecture shall provide the capacity to perform missions according to the mission rates and opportunities specified in the System mission rate table.

Rationale: The Constellation Architecture must be designed to support a minimum mission frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Constellation systems. The Mission Rates and Intervals Table provides the definition for the overall number of missions per year for the Cx Program and the allocation of those missions to the systems. The rates in the table reflect the expected minimum mission rate plus a surge capacity accounted for by the maximum flight rate in conjunction with the minimum interval. All intervals are expressed in calendar days. Budgets will determine opportunities for mission rate surges. The minimum rate is intended to be applied to variable resources; however, in order to preserve the ability to add a mission when budgets permit, long lead or fixed resources should apply the maximum rate. The following assumptions are incorporated into the mission rate plan:

a. Intervals are measured from launch to launch of each system.

b. Concurrent ops scenarios are limited to the ISS Crew rotation/Crewed Lunar missions and Crewed Lunar/Uncrewed Lunar missions.

c. During crewed lunar mission, planned Orion operations for ISS will be limited to docked (quiescent) operations.

d. Crewed Lunar and Uncrewed Lunar missions may be conducted concurrently.

e. There will not be more than one vehicle of the same type launching or landing per day.

f. Missions are based upon the Design Reference Missions described in CxP 70007, Constellation Design Reference Missions and Operational Concepts Document.

g. A lunar mission will consist of one crewed flight (requiring one Orion/Ares I and one Ares V) plus one uncrewed cargo flight (one Ares V) for a total of one Ares I and two Ares V's per lunar mission.

TABLE 3.2.5-1 MISSION RATES AND INTERVALS

<table>
<tr><th>Mission(s)</th><th colspan="2">Minimum
Annual Rate</th><th>Maximum
Annual Rate</th><th>Minimum
Launch Interval per
Integrated Stack Type</th></tr>
<tr><td>ISS</td><td colspan="2">2</td><td>6</td><td rowspan="3">45 days</td></tr>
<tr><td rowspan="2">ISS/Lunar</td><td>ISS</td><td>2</td><td rowspan="2">6</td></tr>
<tr><td>Lunar</td><td>2</td></tr>
<tr><td>Lunar</td><td colspan="2">2</td><td>3</td><td>45 days
(TBR-001-240)</td></tr>
<tr><td>Mars</td><td colspan="2">1 / 26 months
(TBR-001-241)</td><td>1 / 26 months
(TBR-001-241)</td><td>26 months
(TBR-001-242)</td></tr>
<tr><td>Mars Cargo</td><td colspan="2">2 / 26 months
(TBR-001-1434)</td><td>2 / 26 months
(TBR-001-1434)</td><td>26 months
(TBR-001-1435)</td></tr>
</table>

Draft [CA0047-HQ] The Constellation Architecture shall provide the capability to support human Mars missions at consecutive conjunction-class opportunities.

Rationale: Conjunction class Mars mission Earth departure opportunities occur at 26 month intervals due to Earth-Mars orbit phasing. Infrequent mission opportunities will result if this requirement is not enforced. This requirement will also drive launch rates, vehicle production rates, and operational capabilities.

Draft [CA0073-HQ] The Constellation Architecture shall provide the capability to conduct human Mars missions at any injection opportunity in the Earth-Mars synodic cycle for conjunction-class missions.

Rationale: The propulsive energy requirements for round-trip conjunction-class Mars missions can vary from opportunity to opportunity. This requirement ensures that the *transportation systems are not limited to infrequent mission opportunities. The requirement also envelopes return mission velocities. Conjunction-class missions are typified by stay times on Mars on the order of 500 Earth days, a phase angle between Earth and Mars of 180 degrees midway during the mission (hence the name "conjunction-class"), and optimum phasing for outbound and return transfers. Source: Lineberry, Edgar C., Mars Quick Trip Times, internal Lunar and Mars Exploration Program Office presentation, October 25, 1990.*

[CA0207-HQ] The Constellation Architecture shall provide for lunar surface stays of 7 days duration for Lunar Sortie missions.

Rationale: Analysis indicates that for some mission modes combined with mid-latitude landing sites, the Earth-return plane change requirements become excessive for surface durations longer than seven days. In addition, lander-based consumables become excessively massive for longer surface durations. This requirement also permits Lunar Sorties to be fully executed during lunar daylight.

Draft **[CA5289-PO]** The Constellation Architecture shall perform Lunar Outpost missions with a surface duration of at least 210 (TBR-001-039) days.

Rationale: The Lunar Outpost Crew DRM described in the CxP 70007, Constellation Design Reference Missions and Operational Concepts, baselines a continuous human presence on the lunar surface and mission intervals of two per year. As a result, the nominal outpost duration is 180 days on the lunar surface. Thirty additional days allows for overlapping of crews for handoff activities.

[CA6102-PO] The Constellation Architecture shall provide launch attempts on each of no less than four consecutive days for Ares V launches.

Rationale: This requirement reflects the need to afford a high assurance of successful launch in a given month and is based on an Ares V-launch-first mission design approach. Four days provides a balance between launch assurance and a reasonable duration for Lander consumables.

3.2.6 Architecture Definition

[CA0021-PO] The Constellation Architecture shall provide lunar surface dust mitigation.

Rationale: Based on experience during the Apollo Program, the Constellation Program Office (CxPO) recognizes that dust on the lunar surface will be especially harsh to equipment and poses a potential hazard to crewmembers, if carried inside the habitable volumes. Therefore an integrated dust management plan should be developed and allocated to the various systems to enact; this might include the crew, EVA, rovers, surface habitats, and landers. Management strategies for managing the harmful effects of lunar dust must include, but is not limited to, surface obscuration during descent, LSAM descent engine regolith transport, LSAM contamination, contamination during transfer between LSAM and Orion, Orion *contamination, surface infrastructure contamination, surface EVA suits, seals, sampling and science equipment, human exposure and human factors. Mitigation strategies may include, but are not limited to, manual cleaning operations, automated dust removal, dust immobilization, protective personal equipment, design for reliability, etc.*

Draft **[CA0022-HQ]** The Constellation Architecture shall perform lunar surface EVAs with 1, 2, 3, and 4 crewmembers.

Rationale: This requirement is meant to size systems, not to suggest operational approaches. It provides the ability to send any number of crewmembers out EVA with the remainder of the crew residing inside a habitable shirt-sleeve environment.

[CA0029-HQ] The Constellation Architecture shall provide for safe disposal of exploration assets.

Rationale: Efforts should be taken to avoid hazards to the flight crew, general public, NASA personnel, destination surface assets, destination surface environment and other flight systems upon disposal of Constellation mission hardware (e.g., LAS, EDS, SM, fairings, docking adaptors, heat shield, etc.).

[CA0039-HQ] The Constellation Architecture shall launch its US assets from within Kennedy Space Center (KSC)/Eastern Range.

Rationale: The KSC/Eastern Range is NASA's primary launch site for human space missions and is the lowest latitude contiguous Continental US (CONUS) launch site available to NASA. Additionally, the Eastern Range has substantial legacy support infrastructure in place that may be leveraged in support of Constellation missions. This requirement applies specifically to Constellation launch vehicles and spacecraft (Orion, Ares I, Ares V, LSAM). It is not intended to prohibit launch of small cargo or payloads (such as Orbital Replacement Units [ORUs]) on other available launch systems when time, cost or other circumstances are appropriate.

[CA0044-PO] The Constellation Architecture shall return to Earth to a designated U.S. coastal water landing site.

Rationale: Returning to designated U.S. coastal landing sites reduces risk and cost by minimizing necessary recovery force assets, increasing proximity to U.S. medical facilities, increasing security, and ensuring a prepared landing site free of hazards. Operational considerations may dictate landings at non-designated locations.

[CA0046-PO] The Constellation Architecture shall conduct Lunar Sortie missions so that surface stays are conducted during periods of lunar daylight.

Rationale: Initial Lunar Sortie missions will have operational lighting constraints that will drive injection window frequency, launch scrub turnaround, and element on-orbit lifetime requirements. Crew productivity during Lunar Sortie mission surface stays will be maximized during lunar daylight. Consequently, sufficient ambient light for surface activities must be present. Further, daylight conditions also aid accurate *landings and hazard avoidance. This requirement is specific to Lunar Sortie missions and does not exclude night-time operations during Lunar Outpost missions.*

[CA0121-HQ] The Constellation Architecture shall utilize an Earth Orbit Rendezvous (EOR) - Lunar Orbit Rendezvous (LOR) mission approach for crewed lunar missions.

Rationale: CxP 70007, Constellation Design Reference Missions and Operational Concepts, indicates that the crew will launch in the Orion using the Ares I and the LSAM using the Ares V during separate launches, which minimizes initial mass to Low Earth Orbit and overall mission costs while maximizing crew safety and the probability of mission success. Since the Ares V/LSAM includes the propulsion system needed for Trans-Lunar Injection, this launch strategy necessitates that Orion with the crew, and Ares V/LSAM rendezvous in Earth orbit. The docked Orion/LSAM configuration transfers to LLO. The LSAM accesses the lunar surface while Orion remains in LLO. Thus, the LSAM and Orion require a lunar orbit rendezvous when the LSAM returns from the lunar surface to transfer the crew from the LSAM to the Orion. Orion undocks from the LSAM for the return to Earth. This concept is supported by the results of NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. The EOR-LOR approach may extend the lunar architecture to future crewed missions to Mars where an EOR/Mars Orbit Rendezvous architecture is the current baseline.

[CA0181-HQ] The Constellation Architecture shall perform contingency EVA.

Rationale: A contingency EVA is one that is performed to affect the safe return of the crew and vehicle. CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), specifies a programmatic safety objective (ref. NGO CXP-O35) "to provide the capability for Contingency EVA during all practical mission phases". An inspection/corrective action task may be required to assess the condition of the vehicle and/or perform a corrective action to ensure that the vehicle is in a safe configuration for critical operations. Potential inspection/corrective action tasks will be identified as vehicle designs mature and Hazard Analysis is performed. One unique example of a contingency EVA is for the situation where Orion and LSAM have achieved a sufficient structural attachment during docking but the pressure in the vestibule between vehicles cannot be maintained. In this case, the full crew transfers externally from LSAM to Orion.

[CA0281-HQ] The Constellation Architecture shall deliver the crew for lunar surface missions with two launches consisting of one Ares V+LSAM launch and a separate Ares I+Orion launch.

Rationale: The nominal launch sequence required to support Lunar Sortie and Outpost missions will utilize separate launch systems to provide crew and cargo access to Low Earth Orbit. This approach allows the Constellation Program to establish a baseline crew transportation system that can provide crew access to Earth orbit in support of both near term and long term Exploration Vision goals. Lunar Outpost missions will require additional Ares V launches to deliver uncrewed *cargo to the lunar surface. This mission approach was the result of numerous trade studies and performance analyses. Exploration Systems Architecture Study (ESAS) determined that a single Ares V launch represents the best balance of performance, cost and risk trades, documented in NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study.*

Draft **[CA0287-PO]** The Constellation Architecture shall provide assets for the crewmembers to explore distances no less than 10 (TBR-001-752) km (5.4 nmi) from the landing point for Lunar Sortie missions.

Rationale: One of the objectives for lunar exploration on Lunar Sortie missions is to observe as many different rock types, regolith characteristics, and natural resources as possible. Apollo surface missions demonstrated that a greater variety of samples and observations resulted as the crewmembers traveled further from the lunar excursion module. These explorations are constrained by the present proven maximum safe walk back distance for a suited crewmember of 10 (TBR-001-752) km (5.4 nmi).

[CA0316-PO] The Constellation Architecture shall provide a common docking mechanism.

Rationale: Provides common docking tolerances for final docking between Constellation systems such that system reliability and confidence is increased. The common docking mechanism does not necessarily apply to ISS or other external systems. The docking mechanism will be provided as Government Furnished Equipment (GFE) to the systems.

Draft **[CA0353-PO]** The Constellation Architecture shall be capable of utilizing pre-deployed surface infrastructure.

Rationale: The Constellation Architecture elements will be able to utilize functionality contained within pre-deployed infrastructure to meet outpost mission requirements. Predeployed mission assets could include surface infrastructure such as habitats, power systems, in-situ resource utilization equipment, exploration elements, and landing navigation beacons.

Draft **[CA0405-HQ]** The Constellation Architecture shall utilize a single cargo launch per Lunar Outpost crew rotation mission.

Rationale: Mission approach was the result of numerous trade studies and performance analysis. Single cargo launch that is separate from the crew launch, per crew rotation mission represents the best balance of performance, cost and risk trades.

Draft **[CA0407-PO]** The Constellation Architecture shall provide mobility assets on the lunar surface for crewmembers to traverse distances no less than (TBD-001-013) km from the outpost for Lunar Outpost missions.

Rationale: Exploration of the surface of the Moon is an essential function of the Vision for Space Exploration. The surface mobility strategy for outpost missions is still in development and will probably include combinations of EVA suits, unpressurized rovers, and pressurized rovers. In addition, the hub and spoke outpost strategy (see DRM description for lunar outpost) can extend the effective exploration range for the astronauts while still satisfying safety (walk back) requirements, thus the range for outpost missions is currently undefined.

Draft **[CA0465-HQ]** The Constellation Architecture shall perform Martian Surface EVA.

Rationale: Identifies the need for crews to have the capability to leave the vehicle to perform activities related to accomplishing mission objectives.

[CA3175-PO] The Constellation Architecture shall perform unscheduled EVA.

Rationale: An unscheduled EVA, while not part of the pre-mission plan, is performed to achieve and/or enhance mission objectives. As stated in CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), "one aspect of increasing crew survival and mission success is to give the crew the ability to access as much of the transportation system as possible." An EVA inspection/corrective action task may be required to assess the condition of the vehicle and/or to perform a corrective action to ensure that the vehicle is capable of carrying out mission objectives. Potential inspection/corrective action tasks will be identified as vehicle designs mature and approved by the program on a case by case basis. One possible example of an inspection/corrective action for Orion would be to either confirm or effect full deployment of a solar array. Another example may be to inspect for and remove Foreign Object Debris (FOD) in the docking interface to enable docking between Orion and LSAM/EDS in LEO to allow a lunar mission to continue.

[CA3184-PO] The Constellation Architecture shall perform each ISS mission utilizing a single launch.

Rationale: This requirement establishes the mission type for the Constellation Architecture in accordance with the ISS DRM.

Draft **[CA3211-PO]** The Constellation Architecture shall utilize a direct insertion mission approach for Cargo Lunar Missions.

Rationale: Establishes the cargo-delivery method for Lunar cargo Missions. NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study, showed that an alternate, cargo-only configuration was the most effective way to use Constellation Systems to deliver cargo for lunar missions. Larger cargo components can be delivered by removing the ascent stage used on crew missions and other components.

Draft **[CA3214-HQ]** The Constellation Architecture shall utilize Ares V to launch cargo into a (TBD-001-072) Earth orbit for Mars missions.

Rationale: Establishes Ares V as the launch vehicle for cargo flights in support of Mars missions. This requirement is present in order to assess impacts of Mars mission requirements on Ares V design solutions.

Draft **[CA5247-PO]** The Constellation Architecture shall utilize the Ares V to launch LSAM for Lunar Outpost Cargo missions.

Rationale: Establishes LSAM as the cargo-delivery method for Lunar Outpost and Ares V as the launch vehicle for the Lunar Cargo Mission. NASA-TM-2005-214062, Exploration Systems Architecture Study (ESAS), showed that an alternate, cargo-only configuration of LSAM on a single Ares V launch is the most effective way to use Constellation Systems to deliver cargo for Lunar Outpost missions. Larger cargo components can be delivered by LSAM by removing the ascent stage used on crew missions and other components.

3.2.7 Safety (System, Public, and Planetary)

[CA0100-HQ] The Constellation Architecture shall comply with NPR 8715.5, Range Safety Program, Preface and Sections 1.1-1.2, 1.3.7, 1.4, 2.1, 2.3-2.4, 3.1-3.2, 3.3-3.4, and Appendix A (TBD-001-263).

Rationale: Safety of the public, ground personnel and property is imperative. NPR 8715.5, Range Safety Program, provides risk guidelines, a process and methodology of calculating Expectation of Casualty (Ec), Probability of Casualty (Pc), and Probability of Impact (Pi), and a process for accepting risk levels above the guidelines. The Entry and Launch Constellation Range Safety Panels, chartered via CxPMD-018 and CxPMD-003 (see CxP 70070-ANX01, Constellation Program, Program Management Plan, Annex 1: Boards and Panels Structure), have responsibility for implementing applicable sections of NPR 8715.5 for the Constellation Program. The selected (tailored) sections of the NPR also address tailoring of the host ranges' range safety requirements (such as AFSPCMAN 91-710, Range Safety User Requirements Manual) for CxP.

[CA0213-PO] The Constellation Architecture shall control critical hazards. The hazards must be identified and controlled using the hazard identification and mitigation process described in CxP 70038, Constellation Program Hazard Analyses Methodology. The hazards must be controlled without the use of EVA, emergency operations or emergency systems.

Rationale: Control of mission critical failures is dictated by programmatic decision to ensure mission success. The Constellation Program will define hazard controls that may include failure tolerance. The Constellation Program will derive the specific hazard controls and implementation from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

[CA0214-PO] The Constellation Architecture shall control hazards that can lead to catastrophic events with no less than single failure tolerance, except for areas approved to use Design for Minimum Risk. The level of failure tolerance must be determined using the hazard identification and mitigation process described in CxP 70038, Constellation Program Hazard Analyses Methodology. The failure tolerance requirement cannot be satisfied by use of EVA, emergency operations or emergency systems.

Rationale: The Constellation Program has established a minimum of single failure tolerance or DFMR to control catastrophic hazards. However, single failure tolerance may not be adequate in all instances to control catastrophic hazards. Thus, the level of failure tolerance needed is commensurate with the severity of the hazard, and likelihood of occurrence. The Constellation Program will derive the specific level of failure tolerance and implementation (similar or dissimilar redundancy, backup systems) from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

[CA0215-PO] The Constellation Architecture System shall comply with the requirement in JPR 8080.5, JSC Design and Procedural Standards, Section G-2.

Rationale: Fault tolerance is defeated if a single event can eliminate all modes of tolerance. This requirement mandates separation of redundant systems, subsystems, and elements.

[CA0569-PO] The Constellation Architecture shall dispose of expendable modules and other orbital debris in accordance with NPR 8715.6, NASA Procedural Requirements for Limiting Orbital Debris.

Rationale: The Constellation Architecture will jettison several objects during nominal and contingency scenarios (e.g., docking adaptors, EDS, LSAM, SM, heat shield, etc.) that will or could (in certain abort scenarios) either remain in Low-Earth Orbit or impact Earth's surface. The historical practice of abandoning spacecraft and upper stages at the end of mission life has allowed roughly 2 million kg of debris to accumulate in orbit. If this practice continues, collisions between these objects will, within the next 50 years, become a major source of small debris, posing a threat to space operations that is virtually impossible to control. The most effective means for preventing future collisions is to require that all spacecraft and upper stages be removed from the environment in a timely manner. Such a requirement, however, would entail great cost in many cases, and there are regions of space where, for the immediate future, disposal of these systems could be made without creating a significant risk to future users. As a result, a variety of disposal options are presented in the NPR 8715.6, NASA Procedural Requirements for Limiting Orbital Debris process. These options represent an effective method for controlling growth of the environment while limiting the cost impact on future programs.

[CA5812-HQ] The Constellation Architecture shall implement GPS metric tracking for ascent flight operations per tailored GPS Metric Tracking System requirements documented in CxP 70155-02 and CxP 70115-03, Constellation Program Tailored Range Safety Requirements, Volume 2: Ares I and Volume 3: Ares V.

Rationale: To comply with future Launch Range Modernization objectives, NASA plans to include GPS metric tracking as a range tracking source for Constellation launch vehicles that will launch after 2010, with the understanding that the Eastern Range will make GPS metric tracking a standard part of the range infrastructure with which those NASA vehicles will interface (per Space Partnership Council, May 25, 2006 and Michael O'Brien memo to Secretary Sega of 9/8/2006). Specific range requirements on the GPS Metric Tracking System will be documented in CxP 70155-02 and CxP 70155-03, Constellation Program Tailored Range Safety Requirements, Volume 2: Ares I and Volume 3: Ares V.

[CA6041-PO] The Constellation Architecture shall maintain a safe configuration without the need for ground and crew interaction for no less than 24 hours during quiescent flight mission phases following a single failure of any safety and mission critical function.

Rationale: A robust architecture capable of maintaining a safe configuration after a single failure without immediate ground or crew action has the potential to reduce operations life cycle costs. This requirement covers quiescent flight mission phases, and does not include dynamic phases (e.g., ascent, proximity and docking operations, entry and post-landing). Maintaining a safe configuration means re-instating inhibits against a hazardous condition, if needed, and remaining in a non-hazardous condition.

[CA6106-PO] Constellation Architecture shall capture mission data essential for reconstruction of catastrophic events.

Rationale: Constellation program events and activities, such as lunar landing, scheduled EVAs, or crew communications and conferences, are of national importance and historic importance, and interest, and it is the responsibility of NASA, per the Space Act of 1958, to distribute this information to the public and the NASA Authorization Act of 2005. In addition, this meets the goals of the Constellation program of promoting public participation, CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-G14], and to effectively communicate the benefits of exploration to the public, CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O08]. The audio and video systems shall be integrated in order to facilitate synchronized imagery to the ground and reduce crew and timeline impacts on operational setup and implementation, during events. From a technical view, CxPO wants the capability to provide audio / motion imagery prior to lunar orbit, but may operationally not use this capability depending on Lander checkout timelines. Lunar ascent and re-docking to Orion is required due to fact that there will be no crewmember in the Orion during this phase of flight to support imaging of re-docking activities. This data will be transmitted to Mission Systems using the Space Network during LEO operations and using the Deep Space Network(possibly with lunar relay support) when operating beyond LEO. Based on the Federal Communications

Commission's planned transition to a digital television standard by the end of 2009, the majority of US household will be High Definition capable, thus becoming the defacto television standard, by the time this vehicle is scheduled to fly.

3.2.8 Command and Control

[CA0449-PO] The Constellation Architecture shall provide command and control of systems per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification.

Rationale: The crew and ground need to be able to command and control exploration systems during all phases of flight (within the comm. constraints) in order to safely and effectively accomplish Constellation mission objectives. The interoperability specification provides this common mechanism. Note that callout of industry and international standards are included in this specification.

[CA5604-PO] The Constellation Architecture shall perform concurrent in-space vehicle operations.

Rationale: The Cx architecture must manage its systems in a manner consistent with established flight rates, intervals, durations, and per approved manifests. This may lead to overlapping missions in different mission classes (i.e. ISS and Lunar). A guiding premise is that whenever a crew is in space, at the ISS or on the lunar surface, there are always accompanying the crews an adequate complement of Earth return vehicles that can be activated – quiescent docked Orion vehicle at ISS, quiescent Orion in LLO with active LLV on the lunar surface. The Mission Systems are sized for nominal concurrent vehicle complements with operating margin and sharing built into nominal resources to monitor and control low probability contingency situations. This requires the ability to efficiently manage multiple missions and flight systems concurrently and to uniquely and unambiguously identify and control the individual vehicles. CA0036-HQ establishes mission rates, intervals and overlapping mission classes, from which the needs for concurrent operations of multiple vehicles are derived. This requirement establishes requirements that each system will need to reflect based on their assessment of its implications. Performing concurrent operations of multiple vehicles (e.g. Orion and LLV for lunar missions or multiple Orions during ISS missions) in multiple locations (i.e., Earth Orbit, lunar orbit, lunar surface and in transit) drives facility, staffing and infrastructure resources that must be determined at the system level, but integrated at the architecture level. This requirement (CA5604-PO) does not address parallel ground processing of vehicles, and pre-flight operations preparations.

3.2.9 Health and Status

[CA0216-PO] The Constellation Architecture shall provide fault detection, isolation and recovery.

Rationale: NPR 8705.2, Human-Rating Requirements for Space Systems, mandates FDIR for faults of human-rated systems that affect critical functions. FDIR is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault detection enables crew abort or flight termination (in case of non-recoverable failures). Fault isolation further enables common-mode failure identification, in-flight maintenance and fleet supportability.

[CA0217-PO] The Constellation Architecture shall provide Health and Status information to the Constellation Systems and crew.

Rationale: Health and Status encompasses many classes of information such as subsystem status, flight performance, and caution and warning. This information needs to be shared between Constellation elements to ensure crew safety and mission success.

[CA6050-PO] The Constellation Architecture shall monitor the status of safety inhibits associated with functions whose inadvertent operation has catastrophic hazard potential.

Rationale: Knowledge of the status of safety inhibits will allow flight and/or ground crew to make operational decisions based on the that information. A safety inhibit is a design feature that provides a physical interruption between an energy source and a function, such as a relay or transistor between a battery and a pyro initiator, or a latch valve between a propellant tank and a thruster. An integrated analysis is used to determine whether direct or indirect (inferential) monitoring is most appropriate, and the appropriate sampling rate.

3.2.9.1 Inhibit Monitoring Reliability

[CA6051-PO] Monitoring the status of a safety inhibits shall not reduce the reliability of the inhibit or compromise the safety of the function being monitored.

Rationale: The effect of monitoring should not present new hazards, for example, by introducing leak paths or sneak circuits.

3.2.10 Communications and Communications Security

[CA0296-HQ] The Constellation Architecture shall communicate between systems per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification.

Rationale: Communication is essential to successful mission execution. Communication between systems is necessary for accomplishment of all mission objectives and includes data, voice, and motion imagery. The Constellation Architecture Communication Interactions table identifies the communication interactions between systems of the Constellation Architecture by performance range and link class. Requirements for specific communication links between systems are captured in the system-to-system Interface Requirements Documents

(IRDs). Link classes are defined in the CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification, and include the Radio Frequency (RF) Operational Point to Point, RF High Rate Point to Point, RF Contingency Voice, RF Recovery and Hardline classes.

TABLE 3.2.10-1 CONSTELLATION ARCHITECTURE COMMUNICATION INTERACTIONS

	Orion	LSAM	EVA	DSS	Ares I	Ares V	ISS	GS	MS	C&T	FCE
Orion	RFCV (30 (TBR-001-753) km)	Hardline (Direct) RFOP2P (800 (TBR-001-990) km) RFCV (30 (TBR-001-991) km)	Hardline (Umbi)	RFOP2P (800 (TBR-001-992) km) RFCV (800 (TBR-001-993) km)	Hardline (Direct)	N/A	Hardline (Direct) RFOP2P (800 (TBR-001-994) km) RFCV (30 (TBR-001-995) km)	Hardline (Direct) Recovery (10 (TBR-001-996) km)	N/A (via C&T)	RFOP2P RFHRP2P RFCV	(TBD-001-1312)
LSAM		Hardline (Umbi) RFPMP (10 (TBR-001-997) km) RFCV (30 (TBR-001-998) km)	Hardline (Umbi) RFPMP (10 (TBR-001-999) km) RFCV (10 (TBR-001-1000) km)	Hardline (Direct) RFPMP (10 (TBR-001-1001 km) RFOP2P (800 (TBR-001-1002) km) RFCV (800 (TBR-001-1004) km)	N/A	Hardline (Direct)	N/A	Hardline (Direct)	N/A (via C&T)	RFOP2P RFHRP2P RFCV	(TBD-001-1312)
EVA			Hardline (Umbi) RFPMP (10 (TBR-001-1005) km) RFCV (10 (TBR-001-1007)	Hardline (Umbi) RFPMP (10 (TBR-001-1008) km) RFCV (10 (TBR-001-1009)	N/A	N/A	N/A	Hardline (Direct)	N/A (via C&T)	N/A	(TBD-001-1312)

	Orion	LSAM	EVA	DSS	Ares I	Ares V	ISS	GS	MS	C&T	FCE
			km)	km)							
DSS				Hardline (Umbi) RFPMP (10 (TBR-001-1010) km) RFCV (10 9TBR-001-1011) km)	N/A	Hardline (Direct)	N/A	Hardline (Direct)	N/A (via C&T)	RFOP2P RFHRP2P RFCV	(TBD-001-1312)
Ares I					N/A	N/A	N/A	Hardline (Direct)	N/A (via C&T)	RFOP2P	(TBD-001-1312)
Ares V						N/A	N/A	Hardline (Direct)	N/A (via C&T)	RFOP2P	(TBD-001-1312)
ISS							N/A	N/A	N/A (via C&T)	N/A - Outside Cx Program	(TBD-001-1312)
GS								N/A	N/A (via C&T)	Hardline (Direct) (NISN)	(TBD-001-1312)
MS									N/A (via C&T)	Hardline (Direct) (NISN)	(TBD-001-1312)
C&T										N/A	(TBD-001-1312)

[CA0476-PO] The Constellation Architecture shall simultaneously communicate between at least six systems during ISS operations.

Rationale: During ISS phase missions the driving scenario for simultaneous communications occurs during pre-launch/launch activities: six systems include MS, GS, Ares I, Orion, and a provision for two test paths.

[CA0993-PO] The Constellation Architecture shall record system-generated digital data.

Rationale: Data recording is required through all stages of the life cycle of data, from generation to downlink to archival. System-generated data includes Health and Status data, mission and safety critical data, commands, voice, video and any other data generated by one of the Constellation systems. Data is recorded for a number of purposes: for use in real-time by various applications, for evaluation of historical performance in order to effectively utilize and benefit from past and current experiences and develop lessons learned per CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O40], and to reconstruct events after a failure. Recording data onboard flight vehicles for later downlink facilitates troubleshooting issues that occur during communication outages. Recording and archiving data on the ground facilitates long-term trending and incorporation of lessons learned.

[CA3007-PO] The Constellation Architecture shall provide data reconfiguration.

Rationale: Different phases of flight development and execution will require different configurations of the software and data associated with Constellation systems in order to achieve mission objectives. Data to be reconfigured includes stored commands, onboard automated sequences, procedures and files, changes to software constants and variables, telemetry downlink configuration details, changes to any parameters associated with individual instances of system hardware or hardware health and changes to any parameters associated with operational philosophy. System data must be configurable in real-time in order to respond to changes brought on by failures, changes in the space environment or changes to mission objectives. Historical experience shows that when a system's software configuration is not modifiable by other systems, there is a significant increase in life cycle costs per CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O11] and an increase in the burden on ground and mission operation support of system operation through the need to develop operational "work-arounds" due to software configuration deficiencies per CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O34]. Software variable changes in previous vehicle architectures have required re-delivery of flight software driving overall programmatic cost throughout the life cycle.

[CA3021-PO] The Constellation Architecture shall provide access to system digital data per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification.

Rationale: The digital data of every system must be accessible to every other system, as applicable, CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-G07, CxP-G08] in order to ensure adequate communication during vehicle development as well as mission development and execution. Systems will produce and require access to many different types of data, some examples are: vehicle system descriptions and *specifications, test and flight telemetry and commands, telemetry and command description information, vehicle software, telemetry system configuration files, self-test and System-generated test data, and vehicle software configuration files. Access to system digital data is critical to the maintenance, sustenance and ability to upgrade each Constellation system [CxP-O05]. In order to fully illuminate lessons learned, flight and test data must be accessed to make it available for examination [CxP-O40].*

[CA3043-PO] The Constellation Architecture shall have a Packet Loss Rate (PLR) of not greater than 1 E-5 (TBR-001-105) given 1500 byte packets (TBR-001-105) for end-to-end communications.

Rationale: Internet Protocol (IP) based communications requires well defined end-to-end communication performance. Constellation communications concepts are based on multi-hop, packet switched, routed communication paths between systems. It is necessary to specify performance of the entire path from source to destination rather than hop-by-hop to ensure reliable data delivery. This packet loss number is determined based on IDAC2, TDS SIG-13-201.

[CA3051-PO] The Constellation Architecture shall implement multi-hop communications between Systems.

Rationale: Not all Systems that need to communicate will be directly connected (e.g. the target system for a command may be behind the Moon as viewed from the Earth; missions operations will need to communicate with in-space systems via Communication and Tracking Networks). This requirement ensures that systems can use other systems as intermediate relays to establish communications that would otherwise not be possible.

[CA5065-PO] The Constellation Architecture shall provide audio and high resolution motion imagery for distribution to the public.

Rationale: Constellation program events, such as Earth ascent, lunar landing, Orion/LSAM rendezvous, and all scheduled EVAs are of national importance and must be documented as recorded or real-time motion imagery and audio. Meeting the program goal of promoting public participation CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-G14], and the objective to effectively communicate the benefits of exploration to the public CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O08], dictates the employment of motion imagery and audio technology commensurate with the magnitude of the program events. High resolution motion imagery during ascent can be satisfied with ground-based assets rather than spacecraft assets for distribution to the public. High resolution motion imagery is defined in (TBD-001-1404) document. This requirement is further sub-allocated to various Constellation systems dependent on flight phase and mission events.

[CA5817-PO] The Constellation Architecture shall ensure the privacy of all crew Health and Status data.

Rationale: Provisions of the Privacy Act of 1974, as amended, as regarding control of records, information exchange, and release of crewmember health information to the public will be strictly followed. Communications pertaining to an individual's health care will be private as regulated by the controls, regulations, provisions, and penalties of the Privacy Act of 1974.

[CA5820-PO] The Constellation Architecture shall provide imagery of mission critical and safety related events.

Rationale: Imagery (motion and still) is an essential tool for evaluating nominal and off-nominal mission operations, for engineering analysis, and for verifying the health and safety of the crew and vehicle. Imagery of stage separations, heat shield, solar panels, antenna deployments and docking mechanisms are examples of mission and safety critical mechanisms that affect mission success. Imagery of crewmembers, especially during EVA, is also extremely valuable to both safety and mission success. Imagery options include external, internal and remote sources.

[CA5821-PO] The Constellation Architecture shall distribute mission data to authorized external entities.

Rationale: Among the high level Program goals and objectives are to "Promote intra-agency, inter-agency, international, commercial, scientific community, and public participation in exploration to further U.S. scientific, security, and economic interests" CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-G14] and to "Effectively communicate the benefits of exploration to the public and key stakeholders," CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O08]. The exchange of selected mission data is necessary to satisfy these goals. Also, MS must distribute data to external entities as defined by CxP 700025 Constellation Program Functional Analysis Document [ACON.2.15.8.2] which states that "MS provides for distribution of mission data, and vehicle data to international participants, data to principal investigator organizations; real-time and non-real-time engineering support facilities; public affairs organizations; universities, other government agencies." "External entities" include the public, news media, academic institutions, governments, and scientists.

[CA6065-PO] The Constellation Architecture shall simultaneously communicate between at least (TBD-001-1313) systems during lunar phase operations.

Rationale: The Constellation Architecture must be sized appropriately to support the maximum number of simultaneously communicating systems. This size drives Program and Agency investment in infrastructure. Communication paths must be provisioned for test operations involving operational flight systems using the end-to end Constellation Architecture network. The number of systems requiring simultaneous communications is determined by the Constellation Concept of Operations and Functional Flow Block Diagram (FFBD) analysis. The number of simultaneous systems will be obtained from the driving scenarios developed in *lunar-phase CONOPs work based on the results of a study planned for Integrated Design Analysis Cycle IDAC-4.*

[CA6105-PO] The Constellation Architecture shall perform ascent flight operations using space-based communications and tracking infrastructure, and ground-based C-band radars.

Rationale: Reducing required investments in dedicated ground based tracking and communications sites will streamline operations and is intended to reduce CxPO life cycle costs. Space-based communications infrastructure includes the Space Network (TDRSS). Space-based tracking infrastructure includes the space network, GPS, and onboard sensors. Orion and Ares data necessary for controlling ascent flight operations are transmitted from Orion to the SN on a functional "Mission Operations Link" (MOL) and subsequently forwarded to the MCC, where it may be further disseminated to other ground-based destinations such as the ROCC. NASA and DoD C-bands provide independent navigational assessment for Range Safety operations. No other ground stations are necessary for supporting flight operations. This requirement does not address Development Flight Instrumentation (DFI) which is considered a separate system for collection, storage, and transmission of additional engineering flight data.

[CA6210-PO] The Constellation Architecture shall communicate with an end-to-end latency of not greater than that shown in Communication End-to-End Latency Table.

*Rationale: Maximum end-to-end latencies are essential to ensure the performance of information paths across multiple systems. Information latencies are critical to certain operations and phases of flight, including, but not limited to ascent abort notifications and range safety decision making. End-to-end latency is the time from the instant that an event is detected until the instant that the resulting information is displayed, processed, or acted upon at its final destination. These values are "as specified" at the ISTIM and will be updated by an IDAC4/ODAC2 TDS. *The end-to-end value includes free space propagation time of (TBD-001-1507) seconds.*

TABLE 3.2.10-2 COMMUNICATION END-TO-END LATENCY TABLE

	Range Safety	Launch/Ascent Voice	Launch/ Ascent CMD
Cx End-to-End	3.1s * (TBR-001-1436)	2.7s* (TBR-001-1437)	2.7s* (TBR-001-1438)
Ares	0.25 s (TBR-001-1439)	N/A	N/A
Orion	1 sec (TBR-001-1440)	1 sec (TBR-001-1441)	1 sec (TBR-001-1442)
CTN	1.225 s (TBR-001-1443)	1.225s (TBR-001-1444)	1.225s (TBR-001-1445)
MS	0.35s (TBR-001-1446)	0.35s (TBR-001-1447)	0.35s (TBR-001-1448)
GS/NISN to USAF	0.12 s (TBR-001-1449)	N/A	N/A

3.2.11 Guidance, Navigation, and Control

[CA0314-PO] The Constellation Architecture shall perform RPODU independent of lighting conditions.

Rationale: This requirement preserves mission flexibility to rendezvous and dock between Systems during any part of the orbit. This also supports anytime abort from the lunar surface.

Given the state of relative navigation sensor technology, it is expected that Systems can incorporate sensors or suites of sensors which enable the Systems to meet this requirement. This does not necessarily dictate that each individual sensor must be capable of operating in any lighting condition.

Some lighting conditions (e.g. sun within sensor or crew field of view) may require closing rate decrease, null, or even temporary backout during proximity operations to ensure a safe trajectory during periods of degraded navigation, however, a proximity operations abort is not required. This requirement is applicable in both Earth and lunar orbits.

Draft [CA0356-PO] Constellation Architecture systems shall land within 100 (TBR-001-012) m (328 ft) of a designated landing point on the lunar surface for Lunar Outpost Missions.

Rationale: The specified "precision" landing accuracy satisfies Constellation Program objectives for outpost missions in which a lander must be positioned more precisely on the lunar surface, for example to enable landing relative to other pre-positioned assets. A well characterized landing site is assumed. This requirement addresses the location of the actual touchdown point with respect to the pre-mission planned touchdown point on the lunar surface, which implies a portion of the accuracy is allocated to map-tie error. (TBR-001-012) reflects uncertainty in the actual required precision landing accuracy as well as the allocation of landing accuracy performance between the lander, Mission Systems, and possible in-situ navigation aids. The (TBR-001-012) will be removed upon further analysis and pending additional program-level direction regarding lunar surface mission objectives.

Draft [CA0529-PO] The Constellation Architecture systems shall land within 1 (TBR-001-044) km (.54 nmi) of a designated landing point on the lunar surface for Lunar Sortie Missions.

Rationale: The specified "coarse" landing accuracy satisfies Constellation Program objectives for landing safely near the desired exploration site. Furthermore this accuracy is assumed to be achievable with navigation techniques demonstrated on Apollo missions, without the use of pre-positioned lunar infrastructure or extensive reconnaissance of potential landing sites. This requirement addresses the location of the actual touchdown point with respect to the pre-mission planned touchdown point on the lunar surface, which implies a portion of the accuracy is allocated to map-tie error. (TBR-001-044) reflects uncertainty in the specific lunar sortie mission objectives, and the corresponding landing accuracy required to achieve them. The accuracy could be improved in order to reach a wider range of scientifically *interesting sites; and the (TBR-001-044) will be removed upon additional program-level direction regarding lunar surface mission objectives.*

Draft [CA0826-PO] The Constellation Architecture shall determine EVA crew and rover location to within (TBD-001-097) m (ft) and within a latency of (TBD-001-187) minutes during lunar surface operations.

Rationale: Location of EVA crewmembers and lunar rovers is necessary to navigate to EVA sites and return to lander safely. A latency is required to limit the time available to perform the navigation so as not to unnecessarily constrain surface operations. Trade study TDS 12-2 has been commissioned to determine the TBD value.

Draft [CA3141-PO] The Constellation Architecture shall determine stationary element location anywhere on the lunar surface to within (TBD-001-068) m ((TBD-001-068) ft) with 95% probability.

Rationale: Determining the location of stationary, landed elements on the lunar surface is essential to enable surface mobility activities, subsequent precision landings, and to provide a navigational tie between surface landmarks and the lunar reference frame. This requirement pertains to landed elements such as LSAM and DSS and not to subsequently deployed entities such as rovers and EVA crew. Accuracy requirement may be different for landing sites with and without direct line-of-site visibility to the Earth. Trade study TDS 12-2 has been commissioned to determine the (TBD-001-068) value (may be a table of values).

[CA5601-PO] The Constellation Architecture shall provide onboard manual control of flight path, attitude, and attitude rates of crewed systems when the human can operate the system within vehicle margins.

Rationale: This requirement flows down from NPR 8705.2, Human-Rating Requirements for Space Systems. Manual control of spacecraft attitude, attitude rate and flight path provides additional margin for mission success and crew safety. On-going studies will determine the flight regimes for which this capability will be operationally utilized.

[CA5602-PO] The Constellation Architecture shall perform RPODU independent of ground overflight constraints.

Rationale: Independence from the need to perform critical events within view of a ground station increases the flexibility of where and when RPODU operations can be conducted.

3.2.12 Reliability and Availability

[CA0037-PO] The Constellation Architecture shall be prepared to support launch attempts within 6 days following a missed TLI opportunity.

Rationale: It is important to provide the capability to recycle the vehicles and mission elements in time to meet the next TLI window in the event of a missed window. The

TLI windows are typically six hours long and occur approximately every 10 days once the initial launch occurs. Since four launch attempts per window are maintained [CA00125-PO], the first attempt for the second TLI window occurs six days after the fourth attempt for the first TLI window. Redesignating to backup lunar landing sites may be necessary to maintain acceptable sortie lighting conditions [CA0046-PO]. Recycle capability should include limited corrective maintenance actions as well as recycle from a weather delay.

[CA0038-HQ] The Constellation Architecture shall provide an initial launch opportunity of the Ares I no later than 90 minutes after launch of the Ares V.

Rationale: A short interval following the first launch increases the probability that vehicle systems, ground infrastructure and weather will support an on-time second launch. Intervals of approximately ninety minutes (about one orbit period) or less allow for favorable rendezvous phasing without large ascent performance penalties.

[CA0040-PO] The Constellation Architecture shall provide the capability to launch flight systems independent of ambient lighting conditions.

Rationale: Use of night time launch windows greatly increases the opportunities for launch to a successful rendezvous orbit. Launch windows to rendezvous with an object already in space frequently fall in darkness. For example, about 40% of the launch opportunities to the International Space Station occur in darkness when assessed over a one year period.

[CA0071-PO] The Constellation Architecture shall remain in a launch ready state as specified in the System Launch Readiness Table.

Rationale: This requirement addresses each system's ability to remain in a final launch ready state beginning with the terminal count (where the vehicle onboard systems are commanded to a flight status and the on-board systems assume primary processing functions for launch commands and other systems are ready to transition from Ground System provided services to vehicle provided services) through the end of the Launch Window. This represents a time where no additional servicing or reconfiguration is required to support launch (except routine services nominally kept through T-0) regardless of the actual launch window determined from orbital mechanics. The companion rendezvous launch window requirement defines the actual launch vehicle window length based on system performance including yaw steering and downrange over-flight and impact points.

TABLE 3.2.12-1 SYSTEM LAUNCH READINESS

Mission	Applicable Systems	Launch Ready State (Duration – Not Less Than)
ISS	Orion, Ares I, EVA, GS, MS, FCE (TBD-001-1312)	2 Hours
Lunar Sortie	Orion, Ares V, Ares I, EVA, GS, LSAM, MS, FCE (TBD-001-1312)	2 Hours

Lunar Outpost	Orion, Ares V, Ares I, EVA, LSAM, GS, MS, FCE (TBD-001-1312)	2 Hours
Lunar Cargo	Ares V, GS, LSAM, MS, FCE (TBD-001-1312)	4 (TBR-001-979) Hours

[CA0123-PO] The Constellation Architecture shall have a probability of crew launch of not less than 99 (TBR-001-021)% during the period beginning with the decision to load cryogenic propellants and ending at the expiration of the EDS and LSAM LEO loiter.

Rationale: A high probability of launch for the second vehicle in the launch sequence for a crewed lunar mission is critical in order to ensure successful rendezvous of the LSAM/EDS and Orion and subsequent TLI. The probability of launch is the cumulative probability that the Ares I can successfully launch over the multiple launch opportunities that are available for a given lunar mission opportunity. This requirement decomposes into other "probability of go" requirements: Orion system ready; Orion abort landing site requirements met; Ares I system ready; Ares I weather related launch constraints, and the ground systems reliability are met. This requirement is inclusive of both the probability of delay and the probable duration of such delay to perform review, repair or replacements in time to meet a specified mission opportunity. The value of 99% in this requirement is an allocation from the portion of the LOM requirement that addresses the "Probability of No Second Launch" which would expire the orbiting EDS/LSAM. The TBR will be closed during the IDAC4 cycle after the LOM requirements TBRs are removed as well as the TBRs closed for the DSNE Ascent Abort Sea State threshold for the Search and Rescue Forces.

TABLE 3.2.12-2 LAUNCH PROBABILITY AND CONTRIBUTING CONDITIONAL PROBABILITIES

	Crewed Launch	Cargo Launch
Net Probability of Launch:* *Range Safety and C&T Networks excluded	0.99 (TBR-001-021)	(TBD-001-517)
Contributing Conditional Probabilities:		
Orion hardware availability	0.98 (TBR-001-937)	(TBD-001-967)
Orion probability of meeting abort zone weather constraints	0.98 (TBR-001-938)	(TBD-001-968)
Ares I hardware availability	0.98 (TBR-001-939)	(TBD-001-969)
Ares I probability of meeting launch site weather constraints	0.95 (TBR-001-940)	N/A
MS hardware/system availability	0.999 (TBR-001-1411)	(TBD-001-970)
GS hardware/system availability	0.99 (TBR-001-1412)	(TBD-001-973)
Ares V hardware availability	N/A	(TBD-001-971)
Ares V probability of meeting launch site weather constraints	N/A	(TBD-001-972)
EVA hardware/system availability	0.999 (TBR-001-562)	N/A

	Crewed Launch	Cargo Launch
LSAM hardware availability	N/A	(TBD-001-064)
Probability of meeting Range Safety Constraints and C&T Networks Availability Constraints	0.98	0.98

[CA0125-PO] The Constellation Architecture shall provide launch attempts on each of no less than seven consecutive days for Ares I launches.

Rationale: This requirement reflects the need to afford a high assurance of crew launch in a given month and is based on an Ares V-launch-first mission design approach. Seven days protects for a lunar mission where the Ares V launches on the fourth day of its consecutive launch opportunities. This provides a balance between launch assurance and a reasonable duration for Orion consumables. This is the driving design case for Orion/Ares I/Ground Systems.

[CA5600-PO] The Constellation Architecture shall have a probability of cargo launch of not less than (TBD-001-517)% during the period beginning with the decision to load cryogenic propellants and ending 3 days after the initial planned launch attempt.

Rationale: A high probability of launch for both vehicles for the lunar mission is required to ensure sustainable exploration architecture. The period time desired for launch is driven by a balance of range considerations, lunar lighting conditions, and ground/crew personnel limitations. This requirement decomposes into other "probability of go" requirements: Ares V system ready, LSAM system ready, Ares I weather related launch constraints, and the ground systems reliability are met.

3.2.13 Maintainability, Supportability, and Logistics

In addition to the requirements contained in this section, more detailed maintenance-related requirements, including specific design requirements and definition of common tools, can be found in CxP 70024, Constellation Program Human-System Integration Requirements (HSIR) document.

Draft **[CA0550-PO]** The Constellation Architecture shall be maintainable during each design reference mission within the limits of the maintenance resources shown in the Maintenance Resources table.

Rationale: System hardware designs must enable implementation of maintenance concepts that meet constrained resources. Maintenance resources include spares, tools, support equipment (with limits defined by mass and volume), and crew time. The appropriate balance of these resources will differ between reference missions. Therefore, system designs must accommodate the range of maintenance concepts and resource constraints.

TABLE 3.2.13-1 MAINTENANCE RESOURCES

	Mass (kg)	Volume (m^3)	Crew Time (hours)
Lunar Outpost	(TBD-001-977)	(TBD-001-981)	(TBD-001-985)

Mars	(TBD-001-978)	(TBD-001-982)	(TBD-001-701)

[CA3293-PO] The Constellation Architecture shall accept software updates without requiring LRU removal.

Rationale: The ability to reprogram devices and update software is needed for maintainability. CxP 70007, Constellation Design Reference Missions and Operational Concepts, Section 4.1.3, stipulates a general approach to maintenance that includes repair of failed items. Also, Constellation Design Reference Missions and Operational Concepts Document, Section 4.1.4, indicates a preference for direct access to LRUs. Access at the LRU level reduces cost and schedule impact and improves in-flight maintenance by avoiding disassembly to obtain access. An update capability also contributes to mission success and crew safety goals. Updates can be applied in every feasible mission phase. Changes to configuration data and software are included in the scope of software updates. Firmware updates may be included where deemed feasible by Constellation projects.

[CA5814-PO] The Constellation Architecture shall be assembled at the Launch Site without deintegration of systems and elements.

Rationale: Assembly of flight systems (e.g., Orion and Ares I) and Ground Support Equipment (GSE) into flight configuration at the launch site must be achievable without expensive disassembly, reassembly, and recertification. These systems must fit together without violating physical envelopes when they are transferred to NASA ownership ("DD250'ed"). That is, assembly must be achievable with no routine de-integration of previously assembled (and certified) hardware during the flight hardware integration process.

[CA5815-PO] The Constellation Architecture shall provide access for integration of time-critical cargo components no later than 12 (TBR-001-964) hours prior to a scheduled launch.

Rationale: There will be time-critical and perishable cargo provisioning to support ISS, Lunar Sortie and Lunar Outpost missions. These items cannot be integrated into the vehicle during normal processing but must be done at the pad near to the time of launch.

[CA5935-PO] The Constellation Architecture shall include the tools required for on-orbit maintenance and reconfiguration.

Rationale: Requiring Systems to provide the tools needed for that System's planned and unplanned on-orbit maintenance encourages the tool set to be minimized to conserve mass and volume. A minimal set of tools for each System also reduces the training and support requirements for the System. Systems are encouraged to save weight and volume by establishing common tool usage with other systems during same DRM, tool lists will be managed within the framework of the commonality database.

[CA5962-PO] The Constellation Architecture systems shall remain in an integrated configuration for 100 days without the need for vehicle destacking.

Rationale: Goal is to provide operability for scenarios where remaining stacked allows flexibility in meeting downstream launch schedules. This also provides flexibility and avoids operations re-work within the integration facility to resume the launch flow in an expedited manner. The value will drive lower level system time, age and cycle requirements. Reasons for this integrated configuration period include a stand down condition and advanced vehicle stacking. The 100 days assumes a fully stacked and loaded Orion (Reference: CxP 70136-ANX01, Constellation Program Loads Data Book, Annex 1: System -to- System Interface Loads Data) and is based on one Lunar launch attempt (up to 15 days) at the pad before roll back, up to 71 days in the Vehicle Assembly Building (VAB), followed by another Lunar launch attempt (up to 14 days) at the pad for launch. Routine/preventative maintenance and periodic servicing is assumed to maintain systems in this stacked configuration including; conditioned purges, contingency fluids servicing/de-servicing, functional re-verifications, and return all expendable commodities to flight levels prior to resumption of integrated processing.

[CA5963-PO] The Constellation Architecture shall meet its requirements during and after cumulative exposure to the natural environments (given in CxP 70023, Constellation Program Design Specification for Natural Environments [DSNE]) at the launch pad for 30 (TBR-001-1108) days.

Rationale: This requirement establishes maximum exposure time to the natural environment that the integrated stack may experience. Goal is also to provide operability for scenarios where remaining stacked at the launch pad allows flexibility in meeting downstream launch schedules. This also provides flexibility and avoids operations re-work within the integration facility to resume the launch flow in an expedited manner. Reasons for this integrated configuration period include a launch scrub until the next lunar launch window.

The 30 (TBR-001-1108) days is based on two Ares V/LSAM on-orbit LEO loiter periods (each 14 days) where Ares I/Orion rolls back to the VAB in between the two Ares V launches. The DSNE would be applicable this entire period (reference CA0048-PO). Routine maintenance and periodic servicing is assumed to maintain systems in this stacked configuration.

[CA5964-PO] The Constellation Architecture shall produce Program Verified Engineering Build software and data products within the time limits identified in the Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Program Verified Engineering Build is a set of software and data products that contain new requirements (capabilities) and problem fixes. The time period starts when the software content definition is baselined and ends when the program verification/validation activities are completed. Exchanged products are *defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. Data products contain representative launch geometry values and actual values for other parameters. It has completed full Program Verification/Validation and has been configured to meet Integrated Build event requirements. Data definitions must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. Project level activities include: participation in the build content definition, software design, code, project-level integration, test and delivery of Project Verified Engineering Builds to the Program. It is assumed that tools used to support the distribution of Program Software Builds will also support the distribution of Project Software Builds.*

TABLE 3.2.13-2 TIME ALLOCATIONS FOR ENGINEERING BUILDS

Requirement	Threshold	Objective
Project (Orion, Ares I, LSAM, Ares V, EVA, GS, MS)	7 months (TBR-001-1029)	2.5 months
Constellation Program	2 months	0.5 month
Total	9 months	3 months

[CA5965-PO] The Constellation Program shall integrate and test Project Verified Engineering Builds within the time limits allocated to the Constellation Program in the Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The time period starts with the delivery of the last Project Verified Engineering Build planned for the targeted Program Verified Engineering Build and ends when the program level verification/validation activities are completed. Exchanged products are defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. The requirement is to be attained without increasing staff through efficient design of tools and test approaches as supported by the Constellation architecture. Activities include: lead the build content definition, integration of Project Verified Engineering Builds, program test and verification integration testing, and distribution of Program Verified Engineering Builds. It is assumed that tools used to support the distribution of Program Software Builds will also support the distribution of Project Software Builds.

[CA5966-PO] The Constellation Architecture shall produce Program Verified Flight Build software and data products to support the mission class within the time limits identified in Time Allocations for Flight Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Program Verified Flight Build is a set of software and data products that is based on a Program Verified Engineering Build, has mission specific (launch geometry derived) data and has completed Program Level Verification/Validation. The time period starts when the software content definition is baselined and ends when the program level verification and validation activities are completed. Exchanged products are defined in the Product Exchange Matrix. The only software changes expected are corrections of selected non-conformances. Data parameter values must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation architecture. Project level activities include: participation in the build content definition, flight specific configuration activity (data reconfiguration), corrections of non-conformances as required (using the Fast Track process), and delivery of Project Verified Flight Builds. It is assumed that tools used to support the distribution of Program Software Builds will also support the distribution of Project Software Builds. Times are contiguous days.

TABLE 3.2.13-3 TIME ALLOCATIONS FOR FLIGHT BUILDS

Requirement	Threshold	Objective
Project (Orion, Ares I, LSAM, Ares V, EVA, GS, MS)	14 days	4 days
Constellation Program	14 days	3 days
Total	28 days	7 days

[CA5967-PO] The Constellation Program shall integrate and test Project Verified Flight Builds to create a Program Verified Flight Builds to support the mission class within the time limits allocated to the Constellation Program in Time Allocations for Flight Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The time period starts with the delivery of the last Project Verified Flight Build planned of a Program Verified Flight Build and ends when the Program level verification/validation activities are completed. Exchanged products are defined in the Product Exchange Matrix. The requirement is to be attained without increasing staff through efficient design of reconfiguration as *supported by the Constellation architecture. Program level activities include: lead the build content definition, integration of Project Verified Flight Builds, program test and verification integration testing, and distribution of Program Verified Flight Builds. It is assumed that tools used to support the distribution of Program Software Builds will also support the distribution of Project Software Builds. Times are contiguous days.*

[CA5968-PO] The Constellation Architecture shall produce day of launch updates for software parameters and data products to configure the systems.

Rationale: A day of launch update is a set of software and data products based on the Program Verified Flight Build and the approved final flight parameter updates for launch day environments (winds), orbit geometry (target tracking), and other I-loads as required.

[CA5969-PO] The Constellation Program shall produce day of launch updates for software parameters and data products to configure the systems.

Rationale: A day of launch update is a set of software and data products based on the Program Verified Flight Build and the approved final flight parameter updates for launch day environments (winds), orbit geometry (target tracking), and other I-loads as required.

[CA5970-PO] The Constellation Architecture shall provide rapid resolutions for selected non-conformances during the engineering and flight build phases to the discovering organization and other Program organizations in the time limits identified in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track process is used for rapid resolution of problems found in the production of Flight Releases and Engineering Releases. The time period starts after formal documentation of the non-conformance and ends when the resolution is submitted for re-integration into the program test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. A set of Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

TABLE 3.2.13-4 TIME ALLOCATIONS FOR FAST TRACK PROCESS

Requirement	Threshold	Objective
Project (Orion, Ares I, LSAM, Ares V, EVA, GS, MS)	48 hours	12 hours
CxP	24 hours	12 hours
Total	72 hours	24 hours

[CA5971-PO] The Constellation Program shall integrate and test resolutions for selected non-conformances during the engineering and flight build phases within the time limits allocated to the Constellation Program in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track process is used for rapid resolution of problems found in the production of Flight Releases and Engineering Releases. The time period starts after formal documentation of the non-conformance resolution and ends when the resolution is re-integrated into the program test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. A set of Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

[CA5972-PO] The Constellation Program shall integrate, manage the configuration of, and distribute data and software products.

Rationale: All Constellation projects will deliver products, which will be combined into integrated product sets. The resultant product sets will be used for development, test, training and mission execution activities and must be available to all components of the program. The configurations will be managed throughout the life of the Constellation Program.

[CA5973-PO] The Constellation Architecture shall provide the infrastructure to maintain systems through their operational life cycles.

Rationale: Logistics Infrastructure enables the sustainment of safe and efficient operations. Examples of critical infrastructure elements include Inventory Management Systems for tracking program assets both in-flight and on the ground; capabilities to manage and present information necessary to support maintenance operations on ground and in flight; software and data management tools and tools and test equipment for in-flight maintenance.

[CA6002-PO] The Constellation Architecture shall conduct ground operations for a single Ares I/Orion mission within the time limits identified in the Critical Path Allocations for Ares I/Orion Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and ground system designs that result in reduced ground operations time and labor *without sacrifices to performance or design cost. The critical path constraints levied in Critical Path Allocations for Ares I/Orion Ground Operations Table, along with labor-hour constraints defined in CA6002-PO, are intended to drive the design of the flight and ground systems to enable such reductions. The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather they are intended to be a design target for the system developers.*

In Critical Path Allocations for Ares I/Orion Ground Operations Table, the Ground Operations processing flow is broken down into six sequential time periods between key processing milestones. The sum of the six time periods is the overall Critical Path anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming “single-string” for the integrated operations Ground Systems (i.e., one Ares I Mobile Launcher, one Ares I VAB high bay, one control room for Ares I operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx ground operations.

The values identified in Critical Path Allocations for Ares I/Orion Ground Operations Table are intended to apply to nominal operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy Expendable Launch Vehicle (ELV) systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.2.13-5 CRITICAL PATH ALLOCATIONS FOR ARES-I/ ORION GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Start of Ares I Stacking to Ready for Orion Integration	249 (TBR-001-1200)	228 (TBR-001-1201)	Integration of the Ares I on the ML from beginning with stacking of the First Stage Aft Booster Assembly	Ares I, GS
Ready for Orion Integration to Integrated Stack Ready for Powered Testing	55 (TBR-001-1202)	44 (TBR-001-1203)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA

Ready for Powered Testing to Finish of Powered Testing	95 (TBR-001-1204)	56 (TBR-001-1205)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares I, Orion, GS, EVA
Finish of Powered Testing to Pad Connection and Validation Complete	61 (TBR-001-1206)	38 (TBR-001-1207)	From the end of powered testing in the VAB until the vehicle is at the launch pad and ready to begin launch preps. Includes vehicle and ground system roll out preparations, roll-out, and ML-Launch pad connections and validations.	GS, Ares I, Orion
Pad Connection and Validation Complete to Launch	68 (TBR-001-1208)	68 (TBR-001-1209)	Begins once pad connections are validated and ends at T-0.	GS, Ares I, Orion, EVA
Launch to Start of Ares I Stacking	208 (TBR-001-1210)	144 (TBR-001-1211)	Refurbishment activities conducted on the ML and/or at Launch Pad. Includes those activities that must be performed on the ML prior to mating the aft booster assembly to the ML for the next flight.	GS

[CA6007-PO] The Constellation Architecture shall conduct ground operations for a single Ares V/LSAM mission within the time limits identified in the Critical Path Allocations for Ares V/LSAM Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and ground system designs that result in reduced ground operations time and labor without sacrifices to performance or design cost. The critical path constraints levied in Critical Path Allocations for Ares V/LSAM Ground Operations Table, along with labor-hour constraints defined in CA6007, are intended to drive the design of the flight and ground systems to enable such reductions.

The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather they are intended to be a design target for the system developers.

In Critical Path Allocations for Ares V/LSAM Ground Operations Table, the Ground Operations processing flow is broken down into six sequential time periods between key processing milestones. The sum of the six time periods is the overall Critical Path anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming "single-string" for the integrated operations Ground Systems (i.e., one Ares V Mobile Launcher, one Ares V VAB high bay, one control room for Ares V operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx ground operations.

The values identified in Critical Path Allocations for Ares V/LSAM Ground Operations Table are intended to apply to nominal operations only. Accordingly, the *values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.*

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy ELV systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.2.13-6 CRITICAL PATH ALLOCATIONS FOR ARES-V/ LSAM GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Start of Ares V Stacking to Ready for LSAM Integration	(TBD-001-1300)	(TBD-001-1301)	Integration of the Ares V on the ML from beginning with stacking of the First Stage Aft Booster Assembly	Ares V, GS
Ready for LSAM Integration to Integrated Stack Ready for Powered Testing	(TBD-001-1302)	(TBD-001-1303)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA
Ready for Powered Testing to Finish of Powered Testing	(TBD-001-1304)	(TBD-001-1305)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares V, LSAM, GS, EVA
Finish of Powered Testing to Pad Connection and Validation Complete	(TBD-001-1306)	(TBD-001-1307)	From the end of powered testing in the VAB until the vehicle is at the launch pad and ready to begin launch preps. Includes vehicle and ground system roll out preparations, roll-out, and ML-Launch pad connections and validations.	GS, Ares V, LSAM
Pad Connection and Validation Complete to Launch	(TBD-001-1308)	(TBD-001-1309)	Begins once pad connections are validated and ends at T-0.	GS, Ares V, LSAM, EVA
Launch to Start of Ares V Stacking	(TBD-001-1310)	(TBD-001-1311)	Refurbishment activities conducted on the ML and/or at Launch Pad. Includes those activities that must be performed on the ML prior to mating the aft booster assembly to the ML for the next flight.	GS

[CA6012-PO] The Constellation Architecture shall produce mission integration products for a single mission within the time limits identified in the Mission Integration Production Time Single Mission Constraints - ISS Table and the Mission Integration Production Time Single Mission Constraints -Lunar Table.

Rationale: The Mission Integration Production Time Single Mission Constraints - ISS Table contains the production time limits (threshold and objective values) for a single crew mission to ISS where-as the Mission Integration Production Time Single Mission Constraints - Lunar Table contains applicable and similar information for a single mission to Lunar (crewed or cargo). The Mission Integration Production Template defines an orderly mission production process beginning with the definition of a baselined set of mission requirements and the ensuing flight design, flight software (reference CA5964), ground vehicle processing (reference CA6002 for ISS and CA6007 for Lunar), flight operations documentation development, vehicle configuration, and crew and launch/flight control training activities necessary to support a mission. The training schedule assumes late crew assignment date is launch minus one year. The Constellation Program ensures the infrastructure supports a shortened template/process over legacy Shuttle Program without increasing manpower to accomplish this.

The process begins with the Cx Mission Requirements Definition (MRD) program freeze point that baselines primary mission objectives, cargo/vehicle configuration, and the launch date. The integrated mission production schedule and the cargo's commitment to joint schedule milestones are established at this time. Factors such as flight software reconfiguration and flight design processes, training, ground processing of flight systems, flight procedures and products development, ground and flight safety processes, and management of standard interfaces for flight systems cargo engineering are controlled through a combination of requirements and management processes.

TABLE 3.2.13-7 MISSION INTEGRATION PRODUCTION TIME SINGLE MISSION CONSTRAINTS - ISS

Task	System Allocation	Time Threshold (Contiguous Days)	Time Objective (Contiguous Days)
Cargo Engineering	CxP, Orion	90 (TBR-001-1095)	50 (TBR-001-1096)
Flight Design	MS	180 (TBR-001-1097)	(TBD-001-1071)
Flight Specific Training	MS	30 (TBR-001-1098)	(TBD-001-1072)
Flight Operations Products	MS	105 (TBR-001-1099)	(TBD-001-1073)
Total **		8 (TBR-001-1101) Months*	4 (TBR-001-1102) Months*

NOTES:

* Total time represents the critical path and is contiguous minus weekends/holidays and assumes 5 day/week, 8 hr/day work schedule.

** Refer to CA5964 and CA6002 for specific Software Reconfiguration and Ground Processing requirements.

TABLE 3.2.13-8 MISSION INTEGRATION PRODUCTION TIME SINGLE MISSION CONSTRAINTS - LUNAR

Task	System Allocation	Time Threshold (Contiguous Days)	Time Objective (Contiguous Days)

Cargo Engineering	CxP, Orion, LSAM	(TBD-001-1074)	(TBD-001-1075)
Flight Design	MS	(TBD-001-1076)	(TBD-001-1077)
Flight Specific Training	MS	(TBD-001-1078)	(TBD-001-1079)
Flight Operations Products	MS	(TBD-001-1080)	(TBD-001-1081)
Total **		(TBD-001-1082)*	(TBD-001-1083)*

NOTES:

* Total time represents the critical path and is contiguous minus weekends/holidays and assumes 5 day/week, 8 hr/day work schedule.

** Refer to CA5964 and CA6002 for specific Software Reconfiguration and Ground Processing requirements.

[CA6020-PO] The Constellation Architecture shall operate in any excursion attitude for at least 3 hours without exceeding thermal limits.

Rationale: Possible excursion attitudes for in-space transportation vehicles are defined as all attitudes in a 360 deg full sphere that are outside the planned mission attitudes (e.g. rendezvous and proximity operations attitudes) over the full range of Beta angles (time of year dependent). The ability to operate in excursion attitudes means that the flight systems maintain operational capability despite the excursion. This flexibility reduces the amount of preflight and real-time mission analysis required to find select attitudes for varying periods of time throughout the entire mission profile, and results in life cycle cost avoidance for ground operations and engineering teams. This requirement is focused on thermal limits because other attitude constraints such as power and communications are easily analyzed both in permission planning and in real time operations.

[CA6020-PO-Objective] The Constellation Architecture shall autonomously determine mission attitudes through all flight phases based on flight system constraints and mission reserves for lunar missions.

Rationale: Possible excursion attitudes are defined as all attitudes in a 360 deg full sphere that are outside the planned mission attitudes (e.g. rendezvous and proximity operations attitudes) over the full range of Beta angles (time of year dependent). The excursion attitude period is the period of time the flight system is in a static attitude. Whether or not that excursion period must also encompass maneuver times into and out of those attitudes is derived from flight system survivability analysis. The ability to operate in excursion attitudes means that the flight systems continues to operate during the excursion attitude period, and return to nominal operations without sustaining hardware damage after returning to the planned mission attitudes (e.g. maneuver for Public Affairs Office [PAO] event communications, maneuver to an attitude allowing photography through Orion's windows, and pointing to support a science payload's requirements). This requirement provides greater operability of the flight systems by allowing periodic attitude excursions bounded by the planned mission attitudes and provides a mechanism for attitude-related vehicle performance characterization during mission execution. Flight experience allows building attitude induced flight system *performance data and evolving to fewer flight constraints while limiting upfront attitude certification analysis costs. This flexibility reduces the amount of preflight and real-time mission analysis required to find select attitudes for varying periods of time throughout the entire mission profile, and results in life cycle cost avoidance for ground operations and engineering teams. Onboard tools for the flight crew are derived from flight data plus the certified mission attitudes; hence the attitude baseline grows with flight experience. The flight crew can select an attitude (pre-planned or off-nominal) to meet mission objectives while balancing the needs of power generation, thermal and structural protection, and communications coverage.*

[CA6022-PO] The Constellation Architecture shall provide for autonomous onboard consumables tracking and management for Lunar missions.

Rationale: Autonomous onboard consumables tracking and management moves mission execution decision-making to the flight crew, while reserving pre-mission planning decision-making to ground operators. Consumables per this requirement are limited to those resources that are consumed in the course of conducting a given mission to provide power, regulate active cooling, and include propellant, crew water, and atmospheric constituents. Gases used to regulate pressure to supply the above consumables are also included. Management of consumables means tracking usage against redlines and predicting reserves to meet upcoming mission objectives, including failure down-mode selection based on preserving crew survivability and a prioritized set of mission objectives. Autonomous consumables management reduces life cycle cost for in-flight ground operations and engineering teams while increasing operability, crew and vehicle safety, and mission success probabilities. As flight experience is gained and flight system performance better understood, addition of incremental autonomy for crewed vehicles for lunar missions will be necessary in order to meet anytime return without communications (reference CA0416-PO). This implies some level of automation for loitering vehicles while the crew is on the lunar surface. As designs are assessed to provide an automatic integrated onboard management of consumables, mission timeline, and trajectory planning for Lunar Outpost missions, additional consumables may be identified to manage via this capability.

[CA6022-PO-Objective] The Constellation Architecture shall provide for automatic integrated onboard management of consumables, mission timeline, and trajectory planning for Lunar Outpost missions.

Rationale: Autonomous onboard consumables tracking and management moves mission execution decision-making to the flight crew, while reserving pre-mission planning decision-making to ground operators. Consumables per this requirement are limited to those resources that are consumed in the course of conducting a given mission to provide power, regulate active cooling, and include propellant, crew water, and atmospheric constituents. Gases used to regulate pressure to supply the above consumables are also included. Management of consumables means tracking usage against redlines and predicting reserves to meet upcoming mission *objectives, including failure down-mode selection based on preserving crew survivability and a prioritized set of mission objectives. Autonomous consumables management reduces life cycle cost for in-flight ground operations and engineering teams while increasing operability, crew and vehicle safety, and mission success probabilities. As flight experience is gained and flight system performance better understood, addition of incremental autonomy for crewed vehicles for lunar missions will be necessary in order to meet anytime return without communications (reference CA0416-PO). This implies some level of automation for loitering vehicles while the crew is on the lunar surface. As designs are assessed to provide an automatic integrated onboard management of consumables, mission timeline, and trajectory planning for Lunar Outpost missions, additional consumables may be identified to manage via this capability.*

[CA6024-PO] The Constellation Architecture shall require no more than 2 hours per week contiguous real-time command and control (consisting of 12 (TBR-001-1105) man-hours) during nominal quiescent operations for ISS missions.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting ground commanding and control interaction with a quiescent vehicle to specific periods and specific manpower intensity under nominal quiescent operations (i.e. no Orion system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent vehicle (e.g. Orion docked to ISS) would require very little routine command interaction from ground controllers. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control manning (e.g. reduced ground controller shifts and teams). Assumption is that six dedicated operations personnel send commands (e.g. crew uplink messages, state vectors, scripts) during this active command and control period each week during initial operations capability phasing to zero dedicated operators as the objective requirement is met.

[CA6024-PO-Objective] The Constellation Architecture shall require no real-time support during quiescent operations for ISS missions.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting ground commanding and control interaction with a quiescent vehicle to specific periods and specific manpower intensity under nominal quiescent operations (i.e. no Orion system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent vehicle (e.g. Orion docked to ISS) would require very little routine command interaction from ground controllers. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control manning (e.g. reduced ground controller shifts and teams). Assumption is that 6 dedicated operations personnel send commands (e.g. crew uplink messages, state vectors, scripts) during this active command and control period each week during initial *operations capability phasing to zero dedicated operators as the objective requirement is met.*

[CA6026-PO] The Constellation Architecture shall require no more than 1 hour per day contiguous real-time active monitoring (consisting of 10 (TBR-001-1105) man-hours) during nominal quiescent operations for ISS missions.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting ground active monitoring required by a quiescent vehicle to specific periods and specific manpower intensity under nominal operating conditions (i.e. no Orion system failures) will contribute to reduced operations and sustaining engineering life cycle costs. It is expected that a quiescent vehicle (e.g. Orion docked to ISS) would require very little routine active telemetry monitoring by ground controllers. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). This requirement does not preclude the fact that Health and Status data from quiescent vehicles will be provided near continuously from the Orion for fault annunciation and trending. Ground controllers and engineering teams supporting other active vehicles (e.g. Outpost) can monitor for trends and fault annunciations as part of the active vehicle routine tasks. Dedicated personnel can be called in to resolve anomalies when needed. Assumption is ten dedicated engineering support personnel monitor trends and archived subsystems data during this active monitoring period without need for operations personnel, unless anomalies occur.

[CA6027-PO] The Constellation Architecture shall require no more than 2 (TBR-001-1106) hour per week contiguous real-time command and control (consisting of (TBD-001-1085) man-hours) during nominal quiescent operations for Lunar missions.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting ground commanding and control interaction with a quiescent vehicle to specific periods and specific manpower intensity under nominal operating conditions (i.e. no Orion and LSAM system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent vehicle (e.g. Orion in LLO, LSAM in LEO, and LSAM on the Lunar surface during Outpost stays) would require very little routine command interaction from ground controllers. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). Assumption is that dedicated operations personnel send commands (e.g. crew uplink messages, state vectors, scripts) during this active command and control period each week.

[CA6028-PO] The Constellation Architecture shall require no more than 1 (TBR-001-1106) hour per day contiguous real-time active monitoring (consisting of (TBD-001-1120) man-hours) during nominal quiescent operations for Lunar missions.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting ground active monitoring required by a quiescent vehicle to specific periods and specific manpower intensity under nominal quiescent operations (i.e. no Orion and LSAM system failures) will contribute to reduced operations and sustaining engineering life cycle costs. It is expected that a quiescent vehicle (e.g. Orion in LLO, LSAM in LEO, LSAM on lunar surface during outpost stays) would require very little routine active telemetry monitoring by ground controllers. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). This requirement does not preclude the fact that Health and Status data from quiescent vehicles will be provided near continuously from the Orion for fault annunciation and trending. Ground controllers and engineering teams supporting other active vehicles (e.g. Outpost) can monitor for trends and fault annunciations as part of the active vehicle routine tasks. Dedicated personnel can be called in to resolve anomalies when needed. Assumption is that dedicated engineering support personnel monitor trends and archived subsystems data during this active monitoring period without need for operations personnel, unless anomalies occur.

3.2.14 Reserved

3.2.15 Environmental Conditions

[CA0048-PO] The Constellation Architecture shall meet its requirements during and after exposure to the environments defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE).

Rationale: This requirement assures the Constellation Architecture will meet its requirements in any natural environment which it is likely to encounter. It also minimizes costs and causes all CxP architecture systems and elements to be designed to a consistent set of environment specifications. This assures that operating ranges can be defined and the architecture qualified for operations across those ranges. CxP 70023, Design Specification for Natural Environments (DSNE) specifies the environment parameters that define these design ranges and limits. Integrated vehicle configurations to be considered in the assessment of natural environment effects for the Constellation Architecture include: Orion/Ares I/GS, Orion/ISS, Orion/Ares I, Orion/Ares V-EDS/LSAM, Orion/LSAM, Ares V/LSAM/GS, and Ares V/LSAM.

[CA0991-PO] The Constellation Architecture shall meet its requirements during and after exposure to the lightning direct and indirect environments specified in CxP 70023, Constellation Program Design Specification for Natural Environments, Sections 3.1.11, 3.2.12, 3.5.3, and 3.7.3 and in accordance with CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document, Section 3.5.

Rationale: There is no known technology to prevent lightning strikes from occurring; however, the effects of lightning can be mitigated with appropriate design techniques.

[CA5552-PO] The Constellation Architecture shall meet its requirements during and after exposure to the induced environments as specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can affect overall system performance and lead to system or mission failure if not properly considered in the design. Induced environments can also affect operations planning and a multitude of integrated systems trades and analyses.

3.3 DESIGN AND CONSTRUCTION STANDARDS

3.3.1 Electrical

[CA0817-PO] The Constellation Architecture shall meet the electrical bonding requirements of NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, and Flight Equipment.

Rationale: Proper electrical bonding is required to meet performance, safety, and electromagnetic compatibility requirements.

[CA0990-PO] The Constellation Architecture shall comply with CxP 70050-01, Constellation Program Electrical Power System Specification, Volume 1: Electrical Power Quality Performance for 28Vdc and CxP 70050-02, Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28Vdc.

Rationale: The Power Quality Specification is required to ensure commonality and standardization across the Cx systems.

3.3.1.1 Electromagnetic Environmental Effects

[CA0554-PO] The Constellation Architecture shall meet its requirements while in the presence of another CA system's induced electromagnetic environment in accordance with CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document.

Rationale: All Constellation systems, subsystems, and equipment will create a complex electromagnetic environment that will vary with time, mission phase, system operation, and so forth. Incompatibilities with this electromagnetic environment will impact Constellation Architecture operations and performance.

[CA0555-PO] The Constellation Architecture shall meet its requirements in the presence of the external electromagnetic environment defined in CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document.

Rationale: All Constellation systems, subsystems, and equipment should be compatible with the external electromagnetic environment in order to meet Constellation Architecture operations and performance requirements.

[CA5811-PO] The Constellation Architecture shall be electromagnetically compatible with external interfaces in accordance with CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document.

Rationale: All Constellation systems, subsystems, and equipment must be compatible with external interfaces in order to meet Constellation Architecture operations and performance requirements. External interfaces include interfaces with transportation systems, recovery systems, RF systems (e.g. Tracking and Data Relay Satellite System [TDRSS], Range Safety), and other vehicles (e.g. ISS).

3.3.2 Structures and Mechanisms

[CA3004-PO] The Constellation Architecture shall comply with JSC 62809, Constellation Spacecraft Pyrotechnic Specification.

Rationale: This document provides requirements for all phases of pyrotechnics use, including design, development, qualification, production, acceptance, shipping, storage, handling, installation, and checkout for Constellation Program spacecraft and launch systems. It also contains requirements from the functional system level to those related to specific pyrotechnic devices and components thereof. Control avionics and circuitry, Ground Support Equipment (GSE), and launch accessory systems are also covered. The requirements of this specification apply to all pyrotechnic components (explosive-loaded and explosively-actuated, non-loaded devices) as well as providing definitions of pyrotechnic components.

[CA3005-PO] The Constellation Architecture shall comply with NASA-STD-(I)-6016, Standard Materials and Processes Requirements for Spacecraft.

Rationale: This document defines the minimum requirements for manned spacecraft Materials and Processes (M&P) and provides a general control specification for incorporation into NASA program/project hardware procurements and technical programs.

[CA3187-PO] The Constellation Architecture shall comply with CxP 70135, Constellation Program Structural Design and Verification Requirements.

Rationale: CxP 70135, Constellation Program Structural Design and Verification Requirements, presents common structural design and verification requirements to ensure consistent design, development, and verification of Constellation hardware. This document describes general design requirements, design loads, factors of safety and margins of safety, design and stress analysis requirements, structural materials criteria and discusses secondary structure accommodation for human interface and nonstandard fasteners. When the various Constellation systems are assembled (e.g., Orion integrated with Ares I) some analyses and/or tests of the integrated system are necessary to verify that the assembled system meets the *requirements of CxP 70135, Constellation Program Structural Design and Verification Requirements.*

[CA3193-PO] The Constellation Architecture shall comply with NASA-STD-(I)-5019, Fracture Control Requirements for Spaceflight Hardware.

Rationale: This document establishes the fracture control requirements for all human-rated spaceflight systems including payloads, propulsion systems, orbital support equipment, and planetary habitats. These requirements are not imposed on systems other than human-rated spaceflight but may be tailored for use in specific cases where it is prudent to do so, such as when national assets are at risk.

[CA3222-PO] The Constellation Architecture shall comply with JSC 62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications.

Rationale: This document specifies the minimum structural design requirements for the design, development, and verification of flight windows, glass and ceramic structure included in the vehicle/element, Orbital Replacement Units, Orbital Support Equipment (OSE), and Flight Support Equipment (FSE). This document primarily addresses structural design requirements for glass and ceramics. This document does not apply to windows made from non-brittle materials.

[CA3237-PO] The Constellation Architecture shall comply with NASA-STD-5017, Design and Development Requirements for Mechanisms, Sections 1 through 4.

Rationale: This standard establishes uniform design and development requirements for the design of mechanisms whose correct operation is required for safety or program success. It defines requirements for flight mechanisms that are designed, built, or acquired by or for NASA.

3.3.3 Reserved

3.3.4 Human Engineering

[CA0042-PO] The Constellation Architecture shall comply with the human system integration requirements defined in CxP 70024, Constellation Program Human-Systems Integration Requirements, Appendix J, Allocation Matrix.

Rationale: The human systems integration requirements define parameters of a habitable environment, capabilities and limitations of the flight and ground crew that drive the design of Constellation Architecture systems to achieve mission objectives, and provides the parameters that protects the health and safety of the crew and allow them to perform their functions in an efficient and effective manner. The HSIR defines requirements for anthropometry, biomechanics, strength and field of view, atmosphere, crew fire protection, potable water, thermal, acceleration, vibration, acoustics, ionizing and non-ionizing radiation, general safety, layout, orientation, translation, restraints and mobility, hatches, windows, lighting, food preparation, personal hygiene, body waste management, stowage and trash management, user *interfaces, maintenance and housekeeping, information management, and exercise and medical requirements.*

3.3.5 Communications Standards

[CA0383-PO] The Constellation Architecture shall protect systems and information as specified in the CxP 70170, Constellation Program Information Technology (IT) Functional Security Requirements, Table 1: Applicability Matrix for Functional Security Requirements.

Rationale: The CxP is required to comply with Federal and Agency requirements, including NPR 2810.1, Security of Information Technology, and FIPS 200, Minimum Security Requirements for Federal Information and Information Systems, to protect against security threats that might degrade, disable, or destroy the operational capability of Cx systems.

[CA5800-PO] The Constellation Architecture shall comply with CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification.

Rationale: Communication is essential to successful mission execution. Communication between systems is necessary for accomplishment of all mission objectives and includes data, voice, and motion imagery. Requirements for specific communication links between systems are captured in the system-to-system IRDs. Link classes are defined in CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification, and include the RF Operational Point to Point, RF High Rate Point to Point, RF Contingency Voice, RF Recovery and Hardline classes.

3.3.6 EVA Standards

[CA3167-PO] The Constellation Architecture shall comply with the requirements in CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification, Appendix B.

Rationale: Requirements that are driven by EVA but common across the Constellation Architecture are included in CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification. All Constellation Architecture systems that will or may interface with EVA crewmembers must conform to this EVA Specification.

3.3.7 Navigation Standards

[CA3252-PO] The Constellation Architecture shall perform navigation per CxP 70142, Constellation Program Navigation Standards Specification Document.

Rationale: Navigation utilizes Constellation flight systems, Ground Systems, and external systems (such as C&TN) in an integrated manner to accomplish the *mission. Interoperability of these systems necessitates common astrodynamic coordinate systems, time specifications, planetary ephemerides, planetary geometries, solar radiation assumptions, etc. The planned delivery and baselining of this document is for System Design Review (SDR).*

[CA5618-PO] The Constellation Architecture shall use a continuous reference time scale for the representation and exchange of timing information per CxP 70022-01 C3I Interoperability Specification, Volume 1, Section 3.5.5 Time Exchange, and CxP 70022-04, C3I Interoperability Specification, Volume 4: Information Representation Specification.

Rationale: With multiple Constellation Systems operating concurrently, and missions potentially spanning periods of several years, the requirement establishes a continuous time scale with a common reference epoch, and conventions for expressing elapsed time across the program. This does not preclude the use of UTC, but provides an alternative to UTC for internal program interfaces or machine interfaces that require use of continuous times (no leap seconds).

3.3.8 Other Standards

[CA5680-PO] The Constellation Architecture shall comply with the provisions of NASA-STD-5005B, Ground Support Equipment.

Rationale: This standard ensures that uniform engineering practices, methods and essential criteria are employed in the design of Ground Support Equipment (GSE) used within NASA. Tailoring of this NASA Standard will comply with the tailoring process described in CxP 70013, Constellation Program System Engineering Management Plan.

3.3.9 Test Standards

[CA4111-PO] The Constellation Architecture shall comply with CxP 70036, Constellation Program Environmental Qualification and Acceptance Testing Requirements (CEQATR).

Rationale: CxP 70036, Constellation Program Environmental Qualification and Acceptance Testing Requirements (CEQATR) Document contains both qualification and acceptance testing requirements for natural and induced environments as well as minimum design screening requirements that are beyond the expected environments. As with other design and construction standards, CxP 70036, Constellation Program Environmental Qualification and Acceptance Testing Requirements (CEQATR) Document will drive the design because the design must take into account that it will need to encompass a larger range of environments or minimum screening environments, whichever is greater, as part of the equipment's certification program.

3.4 EXTERNAL INTERFACES

[CA0069-HQ] The Constellation Architecture shall interface with the Communications and Tracking Network per CxP 70118-01 through CxP 70118-06, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volumes 1 through 6.

Rationale: The Constellation Architecture and C&TN share physical and functional interfaces which are identified in CxP 70118-01 through CxP 70118-06, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 1 through 6. These are critical as the Constellation Architecture is dependent on the C&TN assets for communication.

[CA0077-HQ] Orion shall interface with ISS per CxP 70031, Constellation Program Orion -To- International Space Station (ISS) Interface Requirements Document (IRD).

Rationale: The Orion and ISS share physical and functional interfaces which are identified in CxP 70031, Constellation Program Orion -To- International Space Station (ISS) Interface Requirements Document (IRD).

[CA5750-PO] The Constellation Architecture shall interface with ascent entities in accordance with CxP 70159, Constellation Program Support Requirements Document.

Rationale: For ascent, the Eastern Range provides wind tower, balloon and wind profiler data for launch operations. The Eastern Range Operations Control Center (ROCC) by the 45th Space Wing schedules the C-band tracking stations. The hi-speed C-band tracking data is used for launch and abort operations. Unique agreements with each range entity (per the PSRD) will be developed based on specific site needs over the life of the Cx Program. This assumes that within any given branch of Department of Defense (DoD), that the agreements may vary by DoD facility.

Draft **[CA5940-PO]** The Constellation Architecture shall interface with the Lunar Precursor and Robotic Program (LPRP) per (TBD-001-1026).

Rationale: Surface element location, voice, and video will be necessary from the LPRP to Constellation systems.

[CA5941-PO] The Constellation Architecture shall interface with entry range entities in accordance with CxP 70159, Constellation Program Support Requirements Document.

Rationale: The C-band tracking data is used for abort and entry operations. Entry ranges will be phased in with landing sites, beginning with a small set for ISS landing sites and expanding as lunar mission landing sites are phase in. Unique agreements with each range entity and Memorandums of Understanding (MOU) (per CA0100-HQ) will be developed based on the specific sites coming and going over the life of the Cx Program. This assumes that within any given branch of DoD, that the agreements will vary by DoD facility.

[CA5942-PO] The Constellation Architecture shall interface with the Global Positioning System per the IS-GPS-200 Rev. D, Navstar Global Positioning System Interface Specification, and the ICD-GPS-705, Navstar GPS Space Segment/User Segment L5 Interfaces.

Rationale: Data from GPS is required for Guidance, Navigation, and Control (GN&C) and the flight control system for Constellation systems.

[CA6069-PO] The Constellation Architecture shall utilize the communication and tracking services provided by Space Operations Mission Directorate (SOMD) Space Communications and Navigation (SCAN) as specified in CxP 70169, Constellation -to- CTN Architecture & Services Requirements Document, for communication and tracking of Constellation Flight Systems.

Rationale: The SOMD Space Communications and Navigation Program provides NASA's communication and tracking infrastructure including the Ground Network, Space Network, Deep Space Network. SCAN also provides the interface between Constellation and NISN for institutional ground data transport, and coordination with external service providers including the DoD. CxP 70169 allocates the functions and services of the CTN system, provided by SCAN, within the Constellation Architecture.

3.5 PHYSICAL CHARACTERISTICS

[CA0023-PO] The Constellation Architecture shall conform to a Control Mass for each flight System per the CxP 70151, Constellation Program Mass Properties Control Plan.

Rationale: Control Masses are necessary to perform the analyses that show the mission architectures will close and Control Mass is particularly critical to sizing the propulsive systems. Control masses for the flight systems are necessary for design of the Ground System launch platform and transporter. Program-defined flight-system control masses, along with mass delivered to orbit and timing of any masses jettisoned, are required to manage the Program Mass Reserve.

3.6 RESERVED

3.7 SYSTEMS

Allocations have been made from the Architecture to the Systems. Section 3.7 documents these allocations in requirements with subsections for each System. Within the "Systems" section, the allocations representing functional, performance, design and construction standards requirements will be documented. The interfaces external to a System and physical characteristics will also be captured.

3.7.1 Orion

3.7.1.1 Orion Description

The Orion System consists of a Crew Module (CM), a Service Module (SM), a Launch Abort System (LAS), and a Spacecraft Adapter (SA), and transports crew and cargo to orbit and back. Orion System will be used in all phases of the Constellation Program. Initially, Orion transports crew and cargo to and from the ISS and an uncrewed (TRADE) configuration transports pressurized cargo to and from ISS. It will subsequently transport crew and cargo to and from a lunar orbit for short and extended duration missions. Finally, Orion or a derivative will support missions to a Mars transfer vehicle, and then return the crew and cargo to earth after separation from this vehicle. There may be unique configurations to accommodate the needs of each defined DRM.

3.7.1.2 Orion Requirements

[CA0056-PO] Orion shall return the crew and cargo from Lunar Rendezvous Orbit (LRO) to the Earth surface.

Rationale: CxP 70007, Constellation Design Reference Missions and Operational Concepts, indicates that Orion is the Constellation system that will return the crew and cargo to the Earth surface. Orion includes the propulsion system and propellant to perform the TEI from LRO and any subsequent trajectory correction maneuvers. Orion includes the heat shield needed for reentering the Earth's atmosphere and the landing systems needed for return to the Earth surface.

[CA0091-PO] Orion shall deliver the crew from the Earth surface to the Lunar Destination Orbit (LDO) for crewed lunar missions.

Rationale: The Orion launches on the human-rated Ares I. Thus, Orion is the designated Constellation System, per CxP 70007,Constellation Design Reference Missions and Operational Concepts, designed to deliver the crew and cargo from the launch site to Earth Rendezvous Orbit (ERO) and subsequently from ERO to the Lunar Destination (LDO). This requirement is based on the results of NASA-TM-2005-214062, Exploration Systems Architecture Study, which indicates that using Orion rather than the LSAM balances performance, cost and risk for the Constellation Program.

[CA3203-PO] Orion shall return the crew and pressurized cargo from the ISS to the Earth surface.

Rationale: CxP 70007, Constellation Design Reference Missions and Operational Concepts, indicates that the Orion is the Constellation System that will return the crew and cargo to the Earth surface. Design considerations for Orion need to include features that are essential to returning crew and cargo safely to the Earth surface.

[CA5312-PO] Orion shall deliver the crew and cargo from the Earth surface to the ISS.

Rationale: The requirement is consistent with CxP 70007, Constellation Design Reference Missions and Operational Concepts, which indicates that Orion is the Constellation System designated to deliver the crew and cargo to the ISS. Orion design must provide for safe launch, free flight, rendezvous, proximity operations, docking and other joint operations with the ISS. Orion is required to provide a capability to deliver active and passive cargoes in the pressurized cabin environment *and the unpressurized section. The amount of either type of cargo will be determined on a per mission basis. For unpressurized cargo, the ISS Control Moment Gyroscope (CMG) is the benchmark for mass, volume, dimensions, and delivery capability.*

[CA5748-PO] Orion shall provide two independent, non-mission specific, electrical power interfaces designated for unpressurized cargo each capable of providing power up to 1.0 kilowatt (kW) maximum.

Rationale: This requirement refers to the physical capability of the interface and its accessibility by the unpressurized cargo. The actual power or energy that will be transferred across the interface is not specified but will be limited to be within the inherent capability of the power system and will not drive the sizing of the arrays or batteries. Cargo electrical load availability and levels will be defined on a per mission basis. A mission kit could be used to implement this requirement for missions requiring powered unpressurized cargo. The intent of this requirement is to be allocated to the Service Module.

[CA5749-PO] Orion shall provide a standard, redundant, non-flight critical data bus interface for unpressurized cargo.

Rationale: The unpressurized cargo may need to receive commands, transmit Health and Status data to the Orion or transmit scientific data to the Orion for storage and/or for transmission to the ground. The requirement provides for a "data port" in the unpressurized cargo area for use by the cargo if needed, i.e., a mission kit may be used to implement this requirement. The intent of this requirement is to be allocated to the Service Module. Data rate and other data interface capabilities will be defined on a per mission basis.

3.7.1.2.1 Orion Mission Success

[CA0088-PO] Orion shall limit their contribution to the risk of Loss of Mission (LOM) for a Lunar Sortie mission to no greater than 1 in 50.

Rationale: The 1 in 50 means a .02 (or 2%) probability of LOM due to the Orion during any Lunar Sortie mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA0399-PO] Orion shall limit their contribution to the risk of Loss of Mission (LOM) for an ISS Crewed mission to no greater than 1 in 250.

Rationale: The 1 in 250 means a .004 (or .4%) probability of LOM due to the Orion during any ISS Crewed mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program

Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA3022-PO] Orion shall limit their contribution to the risk of Loss of Mission (LOM) for an ISS Cargo mission to no greater than 1 in 240 (TBR-001-1303).

Rationale: The 1 in 240 (TBR-001-1303) means a .00417 (TBR-001-1303) (or .417(TBR-001-1303)%) probability of LOM due to Orion during any ISS Cargo mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA3023-PO] The Orion shall limit their contribution to the risk of Loss of Mission (LOM) for a Lunar Outpost Crew mission to no greater than 1 in (TBD-001-515).

Rationale: The 1 in (TBD-001-515) means a (TBD-001-515) (or (TBD-001-515)%) probability of LOM due to Orion during any Lunar Outpost Crewed mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.7.1.2.2 Orion Crew Survival

[CA0194-PO] Orion shall provide for crew survival, without permanent crew disability, for at least 36 hours with the hatch closed in sea state conditions defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), sections 3.5.18 through 3.5.20 and 3.6.18 through 3.6.20.

Rationale: This requirement is needed to provide crew survival after a water landing in a sea state where the hatch cannot be opened. The 36 hours assumes the longest time that the ground support would take to recover the crew. This assumes that the power system will have to provide the basic ventilation and emergency systems. The requirement was developed for water landing to address the design case for the developers.

[CA0274-PO] Orion shall provide an Emergency Entry mode that is available from the command of SM separation through Earth landing.

Rationale: The history of human space flight includes failures which degrade the performance of critical entry and landing systems and put the crew at extreme risk. The Emergency Entry mode improves crew survivability in extreme cases of failures in primary systems from Service Module (SM) separation through landing. This mode includes simple, inexpensive Software (SW) and Hardware (HW) implementations to down-mode from guided to ballistic entry, and to provide alternate automatic or manual initiation of critical events such as SM separation, Reaction Control System (RCS) jet firings, parachute deployment, and landing *attenuation. This mode may use primary RCS, power and Guidance Navigation and Control (GN&C) computer systems dissimilarly to nominal modes (e.g., reboot computers into "safe mode", blow-down RCS for spin-stabilization, manifold reconfiguration, visual navigation, etc.) in scenarios such as SW faults and computer crashes, low power, and partial loss of a propellant. This is not a requirement for but does not preclude separate back-up systems for RCS, power and GN&C beyond primary system redundancy; the Emergency Entry mode is not to be included in fault tolerance and reliability calculations. It is intended to be a final safety net, a "last chance" for the crew to return to Earth in extreme, unanticipated scenarios.*

[CA0325-PO] Orion shall provide for Earth landing throughout each mission phase.

Rationale: This requirement provides for Earth landing on water or land (not necessarily CONUS) following any event during the mission that requires an abort or early return to Earth, e.g., unanticipated circumstances put the crew at risk or prevents mission completion. This requirement is intended to cover scenarios in which the timing of the abort or early return necessitates Earth landing requirements to be relaxed to provide for landing on water or land. Relaxing Earth landing targets from designated CONUS sites adds flexibility in mission planning, increasing crew safety. Aborts or early return can occur at any time, requiring the capability to land regardless of lighting conditions.

[CA0493-PO] Orion shall provide a habitable environment for the assigned crew for a single event of at least 2 (TBR-001-002) hours in duration while Orion is still docked to and isolated from the ISS.

Rationale: Allows the crew a minimum safe haven capability for the ISS to wait out transient hazardous conditions without departing from the ISS. The consumables are enveloped by the lunar case. The power and thermal may be enveloped for the ISS worst-case attitude.

[CA0532-PO] Orion shall sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 144 hours.

Rationale: The 144 hours is associated with the nominal 120 hour expedited return time an unpressurized Orion needs to sustain the life of suited crewmembers during the trip back to Earth with an additional 24 hours of margin. For ISS missions, the amount of time needed to return the crew will be much less - on the order of a few hours.

[CA0983-PO] Orion shall maintain structural integrity and float for a minimum of 36 hours in the wind and sea state conditions defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18, following a water landing.

Rationale: By having the analysis include the maximum flotation duration it will define the length of time within which the Orion must be recovered and the limits for post-landing Orion habitation by the crew. The loads induced by the sea state will be *in the Structural Design Verification Requirements document and satisfaction of those requirements will aid in the closure of this requirement.*

[CA0984-PO] Orion shall assure crew survival during landing touchdown in wind and sea state conditions as defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18, for all water landings.

Rationale: This requirement assures that the crew will be able to survive the worst-case landing impact conditions following in-water launch abort.

[CA3108-PO] Orion shall provide suit stowage such that a suit can be accessed within 2 (TBR-001-157) minutes per crew member for donning.

Rationale: Suits need to be stowed in Orion such that they are readily accessible to facilitate the full crew donning their suits while the Environmental Control and Life Support System (ECLSS) feeds the leak. The two minutes for each crewmember to retrieve their suit (in order to begin the donning process) is a subset of the ECLSS requirement to feed the leak per CA3105-PO. The suit retrieval time is not necessarily always required at the beginning of the feed the leak period, as it likely will be more efficient in the Orion Volume provided to have sets of crewmembers retrieve and don their suits serially.

[CA3138-PO] Orion shall provide fire detection and suppression for the Orion pressurized volume.

Rationale: This is to provide cabin fire detection and suppression. The type of fire detection and suppression required in the avionics bays will be a function of materials selection, proximity to ignition sources and oxidizers.

[CA3259-PO] Orion shall provide visual aids for search and rescue/recovery independent of ambient lighting conditions.

Rationale: Visual aids (e.g. flashing light beacons and dye bags) are necessary in rescue/recovery operations in varying lighting, land or sea, and weather conditions to facilitate locating the vehicle and crew, especially where the vehicle communications system is inoperable.

[CA4154-PO] Orion shall perform the functions necessary to return the crew to the surface of the Earth in at least 144 hours with an unpressurized cabin.

Rationale: Vehicle functions to return the crew to the surface of the Earth in an unpressurized cabin pertain to the functions that are needed to get the crew back to Earth. Examples of critical vehicle functions include but are not limited to propulsion, communications, guidance, navigation, control, parachutes, etc. The 144 hours is coupled to Orion and EVA System requirements to sustain the crews' life for the length of time to return the crew to Earth. The 144 hour clock begins when the crew begins utilizing Orion resources and does not address any time spent on the LSAM. As Orion may lose pressure during the lunar loiter time, the vehicle may need to *function with an unpressurized cabin for longer than 120 hours. The additional 24 hours here allow for margin and operational flexibility.*

[CA6074-PO] Orion shall provide the capability to isolate any suit-umbilical channel.

Rationale: In order to meet the intent of JPR 8080.5A F-22, the system must be capable of isolating a major suit leak such that pressure can be maintained the main suit loop so that the other crewmembers will not perish. This requirement may be met by either incorporating an automatic or manual (e.g. disconnecting the umbilical) isolation mechanism.

[CA6075-PO] Orion shall maintain the suit loop at a pressure no less than 15.4 (TBR-001-1431) kPa (2.2 psia) for at least 5 (TBR-001-1432) min with an equivalent maximum hole diameter of 6.4 (TBR-001-1433) mm (0.25 in).

Rationale: [CA6072-PO] requires that the Constellation Architecture provide a feed-the-suit leak capability to allow for time to locate and either repair or isolate the leak. The vehicle ECLSS will have to support the suit loop pressure until the leak can be located and isolated. It not safe to assume that the emergency oxygen provided by EVA System will be available to aid in feeding the leak.

3.7.1.2.2.1 Orion Crew Survival Probabilities

[CA0398-PO] Orion shall limit their contribution to the risk of Loss of Crew (LOC) for an ISS Crew mission to no greater than 1 in 1700.

Rationale: The 1 in 1700 means a .00059 (or .059%) probability of LOC due to the Orion during any ISS Crew mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA0501-PO] Orion shall limit their contribution to the risk of Loss of Crew (LOC) for a Lunar Sortie mission to no greater than 1 in 200.

Rationale: The 1 in 200 means a .005 (or .5%) probability of LOC due to Orion during any Lunar Sortie mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA3040-PO] Orion shall limit their contribution to the risk of Loss of Crew (LOC) for a Lunar Outpost Crewed Mission to no greater than 1 in (TBD-001-559).

Rationale: The 1 in (TBD-001-559) means a (TBD-001-559) (or (TBD-001-559)%) probability of LOC due to Orion during any Lunar Outpost Crewed mission. This *requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.*

[CA5913-PO] Orion shall limit the risk of Loss of Crew (LOC) during a pad or ascent abort initiated within the conditions outlined in Table XXX (TBD-001-1401) or Orion initiated failures to no greater than 1 in (TBD-001-947).

Rationale: The 1 in (TBD-001-947) means a (TBD-001-947) (or (TBD-001-947)%) probability of LOC during any ascent abort initiated within the conditions outlined in Table XXX (TBD-001-1401) or Orion initiated failures. Table XXX (TBD-001-1401) will be jointly developed between Ares and Orion to define ascent abort conditions that potentially allow a successful Orion abort.

Conditions exceeding this table are expected to result in LOC. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO): Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.7.1.2.2.2 Orion Emergency Egress, Aborts and Return for Survivability

[CA0170-PO] Orion shall automatically determine the need for an abort.

Rationale: In cases where response time constraints impact crew safety risk requirements, the Orion should be able to automatically determine the need to abort. Abort determination is based on independent sensor information from the Orion alone and/or from other systems depending on flight phases.

[CA0333-PO] Orion shall perform aborts from the time the Orion abort system is armed on the launch pad until the mission destination is reached.

Rationale: Abort at any time is part of NPR 8705.2, Human-Rating Requirements for Space Systems, as well as the program policy on crew safety. This Orion requirement will cover all of the flight phases from abort system arming on the launch pad through docking with the ISS or LSAM landing. The Orion must be capable of supporting an LSAM Descent abort and subsequent redocking. After reaching the destination, all other scenarios are covered by the return capabilities.

[CA0334-PO] Orion shall provide the suited crew with the capability for unassisted emergency egress during pre-launch activities after hatch closure within 2 (TBR-001-122) minutes total starting from initiation of egress in the seated and restrained position to complete crew egress from the vehicle.

Rationale: For contingency situations, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons. This should drive design of seat restraints, hatch mechanisms, launch suit, and *egress paths in the pre-launch orientation to allow the crew to egress without ground crew assistance.*

[CA0335-PO] Orion shall provide two (TBR-001-545) ground crew and six suited flight crew with the capability for unassisted emergency egress during pre-launch pad activities prior to hatch closure within 2 (TBR-001-202) minutes total starting from initiation of egress to complete crew egress from vehicle.

Rationale: For contingency situations, where no ground crew is immediately available in the white room to assist, six suited flight crew plus two ground crew will need the capability to egress the vehicle for safety reasons. This should drive design of seat restraints, internal access platforms, hand holds, launch suit and egress paths in the pre-launch orientation to allow the ground and suited flight crew to egress without external ground crew assistance. The time for the combined suited crew and ground crew to egress the vehicle may be different than the sum of the individual times for suited crew only or ground crew only.

[CA0416-PO] Orion shall return the crew to the Earth surface independent of communications with the Mission Systems during all mission phases.

Rationale: This requirement ensures the safety of the crew by protecting against the possibility of permanent or unplanned intermittent communication service outages that prevent or limit communications between Mission Systems and the Orion, Communication services include uplink and downlink services (Earth- and space-based), Earth-based navigation equipment, and Ground Operations centers. Communications (voice, command, and telemetry), relative navigation between vehicles, GPS, and other onboard sensors remain operational. For communication service outages that occur while the crew is on the lunar surface or in the LSAM, the Orion can complete the orbit transfer to the LRO, participate in RPODU activities, perform the TEI and complete Earth entry. For ISS missions, the Orion can perform undocking and proximity operations and entry activities using only internal equipment.

[CA0466-PO] Orion shall provide for unassisted emergency egress for suited crew upon landing within 3 (TBR-001-1023) minutes.

Rationale: For contingency or aborted landings, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons, or to assist in search and rescue operations.

[CA0498-PO] Orion shall abort without relying on thrust from the Ares I.

Rationale: Because the health of the Ares I cannot be guaranteed for abort situations the Orion must be able to perform ascent aborts without Ares I thrust. This does not preclude the operational use of Ares I thrust if available and desired.

[CA0522-PO] Orion shall automatically initiate an ascent abort sequence upon notification of Flight Termination System (FTS) indication.

Rationale: If flight termination is required for the launch vehicle, Orion is likely to also be destroyed without a successful ascent abort separating the spacecraft away from the explosion hazard. The type of indication that triggers ascent abort is specified in CxP 70026, Constellation Program Orion -To- Ares I Interface Requirements Document (IRD).

[CA0579-PO] Orion shall provide ascent aborts for ISS missions that result in landing outside the Down-range Abort Exclusion Zone (DAEZ).

Rationale: The DAEZ is a geographical area to be avoided for Orion landings following launch aborts for ISS crewed missions. Ensuring expeditious recovery of the crew for high inclination ISS missions is critical for crew survival due to rough seas and cold water temperature in the North Atlantic. Additionally, landing within close proximity to land masses with pre-positioned recovery forces maximizes crew survival.

[CA5234-PO] Orion shall provide the capability for vehicle landing in zones for Earth ascent aborts defined by Figure (TBD-001-076) for all lunar missions.

Rationale: A landing zone is required to maximize the probability of crew survival and recovery. Some considerations in determining the landing zone are environmental conditions (sea state, winds, etc.) and proximity to recovery forces.

[CA5237-PO] Orion shall return the crew from Lunar Rendezvous Orbit (LRO) to the surface of the Earth within 120 hours from docking with LLV during a lunar sortie mission.

Rationale: This requirement allocates a portion of the 132 hours that the Constellation Architecture needs for early return of the crew to Earth. The 120 hour clock begins with completion of the Orion/LLV docking activities and includes time for crew transfer and TEI preparation. The 12 hour difference in the Architecture expedited return time limit not covered by this requirement allows for Orion transfer to LRO and the subsequent LLV ascent and Rendezvous-Proximity Operation-Docking (RPOD) with Orion. 120 hours for expedited return is the fastest that Orion will touchdown at Earth after docking with LLV. The time requirements for unpressurized crew return operations of 144 hours provides margin and flexibility in addition to the fastest return time.

[CA5439-PO] Orion shall automatically perform abort.

Rationale: In cases where response time constraints impact crew safety risk requirements, Orion should be able to respond to abort conditions automatically.

Per NPR 8705.2, Human-Rating Requirements for Space Systems, this requirement provides crew and passenger survival modes throughout the ascent and on-orbit profile. This does not preclude manually initiated aborts. Automatic abort includes the execution of automated sequences. The requirement is not meant to mandate automated aborts for all flight phases.

[CA5947-PO] Orion shall provide 2 (TBR-001-545) ground crew with the capability for unassisted emergency egress during pre-launch pad activities prior to flight crew ingress within 2 (TBR-001-1025) minutes total starting from initiation of egress to complete crew egress from vehicle.

Rationale: For contingency situations, during preflight cargo stowage and preparations for crew ingress, two ground crew will need the capability to egress the vehicle for safety reasons. This should drive design of cargo stowage equipment, internal access platforms, hand holds, and egress paths in the pre-launch orientation to allow the ground crew to egress without external assistance. The time for the ground crew to egress the vehicle may be different than the times for suited crew only or combined suited crew plus ground crew egress cases.

3.7.1.2.3 Orion Crew Size

Draft **[CA0347-PO]** Orion shall transport at least 6 (TBR-001-082) crewmembers to the Mars Transfer Vehicle (MTV) in the (TBD-001-031) Earth Orbit.

Rationale: Allocation of CA0010. The Mars DRM requires delivery of the flight crew to the MTV prior to initiation of the Mars mission. The Orion is launched on the Ares I to satisfy this requirement. Specifics of the Mars assembly and departure orbit are yet to be determined at this time.

[CA0447-PO] Orion shall have the capability to transport crews of 0, 1, 2, 3, 4, 5 and 6 into LEO with a single launch.

Rationale: Intent is to send a crewed version of Orion with no crew on it and also size the different crew complements. Establishes the maximum crew launch capability required to support all defined phases of Exploration. Lower-level requirements will specify crew size for particular DRMs.

3.7.1.2.4 Orion Cargo Delivery and Return

[CA0547-PO] Orion shall provide a contiguous unpressurized cargo volume of at least 0.57 (TBR-001-750) m3 (20 ft3) with 0.83 m (2.72 ft) per side for lunar missions.

Rationale: Allocation of CA0003-HQ and CA0004-HQ. This capability would be similar to the capability provided by the Apollo Service Module Scientific Instrument Module (SIM) Bay. The goal would be to provide a flexible capability to support a myriad of scientific and engineering activities that may vary from mission to mission. Fields of study that may leverage this capability include: lunar surface mapping, lunar gravity field mapping, space environment measurements, evaluation of environmental exposure of materials and/or components planned for future missions, and infrastructure systems such as navigation or communication satellites that could be deployed from Orion. Specific objectives for each lunar sortie and outpost mission will be defined in a separate ESMD document.

[CA0565-HQ] Orion shall deliver a volume of at least 10.76 (TBR-001-035) m3 (380 ft3) of pressurized and conditioned cargo to and from the ISS per ISS Cargo mission.

Rationale: Establishes a cargo volume for accomplishing ISS objectives. Return of conditioned biomedical samples and removal of waste, trash, and other unwanted ISS components is a key ISS program requirement.

[CA0864-PO] Orion shall deliver a crew of four with at least 365 kg (805 lbm) of pressurized cargo from Earth to ISS.

Rationale: The Mass Delivered requirement is based on analysis. The Orion mass delivered capability varies with the number of crew, but this requirement establishes a reference point for a combination of crew and cargo.

[CA0865-PO] Orion shall return a crew of four along with at least 365 kg (805 lbm) of pressurized cargo from ISS to Earth.

Rationale: The Mass Returned requirement is based on analysis. The Orion mass returned capability varies with the number of crew, but this requirement establishes a reference point for a combination of crew and cargo.

[CA0866-PO] Orion shall deliver at least 2,850 kg (6,283 lbm) (gross) of pressurized cargo from the Earth to the ISS for an ISS Cargo mission.

Rationale: The Mass Delivered requirement is based on the analysis documented in TDS18B. Analysis in TDS18B determined that a 5 m (16.4 ft) diameter Orion would have a 8.58 m3 (303 ft3) available volume limit for cargo and this volume limit would limit the mass storage of the Orion to 2,850 kg (6,283 lbm). TDS18B assumed that secondary structure mass would be accounted for in the vehicle weight.

[CA0868-PO] Orion shall return at least 100 kg (220 lbm) of pressurized cargo from LRO to Earth for crewed lunar missions.

Rationale: This Mass Returned requirement is based on the NASA-TM-2005-214062, Exploration Systems Architecture Study. A mass return capability is required to enable lunar samples and possible scientific experiments to be returned from the lunar surface to Earth. This requirement applies to each crewed lunar mission and is based on the crewed Apollo mission cargo return capability.

[CA3182-PO] Orion shall deliver cargo from the Earth to the ISS for uncrewed ISS missions.

Rationale: This requirement establishes the need for Orion to be able to transport cargo from the Earth's surface and deliver it to ISS for uncrewed ISS missions in addition to the function of Orion transporting crew to and from ISS. Orion will support pressurized cargo delivery for ISS logistical resupply. Automated rendezvous and docking will be needed because of the uncrewed configuration.

[CA5155-PO] Orion shall provide return cargo volume of at least 0.075 (TBR-001-166) m3 (2.65 ft3) from the lunar orbit to the Earth during each crewed lunar mission.

Rationale: This capability should be available to support both Lunar Sortie and Lunar Outpost operations.

[CA5233-PO] Orion shall return at least 2,850 kg (6,283 lbm) of pressurized cargo from the ISS to the Earth for an uncrewed mission.

Rationale: The Mass Returned requirement is based on the analysis documented in TDS18B and (TBD-001-851) analysis. Analysis in TDS18B determined that a 5 m (16.4 ft) diameter Orion would have a 10.76 m3 (380 ft3) available volume limit for Cargo and this volume limit would limit the mass storage of Orion to 2,850 kg (6,283 lbm). TDS18B assumed that secondary structure mass would be accounted for in the vehicle weight. (TBD-001-851) analysis validated this maximum Orion Return Mass based upon center of gravity location and the related vehicle passive stability. Orion Mass Delivered supports ISS up-mass requirements for payloads, crew supplies and other consumables.

[CA5950-PO] Orion shall deliver an unpressurized cargo mass of at least 600 (TBR-001-1026) kg (1,322 lbm) to the ISS.

Rationale: The ISS Control Moment Gyroscope (CMG) with thermal shield is the benchmark for payload delivery (Cargo = CMG, FSE, thermal blanket, active Flight Releaseable Attachment Mechanism (FRAM), adapter plate = 1,315.8 lbm). The capability also allows the delivery of other ISS related payloads as required. The 600 kg (TBR-001-1026) requirement maintains the capability for installation/removal using the SPDM OTCM.

[CA5960-PO] Orion shall provide an unpressurized cargo volume of 2.92 (TBR-001-1027) m3 (103 ft3) with footprint dimensions of 1.25 (TBR-001-1027) m by 1.16 (TBR-001-1027) m (4.1 ft by 3.8 ft) for ISS missions.

Rationale: The ISS Control Moment Gyroscope (CMG) is the benchmark for payload delivery. The capability also allows the delivery of other ISS related payloads as required. The footprint dimensions are defined by the CMG FSE Installation Kit to SAPA ICD D683-96063-10.

[CA5961-PO] Orion shall deliver an unpressurized cargo mass of at least 382 (TBR-001-1028) kg (841 lbm) for lunar missions.

Rationale: The specified mass value is used to size the cargo interface rather than the allocation and was derived by subtracting the mass requirements for a crew of two from the mass requirements for a crew of four. The actual mass allocated to unpressurized cargo is determined on a per mission basis and is traded against crew size and other cargo mass required.

3.7.1.2.5 Orion Mission Rates and Durations

[CA0060-HQ] Orion shall remain docked to the ISS for at least 210 days.

Rationale: Typical ISS mission durations are 180 days. The Orion will remain at the station for the duration of the mission. A 30 day contingency was added for margin for on-orbit life. The contingency days are available to address crew rotation mission *overlaps. The Orion may not be attached to the ISS during the entire crew increment due to ISS mission operations (such as Orion relocation to another port).*

[CA0082-PO] Orion shall loiter uncrewed in LLO for at least 210 (TBR-001-039) days.

Rationale: Lunar missions call for the Orion to remain in lunar orbit while the crew transfers to the surface in the LSAM. The Lunar Outpost Crew DRM described in CxP 70007, Constellation Design Reference Missions and Operational Concepts, baselines a continuous human presence on the lunar surface with two mission intervals per year. To accomplish this, the nominal outpost duration is approximately 180 days. Overlapping of crews will be required for handoff activities. A loiter duration of 210 days provides sufficient overlap and contingency time for these activities. The 210 (TBR-001-039) days also encompasses the 7-day loiter duration for the Lunar Sortie DRM. The Orion will need to maintain its orbit and operational functionality throughout this loiter duration without crew intervention.

[CA3164-PO] Orion shall provide a habitable environment for a crew of four for a minimum of 21.1 days during each lunar mission.

Rationale: Defines the number of days that Orion is required to provide support for the crew based on the maximum mission duration including contingencies and docked operations with LSAM. Includes 16.8 days for nominal mission timeline with crew, plus 4.3 days contingency, and assumes Orion supports crew during Orion-LSAM docked operations.

[CA6084-PO] The Orion shall perform two ISS launches in a year.

Rationale: The Orion must be designed to support a minimum mission frequency which is based on the manifest in order to fulfill the basic requirements of the Ares I Project. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Orion systems.

[CA6084-PO-Objective] The Orion shall perform six ISS launches in a year.

Rationale: The Orion must be designed to support a minimum mission frequency which is based on the manifest in order to fulfill the basic requirements of the Orion Project. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Orion systems.

[CA6103-PO] Orion shall be in a mission ready state for launch attempts on each of no less than seven consecutive days.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. Seven days is based on an Ares V-launch-first mission design approach and protects for a lunar mission *where the Ares V launches on the fourth day of its consecutive launch opportunities. Orion should be designed so that any required servicing can be completed for the next day's launch attempt or with consumables to support the vehicle throughout the seven opportunities.*

[CA6258-PO] The Orion shall perform two Lunar launches in a year.

Rationale: The Orion must be designed to support a minimum mission frequency which is based on the manifest in order to fulfill the basic requirements of the Orion Project. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Orion systems.

[CA6258-PO-Objective] The Orion shall perform three Lunar launches in a year.

Rationale: The Orion must be designed to support a minimum mission frequency which is based on the manifest in order to fulfill the basic requirements of the Orion Project. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Orion systems.

[CA6260-PO] The Orion shall support 2 launches within a 45 calendar day interval, measured from the launch of the first mission to the launch of the second mission.

Rationale: The Orion must be designed to support a minimum mission interval in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission intervals drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, the minimum interval drives turnaround and maintenance activities for the Orion systems. This interval is expressed in calendar days. This requirement is not necessarily intended to apply to a single Orion vehicle, or infer a total ground processing time for a single Orion vehicle.

[CA6260-PO-Objective] The Orion shall provide the capacity to conduct one back to back set of launches per year within 30 days measured from the launch of the first mission to the launch of the second mission.

Rationale: The capacity of the Orion project to conduct a single set of launches in a 30 day interval per year will allow the capability to maintain manifesting mission success goals in the case of a launch slip.

3.7.1.2.6 Orion Architecture Definition

[CA0191-PO] Orion shall perform the orbit transfer from the Ascent Target, defined in the Ascent Target table in Section 3.7.2.2.6, to ISS.

Rationale: After separation from the Ares I, the Orion provides the orbital transfer from the Ascent target to deliver the crew or cargo to ISS. Orion is responsible for all propulsive maneuvers after Ares I separation.

[CA0324-PO] Orion shall return to Earth to a designated U.S. coastal water landing site.

Rationale: Returning to designated U.S. coastal landing sites reduces risk and cost by minimizing necessary recovery force assets, increasing proximity to U.S. medical facilities, increasing security, and ensuring a prepared landing site free of hazards. Operational considerations may dictate landings at non-designated locations.

[CA0351-PO] Orion shall launch independent of ambient lighting conditions.

Rationale: Use of night time launch windows greatly increases the opportunities for launch to a successful rendezvous orbit. Launch windows to rendezvous with an object already in space frequently fall in darkness. For example, about 40% of the launch opportunities to the International Space Station occur in darkness when assessed over a one year period. Since Ares I launches will set up Orion to rendezvous with systems previously inserted into orbit (e.g. ISS and Ares V+EDS), overall mission planning may be severely constrained if night launches are not allowed. Orion will not constrain Ares I ability to launch regardless of ambient lighting conditions.

Draft **[CA0373-PO]** Orion shall transfer the crew from the Earth intercept trajectory to the surface of the Earth in not greater than three days after undocking from the MTV.

Rationale: The Mars DRM specifies jettisoning of the MTV before Orion Earth entry. Three days independent crew flight time in the Orion represents a trade between Orion lifetime and MTV propulsive diversion requirements.

[CA0494-PO] Orion shall perform Earth landing regardless of ambient lighting conditions.

Rationale: The capability to land in day or night lighting conditions will maximize landing opportunities, reducing constraints upon mission planning, and increasing crew survivability.

[CA3166-PO] Orion shall provide for at least two (TBR-001-206) EVA operations of at least four (TBR-001-207) hours duration each on lunar missions independent of other flight vehicles.

Rationale: In keeping with CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Orion needs to have its own EVA capability that extends across all practical mission phases and provides access to as much of the spacecraft as possible. In practice, this means that Orion needs to not only have the functional capabilities required to conduct an EVA (e.g. depress/repress) but also the necessary consumables and stowage of equipment as well (e.g. EVA umbilicals). The decision for the Orion to have the capability to perform EVAs *independent of other vehicles was made at the March 29, 2006 Constellation Control Board (CxCB) and documented in the Board minutes. For additional Programmatic discussions and decisions made pertaining to this requirement, refer to the Constellation Operations Panel and Systems Engineering Control Board minutes during the month of March 2006. Two (TBR-001-206) in space EVA operations have been scoped to address an unscheduled EVA for mission success prior to descent to lunar surface and a contingency EVA for crew survival to transfer the crew from LSAM to Orion. Four (TBR-001-207) hours are anticipated to be the longest duration in space EVA and are consistent with the crew transfer.*

[CA3168-PO] Orion shall provide an external control to depressurize the cabin that is operable by an EVA crewmember.

Rationale: If it becomes necessary for the crew to transfer from LSAM to Orion via contingency EVA, the Orion cabin will have to be depressurized either by ground command or by an EVA crewmember operating an external depress valve/control.

[CA3204-PO] Orion shall perform the orbit transfer from the Ascent Target, defined in the Ascent Target table in Section 3.7.2.2.6, to the Earth Rendezvous Orbit (ERO) for crewed lunar missions.

Rationale: The CxP 70007, Constellation Design Reference Missions and Operational Concepts, indicates that after separation from the Ares I, the Orion provides the remaining delta-V needed to achieve an ERO for rendezvous with Ares V/LSAM.

[CA3207-PO] Orion shall perform the orbit transfer from Low Lunar Orbit (LLO) to the Lunar Rendezvous Orbit (LRO) for crewed lunar missions.

Rationale: The CxP 70007, Constellation Design Reference Missions and Operational Concepts Document, indicates that the Orion remains in orbit around the Moon while the LSAM transports the crew to the lunar surface. This allows the resources needed for Earth return to also remain on-orbit allowing more mass to be delivered to the lunar surface. The Orion uses part of its stored propulsion resources to get to the designated lunar orbit where it will rendezvous with the LSAM and allow the crew to transfer back to the Orion for Earth return. The Orion may transfer to an intermediate orbit between arrival into Lunar Destination Orbit and departure to LRO.

[CA3209-PO] Orion shall perform the Trans-Earth Injection (TEI) for crewed lunar missions.

Rationale: The requirement is consistent with Lunar Sortie and Lunar Outpost DRMs documented in CxP 70007, Constellation Design Reference Missions and Operational Concepts. The Orion includes the propulsion system and propellant to perform the TEI from LRO.

[CA4152-PO] Orion shall provide the infrastructure to perform ISS-based EVAs on ISS missions.

Rationale: For Orion missions to ISS, contingency EVA support will be provided by ISS EVA resources. The rationale for this programmatic decision was based on the assumption that the likelihood of a failure occurring that would not allow safe return to Earth or safe docking to ISS that could be corrected via EVA was extremely low. Once docked to ISS, ISS-based EVA capability using US or Russian spacesuits would be utilized. The decision for Orion to provide the infrastructure to perform ISS-based EVA on ISS missions was made at the March 29, 2006 Constellation Control Board (CxCB) and documented in the Board minutes. For additional Programmatic discussions and decisions made pertaining to this requirement, refer to the Constellation Operations Panel and Systems Engineering Control Board minutes during the month of March 2006.

[CA5148-PO] Orion shall provide the infrastructure necessary for at least three Orion vehicles operating in space concurrently during ISS phase operations.

Rationale: During ISS phase missions the driving scenario for simultaneous communications occurs during LEO Operations: (1) Quiescent Orion docked at ISS, active cargo vehicle undocked and moving to loiter orbit, active 2nd Orion approaching ISS, (2) contingency scenario / emergency on ISS – active undocked Orion, active 2nd Orion, quiescent cargo in loiter orbit. In either case, 3 Orion vehicles are operating concurrently. Orion infrastructure must allow for managing multiple vehicles and for ground control to uniquely identify and control individual vehicles (e.g., unique transponder signals identifiers and command and telemetry format headers).

[CA5240-PO] Orion shall perform an orbit transfer from Low Lunar Orbit to the Lunar Rendezvous Orbit (LRO) within 6 hours after the decision to return has been made.

Rationale: This requirement allocates a portion of the 132 hours that the Constellation Architecture needs to return the crew to the Earth surface. The number of hours allocated allows for the orbit transfer of Orion to LRO.

[CA5319-PO] Orion shall complete the orbit transfer from the Ascent Target to a stable Low Earth Orbit (LEO) independent of communications with Mission Systems.

Rationale: Orion follows a preprogrammed ascent trajectory from the Ascent Target to a stable Earth orbit and communication with Mission Systems is not needed for the successful completion. Nominally, command and telemetry to/from Orion will be used to control/monitor the vehicle during the ascent, but is not required for success. Orion cannot rely on other Constellation Systems (i.e., Ares I) for communication to the Missions Systems during ascent.

[CA6068-PO] Orion shall provide the infrastructure necessary for at least (TBD-001-1316) Orion vehicles operating in space concurrently during lunar phase operations.

Rationale: During lunar phase missions the driving scenario for simultaneous communications will be determined as a product of an IDAC-4 study focused on lunar CONOPs and lunar simultaneous communications needs. Orion infrastructure must allow for managing multiple vehicles and for ground control to uniquely identify *and control individual vehicles (e.g., unique transponder signals identifiers and command and telemetry format headers).*

3.7.1.2.6.1 Orion Control Mass

[CA0827-PO] Orion shall have a Control Mass of 21,877 kg (48,231 lbm) at the Lunar Ascent Target.

Rationale: The Control Mass for Orion was determined by the Orion 606C Point of Departure (POD) and PSE analyses. Mass control is required for the concurrent design of multiple Systems which have an overall performance or mission goal. This mass is consistent with Orion delivery to the Lunar Ascent Target. The control mass applies to the Orion crew module and service module and spacecraft adapter total mass, including cargo. This mass includes all pertinent Orion design mass growth allocation and flight performance reserves necessary to accomplish the mission. This value includes the mass for land-landing scar and the mass of the EVA, FC and FCE requirements.

[CA4134-PO] Orion shall have a Control Mass of 30,257 kg (66,706 lbm) at Lift-Off for the Lunar Mission.

Rationale: The Control Mass for the Orion at Lift-Off is based on the Orion 606C Point of Departure (POD) and PSE analyses. Mass control is required for the concurrent design of multiple Systems which have an overall performance or mission goal. This Control Mass can be determined by summing the Orion Crew Module, Service Module, Spacecraft Adapter and Launch Abort System masses. This Control Mass is needed with the Program Reserve to size Ares Mass Delivered requirements. This value includes the mass of the EVA, FC and FCE requirements.

[CA4135-PO] Orion shall perform all nominal jettison events between 12 (TBR-001-1021) and 30 seconds after Upper Stage Engine ignition command.

Rationale: Time of jettison of the LAS and ESM panels is needed to define performance impacts for Ares I. Performance estimates for Ares I require knowledge of mass and time for all events.

[CA4139-PO] Orion shall have a Control Mass of 20,185 (TBR-001-159) kg (44,500 lbm) at the time of Ares V rendezvous.

Rationale: The Control Mass for Orion at the time of Ares V rendezvous is defined by (TBD-001-1004) analysis. This Control Mass can be determined by summing the Orion Crew Module and Service Module masses and subtracting any used propellant mass. This Control Mass is needed to size Ares V and LSAM Mass Delivered requirements.

[CA4163-PO] Orion shall have a Control Mass of 27,676 kg (61,015 lbm) at Lift-Off for the ISS Mission.

Rationale: The Control Mass for the Orion at Lift-Off is based on the OVEIWG and PSE analyses. Mass control is required for the concurrent design of multiple *systems which have an overall performance or mission goal. This Control Mass can be determined by summing the Orion Crew Module, Service Module, Spacecraft Adapter and Launch Abort System masses for the ISS mission. This Control Mass is needed with the Program Reserve to size Ares Mass Delivered requirements. This value includes the mass of the EVA, FC and FCE requirements.*

[CA4164-PO] Orion shall have a Control Mass of 19,296 kg (42,540 lbm) at the ISS Ascent Target.

Rationale: The Control Mass for the Orion at Lift-Off is based on the Orion DAC-2 analysis. Mass control is required for the concurrent design of multiple Systems which have an overall performance or mission goal. This Control Mass can be determined by summing the Orion Crew Module, Service Module and Spacecraft Adapter masses for the ISS mission. This Control Mass is needed with the Program Reserve to size Ares Mass Delivered requirements. This value includes the mass of the EVA, FC and FCE requirements.

3.7.1.2.6.2 Orion Delta-V

Draft **[CA0406-PO]** Orion shall provide a total delta-V of (TBD-001-012) m/s (f/s) for the Mars Missions.

Rationale: The Program must control the allocation of the responsibility for the propulsive maneuvers in order to allow trades of mass and propulsive capability as the detailed designs of the missions and elements evolve.

[CA0829-PO] Orion shall provide a minimum translational delta-V of 1,492 m/s (4,896 ft/s) for lunar missions.

Rationale: The minimum translational delta-V requirement is based on analysis of the PDR POD Orion configuration against lunar mission requirements. This number is based on the Lunar Polar Outpost and Global Sortie missions and includes the delta-V necessary for orbit circularization from the ascent target, RPOD with the Ares V/LSAM in ERO, altitude maintenance during the lunar surface stay, aligning the Orion parking orbit with the LSAM ascent orbit at worst-case orientation, performing a TEI sequence with a 90 degree plane change, and executing Trajectory Correction Maneuvers (TCMs) during the Earth return for lunar polar outpost missions. It also accounts for GN&C performance dispersions. This excludes the attitude control delta-V. For the PDR POD Orion configuration, this delta-V allows for Polar sortie to 4 degree for nominal return to a designated coastal site within ~17 days, polar sortie to 2 degree with expedited (emergency) return within in-suit (120 hr) and total time from surface to TD (130 hr) timeline requirements, global sortie with 100% temporal and 100% surface coverage (with loiter) with return to CONUS or CA coast within 21.1 days, and global sortie with expedited return from worst case locations ~4-6 hours beyond in-suit and total time from surface to TD timelines.

[CA5948-PO] Orion shall provide propellant tanks sized for a translational delta-V of 1560 m/s (5,118 ft/s) for lunar missions.

Rationale: Provides for an additional Program Manager's reserve should the operational Ares I and Orion designs be capable of carrying additional propellant. The additional delta-V would provide for Polar sortie nominal and expedited return timelines shortened by approximately 20 hours or could extend latitude access to 4 degree latitude for expedited returns. The additional delta-V could also provide Global sortie with expedited return from worst case locations within in-suit and total time from surface to TD timelines or provide the capability to add dry mass/margin (~250 kg) to CM while meeting timeline requirements.

3.7.1.2.7 Orion Safety (System, Public, and Planetary)

[CA0435-PO] Orion shall control critical hazards. The hazards must be identified and controlled using the hazard identification and mitigation process described in CxP 70038, Constellation Hazard Analysis Methodology. The hazards must be controlled without the use of EVA, emergency operations or emergency systems.

Rationale: Control of mission critical failures is dictated by programmatic decision to ensure mission success. The Orion Project will define hazard controls that may include failure tolerance. The Orion Project will derive the specific hazard controls and implementation from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

[CA0436-PO] Orion shall control hazards that can lead to catastrophic events with no less than single failure tolerance, except for areas approved to use Design for Minimum Risk criteria. The level of failure tolerance must be determined using the hazard identification and mitigation process described in CxP 70038. The failure tolerance requirement cannot be satisfied by use of EVA, emergency operations or emergency systems.

Rationale: Constellation has established a minimum of single failure tolerance or DFMR to control catastrophic hazards. However, single failure tolerance may not be adequate in all instances to control catastrophic hazards. Thus, the level of failure tolerance needed is commensurate with the severity of the hazard, and likelihood of occurrence. The Orion Project will derive the specific level of failure tolerance and implementation (similar or dissimilar redundancy, backup systems) from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

[CA0437-PO] Orion shall comply with the requirement in JPR 8080.5, JSC Design and Procedural Standards, Section G-2.

Rationale: Fault tolerance is defeated if a single event can eliminate all modes of tolerance. This requirement mandates separation of redundant systems, subsystems, and elements.

3.7.1.2.8 Orion Command and Control

[CA0134-PO] Orion shall execute commands valid in the current state.

Rationale: The system will execute commands generated internally or from other systems in order to perform the specified function or operation. This process includes checking if the command has valid data values and can be executed now based on the current state or mode. Updates to the corresponding Health and Status parameters provide the execution end item result.

[CA0448-PO] Orion, when operated by the crew, shall be controllable by a single crewmember.

Rationale: Vehicle systems must be designed so that more than one crewmember is not required to operate the vehicle. There may be circumstances where crewmembers are unconscious or incapacitated leaving only a single crewmember capable of vehicle control. Work stations should provide redundant capability from which to command systems and manually operate the vehicle, if necessary. The intent of this requirement is to cover contingency cases where only one crewmember is available to operate Orion. This is a lesson learned from the shuttle cockpit, which has critical switches that are out of the operators reach zone. Therefore, the Orion design must take this into account and place controls within reach of a single operator.

[CA3110-PO] Orion shall accept control of automation.

Rationale: Commands from the crew, ISS, or other Constellation systems will need to select, initiate, inhibit, override, and terminate any automated function on Orion during various operational phases. Reference NPR 8705.2, Human-Rating Requirements for Space Systems, Sections 3.2.7 (34445) and 3.3.5 (34451).

[CA3249-PO] Orion shall provide an interface for the crew to generate commands

Rationale: In order to perform command and control, the crew will need to be able to initiate the sending of commands.

[CA3254-PO] Orion shall generate commands.

Rationale: To perform command and control of the Orion and integrated systems, the Orion will need to be able to initiate the sending of commands to itself and other Constellation Systems.

[CA3255-PO] Orion shall execute valid commands which are addressed to Orion.

Rationale: The system will execute commands generated internally or from other systems in order to perform the specified function or operation. The ability for Constellation systems to command execution on remote Constellation systems is required per the operations concept where the system with crew present, may need to command systems without the crew onboard (e.g. LSAM commanding the Orion).

In addition, the verification that the command is intended to be executed on the system will support the multi-hop routing capability.

[CA5039-PO] Orion shall provide a minimum of 20 Gigabytes of digital storage for recording digital data received from other Constellation Systems.

Rationale: Having storage space for other system's recorded data provides the Constellation Architecture the capability to transfer stored data to ensure that data is available when needed. 20 Gigabytes is based on Orion receiving 200 Mbps of data from Ares during a 12 minute ascent timeframe. The primary driver for the 200 Mbps rate is the flow of several motion imagery streams documenting the real-time performance of the Ares upper stage. Orion is encouraged to provide larger than necessary storage space for early missions in preparation for the larger space requirements in later phases of the program. Additional performance details (duration, etc.) will be defined in CxP 72000, Constellation Program System Requirements for the Orion System.

[CA5040-PO] Orion shall record system-generated digital data received from other Constellation systems.

Rationale: There are times when the quantity/rate of data recorded at certain times exceeds the capability of that system's downlink to send. Sharing data recording across Constellation systems allows for increased downlink capacity for highly dynamic events. Constellation systems must store data for each other in order to pass that data along the ultimate path it must traverse to make it back to Earth.

3.7.1.2.9 Orion Health and Status

[CA0427-PO] Orion shall provide Health and Status (H&S) information to the crew.

Rationale: Provides for processing of H&S information on internal operations of the Orion, as well as other Constellation elements, for use by the Orion crew.

[CA0428-PO] Orion shall generate Health and Status information.

Rationale: Provides for generation of H&S information on internal operations of the Orion. Full definition of the specific data is provided in Orion SRD and multiple Orion/Element IRDs.

[CA0438-PO] Orion shall detect system faults which could result in Loss of Vehicle, loss of life and Loss of Mission.

Rationale: Fault detection is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault detection enables crew abort or flight termination (in case of nonrecoverable failures). Faults subject to detection are further specified by CxP 72000, Constellation Program System Requirements for the Orion System. FDIR is a redundancy management function necessary to manage fault tolerance. This Level II requirement addresses the Loss of vehicle, loss of life, and Loss of mission.

[CA5465-PO] Orion shall isolate detected faults to the level required for recovery of function.

Rationale: Fault isolation is required for crew safety and mission success by identifying the root cause of a system fault, which allows for the safing and recovery of affected systems. In addition, fault isolation enables appropriate recovery steps, or crew abort or flight termination in the case of nonrecoverable failures. Faults subject to isolation are further specified by the CxP 72000, Constellation Program System Requirements for the Orion System .

[CA5466-PO] Orion shall provide recovery from isolated faults.

Rationale: Fault recovery is required for vehicle faults and failures which could lead to Loss of Vehicle, loss of life, Loss of Mission, or loss of system redundancy. Faults subject to recovery are further specified in the CxP 72000, Constellation Program System Requirements for the Orion System. This requirement does not preclude procedural recovery from other faults or failures.

3.7.1.2.10 Orion Communications and Communications Security

[CA0344-PO] Orion shall maintain communications with Mission Systems for at least 36 hours post landing.

Rationale: Recovery forces are required to recover the Orion crew within 36 hours. Mission Systems will be in contact with the Orion before touchdown and therefore would be best positioned to maintain communications and coordinate between Orion, Ground Systems and recovery forces until the recovery forces can establish direct communications with the Orion.

[CA0470-PO] Orion shall transmit and receive with an antenna spherical coverage of 90%, excluding non-Orion structural blockage, for all flight phases until Service Module (SM) separation, for the 18 kbps forward/24 kbps return link as defined by the CxP 70118-01 Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 1: Orion, Section 3.6.1.2.

Rationale: Orion must communicate with MS through C&TN as Orion does not have a direct path to communicate with MS in flight. The 18 kbps forward/24 kbps return link will include critical voice, commands, tracking and telemetry. Percent coverage requirements are determined by analysis of Constellation Concept of Operations, Constellation FFBDs and Orion design trades, with the goal of achieving the highest possible coverage. Link data rate is specified in CxP 70118-01, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 1: Orion. 90% coverage is based on analysis in IDAC2, TDS SIG-13-201. It is understood that 90% spherical coverage is not possible after SM separation because the SM antennas will not be available.

[CA0511-PO] Orion shall record critical data for reconstruction of catastrophic events.

Rationale: Flight data recorded prior to and during a catastrophic event is critical to accident investigations. A goal would be to reconstruct the catastrophic event based on this flight data. The specific environmental conditions the data must survive will be derived from the Orion design and defined in CxP 72000, Constellation Program System Requirements for the Orion System.

[CA3280-PO] Orion shall communicate using an independent, dissimilar, voice only system from pre-launch through separation of the Orion from the Ares Upper Stage.

Rationale: Orion needs an independent, dissimilar, communication capability to improve crew safety and mission success. Orion must be able to communicate with mission operations to ensure safe flight and respond to inflight emergencies in the event of a failure of the primary communication system. Communication must be provided from pre-launch through powered flight until separation of the Orion from the Ares Upper Stage to ensure a reliable means to verbally abort the flight.

[CA3287-PO] Orion shall, during ISS phase operations, communicate simultaneously with Mission Systems, and with one other Constellation system that is within 30 km (16.2 nmi) of Orion.

Rationale: During ISS phase missions the driving scenario for simultaneous communications occurs during LEO Operations: (1) Quiescent Orion docked at ISS, active cargo vehicle undocked and moving to loiter orbit, active 2nd Orion approaching ISS, (2) contingency scenario / emergency on ISS – active undocked Orion, active 2nd Orion, quiescent cargo in loiter orbit. In these scenarios, the Orion vehicles have communications with MS and either ISS or the other Orion vehicle, resulting in a requirement for communications with MS + 1 Constellation system. ISS phase operations indicate that tracking and communications should begin at a minimum of 30-km separation during rendezvous and docking scenarios. As such, Orion should have similar communications ability with other Constellation systems in the same vicinity/distance.

[CA3288-PO] Orion shall communicate simultaneously with ISS and Mission Systems when within 30 km (16.2 nmi) of ISS.

Rationale: Orion must communicate with MS to provide situational awareness and to enable ground commanding. Orion must also communicate with ISS to accomplish rendezvous. The specified range is determined by analysis of Constellation FFBDs and by analysis of ISS visiting vehicle requirements and Orion design trades. The relative range was determined based on IDAC2 and Orion design trades, as well as ISS visiting vehicle requirements. Orion RPOD system relies on S-band range and range-rate measurements with ISS at distances of up to 30 km. This distance allows for confirmation of relative state prior to TPI.

[CA5901-PO] Orion shall accept reconfiguration of stored commands, sequences and data.

Rationale: Orion needs to accept changes to sequences, commands and data parameters already stored onboard, when the ground or missions systems initiate such reconfiguration actions. Reconfiguration actions may impact procedures, operations timelines, or onboard algorithms which operate on commandable data items to support mission activities.

[CA5904-PO] Orion shall execute reconfigurable automation sequences valid in the current state.

Rationale: The system will execute reconfigurable automation sequences based on triggers that may be generated internally or from other systems (by means of commands) in order to perform the specified function or operation. This process includes checking if the sequence has valid data values and can be executed now based on the current state or mode. Results of the execution are provided through updates to the sequencing Health and Status parameters.

[CA6066-PO] Orion shall, during Low Earth Orbit (LEO) operations of a lunar phase mission, communicate simultaneously with Mission Systems, and with (TBD-001-1314) other Constellation systems that are within 100 (TBR-001-1216) km (54 nmi) of Orion.

Rationale: During LEO operations of lunar phase missions the driving scenario for simultaneous communications will be identified by further study in IDAC-4. Communications range requirements will be based on additional navigation inputs (future study) that currently indicate 100 km for ranging during Orion-LLV RPOD is desirable.

[CA6067-PO] Orion shall, during lunar vicinity operations of a lunar phase mission, communicate simultaneously with Mission Systems, and with (TBD-001-1315) other Constellation systems that are within 800 km (432 nmi) of Orion.

Rationale: During LLO operations of lunar phase missions the driving scenario for simultaneous communications will be identified by further study in IDAC4. The 800 km distance of Lunar ship-to-ship measurements was chosen because it allows for the LLV to track the Orion vehicle when it crosses the horizon in a 200+ km altitude orbit with a groundtrack passing over the landing site at the moon. This distance will also allow continuous ship-to-ship measurements during liftoff, ascent, and RPOD operations at the moon and support contingency operations prior to and after LLV landing.

[CA6070-PO] Orion shall communicate with Mission Systems for at least 5 minutes out of every 3 hours independent of the status of the primary communication system while in LEO.

Rationale: The capability to communicate with the Orion when the primary communication system is failed or misconfigured is essential to decreasing the probability of LOM. Mission operations experience has shown that regular communication capabilities provides significant ability to diagnose and correct misconfigured or failed systems ensuring continuation of the mission.

[CA6108-PO] The Orion vehicle shall provide integrated audio and High Definition motion imagery in real-time post-orbit insertion.

Rationale: The activities associated with the flight of a new program are of national and historical importance, and interest and it is the responsibility of NASA, per the Space Act of 1958, to distribute this information to the public and the NASA Authorization Act of 2005. In addition, this meets the goals of the Constellation program of promoting public participation, CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-G14], and to effectively communicate the benefits of exploration to the public, CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O08] Scheduled events can include rendezvous and mating operations, EVAs, or crew communications and press conferences. The audio and video systems shall be integrated in order to facilitate synchronized imagery to the ground and reduce crew, MCC, and timeline, impacts on operational setup and implementation. This data will be transmitted to Mission Systems using the Space Network during LEO operations and using the Deep Space Network when operating beyond LEO. Based on the Federal Communications Commission's planned transition to a digital television standard by the end of 2009, the majority of US households will be High Definition capable, thus becoming the defacto television standard, by the time this vehicle is scheduled to fly.
NOTE: Ares-1/Orion onboard ascent real-time motion imagery from the integrated stack is not required for real-time distribution to the public, but may be made available as a subset of real-time motion imagery collected and downlinked for engineering assessments.

[CA6110-PO] Orion shall provide motion imagery of separation from Ares.

Rationale: Motion imagery of separation from Ares is used for engineering analysis for mission critical events. This data can be recorded onboard Orion for subsequent retrieval post-orbital insertion or upon landing. This imagery requirement is allocated to Orion since Ares real-time transmission of Ares provided motion imagery results in a higher cost solution to Constellation.

[CA6212-PO] Orion shall process range safety telemetry within 1 second (TBR-001-1440) during the launch/ascent phase.

Rationale: Establishes the need for a maximum Orion sub-allocation latency for telemetry during the launch/ascent phase. Latencies for range safety telemetry are critical to ensuring safe flight and to remaining within the operational constraints of the US Eastern Range. Time to process range safety telemetry is determined by the time from the detection of an event until transmission of the data to CTN.

[CA6213-PO] Orion shall process voice within 1 second (TBR-001-1441) during the launch/ascent phase.

Rationale: Establishes the need for Orion sub-allocation maximum latency for voice under the verbal abort scenario during the launch/ascent phase. Latencies for voice *transmissions are critical during the launch/ascent phase to ensure timely response by the crew to verbal abort commands. Time to process voice is determined by the time from the capture of crew voice until transmission of the data to CTN or by the time from receipt of voice data from CTN until production of crew audio.*

3.7.1.2.11 Orion GN&C

[CA0059-PO] Orion shall function as the maneuvering vehicle during RPODU operations with the LSAM/Ares V EDS mated configuration in LEO.

Rationale: Because of launch vehicle constraints, it is necessary to launch Orion separately from the LSAM. Two launches make an Earth orbit rendezvous between the Orion and the LSAM/Ares V EDS necessary. The Orion is crewed during Rendezvous Proximity Operation Docking (RPOD) with LSAM/Ares V EDS, so it will be the maneuvering vehicle. This requirement conforms to the principle that the crewed vehicle should be in control of the rendezvous and docking process. Undocking by Orion is needed to support abort scenarios for return to Earth.

[CA0081-PO] Orion shall function as the maneuvering vehicle during RPODU operations with the ISS.

Rationale: This requirement is consistent with the Earth Orbit to Destination Vicinity, Destination Vicinity Operations and Destination Vicinity to Destination Mission Phases of the Crew Rotation, and Pressurized Cargo to ISS DRMs in CxP 70007, Constellation Design Reference Missions and Operational Concepts. Orion crew sizes of 0 and 1, as specified in CA0388, drive the required levels of automation on the Orion for ISS RPODU.

[CA0131-PO] Orion shall function as the target vehicle during RPOD operations with the LSAM in LLO.

Rationale: Upon return from the lunar surface, the LSAM will dock with the Orion in LLO. The Orion will be uncrewed during RPOD operations with LSAM, so the Orion will nominally function as the target. This requirement conforms to the principle that the crewed vehicle should be in control of the rendezvous and docking process. The contingency case where the Orion functions as the maneuvering vehicle is covered in a separate requirement (CA0369-PO).

[CA0133-PO] Orion shall function as the maneuvering vehicle during undocking and departure proximity operations from LSAM, prior to TEI.

Rationale: After ascent from the lunar surface and docking with the Orion, the crew will transfer from the LSAM to the Orion. The Orion will then undock from LSAM and prepare to return to Earth. The Orion will be crewed during undocking and departure proximity operations, so it will function as the maneuvering vehicle. This requirement conforms to the principle that the crewed vehicle should be in control of the rendezvous and docking process.

[CA0187-PO] Orion shall perform attitude control of the Orion/LSAM mated configuration after docking in LLO.

Rationale: After the LSAM returns from the lunar surface and docks with the Orion, the crew will transfer to the Orion in preparation for return to Earth. Consequently, the Orion will perform the GN&C for the Orion/LSAM mated configuration after docking is complete.

[CA0329-PO] Orion shall perform a guided entry that results in landing within 10 km (5.4 nmi) of the intended target at a designated water landing site.

Rationale: Improved landing target accuracy increases crew safety by reducing the time to recover post landing. Meeting this accuracy is independent of having the day of landing meteorological data available for the designated landing site. However, day of landing wind knowledge could operationally be used to improve landing accuracy. Landing target accuracy is limited by vehicle and parachute performance and atmospheric conditions. The specified accuracy is consistent with the state of the art for ballistic chutes and the limitations of potential landing sites. Designated landing site is defined prior to launch and updated based upon trajectory maneuvers in flight.

[CA0369-PO] Orion shall function as a maneuvering vehicle while performing RPOD with the LSAM in LLO prior to crew transfer back to the Orion for crewed Lunar missions.

Rationale: For nominal missions, the Orion acts as the target during the rendezvous phase in LLO. This requirement covers the contingency case in which the LSAM has an under speed condition or other reason causing the LSAM to be placed in the incorrect orbit, but an orbit which is still accessible by the Orion within planned as well as reserve performance. In this scenario, the Orion is remotely commanded to perform rendezvous maneuvers, including proximity operations. Docking may be completed via LSAM or the Orion. The LSAM then completes the final approach and docking maneuver as the maneuvering vehicle, with the Orion performing the target role. This is not intended as a separate delta-V requirement for Orion. It is intended to ensure that the Orion software and any RPOD hardware are capable of operating as the maneuvering vehicle for this contingency case.

[CA0462-PO] Orion shall function as the maneuvering vehicle during undocking and departure proximity operations from the target vehicle at any attitude, in case of an emergency.

Rationale: This undocking capability is needed at any point during the Orion/ISS or Orion/LSAM docking activities or mated operations. It may be executed prior to Orion gaining structural attachment enough to allow Orion/ISS or Orion/LSAM interface to withstand attitude control loads or after the mated configuration is achieved.

[CA0463-PO] Orion shall provide for undocking within 10 (TBR-001-004) minutes of crew ingress and hatch closure.

Rationale: The duration defined allows for a quick getaway capability to a predetermined distance. Once the distance is achieved, state vector updates and initiation of other functions can be performed. The requirement does not imply that all nominal systems are required to be operational within this time, just the systems necessary to achieve safe separation and crew survival.

[CA0497-PO] Orion shall provide manual control of flight path, attitude, and attitude rates when the human can operate the vehicle within system margins.

Rationale: This requirement flows down from NPR 8705.2, Human-Rating Requirements for Space Systems. Manual control of spacecraft attitude, attitude rate and flight path provides additional margin for mission success and crew safety.

[CA3142-PO] Orion shall perform navigation and attitude determination during all mission phases including prelaunch.

Rationale: Navigation and attitude determination are required onboard Orion to accomplish mission critical activities such as communications antenna pointing, maneuver execution and performance monitoring, entry guidance, and docking. Navigation may include maintenance of a ground uploaded vehicle state or updates of the vehicle state by processing data from onboard sensors. All mission phases include prelaunch activities through touch down and recovery including aborts, even when Orion is not the controlling vehicle.

[CA3248-PO] Orion shall compute rendezvous maneuvers when performing relative navigation with the target vehicle.

Rationale: Onboard computations of rendezvous maneuvers are necessary for successful rendezvous execution and provide operational flexibility and efficiency. When Orion is within onboard relative navigation sensor range, onboard relative state knowledge generally exceeds that available to Mission Systems which makes the onboard solutions better than that available to Mission Systems. When beyond relative navigation range, Mission Systems will compute maneuvers (reduces flight software and crew training). This function allows contingency Orion chaser operations with the target LSAM in LLO.

[CA4128-PO] Orion shall perform attitude control of the Orion/LSAM mated configuration after Ares V EDS undocking through Orion/LSAM separation in LLO.

Rationale: This capability is required in the event of a contingency with the LSAM in which Orion must take over control of the Orion/LSAM stack post TLI. Consistent with the Lunar Sortie and Lunar Outpost Crew DRMs, and CA5290; the LSAM normally performs this function.

[CA5286-PO] The Orion shall perform target vehicle functions during undocking and departure proximity operations from LSAM prior to lunar descent.

Rationale: Since Orion is uncrewed as the LSAM undocks and departs for the lunar surface, Orion will act as the target. This requirement conforms to the principle that the crewed vehicle should be in control of the rendezvous and docking process.

[CA5819-PO] Orion shall perform Trajectory Correction Maneuvers (TCMs) during the Trans-Lunar Coast (TLC).

Rationale: This requirement ensures the safety of the crew by providing Orion with the capability to perform TCMs during the trans-Earth cruise in the event the LSAM is not capable of performing the maneuvers, as baselined for the Lunar Sortie and Lunar Outpost (Crew and Cargo) DRMs documented in CxP 70007, Constellation Design Reference Missions and Operational Concepts.

[CA5921-PO] Orion shall perform separation functions with the Ares I.

Rationale: This requirement is necessary to identify ownership of the separation function. The actual separation function (Orion Service Module from the Orion Spacecraft Adapter) resides entirely with the Orion. Orion separation functions include sending the command to Ares I to inhibit Ares RCS firings prior to separation and sending another command to fire Orion's separation mechanism. The criteria for determining when Orion will command separation may include allowing for Orion to accommodate a period of rate damping that Ares I nominally performs after upper stage shutdown. Because Ares I thrust cannot be counted on for an abort, Orion will have to verify that it can meet this requirement without Ares RCS rate damping. But, for the failure modes where Ares I can improve the separation environment by damping rates, the Ares I avionics should always try to damp rates unless it has received the RCS inhibit command from Orion.

3.7.1.2.12 Orion Reliability and Availability

[CA0178-PO] Orion shall have a probability of launch of not less than 98% (TBR-001-937), exclusive of weather, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses system reliability. System reliability and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements. The value of 98% in this requirement is an allocation from the parent requirement (CA-0123-PO) which, in turn, addresses the "Probability of No Second Launch" which would expire the orbiting EDS/LSAM. The TBR will be closed during the IDAC4 cycle after the (CA-0123-PO) parent requirement TBRs are removed.

[CA6100-PO] The Orion shall provide 6 hours (TBR- 001-1300) crew support consumables per launch opportunity for (TBD-001-1400) launch opportunities without top off.

Rationale: This requirement defines the amount of consumables that is required to be supplied by Orion to support the crew for each launch attempt. If subsequent launch attempts reduce overall mission duration through use of contingency days, this credit may be accounted for in initial consumables loading.

[CA6205-PO] Orion systems failures, identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1502)% that would result in a scrubbed launch, shall be maintainable as follows:

a. No less than 45% (TBR-001-1419) can be remedied to support a launch attempt within one day.

b. No less than 65% (TBR-001-1420) can be remedied to support a launch attempt within two days.

c. No less than 70% (TBR-001-1421) can be remedied to support a launch attempt within three days.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses Ares I system maintainability. The intent is to drive a capability to correct those failures discovered (latent defects) after deciding to load cryogenic propellants that will cause a launch scrub in order to maximize the number of launch attempts that are utilized. The duration for repair time includes the time to establish access, set up, diagnose, perform corrective maintenance, closeout, and complete any retest required in time to make the launch attempt. As this is a design-to requirement, administrative and logistics delay is not included (for example: time searching for a spare part).

The intent of extending through only 70% of failures is to prevent this requirement from driving counterproductive system complexity and increased effort or difficulty for nominal operations and sustainment scenarios. The expectation is that operability assessments should influence the developer's selection of which of the most likely failures to target.

The values used above (45%,65%, and 70%) correspond with the Delta II history of times to repair. The intention of this requirement is to inform design with the historical data as a first iteration until the supplier data becomes available. At that time, the analysis will be updated.

3.7.1.2.13 Orion Maintainability, Supportability, and Logistics

[CA5495-PO] Orion shall sustain operations using only onboard equipment and spares without resupply or support from personnel other than the crew.

Rationale: During Orion flight operations, the crew may be required to address situations without the support of ground personnel or the ISS. The ability to maintain operations autonomously is critical in contingencies.

[CA5974-PO] Orion shall produce and deliver Project Verified Engineering Build software and data products to the Constellation Program within the time limits identified in Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Engineering Build is a set of software and data products that contain new requirements (capabilities) and problem fixes. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Engineering Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. Data products contain representative launch geometry values and actual values for other parameters. It has completed Project Level Verification /Validation and has been configured to meet Integrated Build event requirements. Data definitions must be available in time to support generation of data products for the release. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation architecture. Project level activities include: participation in the build content definition, software design, code, and project-level Integration, test and delivery of the Project Verified Engineering Builds to the Program.

TABLE 3.7.1.2.13-1 TIME ALLOCATIONS FOR ENGINEERING BUILDS

Requirement	Threshold	Objective
Orion	7 months (TBR-001-1037)	2.5 months

[CA5975-PO] Orion shall produce and deliver Project Verified Flight Build software and data products to support the mission class within the time limits identified in Time Allocations for Flight Builds Table after the completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Flight Build is a set of software and data products that is based on a Project Verified Engineering Build, has mission specific (launch geometry derived) data and has completed Project Level Verification/Validation. Few software changes are expected. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Flight Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Data parameter values must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the

Constellation Architecture. Project level activities include: participation in the build content definition, flight specific configuration activity (data reconfiguration), Fast Track activities as required, and delivery of Project Verified Flight Builds. Times are contiguous days.

TABLE 3.7.1.2.13-2 TIME ALLOCATIONS FOR FLIGHT BUILDS

Requirement	Threshold	Objective
Orion	14 days	4 days

[CA5976-PO] Orion shall support day of launch updates for software parameters and data products to configure the systems.

Rationale: A day of launch update is a set of software and data products based on the Program Verified Flight Build and the approved final flight parameter updates for launch day environments (winds), orbit geometry (target tracking), and other I-loads as required.

[CA5977-PO] Orion shall produce and deliver resolutions for selected non-conformances during the engineering and flight release phases to the discovering organization and the Constellation Program in the time limits identified in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track build process is used for rapid resolution of problems found in the production of Flight Builds and Engineering Builds. The time period starts after documentation of the non-conformance and ends when the resolution is submitted for re-integration into the test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

TABLE 3.7.1.2.13-3 - TIME ALLOCATIONS FOR FAST TRACK PROCESS

Requirement	Threshold	Objective
Orion	48 hours	12 hours

[CA6003-PO] Orion shall conduct ground operations for a single Ares I/Orion mission within the time limits identified in the Orion Critical Path Allocations for Ares I/Orion Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and ground system designs that result in reduced ground operations time and labor without sacrifices to performance or design cost. The critical path constraints levied in Orion Critical Path Allocations for Ares I/Orion Ground Operations Table, along with labor-hour constraints defined in CA6003, are intended to drive the design of the flight and ground systems to enable such reductions. The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather, they are intended to be a design target for the system developers.

In Orion Critical Path Allocations for Ares I/Orion Ground Operations Table, the Orion Ground Operations processing flow is broken down into sequential time periods between key integrated processing milestones. The sum of the four time periods is the overall critical path portion affecting Orion anticipated for nominal Constellation Ground Operations. The critical path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming "single-string" for the integrated operations Ground Systems (i.e., one Ares I Mobile Launcher, one Ares I VAB high bay, one control room for Ares I operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx ground operations.

The values identified in Orion Critical Path Allocations for Ares I/Orion Ground Operations Table are intended to apply to nominal Orion operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy Expendable Launch Vehicle (ELV) systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.7.1.2.13-4 ORION CRITICAL PATH ALLOCATIONS FOR ARES-1/ORION GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)	Notes	Allocation

	Threshold	Objective		
Ready for Orion Integration to Integrated Stack Ready for Powered Testing	53 (TBR-001-1202)	44 (TBR-001-1203)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA
Ready for Powered Testing to Finish of Powered Testing	67 (TBR-001-1204)	56 (TBR-001-1205)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares I, Orion, GS, EVA
Finish of Powered Testing to Pad Connection and Validation Complete	46 (TBR-001-1206)	38 (TBR-001-1207)	From the end of powered testing in the VAB until the vehicle is at the launch pad and ready to begin launch preps. Includes vehicle and ground system roll out preparations, roll-out, and ML-Launch pad connections and validations.	GS, Ares I, Orion
Pad Connection and Validation Complete to Launch	82 (TBR-001-1208)	68 (TBR-001-1209)	Begins once pad connections are validated and ends at T-0.	GS, Ares I, Orion, EVA

[CA6013-PO] Orion shall produce cargo engineering products for a single mission within 90 days (TBR-001-1095) for crewed ISS missions.

Rationale: The Mission Integration Production defines an orderly mission production process beginning with the definition of a baselined set of mission requirements and the ensuing flight design, flight software, ground vehicle processing, flight operations documentation development, vehicle configuration, and crew and launch/flight control training activities necessary to support a mission. Orion portions of that production effort are in software reconfiguration (CA5964) and cargo engineering. Cargo engineering is used to support ground processing and is managed to a shorter process based on reduced complexity, reduced numbers of interfaces, and standard interfaces between flight systems and cargo for each ISS mission. Days are based on contiguous work days (no weekend or holiday work, 8 hrs/day, 5 days/week).

[CA6013-PO-Objective] Orion shall produce cargo engineering products for a single mission within 50 days (TBR-001-1096) for crewed ISS missions.

Rationale: The Mission Integration Production defines an orderly mission production process beginning with the definition of a baselined set of mission requirements and the ensuing flight design, flight software, ground vehicle processing, flight operations documentation development, vehicle configuration, and crew and launch/flight control training activities necessary to support a mission. Orion portions of that production effort are in software reconfiguration (CA5964) and cargo engineering. Cargo engineering is used to support ground processing and is managed to a shorter process based on reduced complexity, reduced numbers of interfaces, and standard interfaces between flight systems and cargo for each ISS mission. Days are based on contiguous work days (no weekend or holiday work, 8 hrs/day, 5 days/week).

[CA6015-PO] Orion shall produce cargo engineering products for a single mission within (TBD-001-1074) days for Lunar missions.

Rationale: The Mission Integration Production defines an orderly mission production process beginning with the definition of a baselined set of mission requirements and the ensuing flight design, flight software, ground vehicle processing, flight operations documentation development, vehicle configuration, and crew and launch/flight control training activities necessary to support a mission. Orion portions of that production effort are in software reconfiguration (reference CA5964) and cargo engineering. Cargo engineering is used to support ground processing and is managed to a shorter process based on managing to standard interfaces between flight systems and cargo for each Lunar mission. Days are based on contiguous work days (no weekend or holiday work, 8 hrs/day, 5 days/week).

[CA6015-PO-Objective] The Orion shall produce cargo engineering products for a single mission within (TBD-001-1075) days for Lunar missions.

Rationale: The Mission Integration Production defines an orderly mission production process beginning with the definition of a baselined set of mission requirements and the ensuing flight design, flight software, ground vehicle processing, flight operations documentation development, vehicle configuration, and crew and launch/flight control training activities necessary to support a mission. Orion portions of that production effort are in software reconfiguration (reference CA5964) and cargo engineering. Cargo engineering is used to support ground processing and is managed to a shorter process based on managing to standard interfaces between flight systems and cargo for each Lunar mission. Days are based on contiguous work days (no weekend or holiday work, 8 hrs/day, 5 days/week).

[CA6029-PO] Orion shall operate in a quiescent mode at ISS with no more than 2 hours per week contiguous real-time command and control from Mission Systems under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting command and control interaction with a quiescent Orion docked to ISS to specific periods under nominal operating conditions (i.e. no Orion system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent Orion would require very little routine command and control interaction. Managing this interaction within a specific period enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). The objective strives to eliminate nominal command and control between ground controllers and a quiescent Orion, hence eliminating need for dedicated flight control teams for a quiescent Orion at ISS under nominal quiescent operations.

[CA6029-PO-Objective] Orion shall require no real-time support during quiescent operations while docked with ISS under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting command and control interaction with a quiescent Orion docked to ISS to specific periods under nominal operating conditions (i.e. no Orion system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent Orion would require very little routine command and control interaction. Managing this interaction within a specific period enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). The objective strives to eliminate nominal command and control between ground controllers and a quiescent Orion, hence eliminating need for dedicated flight control teams for a quiescent Orion at ISS under nominal quiescent operations.

[CA6031-PO] Orion shall operate in a quiescent mode for Lunar missions with no more than 2 (TBR-001-1106) hours per week contiguous real-time command and control from Mission Systems under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting command and control interaction with a quiescent Orion in Lunar Orbit Maintenance to specific periods under nominal operating conditions (i.e., no Orion system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent Orion would require very little routine command and control interaction. Managing this interaction within a specific period enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). The assumption is that operations personnel send commands (e.g. crew uplink messages, state vectors, scripts) during this active command and control period each week.

[CA6032-PO] Orion shall operate with no more than 1 hour per day contiguous (consisting of 1 (TBR-001-1110) man-hours) monitoring by dedicated Orion engineering teams while in a quiescent mode for ISS missions under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations and flight systems' engineering support teams. Limiting ground active monitoring required by a quiescent vehicle to specific periods and specific manpower intensity under nominal operating conditions (i.e. no Orion system failures) will contribute to reduced operations and sustaining engineering life cycle costs. It is expected that a quiescent vehicle (e.g. Orion docked to ISS) would require very little routine active telemetry monitoring by dedicated ground controllers and engineering teams. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time dedicated ground control and engineering team manning (e.g. numbers of dedicated shifts and numbers of teams). This requirement does not preclude the fact that Health and Status data from quiescent vehicles will be provided near continuously from the Orion for fault annunciation and trending. Ground controllers and engineering teams supporting other active vehicles (e.g. ISS) can monitor for trends and fault annunciations as part of the active vehicle routine tasks. Dedicated *personnel can be called in to resolve anomalies when needed. Assumption is one engineering support person monitoring trends and archived subsystems data during this active monitoring period without need for operations personnel, unless anomalies occur.*

[CA6033-PO] Orion shall operate with no more than 1 hour per day contiguous (consisting of 1 (TBR-001-1111) man-hours) monitoring by dedicated Orion engineering teams while in a quiescent mode for Lunar missions under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations and flight systems' engineering support teams. Limiting ground active monitoring required by a quiescent vehicle to specific periods and specific manpower intensity will contribute to reduced operations and sustaining engineering life cycle costs. It is expected that a quiescent vehicle (e.g. Orion in Lunar Orbit Maintenance) would require very little routine active telemetry monitoring by ground controllers and engineering teams. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control and engineering team manning (e.g. numbers of dedicated shifts and numbers of teams). This requirement does not preclude the fact that Health and Status data from quiescent vehicles will be provided near continuously from the Orion for fault annunciation and trending. Ground controllers and engineering teams supporting other active vehicles (e.g. ISS or Outpost) can monitor for trends and fault annunciations as part of the active vehicle routine tasks. Assumption is that engineering support personnel monitor trends and archived subsystems data during this active monitoring period without need for operations personnel, unless anomalies occur.

3.7.1.2.14 Orion Habitability and Human Factors

[CA0288-PO] Orion shall control cabin pressure to a selectable setpoint between 103 kPa (14.9 psia) to 62 kPa (9.0 psia) with 0.7 kPa (0.1 psia) increments, while simultaneously meeting the oxygen materials limit in CA3061-PO and the full range of Partial Pressure Oxygen (ppO2) selectability defined in CA3133-PO.

Rationale: This is to provide pressure selectability to facilitate docking from the maximum ISS operational pressure to the minimum nominal limit with a 30% oxygen materials limit and 17 kPa (2.5 psia) ppO2 crew limit. This is to have common approach to cabin pressure management across Constellation Architecture.

[CA0426-PO] The Orion's Net Habitable Volume shall be no less than 10.76 m3 (380 ft3).

Rationale: Establishing a minimum net habitable volume ensures that the Orion protects for sufficient unencumbered volume for the crew to execute tasks safely and effectively to include contingency response, such as emergency egress. The 10.76 m3 (380 ft3) equals a DAC2 evaluated volume of 9.03 m3 (319 ft3) with an approximate 20% increase for task and analysis uncertainty. The 4-crew lunar *configuration was selected based upon the longer mission duration, and greater number of undefined tasks with the expectation that the same volume will be adequate for a 6-crew ISS mission because of the shorter duration and fewer undefined tasks.*

[CA0886-PO] Orion shall provide not less than two vestibule pressurization cycles per mission.

Rationale: The responsibility for vestibule pressurization must be allocated between the Orion and LSAM and between the Orion and ISS. This requirement allocates responsibility for two pressurization cycles to Orion. Primary and contingency vestibule pressurization should account for each docking in which the crewed Orion is the active vehicle. The LSAM will perform the vestibule pressurization when the crewed LSAM docks with the Orion. For missions to ISS, it is assumed that the ISS is also capable to perform vestibule repressurizations and could perform any additional contingency repressurizations of the vestibule.

[CA3061-PO] The Orion shall limit the maximum oxygen concentration within the pressurized cabin to 30% (TBR-001-109) by volume.

Rationale: Oxygen concentration limits should not exceed 30% by volume to minimize risk of fire.

[CA3105-PO] Orion shall maintain the cabin environment at a pressure of no less than 55 kPa (8.0 psia) for at least 70 (TBR-001-1301) minutes with an equivalent cabin hole diameter of 0.64 cm (0.25 in).

Rationale: This is one of the requirements that define vehicle response to a cabin leak. . The Orion ECLSS must feed the leak for a discrete amount of time in which the crew must be suited and pressurized with confidence (i.e. leak checked) prior to total cabin depressurization. This requirement defines the cabin pressure maintenance required to allow time for alarm notification, vehicle troubleshooting, suit retrieval per CA3108-PO, suit donning and connection to vehicle life support per CA3058-PO, and suit loop leak check with maximum of 1 leak troubleshoot and repair event. The 0.64 cm (0.25 in) hole is derived from expected leak rates from lost seals on overboard hatches and feed-throughs and previous spaceflight precedent.

[CA3106-PO] Orion shall maintain the cabin environment at a pressure to support pre-breathe as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), [HS6091], with an equivalent cabin hole diameter of 0.64 cm (0.25 in) and a suit pressure per CA5659-PO.

Rationale: This is one of the requirements that define vehicle response to a cabin leak. It will require the time the cabin pressure must be maintained to allow the crew to don suits, the time the cabin pressure must be maintained to prebreathe, suit pressure for depress events, and the number of cabin leak or cabin repress events the vehicle must support for either ISS or lunar missions. This requirement defines *the cabin pressure maintenance required allows time for the crew to pre-breathe in order to de-nitrify their blood before they go to reduced pressures in the suit. The 0.64 cm (0.25 in) hole is derived from expected leak rates from lost seals on overboard hatches and feed-throughs, and previous spaceflight precedent.*

[CA3133-PO] Orion shall control cabin oxygen partial pressure to a selectable setpoint between 17 kPa (2.5 psia) ppO2 and 21 kPa (3.1 psia) ppO2 with 0.7 kPa (0.1 psia) increments.

Rationale: This is to allow oxygen partial pressure selectability to facilitate operations from ambient ISS oxygen partial pressures to the ppO2 crew limit. This is to have common approach to cabin pressure management across Constellation Architecture. This matches the indefinite ranges specified in HSIR requirement HS3005B to allow the greatest range of system capability.

[CA3140-PO] Orion shall provide oxygen and nitrogen storage to survive from the largest gas consumable combination of two pressure events (i.e., EVA, contaminated atmosphere, and unrecoverable cabin leak).

Rationale: Gas must be allocated to respond to cabin pressure events. The EVA event, which only applies to Lunar missions, includes gas for suit donning, suit purge, prebreathe, cabin depress, and cabin repress to 70 kPa (10.2 psia). The contaminated atmosphere event includes gas for emergency breathing apparatus if applicable, and cabin depress/repress to initial pressure, if applicable. Unrecoverable cabin leak includes gas required to maintain cabin at 55 kPa (8 psia) while crew dons suits, purges suit loop, and performs prebreathe. Of the two pressure events, there can be more than one EVA event or contaminated atmosphere event. Once the vehicle volume and prebreathe details are known, an analysis shall be performed to determine which scenarios are the driving cases for consumables sizing. The ISS mission is not intended to be the driving case and may require repressurization to a pressure less than 14.7 psia for the second event, with additional contingency makeup gas to be provided by the ISS.

[CA5711-PO] Orion shall return the Orion pressurized volume to a habitable environment following the contamination of the cabin atmosphere following a fire, toxic release, and docking with another vehicle that has suffered such an event.

Rationale: A contamination event should not automatically cause long-term contingency operations or termination of the mission. If all safety- and mission-critical systems and backups are still operational following cleanup, the crew and mission management should have the option of returning to normal operations and continuing with the mission.

3.7.1.2.15 Orion Environmental Conditions

[CA0374-PO] Orion shall meet its requirements during and after exposure to the environments defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, 3.3, 3.5, 3.6 and 3.7.

Rationale: The Orion will be exposed to a variety of natural environments that could make it unable to meet its requirements, potentially in combination with induced environments. This requirement defines the limits of these effects and assures that they will be mitigated by the design. Natural environment effects for the Orion also need to be considered for the integrated vehicle configurations: Orion/LSAM, Orion/LSAM/Ares V-EDS, Orion/Ares I, Orion/Ares I/GS and Orion/ISS.

[CA5555-PO] Orion shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can degrade system performance, shorten system life, and lead to system or mission failure if not properly considered in the design.

[CA5560-PO] Orion shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can degrade system performance, shorten system life, and lead to system or mission failure if not properly considered in the design. Therefore, the production of induced environments must be limited and controlled to allow proper performance and function of other sub-systems and other systems when operating in mated configurations.

3.7.1.3 Reserved

3.7.1.4 Orion External Interfaces

[CA0361-PO] Orion shall interface with Ares V per CxP 70119, Constellation Program Orion -To- Ares V Interface Requirements Document (IRD).

Rationale: The Orion and Ares V share physical and functional interfaces which are identified in CxP 70119, Constellation Program Orion -To- Ares V Interface Requirements Document (IRD).

[CA0429-PO] Orion shall interface with the Ares I per CxP 70026, Constellation Program Orion -To- Ares I Interface Requirements Document (IRD).

Rationale: The Orion and Ares I share physical and functional interfaces which are identified in CxP 70026, Constellation Program Orion -To- Ares I Interface Requirements Document (IRD).

[CA0800-PO] Orion shall interface with the LSAM per CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document.

Rationale: Orion and LSAM share physical and functional interfaces which are identified in CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document .

[CA0893-PO] Orion shall interface with Ground Systems per CxP 70028, Constellation Program Ground Systems (GS) -To- Orion Interface Requirements Document (IRD).

Rationale: Orion and Ground Systems share physical and functional interfaces which are identified in CxP 70028, Constellation Program Ground Systems (GS) -To- Orion Interface Requirements Document (IRD).

[CA0894-PO] Orion shall interface with Mission Systems per CxP 70029, Constellation Program Orion -To- Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: Orion and Mission Systems share physical and functional interfaces which are identified in CxP 70029, Constellation Program Orion -To- Mission Systems (MS) Interface Requirements Document (IRD).

[CA0895-PO] Orion shall interface with EVA Systems per CxP 70033, Constellation Program Orion - To - EVA Systems Interface Requirements Document.

Rationale: Orion and EVA systems share physical and functional interfaces which are identified in the Orion to EVA Interface Requirements Document.

[CA0896-PO] Orion shall interface with the Communications and Tracking Network per CxP 70118-01, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document (IRD), Volume 1: Orion.

Rationale: Orion and C&TN share physical and functional interfaces which are identified in CxP 70118-01, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 1: Orion.

3.7.1.5 Orion Physical Characteristics

[CA0386-HQ] Orion shall have an outer mold line that is derived from the Apollo Command Module (CM) design as defined in CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line.

Rationale: By using a derivative of the same outer mold line as the Apollo CM, Orion designers will be able to utilize the aero/aerothermal databases and test/flight databases developed during the Apollo Program. The use of this flight-proven design is seen as a significant cost/schedule savings for the Orion development effort when compared with establishing a new design without flight heritage. The dimensions of the Orion will be based on the optimal size for meeting mission requirements.

[CA5933-PO] Orion shall include a Service Module (SM) that is configurable as a standalone element.

Rationale: This requirement allows flexibility in the applicability of Orion through the use of a “smart” Service Module (SM). The SM can serve as a propulsion stage or a spacecraft bus in support of missions other than the ones associated with the ISS, Lunar and Mars DRMs. As a standalone element, the SM has the same general configuration as if integrated with the Crew Module (CM), but it can be augmented to carry any required CM equipment (avionics, power, thermal, GN&C, C&T) in a mission specific kit and a fairing to perform missions without the CM. Examples of applicable missions could include reservicing of the Hubble Space Telescope (HST), *deorbiting of the HST, an ISS-based space tug, a generic near Earth space tug, long life multi-satellite smart dispenser, and delivery of new modules or other unpressurized cargo to the ISS.*

3.7.2 Ares I

3.7.2.1 Ares I Description

The Ares I is the launch vehicle for Orion. It consists of a 5-segment solid rocket booster first stage and a cryogenic liquid hydrogen/oxygen fueled upper stage consisting of a structural tank assembly and a J-2x engine. The first stage is reusable and the upper stage is discarded after Orion has separated during ascent.

3.7.2.2 Ares I Requirements

3.7.2.2.1 Ares I Mission Success

[CA1065-PO] Ares I shall limit their contribution to the risk of Loss of Mission (LOM) for any mission to no greater than 1 in 500.

Rationale: The 1 in 500 means a 0.002 (or 0.2 %) probability of loss of Ares I mission for any Constellation DRM. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals and Objectives, Safety GoalCxP-G02: Provide a substantial increase in safety, crew survival, and reliability of the overall system over legacy systems.

[CA5805-PO] The Ares I shall control hazards that can lead to catastrophic events with no less than single failure tolerance, except for areas approved to use Design for Minimum Risk criteria. The level of failure tolerance must be determined using the hazard identification and mitigation process described in CxP 70038, Constellation Program Hazard Analyses Methodology. The failure tolerance must be achieved without the use of a pad or ascent abort.

Rationale: The Program has established a minimum of single failure tolerance or DFMR to control catastrophic hazards. However, single failure tolerance may not be adequate in all instances to control catastrophic hazards. Thus, the level of failure tolerance needed is commensurate with the severity of the hazard, and likelihood of occurrence. The Ares I Project will derive the specific level of failure tolerance and implementation (similar or dissimilar redundancy, backup systems) from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

[CA5916-PO] Ares I shall control critical hazards that do not cause a pad or ascent abort . The hazards must be identified and controlled using the hazard identification and mitigation process described in CxP 70038, Constellation Program Hazard Analyses Methodology.

Rationale: Control of mission critical failures is dictated by programmatic decision to ensure mission success. The Ares I Project will define hazard controls that may include failure tolerance. The Ares I Project will derive the specific hazard controls and implementation from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

3.7.2.2.2 Ares I Crew Survival

[CA0258-PO] Ares I shall comply with the requirement in JPR 8080.5, JSC Design and Procedural Standards, Section G-2.

Rationale: Fault tolerance is defeated if a single event can eliminate all modes of tolerance. Designing out common cause failures strengthens the fidelity of fault tolerant systems. This requirement addresses and extends the applicability of NPR 8705.2, Human-Rating Requirements for Space Systems, requirement 34493, to more than just software common cause failures. This requirement complements JPR 8080.5, JSC Design and Procedural Standards, Section G-2, which mandates separation of redundant systems, subsystems, and elements.

[CA5435-PO] Ares I shall automatically determine the need for an abort.

Rationale: In cases where response time constraints impact crew safety risk requirements, the Ares I should be able to automatically determine the need to abort. Abort determination is based on independent sensor information from the Ares I alone and/or from other systems depending on flight phases.

3.7.2.2.2.1 Ares I Crew Survival Probabilities

[CA5914-PO] Ares I shall limit failures which exceed the conditions outlined in Table XXX (TBD-001-1401) to no greater than 1 in (TBD-001-948) Ares I LOM failures.

Rationale: The 1 in (TBD-001-948) means a (TBD-001-948) (or (TBD-001-948)%) probability of exceeding the conditions outlined in Table XXX (TBD-001-1401)from an Ares I initiated ascent abort. Table XXX will be jointly developed between Ares and Orion to define ascent abort conditions that potentially allow a successful Orion abort. Conditions exceeding this table are expected to result in LOC. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO): Provide a substantial increase in safety, crew survival, and reliability of the overall system over legacy systems.

3.7.2.2.2.2 Ares I Emergency Egress, Aborts and Return for Survivability

[CA5159-PO] Ares I shall provide unassisted emergency egress for six (TBR-001-211) ground crew conducting prelaunch activities within the Ares I during prelaunch pad operations within 2 (TBR-001-168) minutes starting from the initiation of the egress to the arrival of the last ground crewmember at the Ares I exit point.

Rationale: For contingency situations, ground crew will need the capability to safely egress the Ares I. This should drive Ares I internal access requirements, design of

Ares I interior egress paths, and GSE to allow ground crew conducting prelaunch activities within the Ares I to exit without additional assistance. This requirement assumes that all Ares I unique GSE required by Ground Crew for Ares I internal activities is designed and provided by Ares I. The egress time is from the initiation of egress until the last ground crew exits the Ares I. Launch pad egress is covered by Ground Systems.

3.7.2.2.3 Reserved

3.7.2.2.4 Reserved

3.7.2.2.5 Ares I Mission Rates and Durations

[CA6087-PO] Ares I shall perform four launches in a year.

Rationale: The Ares I must be designed to support a minimum launch frequency which is based on the manifest in order to fulfill the basic requirements of the Constellation Program. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Ares I systems. Ares I should be designed to support 2 missions per year during the ISS phase of the program. Ares I should be designed to support 2 ISS and 2 Crewed Lunar Missions per year during the overlapping ISS and Lunar phase of the program.

[CA6087-PO-Objective] Ares I shall perform six launches in a year.

Rationale: Ares I must be designed to support a launch frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Ares I systems. Ares I should be designed to support 6 ISS flights during the ISS phase of the program. Ares I should be designed to support 3 ISS and 3 Crewed Lunar Missions per year during the overlapping ISS and Lunar phase of the program.

[CA6089-PO] Ares I shall perform back to back launches within 45 calendar days, measured from the launch of the first integrated stack to the launch of the second integrated stack.

Rationale: Ares I must be designed to support a minimum launch interval in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission intervals drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, the minimum interval drives turnaround and maintenance activities for the Constellation systems. This interval is expressed in calendar days.

[CA6089-PO-Objective] Ares I shall provide the capacity to conduct one back to back set of launches per year within 30 days measured from the launch of the first vehicle to the launch of the second vehicle.

Rationale: The capacity of Ares I project to conduct a single set of launches in a 30 day interval per year will allow the capability to maintain manifesting mission success goals in the case of a launch slip.

3.7.2.2.6 Ares I Architecture Definition

[CA0389-HQ] Ares I shall use a single 5-segment Solid Rocket Booster modified from the Space Shuttle Solid Rocket Booster (SSRB) for first stage propulsion and a single modified Apollo J-2X engine for second stage propulsion.

Rationale: The Ares I will take advantage of the flight proven propulsion systems components developed for the Space Shuttle and Apollo. These launch vehicle components, which have supported over 100 Space Shuttle and numerous Apollo missions, have extensive test/flight experience databases available for Ares I designers to leverage. In addition, Ares I designers will be able to leverage the ground processing/production facilities, workforce and tooling already in place to support Space Shuttle operations. The use of these flight-proven technology and existing ground infrastructure is seen as a significant cost/schedule savings for the Ares I development effort when compared with developing a new design without flight heritage.

[CA1023-PO] Ares I shall provide liftoff clearance between the Ares I integrated stack vehicle and the launch facility.

Rationale: The GN&C subsystem and ground structure to launch vehicle physical interface need to be designed such that recontact is an extremely low probability event. Recontact at any point in the vertical rise phase of flight may be catastrophic and could mean Loss of Crew, loss of launch elements or ground infrastructure. This involves clearances such as Ares I and Orion access arms, umbilicals, and the Solid Rocket Motor (SRM) nozzle. Specific clearance envelopes will be defined in the Ares I/GS and the Orion/GS IRDs.

[CA3202-PO] Ares I shall launch the Orion from the launch site to the Ascent Target as specified in the Ascent Target Table.

Rationale: Establishes the function of the Ares I for Lunar and ISS missions. The Ares I is tasked to safely transport the Orion from the Earth's surface to the Ascent Target at which point the Orion will separate from the Ares I/Orion integrated vehicle and continue to ERO for Lunar missions or to ISS per CxP 70007, Constellation Design Reference Missions and Operational Concepts. The split of ascent mission phase between the Orion and Ares I is based on results from NASA-TM-2005-214062, Exploration Systems Architecture Study. Injection accuracy thresholds are needed to achieve the proper orbit required for the mission. The allowable deviation from the desired target values is a function of Orion onboard delta-V maneuvering *capability and Ares I upper stage impact footprint. Failure to achieve the accuracy on a specific mission may be acceptable if Orion has sufficient delta-V margin to achieve mission objectives. Failure to achieve injection accuracy may cause the launch vehicle impact footprint to impinge on populated areas.*

TABLE 3.7.2.2.6-1 ASCENT TARGET TABLE

	ISS Mission	Lunar Mission
Orbit Injection Parameter		
Apogee	185.2 km (100 nmi)	185.2 km (100 nmi)
Perigee	-20.4 km (-11 nmi)	-20.4 km (-11 nmi)
Inclination	51.6 deg	28.5 (TBR-001-936) deg
Insertion Altitude	129.6 km (70 nmi)	129.6 km (70 nmi)
Orbit Injection Accuracy		
Semi major axis	+/- 14.8 km (8 nmi)	+/- 14.8 km (8 nmi)
Apogee	+/- 12.96 km (7 nmi)	+/- 12.96 km (7 nmi)
Orbit Plane	+/- 0.07 deg	+/- 0.07 deg

[CA3221-PO] Ares I shall change the planned ascent trajectory based on design parameter updates provided prior to launch.

Rationale: Performance and load margins may require an update to the trajectory design based on launch day environmental conditions.

[CA3223-PO] Ares I shall change the planned ascent trajectory based on powered flight rendezvous guidance target updates provided prior to launch.

Rationale: The Ares I must inject into the proper orbital plane for rendezvous. The knowledge of that target is most accurate if obtained near launch time. Changing the ascent trajectory based on updated guidance targets make it possible to achieve rendezvous within system performance capabilities. Performance margins are based on having accurate targets.

[CA5677-PO] Ares I shall launch independent of ambient lighting conditions.

Rationale: Use of night time launch windows greatly increases the opportunities for launch to a successful rendezvous orbit. Launch windows to rendezvous with an object already in space frequently fall in darkness. For example, about 40% of the launch opportunities to the International Space Station occur in darkness when assessed over a one year period. Since Ares I launches will involve rendezvous with Orion previously inserted into orbit, overall mission planning may be severely constrained if night launches are not allowed.

3.7.2.2.6.1 Ares I Control Mass

[CA1000-PO] Ares I shall deliver at least 20,312 kg (44,780 lbm) from Earth to the ISS Ascent Target defined in the Ares I ISS Mission Ascent Target table.

Rationale: The Ares Mass Delivered is the guaranteed mass delivered by the Ares to the ISS Ascent Target based on the Orion 606C POD and PSE analyses. Mass delivered requirements are necessary for the concurrent design of multiple Systems which have an overall performance or mission goal. This requirement includes an Orion ISS Control Mass, a Program Mass Reserve applied at all phases of the ascent. This verification of this requirement must account a LAS jettisoned at the specified time, and a 10 minute Launch Window, performance is calculated at the opening of the launch window. The ISS Mass Delivered quantities are derived from analysis of the Ares design for the Lunar Exploration mission. The Ares Mass Delivered is required to size the Ares to ensure it is capable of delivering the Orion to the ISS Ascent Target. This Mass Delivered requirement is related to the LAS jettison time requirement.

[CA1005-PO] Ares I shall deliver at least 23,265 kg (51,290 lbm) from Earth to the Lunar Ascent Target.

Rationale: The Ares Mass Delivered is the guaranteed mass delivered by the Ares to the Lunar Ascent Target based on Orion 606C Point of Departure (POD) and PSE analyses. Mass delivered requirements are necessary for the concurrent design of multiple Systems which have an overall performance or mission goal. This requirement includes delivery of the Orion Control Mass with a Gross Lift-off Weight and Program Mass Reserve applied during all phases of ascent. This requirement is verified with the specified LAS jettison time and accounts for a 90 minute Launch Window, performance is shown at the opening of the launch window. The Ares Mass Delivered is required to size the Ares to ensure it is capable of delivering the Orion to the ISS Ascent Target. This Mass Delivered requirement is related to the Orion Control Mass requirement and the LAS jettison time requirement. This value is based on the Ares A103 rev A design (includes First Stage Nozzle Extension).

[CA4138-PO] Ares I shall launch an Orion with a Gross Lift-off Weight of 31,645 kg (69,765 lbm) for Lunar missions.

Rationale: The Gross Lift-off Weight that Ares I must accommodate for lunar missions is part of the Mass Delivered requirement. This requirement includes an Orion Control Mass at Lift-off and a Program Mass Reserve.

[CA4165-PO] Ares I shall accommodate an Orion Gross Lift-off Weight of 28,692 kg (63,255 lbm) for the ISS missions.

Rationale: The Gross Lift-off Weight that Ares I must accommodate for ISS missions is part of the Mass Delivered requirement. This requirement includes an Orion Control Mass at Lift-off and a Program Mass Reserve.

3.7.2.2.6.2 Reserved

3.7.2.2.7 Ares I Safety (System, Public, and Planetary)

[CA0566-PO] Ares I shall include Flight Termination Systems in accordance with NPR 8715.5, Range Safety Program, Section 3.3.

Rationale: FTS is needed to protect the general population, including ocean and air traffic, from an errant launch vehicle. Both NPR 8715.5, Range Safety Program, and AFSPCMAN 91-710, Range Safety User Requirements Manual, will be tailored for the Constellation Program and specific references to the tailored requirements will be called out by the appropriate system level SRDs.

[CA1053-PO] Ares I shall execute authenticated United State Air Force (USAF) Flight Control Officer (FCO)-initiated FTS command signals.

Rationale: For crewed Ares I or Ares V launch vehicles, FTS activation is limited to range safety initiation by USAF Flight Control Officers, and automated FTS by the launch vehicle via breakwires or other methods is not permitted. For uncrewed Ares I or Ares V launch vehicles, FTS ordnance may be automatically initiated. Automatic FTS initiation will be disabled/inhibited for crewed flights. Breakwires usage is permissible for vehicle health monitoring, and may result in automatic initiation of abort, but is not okay for auto-initiation of FTS events for crewed vehicles.

[CA1054-PO] Ares I shall generate an indication upon receipt of each Flight Termination command.

Rationale: This requirement provides for the generation of the Orion indication that the FTS has been armed by the FCO, or that a termination command has been received. This enables functions or actions which may be implemented to facilitate launch abort initiation.

[CA1055-PO] Ares I shall provide for flight termination with a 2.0 (TBR-001-154) second delay between "Fire" command receipt and detonation of FTS ordinance.

Rationale: NPR 8705.2, Human-Rating Requirements for Space Systems, states: "Flight termination shall include features that allow sufficient time for abort or escape prior to activation of the destruct system." The delay between "Fire" and actual detonation will be determined by ascent analysis using the Ares I and relative motion simulations.

[CA1056-PO] Ares I shall provide for FTS inhibit.

Rationale: During ground processing a simple and reliable means of inhibiting is needed to prevent inadvertent activation. Inhibiting makes the FTS not only safe from inadvertent ground, or automatic initiation, but also makes the FTS safe from accidental interface with other mechanical initiation features that might be present.

[CA5825-PO] Ares I shall automatically shutdown Ares I elements for detected faults that lead to catastrophic conditions that will occur in less than 2 seconds.

Rationale: This requirement is needed to automatically shutdown systems to avoid Loss of Vehicle (LOV)/LOC conditions when there is not sufficient time to request shutdown from Orion or Mission Systems. The failure to shutdown will lead to a LOV/LOC condition. There are known failure modes for various Ares I systems which occur in less than 2 seconds but can be avoided by shutting down the system. This leads to a LOM condition but provides the Orion sufficient time to separate and escape. This requirement meets the intent of NPR 8705.2, Human-Rating Requirements for Space Systems (Section 3.7.1 34464), Autonomous Operation to respond to failures which occur faster than notification can be sent to crew or mission operators and the intent of NPR 8705.2, Human-Rating Requirements for Space Systems (Section 3.9.15, 34488) Automatic Abort Initiation.

[CA5917-PO] Ares I shall be fitted with Flight Termination Systems (FTSs) which will auto initiate (Altitude Determination System [ADS] or ISDS) upon inadvertent vehicle separation/break-up for uncrewed launches.

Rationale: Automatic initiation of FTS minimizes time delay in response to breakup, hence minimizing launch area risk, minimizing dispersions, and improving protection of people and property.

[CA5919-PO] Ares I shall be capable of uninstalling or physically disabling devices fitted to the Ares I for automatic initiation of FTS for crewed launches.

Rationale: NASA and 45th Space Wing acknowledge that time must be maximized to permit crew abort/escape. Therefore auto FTS will be disabled for crewed launches. Uninstalled or physically disabled could mean, e.g. partially uninstalled, or ordnance removed. The preference would be for it to be uninstalled over just "disabled."

3.7.2.2.8 Ares I Command and Control

[CA1028-PO] Ares I shall perform automated lift-off and ascent operations.

Rationale: This requirement establishes that all of the functions needed to place Orion in the nominal injection orbit be automated. Due to high speed ascent and powered flight control complexity, an automated system will be needed. Also, automation will be needed for ISS cargo missions. It is assumed that the lift-off command covers booster ignition and hold down post separation.

[CA1029-PO] Ares I shall perform autonomous lift-off and ascent operations.

Rationale: This requirement provides for independence from external control (i.e., ground control) for nominal operations. Due to the definitions of automated and autonomous, this requirement is needed in addition to an automated operations requirement to define automated operation independent of ground control. For ascent phase, vehicle autonomy with onboard authority will reduce the reliance on pre-launch mission design, increase vehicle performance, and improve safety. Additionally, for crewed launch vehicles, autonomous operations for critical functions *affecting crew safety are required by NPR 8705.2, Human-Rating Requirements for Space Systems, Section 3.7.1 (34464).*

[CA3112-PO] The Ares I shall accept Control of Automation.

Rationale: Other Constellation systems will need to select, initiate, inhibit, override, and terminate automation on the Ares I during various operational phases. Reference NPR 8705.2, Human-Rating Requirements for Space Systems, Section 3.2.7 (34445).

[CA3256-PO] Ares I shall execute commands valid in the current state.

Rationale: The system will execute commands from other systems in order to perform the specified function or operation. This process includes checking if the command has valid data values and can be executed now based on the current state or mode. Updates to the corresponding Health and Status parameters provide the execution end item result.

[CA3275-PO] Ares I shall execute commands which are addressed to the Ares I.

Rationale: The system will execute commands generated internally or from other systems in order to perform the specified function or operation. The ability for Constellation systems to command execution on remote Constellation systems is required per the operations concept where the system with crew present may need to command systems without the crew onboard (e.g. LSAM commanding the Orion). In addition, the verification that the command is intended to be executed on the system will support the multi-hop routing capability.

3.7.2.2.9 Ares I Health and Status

[CA1084-PO] Ares I shall detect conditions indicating the need to abort.

Rationale: Fault detection enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to detection are further specified by CxP 72034, Crew Launch Vehicle (CLV) Systems Requirements Document (SRD). Crew abort can be initiated by LOC, LOV, or LOM conditions. For Ares I, LOC is generally commensurate with LOV, but LOM is quite different. LOM conditions which lead to abort include early engine shutdowns, Thrust Vector Control (TVC) failures in null position, RCS failures, etc. This satisfies NPR 8705.2, Human-Rating Requirements for Space Systems requirements 3.5.1 and 3.9.15 which require detection of critical system faults and are not limited by LOC, LOV, or LOM conditions.

[CA1085-PO] Ares I shall isolate detected faults to the level required for recovery of function.

Rationale: Fault isolation is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault isolation enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to isolation are further specified by CxP 72034, Crew Launch Vehicle (CLV) Systems

Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle. The level of recovery is governed by the criticality of systems (Loss of Vehicle).

[CA1086-PO] Ares I shall provide recovery from isolated faults.

Rationale: Fault recovery is required for crew safety and mission success by enabling recovery of such critical functions. Faults subject to recovery are further specified by CxP 72034, Crew Launch Vehicle (CLV) Systems Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle. Fault recovery may also be used during ground operations. The level of recovery is governed by the criticality of systems (Loss of Vehicle).

[CA3118-PO] The Ares I shall generate Health and Status information.

Rationale: Provides for generation of Health and Status information on internal operations of the Ares I. Full definition of the specific data is provided in CxP 72034, Crew Launch Vehicle (CLV) Systems Requirements Document (SRD) and multiple CLV/System IRDs.

[CA5816-PO] Ares I shall detect system faults and conditions which indicate loss of redundancy.

Rationale: Fault detection is required for crew safety and mission success by enabling recovery of critical functions. Faults subject to detection are further specified by CxP 72034, Crew Launch Vehicle (CLV) Systems Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance.

[CA6107-PO] Ares shall transmit mission engineering data during ascent.

Rationale: Ares I data recorded onboard Constellation launch vehicles and spacecraft cannot be relied upon as the only method for critical data retrieval because of the risk that flight recorded data will not be recovered after a catastrophic event. Historical precedence shows that having assured access to critical engineering data in the event of a catastrophic event is crucial to quickly and accurately determining the cause and contributing factors. Functionally, a Mission Engineering Link (MEL) from Ares to Air Force assets at the Launch site will allow real-time collection of critical analysis data during first stage and second stage operations. After Launch site loss of signal, the MEL will hand up to SN at a reduced rate to provide access to critical engineering telemetry through the remainder of powered flight. No downrange ground sites are necessary to receive MEL data. MEL data can be recorded at the receiving sites. There is no requirement to deliver this MEL data in real-time for flight operations or for public affairs, but data in the MEL may be routed to ground destinations if there is minimal cost to do so. Since this link is an "insurance" link against a catastrophic failure during ascent, dual string implementation is not required, nor is automated failover to backup systems. This requirement does not address Development Flight Instrumentation (DFI) which is *considered a separate system for collection, storage, and transmission of additional engineering flight data. Post orbital insertion, additional engineering data for the remaining phases of flight will be telemetered to Mission Systems to satisfy this requirement.*

3.7.2.2.10 Ares I Communications and Communications Security

[CA5906-PO] Ares I shall accept reconfiguration of stored commands, sequences and data prior to lift-off.

Rationale: The Ares I needs to accept changes to sequences, commands and data parameters already stored onboard, when the Ground Systems initiates such reconfiguration actions. Reconfiguration actions may impact procedures, operations time-lines, or onboard algorithms which operate on commandable data items to support mission activities.

[CA5912-PO] Ares I shall be able to communicate simultaneously with Orion, Mission Systems, and Ground Systems.

Rationale: Simultaneous communications are required so that the Ares I can communicate with both Orion via hardline and Ground Systems before launch. Before launch, Mission Systems will be receiving Ares I data as well but it will be via Ground Systems. After launch, the Ares I needs to be able to communicate with Orion, Mission Systems, and Ground Systems; some long term engineering telemetry will not be sent to Mission Systems during launch and ascent.

[CA6214-PO] Ares I shall process telemetry destined for Range Safety within 250 msec (TBR-001-1439) during the launch/ascent phase.

Rationale: Establishes the need for a maximum Ares I sub-allocation latency for telemetry during the launch/ascent phase. Time to process telemetry is determined by the time between the detection of an event until delivery of the range safety telemetry to the Orion at the Ares/Orion interface.

3.7.2.2.11 Ares I GN&C

[CA3143-PO] Ares I shall perform navigation and attitude determination from pre-launch through Ares I upper stage separation from the Orion.

Rationale: Navigation and attitude determination are required to successfully execute the ascent phase to meet mission objectives.

3.7.2.2.12 Ares I Reliability and Availability

[CA0072-PO] Ares I shall have a 10 minute planar launch window per crewed launch opportunity for ISS missions.

Rationale: A longer launch window increases the probability of being able to launch within a given launch opportunity. This requirement specifies the capability to steer into the desired orbit plane and does not specify the phasing window. For *rendezvous missions, steering into the target orbit plane reduces launch vehicle payload capability unless the launch occurs at the in-plane launch time. For the ISS orbit inclination, the payload reduction for achieving rendezvous increases rapidly with increasing window duration. The duration specified increases launch probability while also not imposing an unreasonable payload reduction or causing a problem with range safety. A combination of launch azimuth variation and yaw steering is used to minimize the impact to payload performance in achieving desired inertial target plane required for rendezvous within the launch window. TDS 04-016 showed the 10 minute window exists every calendar day for Flight Day 3 rendezvous.*

[CA1008-PO] Ares I shall provide launch attempts on each of no less than seven consecutive days.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. Seven days is based on an Ares V-launch-first mission design approach and protects for a lunar mission where the Ares V launches on the fourth day of its consecutive launch opportunities. The Ares I should be designed so that servicing can be completed for the next day's launch attempt or be designed to last at least seven days without servicing.

[CA1066-PO] Ares I shall have a probability of launch of not less than 98 (TBR-001-939)%, exclusive of weather, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses Ares I system reliability. System reliability and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements. The value of 98% in this requirement is an allocation from the parent requirement (CA-0123-PO) which, in turn, addresses the “Probability of No Second Launch” which would expire the orbiting EDS/LSAM. The TBR will be closed during the IDAC4 cycle after the (CA-0123-PO) parent requirement TBRs are removed.

[CA1068-PO] Ares I shall have a probability of launch of not less than 95 (TBR-001-940)%,due to natural environments as specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) and monthly weather conditions, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch applies to limitations caused by weather conditions. Abort landing site weather conditions are not included because these limitations are determined by Orion design. The launch vehicle should be capable of operating over a wide range of natural environment conditions (particularly upper level winds) without violating LCC (such as structural or control margins, or exposure to lightning). The percentage of acceptable launches for a given set of climatology *data is sometimes referred to as launch probability. The 95% (TBR-001-940) launch probability for Ares I with respect to monthly weather was selected to improve launch probability as much as reasonable over heritage systems as expressed in CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO). The figure is compatible with DSNE launch environment design specifications and was reviewed and approved by the ESAS Requirements Transition Team (ERTT) panel December 20, 2005. The DSNE drives the design of the vehicle to operate within the specified environments. However, the vehicle design must account for variability of day-of-launch conditions. Without this requirement, the vehicle could be in a no-go condition due to natural environments. This requirement is intended to bound the magnitude of the risk of no-go in an average sense; this risk will exceed the limit for certain hours of the day in some months.*

[CA5323-PO] Ares I shall have a 90 minute planar launch window per launch opportunity for crew launch on lunar missions.

Rationale: The duration of the launch window for rendezvous defines the performance penalty necessary to achieve that window. This requirement specifies the capability to steer into the desired orbit plane and does not specify the phasing window. For the exploration mission, the penalty increases more slowly (than for the ISS mission) with increasing window duration. The duration specified increases launch probability while also not imposing an unreasonable performance penalty or causing a problem with range safety. The advantage in launch probability can be traded off with the ability to achieve early rendezvous. A combination of launch azimuth variation and yaw steering is used to minimize the impact to performance in achieving the launch window. A rendezvous launch window consists of the overlap between a planar window and a phasing window. Since the orbital period of LEO is approximately 90 minutes, requiring a planar window of 90 minutes guarantees the overlap with the phasing window and thus a launch opportunity will exist every day. The launch window which results from the overlap of the planar window and phasing window will depend on the flight day of rendezvous and docking, but will typically be significantly less than 90 minutes even for a flight day 3 rendezvous.

[CA6203-PO] Ares I systems failures identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1500)% that would result in a scrubbed launch, shall be maintainable as follows:

a. No less than 45% (TBR-001-1413) can be remedied to support a launch attempt within one day.

b. No less than 65% (TBR-001-1414) can be remedied to support a launch attempt within two days.

c. No less than 70% (TBR-001-1415) can be remedied to support a launch attempt within three days.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses Ares I system maintainability. The intent is to drive a capability to correct those failures discovered (latent defects) after deciding to load cryogenic propellants that will cause a launch scrub in order to maximize the number of launch attempts that are utilized.

The duration for repair time includes the time to establish access, set up, diagnose, perform corrective maintenance, closeout, and complete any retest required in time to make the launch attempt. As this is a design-to requirement, administrative and logistics delay is not included (for example: time searching for a spare part). The intent of extending through only 70% of failures is to prevent this requirement from driving counterproductive system complexity and increased effort or difficulty for nominal operations and sustainment scenarios. The expectation is that operability assessments should influence the developer's selection of which of the most likely failures to target.

The values used above (45%, 65%, and 70%) correspond with the Delta II history of times to repair. The intention of this requirement is to inform design with the historical data as a first iteration until the supplier data becomes available. At that time, the analysis will be updated.

3.7.2.2.13 Ares I Maintainability, Supportability, and Logistics

[CA5713-PO] Ares I shall use refurbishable First Stage Element.

Rationale: Upon arrival back to Earth, the first stage SRB element of the Ares I will be recovered, refurbished and reflown utilizing processes similar to the Space Transportation System (STS) SRBs.

[CA5978-PO] Ares I shall produce and deliver Project Verified Engineering Build software and data products to the Constellation Program within the time limits identified in Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Engineering Build is a set of software and data products that contain new requirements (capabilities) and problem fixes. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Engineering Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. Data products contain representative launch geometry values and actual values for other parameters. It has completed Project Level Verification/Validation and has been configured to meet Integrated Build event requirements. Data definitions must be available in time to support generation of data products for the release. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary *workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation Architecture. Project level activities include: participation in the build content definition, software design, code, and project-level Integration, test and delivery of the Project Verified Engineering Builds to the Program.*

TABLE 3.7.2.2.13-1 TIME ALLOCATIONS FOR ENGINEERING BUILDS

Requirement	Threshold	Objective
Ares I	7 months (TBR-001-1045)	2.5 months

[CA5979-PO] Ares I shall produce and deliver Project Verified Flight Build software and data products to support the mission class within the time limits identified in Time Allocations for Flight Builds Table after the completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Flight Build is a set of software and data products that is based on a Project Verified Engineering Build, has mission specific (launch geometry derived) data and has completed Project Level Verification/Validation. Few software changes are expected. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Flight Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Data parameter values must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation Architecture. Project level activities include: participation in the build content definition, flight specific configuration activity (data reconfiguration), Fast Track activities as required, and delivery of Project Verified Flight Builds. Times are contiguous days.

TABLE 3.7.2.2.13-2 TIME ALLOCATIONS FOR FLIGHT BUILDS

Requirement	Threshold	Objective
Ares I	14 days	4 days

[CA5980-PO] Ares I shall support day of launch updates for software parameters and data products to configure the systems.

Rationale: A day of launch update is a set of software and data products based on the Program Verified Flight Build and the approved final flight parameter updates for launch day environments (winds), orbit geometry (target tracking), and other I-loads as required.

[CA5981-PO] Ares I shall produce and deliver resolutions for selected non-conformances during the engineering and flight release phases to the discovering organization and the Constellation Program in the time limits identified in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track build process is used for rapid resolution of problems found in the production of Flight Builds and Engineering Builds. The time period starts after documentation of the non-conformance and ends when the resolution is submitted for re-integration into the test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

TABLE 3.7.2.2.13-3 - TIME ALLOCATIONS FOR FAST TRACK PROCESS

Requirement	Threshold	Objective
Ares I	48 hours	12 hours

[CA6004-PO] Ares I shall conduct ground operations for a single Ares I/Orion mission within the time limits identified in Ares I Critical Path Allocations for Ares I/Orion Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and Ground System designs that result in reduced ground operations time and labor without sacrifices to performance or design cost. The critical path constraints levied in Ares I Critical Path Allocations for Ares I/Orion Ground Operations Table, along with labor-hour constraints defined in CA6004, are intended to drive the design of the flight systems to enable such reductions.

The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather they are intended to be a design target for the system developers.

In Ares I Critical Path Allocations for Ares I/Orion Ground Operations Table, the Ground Operations processing flow is broken down into five sequential time periods between key Ares I processing milestones. The sum of the five time periods is the overall Ares I Critical Path contribution anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming “single-string” for the *integrated operations Ground Systems (i.e., one Ares I Mobile Launcher, one Ares I VAB high bay, one control room for Ares I operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx Ground Operations.*

The values identified in Ares I Critical Path Allocations for Ares I/Orion Ground Operations Table are intended to apply to nominal Ares I operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy ELV systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.7.2.2.13-4 ARES I CRITICAL PATH ALLOCATIONS FOR ARES-1/ORION GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Start of Ares I Stacking to Ready for Orion Integration	274 (TBR-001-1200)	228 (TBR-001-1201)	Integration of the Ares I on the ML from beginning with stacking of the First Stage Aft Booster Assembly	Ares I, GS
Ready for Orion Integration to Integrated Stack Ready for Powered Testing	53 (TBR-001-1202)	44 (TBR-001-1203)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA
Ready for Powered Testing to Finish of Powered Testing	67 (TBR-001-1204)	56 (TBR-001-1205)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares I, Orion, GS, EVA
Finish of Powered Testing to Pad Connection and Validation Complete	46 (TBR-001-1206)	38 (TBR-001-1207)	From the end of powered testing in the VAB until the vehicle is at the launch pad and ready to begin launch preps. Includes vehicle and ground system roll out preparations, roll-out, and ML-Launch pad connections and validations.	GS, Ares I, Orion
Pad Connection and Validation Complete to Launch	82 (TBR-001-1208)	68 (TBR-001-1209)	Begins once pad connections are validated and ends at T-0.	GS, Ares I, Orion, EVA

3.7.2.2.14 Reserved

3.7.2.2.15 Ares I Environmental Conditions

[CA1069-PO] Ares I shall meet its requirements during and after exposure to the environments defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, and 3.7.

Rationale: The Ares I will be exposed to a variety of natural environments that could make it unable to meet its requirements, potentially in combination with induced environments. This requirement defines the limits of these effects and assures that they will be mitigated by the design. Natural environment effects also need to be considered for the Ares I integrated vehicle configurations: Orion/Ares I and Orion/Ares I/GS.

[CA5557-PO] Ares I shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design.

[CA5562-PO] Ares I shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification .

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design. Therefore, the production of induced environments must be limited and controlled to allow proper performance and function of other sub-systems and other Systems when operating in mated configurations.

3.7.2.3 Reserved

3.7.2.4 ARES I EXTERNAL INTERFACES

[CA0430-PO] Ares I shall interface with Orion per CxP 70026, Constellation Program Orion -To- Ares I Interface Requirements Document (IRD).

Rationale: The Ares I and Orion share physical and functional interfaces which are identified in the CxP 70026, Constellation Program Orion -To- Ares I Interface Requirements Document (IRD).

[CA0897-PO] Ares I shall interface with Ground Systems per CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to-

Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD).

Rationale: The Ares I and Ground Systems share physical and functional interfaces which are identified in CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD).

[CA0898-PO] Ares I shall interface with Mission Systems per CxP 70053, Constellation Program Ares I -to- Mission Systems Interface Requirements Document.

Rationale: The Ares I and Mission Systems share physical and functional interfaces which are identified in CxP 70053, Constellation Program Ares I -to- Mission Systems Interface Requirements Document.

[CA0899-PO] Ares I shall interface with the Communication and Tracking Networks per CxP 70118-02, Constellation Program Systems -to- Communications and Tracking Networks Interface Requirements Document, Volume 2: Ares I.

Rationale: The Ares I and C&TN share physical and functional interfaces which are identified in the CxP 70118-02, Constellation Program Systems -to- Communication and Tracking Network Interface Requirements Document, Volume 2: Ares I.

3.7.2.5 Reserved

3.7.3 Lunar Surface Access Module (LSAM)

3.7.3.1 LSAM Description

The LSAM transports cargo to LLO and crew and cargo from LLO to the lunar surface and back. The LSAM is only intended to support Lunar DRMs. LSAM may be configured with or without crew. The uncrewed configuration transports significant cargo in support of extended Lunar Outpost missions and does not include an ascent capability from the lunar surface. The uncrewed/cargo version of the LSAM, without ascent capability, may be used to store supplies or waste upon completion of its cargo delivery mission. The LSAM is capable of using its descent stage to insert itself and Orion into Low Lunar Orbit (LLO) and carry crew or cargo to the lunar surface. For crewed Lunar Sortie configurations, the LSAM serves as the crew’s home for up to 7 days and uses an ascent stage to return them to LLO. The descent stage serves as the launch platform for the ascent stage and is discarded on the lunar surface. The ascent stage is jettisoned prior to Orion Trans-Earth Injection (TEI) from LLO.

3.7.3.2 LSAM Requirements

[CA3213-PO] The LSAM shall deliver cargo from the Earth surface to the lunar surface for Lunar Outpost Cargo missions.

Rationale: The requirement is consistent with CxP 70007, Constellation Design Reference Missions and Operational Concepts, which indicates that a LSAM in the cargo configuration is the Constellation System used to take outpost infrastructure and supplies to the lunar surface. This requirement is based on results from NASA-TM-2005-214062, Exploration Systems Architecture Study, which indicates that using LSAM rather than the Orion for lunar surface operations during Lunar Outpost Cargo missions balances performance, cost and risk for the Constellation Program. LSAM uses the same interface to Ares V and subsystems required for surface descent operations as LSAM.

3.7.3.2.1 LSAM Mission Success

Draft **[CA0504-PO]** The LSAM shall limit their contribution to the risk of Loss of Mission (LOM) for a Lunar Sortie crew mission to no greater than 1 in 75 (TBR-001-060).

Rationale: The 1 in 75 (TBR-001-060) means a .013 (or 1.3%) probability of LOM due to the LSAM during any Lunar Sortie Crew mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

Draft **[CA3036-PO]** The LSAM shall limit their contribution to the risk of Loss of Mission (LOM) for a Lunar Outpost crew mission to no greater than 1 in (TBD-001-557).

Rationale: The 1 in (TBD-001-557) means a (TBD-001-557) (or (TBD-001-557)%) probability of LOM due to the LSAM during any Lunar Outpost Crew Mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

Draft **[CA3042-PO]** The LSAM shall limit their contribution to the risk of Loss of Mission (LOM) for a Lunar Outpost cargo mission to no greater than 1 in (TBD-001-561).

Rationale: The 1 in (TBD-001-561) means a (TBD-001-561) (or (TBD-001-561)%) probability of LOM due to the LSAM during any Lunar Outpost Cargo Mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.7.3.2.2 LSAM Crew Survival

Draft [CA3139-PO] The LSAM shall provide fire detection and suppression for the LSAM pressurized volume for Lunar Sortie and Lunar Outpost crew missions.

Rationale: This is to provide cabin fire detection, notification, and suppression. The type of fire detection and suppression required in the avionics bays will be a function of materials selection, proximity to ignition sources and oxidizers.

Draft [CA5191-PO] The LSAM shall sustain life of the suited crew without causing permanent disability in an unpressurized cabin for up to 7 (TBR-001-214) hours for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The maximum duration required for LSAM to ascend from the lunar surface, rendezvous/dock with Orion, and carry out the external transfer of the crew from LSAM to Orion is 7 (TBR-001-214) hours. The 7 (TBR-001-214) hours is derived from the 3 hour nominal LSAM-Orion rendezvous timeline plan and the 4 (TBR-001-244) hour EVA timeline to transfer the crew from LSAM to Orion.

Draft [CA5193-PO] The LSAM shall perform the functions necessary to return to LRO within 3 (TBR-001-171) hours with an unpressurized cabin for Lunar Sortie and Lunar Outpost crew missions.

Rationale: Vehicle functions to return the crew to LRO in an unpressurized cabin pertains to one of the functions that are needed to get the crew back to LRO. Examples of critical vehicle functions include but are not limited to propulsion, communications, guidance, navigation, control, docking, etc. The 3 (TBR-001-171) hours is based on the nominal LSAM-Orion rendezvous timeline plan.

Draft [CA5194-PO] The LSAM shall provide suit stowage such that a suit can be accessed within 2 (TBR-001-172) minutes for donning for Lunar Sortie and Lunar Outpost crew missions.

Rationale: Suits need to be stowed in LSAM such that they are readily accessible to facilitate the full crew donning their suits while the ECLSS system feeds the leak. The two minutes for each crewmember to retrieve their suit (in order to begin the donning process) is a subset of the 1 hour ECLSS requirement to feed the leak. The suit retrieval time is not necessarily always required at the beginning of the feed the leak 1 hour period, as it likely will be more efficient in the Orion volume provided to have sets of crewmembers retrieve and don their suits serially.

3.7.3.2.2.1 LSAM Crew Survival Probabilities

Draft [CA0503-PO] The LSAM shall limit their contribution to the risk of Loss of Crew (LOC) for a Lunar Sortie mission to no greater than 1 in 250 (TBR-001-059).

Rationale: The 1 in 250 (TBR-001-059) means a .004 (or .4%) probability of LOC due to the LSAM during any Lunar Sortie mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, *Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.*

Draft **[CA3041-PO]** The LSAM shall limit their contribution to the risk of Loss of Crew (LOC) for a Lunar Outpost Crew mission to no greater than 1 in (TBD-001-560).

Rationale: The 1 in (TBD-001-560) means a (TBD-001-560) (or (TBD-001-560)%) probability of LOC due to the LSAM during any Lunar Outpost Crew Mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.7.3.2.2.2 LSAM Emergency Egress, Aborts, and Return for Survivability

[CA5236-PO] The LSAM shall perform aborts from post TLI until lunar landing for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The Constellation Architecture will have abort capabilities for all mission phases. The LSAM will support aborts during several of these phases that begin following LSAM-EDS separation, when the LSAM becomes an active vehicle, and end when the LSAM lands on the Moon. During trans-lunar coast, the LSAM may provide abort capabilities while docked to Orion. Following undocking in lunar orbit, the LSAM will support aborts during lunar powered descent. Abort opportunities end at lunar landing, transitioning to opportunities for early return.

Draft **[CA5238-PO]** The LLV shall return the crew from the surface of the Moon to docking with Orion in the Lunar Rendezvous Orbit within 6 hours for Lunar Sortie and Lunar Outpost crew missions.

Rationale: This requirement allocates a portion of the 132 hours that LLV needs to provide for crew return to Earth.

[CA5316-PO] The LSAM shall return the crew to Orion independent of communications with the Mission Systems.

Rationale: This requirement ensures the safety of the crew by allowing the Constellation Systems to protect for the possibility of permanent or unplanned intermittent communication service outages that prevent or limit the ability of the Mission Systems to interface with the vehicles used for the given mission. Communication services include uplink and downlink services (Earth- and space-based), Earth-based navigation equipment, and Ground Operations centers. Communications (voice, command, and telemetry) and relative navigation between vehicles, and other onboard sensors remain operational. For communication service outages that occur while the crew is on the lunar surface or in the LSAM, the LSAM can complete the ascent to LRO and participate in RPODU activities using internal equipment along with communications with Orion.

3.7.3.2.3 LSAM Maintainability, Supportability, and Logistics

3.7.3.2.4 LSAM Cargo Delivery and Return

Draft **[CA0062-PO]** The LSAM shall return at least 100 kg (220 lbm) of Payload from the lunar surface to the Lunar Rendezvous Orbit (LRO) during each crewed lunar mission.

Rationale: The LSAM returned mass must include the 100 kg (220 lbm) of Payload specified by ESMD in addition to the crew and Flight Crew Equipment. This requirement applies to each crewed lunar mission and is needed to size the LSAM ascent stage.

Draft **[CA0090-PO]** The LSAM shall deliver at least 500 kg (1,102 lbm) of mass from Earth to the lunar surface during each crewed lunar mission.

Rationale: The LSAM delivered mass for each of its propulsive phases must include the 500 kg (1,102 lbm) of Cargo specified by ESMD in addition to any other mass quantities that are required for that mission phase. This requirement applies to each crewed lunar mission and is needed to size the LSAM descent stage.

Draft **[CA0137-PO]** The LSAM shall deliver at least 20,000 (TBR-001-008) kg (44,092 lbm) of cargo to the lunar surface for Lunar Outpost Cargo missions.

Rationale: This requirement applies to the Lunar Outpost Cargo mission where a large cargo deployment is required for meeting Lunar Outpost mission objectives and is needed to size the LSAM descent stage.

[CA4140-PO] The LSAM shall deliver at least 21,546 (TBR-001-512) kg (47,500 lbm) of mass from the TLC to the Lunar Destination Orbit (LDO).

Rationale: This delivered mass includes the mass of Orion at the time of Ares V EDS rendezvous and the Program Mass Reserve. This requirement applies to each crewed lunar mission and is needed to determine the size of the LSAM for the propellant needed for midcourse corrections during TLC and LOI.

Draft **[CA5156-PO]** The LSAM shall provide return cargo volume of at least 0.075 (TBR-001-167) m3 (2.65 ft3) from the lunar surface to the LLO during each crewed lunar mission.

Rationale: Volume must be allocated for return of lunar samples and possible scientific equipment from the Moon to support Constellation science and engineering objectives. This requirement is tied in part to the return mass requirements. This requirement applies to each crewed lunar mission and the To Be Resolved (TBR) value is based on the crewed Apollo mission cargo return capability.

3.7.3.2.5 LSAM Mission Rates and Durations

Draft **[CA0839-PO]** The LSAM shall meet its requirements after loitering in Low Earth Orbit (LEO) at least (TBD-001-975) days after orbit insertion for crewed lunar missions.

Rationale: The LSAM, in the LSAM/Ares V EDS mated configuration, needs to survive on-orbit (e.g., withstand micrometeoroids and preserve propellant) while awaiting the launch of the Orion. The duration of the loiter is based on the interaction between the Orion launch opportunities, the lunar surface landing location, and the operational lighting conditions needed on the lunar surface for the mission. The loiter duration also needs to include time for Orion/LSAM/Ares V EDS RPOD activities and TLI preparations.

Draft **[CA0842-PO]** The LSAM shall meet its requirements after loitering uncrewed on the lunar surface for at least 210 (TBR-001-039) days for Lunar Outpost Crew missions.

Rationale: LSAM needs to be able to survive on lunar surface for duration of outpost missions. The nominal crewed lunar outpost mission is approximately six months in duration. This requirement reflects that duration plus some contingency days.

Draft **[CA4150-PO]** The LSAM shall sustain crews on the lunar surface for at least 7 days for Lunar Sortie missions.

Rationale: The Lunar Sortie Crew DRM described in CxP 70007, Constellation Design Reference Missions and Operational Concepts, baselines a 7 day lunar surface stay during which the crew operates out of the LSAM. The LSAM must, therefore, include habitability functions in addition to being a flight vehicle. At the conclusion of the surface mission, the LSAM enables the crew to depart the lunar surface.

[CA6091-PO] The LSAM shall perform four launches in a year.

Rationale: The LSAM must be designed to support a minimum mission frequency which is based on the manifest in order to fulfill the basic requirements of the LSAM Program. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the LSAM systems. A lunar mission will consist of one crewed lander and one uncrewed cargo lander for a total of two LSAMs per mission.

[CA6091-PO-Objective] The LSAM shall perform six launches in a year.

Rationale: The LSAM must be designed to support a mission frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the LSAM systems. A lunar mission will consist of one crewed lander and one uncrewed cargo lander for a total of two LSAMs per mission.

[CA6093-PO] The LSAM shall perform back to back launches within 45 calendar days, measured from the launch of the first vehicle to the launch of the second vehicle.

Rationale: The LSAM must be designed to support a minimum mission interval in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission intervals drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, the minimum interval drives turnaround and maintenance activities for the Constellation systems. This interval is expressed in calendar days.

[CA6093-PO-Objective] The LSAM shall provide the capacity to conduct one back to back set of launches per year within 30 days measured from the launch of the first flight to the launch of the second vehicle.

Rationale: The capacity of the LSAM project to conduct a single set of launches in a 30 day interval per year will allow the capability to maintain manifesting mission success goals in the case of a launch slip.

[CA6202-PO] LSAM shall be in a mission ready state for launch attempts on each of no less than 4 consecutive days.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. Four days is based on an Ares V-launch-first mission design approach. Lander should be designed so that any required servicing can be completed for the next day's launch attempt or with consumables to support the vehicle throughout the four opportunities.

3.7.3.2.6 LSAM Architecture Definition

[CA0394-HQ] The LSAM shall include a crew airlock.

Rationale: An LSAM airlock will be used to address the following concerns:

a. Dust Control: A significant issue during Apollo was the quantity of dust that was brought into the Lunar Module (LM) after each EVA.

b. Split-Crew Operations: An airlock will allow two EVA crewmembers to explore the surface while the other two crewmembers remain in the LSAM performing Intravehicular Activity (IVA) tasks in a shirt-sleeve environment.

c. Contingency Support: Provides the capability of performing EVA if an injured or sick crewmember needs to remain in the pressurized volume of the LSAM or if a suit malfunction makes it impossible for all crewmembers to participate in an EVA.

[CA0397-HQ] The LSAM shall utilize a liquid hydrogen/liquid oxygen descent stage propulsion system that can be restarted.

Rationale: The operational concept described in CxP 70007, Constellation Design Reference Missions and Operational Concepts, leads to the LSAM performing multiple functions including Lunar Orbit Insertion (LOI), lunar deorbit, and lunar landing. To execute these functions, the LSAM descent stage propulsion system requires the flexibility to restart the engine. A LH2/LOX propulsion system can be *restarted and provides the delta-V efficiency needed with a system mass that is within the launch vehicle capabilities. The LSAM descent stage design will take advantage of experience with RL-10 derived propulsion systems, which will be used as a design starting point, to achieve the functionality and performance needed for delivery of the required mass to the lunar surface while minimizing the cost and schedule risk associated with LSAM development.*

[CA3200-PO] The LSAM shall utilize a Liquid Hydrogen/Liquid Oxygen (LH2/LOX) descent stage propulsion system that can be throttled.

Rationale: The operational concept described in CxP 70007, Constellation Design Reference Missions and Operational Concepts, leads to the LSAM performing multiple functions including Lunar Orbit Insertion (LOI), lunar descent, and lunar landing. To execute these functions, the LSAM descent stage propulsion system requires the flexibility to throttle the engine to control the propellant usage and engine performance. A LH2/LOX propulsion system can be throttled and provides the delta-V efficiency needed with a system mass that is within the launch vehicle capabilities. The LSAM descent stage design will take advantage of experience with RL-10 derived propulsion systems, which will be used as a design starting point, to achieve the functionality and performance needed for delivery of the required mass to the lunar surface while minimizing the cost and schedule risk associated with LSAM development. This requirement is based on the results documented in NASA TM-2005-214062, Exploration Systems Architecture Study.

[CA3206-PO] The LSAM shall deliver the crew and cargo from Lunar Destination Orbit (LDO) to the lunar surface for Lunar Sortie and Lunar Outpost crew missions.

Rationale: CxP 70007, Constellation Design Reference Missions and Operational Concepts, indicates that the LSAM is the Constellation System used to deliver the crew, along with cargo, to and from the lunar surface. The LSAM includes a propulsion system capable of safely descending from lunar orbit to the lunar surface. This capability is based on the results documented in NASA-TM-2005-214062, Exploration Systems Architecture Study, which indicates that using LSAM rather than the Orion for crewed lunar surface operations balances performance, cost and risk for the Constellation Program.

[CA3208-PO] The LSAM shall deliver the crew and cargo from the lunar surface to the Lunar Rendezvous Orbit (LRO) for Lunar Sortie and Lunar Outpost crew missions.

Rationale: CxP 70007, Constellation Design Reference Missions and Operational Concepts indicates that the crew, along with cargo, uses the LSAM to go to and from the lunar surface. Since the Orion (Earth return vehicle) remains in orbit while the LSAM travels to the lunar surface, the LSAM, which includes a propulsion system capable of safely ascending from the lunar surface to the designated lunar orbit, must rendezvous with the Orion in lunar orbit. This requirement is based on the results documented in NASA-TM-2005-214062, Exploration Systems Architecture Study, which indicates that using LSAM rather than the Orion for crewed lunar *surface operations balances performance, cost and risk for the Constellation Program.*

Draft **[CA3286-PO]** The LSAM shall perform Lunar Sortie missions without the aid of pre-deployed lunar surface infrastructure.

Rationale: This requirement is independent of whether the mission being performed is a Lunar Sortie or Lunar Outpost. For both types of lunar missions, the LSAM must allow for landings on the lunar surface without additional infrastructure. This allows for the LSAM to be designed with maximum mission success, safety, and efficiency. This requirement does not prohibit the execution of missions which may utilize landing near assets previously deployed by either robotic or human missions. In some cases, landing nearby to previously deployed assets may be utilized to fulfill specific mission objectives.

[CA5149-PO] The LSAM shall provide the infrastructure necessary for at least 2 (TBR-001-218) LSAM vehicles operating in space concurrently.

Rationale: Multiple LSAM vehicles will be operated in space concurrently for lunar missions. LSAM crew and cargo vehicles will operate simultaneously. LSAM cargo vehicles, which become portions of the Lunar Outpost, may be considered one integrated vehicle from the standpoint of numbers of ground control centers and control teams but will be operated simultaneously with additional crew or cargo vehicles (either in transit to, in lunar orbit, or on the lunar surface). LSAM infrastructure must allow for managing multiple vehicles and for ground control to uniquely identify and control individual vehicles (e.g., unique transponder signals identifiers and command and telemetry format headers).

[CA5195-PO] The LSAM shall provide for at least 1 (TBR-001-217) microgravity EVA operation of 4 (TBR-001-244) hours independent of other vehicles for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: In keeping with CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), LSAM needs to have its own EVA capability. In practice, this means that LSAM needs to not only have the functional capabilities required to conduct an EVA (e.g. depress/repress) but also the necessary consumables and stowage of equipment as well (e.g. EVA umbilicals). The 1 (TBR-001-217) microgravity EVA operation is based on the Contingency EVA transfer of the crew from LSAM to the Orion.

[CA5303-PO] The LSAM shall land on the lunar surface only under the lighting conditions specified in Table (TBD-001-460) for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: This requirement restricts landing at locations on the lunar surface for given lighting conditions. Certain extreme lighting conditions may adversely affect the ability of the crew to safely land the LSAM and, therefore, will need to be excluded.

3.7.3.2.6.1 LSAM Control Mass

Draft **[CA0836-PO]** The LSAM shall have a Control Mass of 45,000 (TBR-001-075) kg (99,208 lbm) at the time of launch for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The Control Mass for LSAM was determined by (TBD-001-090) analysis and the Cargo mass is defined by CA0209-HQ. Mass control is required for the concurrent design of multiple systems which have an overall performance or mission goal. The LSAM Control Mass is required to properly size the Ares V. The Control Mass includes at least 500 kg (1,102 lbm) for Cargo. The mass of crew is not included in the LSAM Control Mass since the LSAM is uncrewed at launch. This requirement corresponds to the Ares V Mass Delivered requirement.

Draft **[CA5231-PO]** The LSAM shall have a control mass of 53,600 (TBR-001-176) kg (118,168 lbm) at the time of launch, which includes 20,000 kg (44,092 lbm) for cargo for Lunar Sortie Cargo missions.

Rationale: The Control Mass for LSAM was determined by (TBD-001-1007) analysis, which also defines the LSAM Cargo mass. The Control Mass for LSAM was determined by analysis. Mass control is required for the concurrent design of multiple Systems which have an overall performance or mission goal. The Control Mass includes the required 20,000 kg (44,092 lbm) of cargo and corresponds to the Ares V Mass Delivered requirement.

3.7.3.2.6.2 LSAM Delta-V

[CA0837-PO] The LSAM shall provide a minimum translational delta-V of 1,260 (TBR-001-149) m/s (4,134 f/s) for Trajectory Correction Maneuvers (TCMs) during the Trans-Lunar Coast (TLC), and for the Lunar Orbit Injection (LOI) into the Lunar Destination Orbit (LDO) for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The minimum translational delta-V requirement is based on (TBD-001-984) analysis. This includes all delta-V necessary for Trajectory Correction Maneuvers (TCMs) during the Trans-Lunar Coast (TLC), and the Lunar Orbit Injection (LOI) into the Lunar Destination Orbit (LDO) for the LSAM/Orion mated configuration. This excludes the attitude control delta-V. Since the LSAM mass delivered requirements are not constant across all LSAM operational phases, three separate delta-V requirements on the LSAM are necessary to properly size the vehicle.

[CA4141-PO] The LSAM shall provide a least 1,900 (TBR-001-513) m/s (6,234 f/s) of translational delta-V for the descent from the Lunar Destination Orbit (LDO) to the lunar surface for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: The minimum translational delta-V requirement is based on analysis. This includes all delta-V necessary for LSAM descent from LDO to the Lunar surface with crew, Flight Crew Equipment and cargo. This excludes the attitude control delta-V. Since the LSAM mass delivered requirements are not constant across all LSAM *operational phases, three separate delta-V requirements on the LSAM are necessary to properly size the vehicle.*

[CA4143-PO] The LSAM shall provide a minimum translational delta-V of 1,877 (TBR-001-514) m/s (6,158 f/s) for its ascent from the lunar surface to the Lunar Rendezvous Orbit (LRO) for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: The minimum translational delta-V requirement is based on analysis. This includes all delta-V necessary for LSAM ascent from the lunar surface to the LRO with Crew, Flight Crew Equipment and Cargo. This excludes the attitude control delta-V. Since the LSAM mass delivered requirements are not constant across all LSAM operational phases, three separate delta-V requirements on the LSAM are necessary to properly size the vehicle. This requirement does not include delta-V for disposal.

[CA4145-PO] The LSAM shall provide at least 2,671 (TBR-001-571) m/s (8,763 f/s) of translational delta-V for the Lunar Outpost Cargo missions.

Rationale: The minimum translational delta-V requirement is based on (TBD-001-1005) analysis. This includes all delta-V necessary for LSAM Trajectory Correction Maneuvers (TCMs) during Trans-Lunar Coast (TLC) and descent to the lunar surface. This excludes the attitude control delta-V.

3.7.3.2.7 LSAM Safety

Draft [CA0890-PO] LSAM shall control critical hazards. The hazards must be identified and controlled using the hazard identification and mitigation process described in CxP 70038, Constellation Hazard Analysis Methodology. The hazard must be controlled without the use of EVA during flight, emergency operations or emergency systems.

Rationale: Control of mission critical failures is dictated by programmatic decision to ensure mission success. The LSAM will define hazard controls that may include failure tolerance. The LSAM will derive the specific hazard controls and implementation from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology. EVA on the lunar surface may be considered an option for hazard control.

Draft [CA0891-PO] LSAM shall be a minimum of one failure tolerant for controlling catastrophic hazards, except for areas approved to use Design for Minimum Risk criteria. The level of failure tolerance must be determined using the hazard identification and mitigation process described in CxP 70038. The failure tolerance requirement cannot be satisfied by use of EVA during flight, emergency operations or emergency systems.

Rationale: Constellation has established a minimum of single failure tolerance or DFMR to control catastrophic hazards. However, single failure tolerance may not be adequate in all instances to control catastrophic hazards. Thus, the level of failure tolerance needed is commensurate with the severity of the hazard, and likelihood of occurrence. The LSAM will derive the specific level of failure tolerance and *implementation (similar or dissimilar redundancy, backup systems) from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology. EVA on the lunar surface may be considered an option for hazard control.*

Draft **[CA5399-PO]** The LSAM shall comply with the requirement in JPR 8080.5, JSC Design and Procedural Standards.

Rationale: Fault tolerance is defeated if a single event can eliminate all modes of tolerance. This requirement mandates separation of redundant systems, subsystems, and elements.

3.7.3.2.8 LSAM Command and Control

Draft **[CA3111-PO]** The LSAM shall accept control of automation.

Rationale: Other Constellation Systems and the crew will need to select, initiate, inhibit, override, and terminate automation on the LSAM during various operational phases. Reference NPR 8705.2, Human Rating Requirements for Space Systems, Sections 3.2.7 (34445) and 3.3.5 (34451).

Draft **[CA3250-PO]** The LSAM shall provide an interface for the crew to generate commands for Lunar Sortie and Lunar Outpost crew missions.

Rationale: In order to perform command and control, the crew will need to be able to initiate the sending of commands.

Draft **[CA3258-PO]** The LSAM shall execute commands valid in the current state.

Rationale: The system will execute commands from other systems in order to perform the specified function or operation. This process includes checking if the command has valid data values and can be executed now based on the current state or mode. Updates to the corresponding Health and Status parameters provide the execution end item result.

Draft **[CA3272-PO]** The LSAM shall generate commands.

Rationale: To perform command and control, the ground and automated sequences will need to be able to initiate the sending of commands. These commands will be either executed internally or transmitted to another Constellation system to be received and executed.

Draft **[CA3277-PO]** The LSAM shall execute valid commands which are addressed to the LSAM.

Rationale: The system will execute commands generated internally or from other systems in order to perform the specified function or operation. The ability for Constellation systems to command execution on remote Constellation systems is required per the operations concept where the system with crew present may need to command systems without the crew onboard (e.g. LSAM commanding the Orion).

In addition, the verification that the command is intended to be executed on the system will support the multi-hop routing capability.

[CA5434-PO] The LSAM shall automatically determine the need for an abort for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: In cases where response time constraints impact crew safety risk requirements, the LSAM should be able to automatically determine the need to abort. Abort determination is based on independent sensor information from the LSAM alone and/or from other systems.

Draft [CA5440-PO] The LSAM shall automatically perform abort for Lunar Sortie and Lunar Outpost crew missions.

Rationale: In cases where response time constraints impact crew safety risk requirements, the LSAM should be able to respond to abort conditions (i.e. powered descent and landing) automatically. Per NPR 8705.2, Human-Rating Requirements for Space Systems, requirement 34471 provides crew survival modes throughout the powered descent, and on-orbit phase from TLI through the mission destination. This does not preclude manually initiated aborts. Automatic Abort includes the execution of automated sequences. The requirement is not meant to mandate automated aborts for all flight phases.

[CA5801-PO] The LSAM, when operated by the crew, shall be controllable by a single crewmember for Lunar Sortie and Lunar Outpost crew missions.

Rationale: Vehicle systems must be designed so that more than one crewmember is not required to operate the vehicle. There may be circumstances where crewmembers are unconscious or incapacitated leaving only a single crewmember capable of vehicle control. Work stations should provide redundant capability from which to command systems and manually operate the vehicle if necessary.

3.7.3.2.9 LSAM Health and Status

Draft [CA0431-PO] The LSAM shall generate Health and Status information.

Rationale: Provides for generation of H&S information on internal operations of the LSAM. Full definition of the specific data is provided in LSAM SRD and multiple LSAM/System IRDs.

Draft [CA3115-PO] The LSAM shall provide Health and Status information to the crew for Lunar Sortie and Lunar Outpost crew missions.

Rationale: Provides for processing of H&S information on internal operations of the LSAM as well as other Constellation Elements, for use by the LSAM crew.

Draft [CA5469-PO] The LSAM shall detect system faults which could result in Loss of Vehicle, loss of life and Loss of Mission.

Rationale: Fault detection is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault detection enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to detection are further specified by CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, loss of life, and Loss of Mission. FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, loss of life, and Loss of Mission.

Draft **[CA5470-PO]** The LSAM shall isolate detected faults to the level required for recovery of function.

Rationale: Fault isolation is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault isolation enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to isolation are further specified by CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, loss of life, and Loss of Mission. The level of recovery is governed by the criticality of systems (Loss of Vehicle, loss of life, Loss of Mission).

Draft **[CA5471-PO]** The LSAM shall provide recovery from isolated faults.

Rationale: Fault recovery is required for crew safety and mission success by enabling recovery of such critical functions. Faults subject to recovery are further specified by the CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, loss of life, and Loss of Mission. The level of recovery is governed by the criticality of systems (Loss of Vehicle, loss of life, Loss of Mission).

3.7.3.2.10 LSAM Communications and Communications Security

[CA0887-PO] The LSAM shall transmit and receive in any attitude with geometric antenna coverage of at least 90% (TBR-001-755) for low-rate data as defined by CxP 70118-03, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 3: Lunar Surface Access Module (LSAM), Section 3.6.1.2.

Rationale: The LSAM needs a reliable communications link that does not depend on active antenna pointing. LSAM must communicate with MS through C&TN as LSAM does not have a direct path to communicate with MS in flight. The low rate data will include critical voice, commands, tracking, and telemetry. Percent coverage requirements are determined by analysis of Constellation Concept of Operations, Constellation FFBDs, and LSAM design trades with the goal of achieving the highest possible coverage. Link data rate is specified in CxP 70118-03, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 3: Lunar Surface Access Module (LSAM). 90% (TBR-001-755) coverage is based on analysis in IDAC2, TDS SIG-13-201.

Draft **[CA0517-PO]** The LSAM shall have a flight data recorder capable of surviving catastrophic events.

Rationale: Flight data recorded prior to and during a catastrophic event is critical to accident investigations. While the concept of an aircraft flight data recorder provides this capability in the event of an accident where recovery on Earth is possible, it does not ensure recovery of data where recovery by rescue personnel is not practical. As such, a goal would be to have the Orion flight data recorder system transmit the stored data when catastrophic events do not allow Earth-based recovery. Catastrophic events will be identified by the Constellation Program and are (TBD-001-096) at this time.

[CA3289-PO] The LSAM shall communicate simultaneously with Mission Systems, and with 2 (TBR-001-129) other Constellation systems that are within 800 (TBR-001-165) km (432 nmi) of LSAM for Lunar Sortie and Lunar Outpost crew missions.

Rationale: Simultaneous communication is required to so that LSAM can communicate with Orion for rendezvous and docking operations and communicate with MS to provide situational awareness and enable ground commanding. LSAM must also communicate with DSS and Orion during lunar ascent and descent for Lunar Outpost missions. Two (TBR-001-129) systems are based on the driving case of the Lunar Outpost DRM in which the LSAM will communicate with an Orion in LLO, the outpost on the lunar surface, and with MS. The number of simultaneous systems is determined by analysis of Constellation FFBDs and by analysis of LSAM and Orion design trades. The relative range was determined based on IDAC2, TDS SIG-12-003.

Draft **[CA5054-PO]** The LSAM shall record System-generated digital data received from other Constellation Systems.

Rationale: There are times when the quantity/rate of data recorded at certain times exceeds the capability of that system's downlink to send. Sharing data recording across Constellation systems allow for increased downlink capacity for highly dynamic events. Constellation systems must store data for each other in order to pass that data along the ultimate path it must traverse to make it back to Earth.

[CA5902-PO] The LSAM shall accept reconfiguration of stored commands, sequences and data.

Rationale: The LSAM needs to accept changes to sequences, commands, and data parameters already stored onboard, when the Ground or Missions systems initiate such reconfiguration actions. Reconfiguration actions may impact procedures, operations time-lines, or onboard algorithms which operate on commandable data items to support mission activities.

[CA5905-PO] The LSAM shall execute reconfigurable automation sequences valid in the current state.

Rationale: The system will execute reconfigurable automation sequences based on triggers that may be generated internally or from other systems (by means of commands) in order to perform the specified function or operation. This process includes checking if the sequence has valid data values and can be executed now based on the current state or mode. Results of the execution are provided through updates to the sequencing Health and Status parameters.

[CA6109-PO] The LSAM shall provide integrated audio and High Definition motion imagery in real-time in LEO, during trans-lunar cruise, through lunar orbit, lunar landing, lunar surface operations, Lunar accent, and re-docking with Orion.

Rationale: Constellation program events and activities, such as lunar landing, scheduled EVAs, or crew communications and conferences, are of national importance and historic importance, and interest, and it is the responsibility of NASA, per the Space Act of 1958, to distribute this information to the public and the NASA Authorization Act of 2005. In addition, this meets the goals of the Constellation program of promoting public participation, CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-G14], and to effectively communicate the benefits of exploration to the public, CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O08]. The audio and video systems shall be integrated in order to facilitate synchronized imagery to the ground and reduce crew and timeline impacts on operational setup and implementation, during events. From a technical view, CxPO wants the capability to provide audio/motion imagery prior to lunar orbit, but may operationally not use this capability depending on LSAM checkout timelines. Lunar ascent and re-docking to Orion is required due to fact that there will be no crewmember in the Orion during this phase of flight to support imaging of re-docking activities. This data will be transmitted to Mission Systems using the Space Network during LEO operations and using the Deep Space Network (possibly with lunar relay support) when operating beyond LEO. Based on the Federal Communications Commission's planned transition to a digital television standard by the end of 2009, the majority of US household will be High Definition capable, thus becoming the defacto television standard, by the time this vehicle is scheduled to fly.

3.7.3.2.11 LSAM GN&C

[CA0135-PO] The LSAM shall function as the maneuvering vehicle during RPOD operations with the Orion in LLO prior to crew transfer back to the Orion.

Rationale: Upon return from the lunar surface, the LSAM will dock with the Orion in LLO. The LSAM will be crewed, so it will function as the maneuvering vehicle for RPOD with the uncrewed Orion. This requirement conforms to the principle that the crewed vehicle should be in control of the rendezvous and docking process. The contingency case, where the crewed LSAM functions as the target vehicle, is covered in a separate requirement (CA5275-PO).

Draft **[CA0284-PO]** The LSAM shall land within 1 (TBR-001-044) km (0.54 nmi) [with 95% probability] of a designated landing site on the lunar surface independent of lunar vicinity landing aids.

Rationale: The specified landing accuracy satisfies Constellation Program objectives (landing near the desired exploration site), while also satisfying crew safety criteria (landing terrain and hazard avoidance considerations). This specified coarse landing accuracy can be achieved without lunar vicinity (surface or orbiting) navigation aids and will be confirmed by trade study TDS 12-2. This requirement addresses the location of the actual touchdown point with respect to the reference mission planned touchdown point. It does not address the accuracy required for positioning assets relative to one another on the lunar surface in multi-surface element outpost campaigns. Lunar vicinity landing aids include navigation aids located on the lunar surface and/or in lunar orbit.

Draft **[CA0418-PO]** The LSAM shall land within 100 (TBR-001-012) m (328 ft) [with 95% probability] of a designated landing site on the lunar surface using lunar vicinity landing aids.

Rationale: The specified landing accuracy satisfies Constellation Program objectives (landing near the desired exploration site), while also satisfying crew safety criteria (landing terrain and hazard avoidance considerations). This specified precision landing accuracy, which is met through the use of pre-deployed lunar vicinity (surface or orbiting) navigation aids, will be confirmed by trade study TDS 12-2. This requirement addresses the location of the actual touchdown point with respect to the reference mission planned touchdown point. It does not address the accuracy required for positioning assets relative to one another on the lunar surface in multi-surface element outpost campaigns. Lunar vicinity landing aids include navigation aids located on the lunar surface and/or in lunar orbit.

[CA0461-PO] The LSAM shall perform the Lunar Orbit Insertion (LOI) into the Lunar Destination Orbit (LDO).

Rationale: The requirement is consistent with Lunar Sortie and Lunar Outpost (Crew and Cargo) DRMs documented in CxP 70007, Constellation Design Reference Missions and Operational Concepts. The Ares V includes a propulsion system and propellant to perform the TLI maneuver. The requirement is based on the results documented in NASA-TM-2005-214062, Exploration Systems Architecture Study, which indicates that using Ares V rather than the LSAM or the Orion for the TLI balances performance, cost, and risk for the Constellation Program.

Draft **[CA3144-PO]** The LSAM shall perform navigation and attitude determination beginning with Earth orbital operations through LSAM disposal.

Rationale: Navigation and attitude determination are required onboard the LSAM to accomplish mission critical activities, such as communications antenna pointing, maneuver execution and performance monitoring, powered descent, and docking. Navigation may include maintenance of a ground uploaded vehicle state or updates *of the vehicle state by processing data from onboard sensors. LSAM navigation and attitude determination are required when LSAM is the controlling vehicle post TLI, as well as in LEO, prior to Ares I launch in order to verify system integrity.*

Draft **[CA3145-PO]** The LSAM shall compute maneuvers associated with lunar descent and landing beginning with DOI.

Rationale: LSAM onboard maneuver computations are required when LSAM onboard navigation knowledge is better than that available on the ground (e.g. maneuvers occurring on the backside of the Moon).

[CA3205-PO] The LSAM shall perform Trajectory Correction Maneuvers (TCMs) during the Trans-Lunar Coast (TLC).

Rationale: The requirement is consistent with Lunar Sortie and Lunar Outpost (Crew and Cargo) DRMs documented in CxP 70007, Constellation Design Reference Missions and Operational Concepts. The LSAM includes a propulsion system and propellant to perform the trajectory correction maneuvers during Trans-Lunar Coast. The requirement is based on the results documented in NASA-TM-2005-214062, Exploration Systems Architecture Study, which indicates that using LSAM rather than the Ares V or the Orion for the TCMs balances performance, cost, and risk for the Constellation Program.

Draft **[CA3251-PO]** The LSAM shall compute rendezvous maneuvers for lunar orbit operations for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: Onboard computations of rendezvous maneuvers are necessary for successful rendezvous execution and provide operational flexibility and efficiency. When the LSAM is within onboard relative navigation sensor range, onboard relative state knowledge exceeds that available to Mission Systems which makes the onboard solutions better than that available to Mission Systems. This capability is also necessary for LSAM to successfully rendezvous with the Orion in the event of loss-of-communications with Mission Systems. Additionally, this capability is required to return the LSAM to the Orion from an aborted lunar landing.

[CA5275-PO] The LSAM shall function as the target vehicle while performing RPOD with Orion in LLO for Lunar Sortie and Lunar Outpost crew missions.

Rationale: For nominal missions, Orion acts as the target during the rendezvous phase in LLO. This requirement covers the case in which the LSAM has an underspeed condition or other reason causing the LSAM to be placed in the incorrect orbit, but an orbit which is still accessible by Orion within planned, as well as reserve performance. Scenarios in which LSAM is unable to complete proximity operations and docking are also covered by this requirement. In these scenarios, Orion performs all or part of RPOD.

[CA5278-PO] The LSAM shall provide onboard, manual control of flight path, attitude, and attitude rates when the human can operate the system within vehicle margins for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: This requirement flows down from NPR 8705.2, Human-Rating Requirements for Space Systems, manual control of spacecraft attitude, attitude rate, and flight path provides additional margin for mission success and crew safety.

[CA5284-PO] The LSAM shall function as the target vehicle during undocking and departure proximity operations from Orion after crew transfer to Orion.

Rationale: The LSAM is uncrewed, so it will act as the target. This applies after the LSAM has returned from the lunar surface, docked, and transferred the crew to Orion. This requirement conforms to the principle that the crewed vehicle should be in control of the rendezvous and docking process.

[CA5285-PO] The LSAM shall perform maneuvering vehicle functions during undocking and departure proximity operations from Orion prior to lunar descent for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: The LSAM is crewed, so it will act as the maneuvering vehicle. This requirement applies to undock and departure from Orion prior to descent to the lunar surface.

[CA5290-PO] The LSAM shall perform attitude control of the Orion/LSAM mated configuration after separating from the Ares V EDS for Lunar Sortie and Lunar Outpost crew missions.

Rationale: As the Orion/LSAM mated configuration is separating from the Ares V EDS, the LSAM will begin to take control of the Orion/LSAM mated configuration for Trans-Lunar Coast. Since LSAM will control the mated configuration and has the best view of the departing Ares V EDS, it will perform the active control functions for the mated configuration.

[CA5293-PO] The LSAM shall provide target vehicle interfaces in the LSAM/Ares V EDS mated configuration, during RPODU operations with Orion in LEO, for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The LSAM provides the docking interface, the relative navigation, and relative attitude estimation interfaces, such as physical targets and radiometric tracking for RPODU with Orion.

3.7.3.2.12 LSAM Reliability and Availability

Draft **[CA5532-PO]** The LSAM shall be prepared to launch again 4 (TBR-001-183) days prior to the next lunar injection window following a missed window.

Rationale: It is important to provide the capability to recycle the vehicles and mission elements in time to meet the next lunar injection window in the event of a scrubbed launch. The LSAM/Ares V will be launched at least 1 day prior to the Orion/Ares I lunar launch, when applicable. The lunar injection windows are typically four days long and occur every 30 (TBR-001-919) days.

Draft **[CA5605-PO]** The LSAM shall have a probability of launch of not less than (TBD-001-064)% during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses LSAM system reliability. System reliability and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements. The value of (TBD-001-064)% in this requirement is driven by the Lunar Campaign needs.

[CA6207-PO] LSAM systems failures identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1504)% that would result in a scrubbed launch, shall be maintainable as follows:

a. No less than 30% (TBR-001-1425) can be remedied to support a launch attempt within one day.

b. No less than 45% (TBR-001-1426) can be remedied to support a launch attempt within two days.

c. No less than 50% (TBR-001-1427) can be remedied to support a launch attempt within three days.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses Ares I system maintainability. The intent is to drive a capability to correct those failures discovered (latent defects) after deciding to load cryogenic propellants that will cause a launch scrub in order to maximize the number of launch attempts that are utilized.

The duration for repair time includes the time to establish access, set up, diagnose, perform corrective maintenance, closeout, and complete any retest required in time to make the launch attempt. As this is a design-to requirement, administrative and logistics delay is not included (for example: time searching for a spare part).

The intent of extending through only 50% of failures is to prevent this requirement from driving counterproductive system complexity and increased effort or difficulty for nominal operations and sustainment scenarios. The expectation is that operability assessments should influence the developer's selection of which of the most likely failures to target.

The values used above (30%,45%, and 50%) correspond with the Space Shuttle Program history of times to repair. The intention of this requirement is to inform design with the historical data as a first iteration until the supplier data becomes available. At that time, the analysis will be updated.

3.7.3.2.13 LSAM Maintainability, Supportability, and Logistics

[CA5505-PO] The LSAM shall sustain operations using only onboard equipment and spares without resupply.

Rationale: During LSAM flight operations the crew may be required to address situations without the support of ground personnel. The ability to maintain operations autonomously is critical in contingencies.

[CA5982-PO] The LSAM project shall produce and deliver Project Verified Engineering Build software and data products to the Constellation Program within the time limits identified in Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Engineering Build is a set of software and data products that contain new requirements (capabilities) and problem fixes. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Engineering Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. Data products contain representative launch geometry values and actual values for other parameters. It has completed Project Level Verification/Validation and has been configured to meet Integrated Build event requirements. Data definitions must be available in time to support generation of data products for the release. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation architecture. Project level activities include: participation in the build content definition, software design, code, and project-level Integration, test and delivery of the Project Verified Engineering Builds to the Program.

TABLE 3.7.3.2.13-1 TIME ALLOCATIONS FOR ENGINEERING BUILDS

Requirement	Threshold	Objective
LSAM	7 months (TBR-001-1054)	2.5 months

[CA5983-PO] The LSAM project shall produce and deliver Project Verified Flight Build software and data products to support the mission class within the time limits identified in Time Allocations for Flight Builds Table after the completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Flight Build is a set of software and data products that is based on a Project Verified Engineering Build, has mission specific (launch geometry derived) data and has completed Project Level Verification/Validation. Few software changes are expected. The time period starts when the software content *definition is baselined and ends with the delivery of a Project Verified Flight Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Data parameter values must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation Architecture. Project level activities include: participation in the build content definition, flight specific configuration activity (data reconfiguration), Fast Track activities as required, and delivery of Project Verified Flight Builds. Times are contiguous days.*

TABLE 3.7.3.2.13-2 TIME ALLOCATIONS FOR FLIGHT BUILDS

Requirement	Threshold	Objective
LSAM	14 days	4 days

[CA5985-PO] The LSAM shall produce and deliver resolutions for selected non-conformances during the engineering and flight release phases to the discovering organization and the Constellation Program in the time limits identified in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track build process is used for rapid resolution of problems found in the production of Flight Builds and Engineering Builds. The time period starts after documentation of the non-conformance and ends when the resolution is submitted for re-integration into the test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

TABLE 3.7.3.2.13-3 TIME ALLOCATIONS FOR FAST TRACK PROCESS

Requirement	Threshold	Objective
LSAM	48 hours	12 hours

[CA6008-PO] The LSAM shall conduct ground operations for a single Ares V/LSAM mission within the time limits identified in the LSAM Critical Path Allocations for Ares V/LSAM Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by *balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and ground system designs that result in reduced ground operations time and labor without sacrifices to performance or design cost. The critical path constraints levied in LSAM Critical Path Allocations for Ares V/LSAM Ground Operations Table, along with labor-hour constraints defined in CA6008, are intended to drive the design of the flight and ground systems to enable such reductions. The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather they are intended to be a design target for the system developers.*

In LSAM Critical Path Allocations for Ares V/LSAM Ground Operations Table, the LSAM Ground Operations processing flow is broken down into four sequential time periods between key LSAM processing milestones. The sum of the time periods is the overall Critical Path anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming "single-string" for the integrated operations Ground Systems (i.e., one Ares V Mobile Launcher, one Ares V VAB high bay, one control room for Ares V operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx Ground Operations.

The values identified in LSAM Critical Path Allocations for Ares V/LSAM Ground Operations Table are intended to apply to nominal LSAM operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy ELV systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.7.3.2.13-4 LSAM CRITICAL PATH ALLOCATIONS FOR ARES-V/LSAM GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		

Ready for LSAM Integration to Integrated Stack Ready for Powered Testing	(TBD-001-1302)	(TBD-001-1303)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA
Ready for Powered Testing to Finish of Powered Testing	(TBD-001-1304)	(TBD-001-1305)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares V, LSAM, GS, EVA
Finish of Powered Testing to Pad Connection and Validation Complete	(TBD-001-1306)	(TBD-001-1307)	From the end of powered testing in the VAB until the vehicle is at the launch pad and ready to begin launch preps. Includes vehicle and ground system roll out preparations, roll-out, and ML-Launch pad connections and validations.	GS, Ares V, LSAM
Pad Connection and Validation Complete to Launch	(TBD-001-1308)	(TBD-001-1309)	Begins once pad connections are validated and ends at T-0.	GS, Ares V, LSAM, EVA

[CA6017-PO] The LSAM shall produce cargo engineering products for a single mission within (TBD-001-1074) days for Lunar missions.

Rationale: The Mission Integration Production defines an orderly mission production process beginning with the definition of a baselined set of mission requirements and the ensuing flight design, flight software, ground vehicle processing, flight operations documentation development, vehicle configuration, and crew and launch/flight control training activities necessary to support a mission. LSAM portions of that production effort are in software reconfiguration (CA5964) and cargo engineering. Cargo engineering is used to support ground processing and is managed to a shorter process based on managing to standard interfaces between flight systems and cargo for each Lunar mission. Days are based on contiguous work days (no weekend or holiday work, 8 hrs/day, 5 days/week).

[CA6017-PO-Objective] The LSAM shall produce cargo engineering products for a single mission within (TBD-001-1075) days for Lunar missions.

Rationale: The Mission Integration Production defines an orderly mission production process beginning with the definition of a baselined set of mission requirements and the ensuing flight design, flight software, ground vehicle processing, flight operations documentation development, vehicle configuration, and crew and launch/flight control training activities necessary to support a mission. LSAM portions of that production effort are in software reconfiguration (CA5964) and cargo engineering. Cargo engineering is used to support ground processing and is managed to a shorter process based on managing to standard interfaces between flight systems and cargo for each Lunar mission. Days are based on contiguous work days (no weekend or holiday work, 8 hrs/day, 5 days/week).

[CA6034-PO] The LSAM shall require no more than 2 (TBR-001-1106) hours per week contiguous real-time command and control from Mission Systems during LSAM quiescent Lunar operations under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting commanding and control interaction with a quiescent LSAM in LEO or on the Lunar surface to specific periods under nominal operating conditions (i.e. no LSAM system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent LSAM would require very little routine command and control interaction. Managing this interaction within a specific period enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). Assumption is that operations personnel send commands (e.g. crew uplink messages, state vectors, scripts) during this active command and control period each week.

[CA6035-PO] LSAM shall operate with no more than 1 (TBR-001-1107) hour per day contiguous (consisting of (TBD-001-1086) man-hours) monitoring by dedicated LSAM engineering teams while in a quiescent mode for Lunar operations under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations and flight systems' engineering support teams. Limiting ground active monitoring required by a quiescent vehicle to specific periods and specific manpower intensity under nominal operating conditions (i.e. no LSAM system failures) will contribute to reduced operations and sustaining engineering life cycle costs. It is expected that a quiescent vehicle (LSAM in LEO or on the Lunar surface during outpost stays) would require very little routine active telemetry monitoring by dedicated ground controllers and engineering teams. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control and engineering team manning (e.g. numbers of dedicated shifts and numbers of teams). This requirement does not preclude the fact that Health and Status data from quiescent vehicles will be provided near continuously from the LSAM for fault annunciation and trending. Ground controllers and engineering teams supporting other active vehicles (e.g. Outpost) can monitor for trends and fault annunciations as part of the active vehicle routine tasks. Dedicated personnel can be called in to resolve anomalies when needed. Assumption is that engineering support personnel monitor trends and archived subsystems data during this active monitoring period without need for operations personnel, unless anomalies occur.

3.7.3.2.14 LSAM Habitability and Human Factors

Draft **[CA0813-PO]** The LSAM shall provide a habitable environment for a crew of four for a minimum of 180 (TBR-001-033) hours during each lunar mission, beginning prior to separation from Orion in lunar destination orbit up to initiation of ascent from the lunar surface for Lunar Sortie and Lunar Outpost crew missions.

Rationale: Defines the duration for which the LSAM will need to support the crew during the lunar mission which includes joint operations with Orion The duration of 180 (TBR-001-033) hours accounts for the durations of separation maneuvers (0.3 hours), descent (1.0 hour), surface mission (168 hours), and reserves (10.7 hours) for uncertainties (e.g. missed ascent opportunity, operational timeline unknowns, to-be-defined duration after switch-over from Orion to LSAM crew support systems prior to undocking, etc.)

Draft [CA0814-PO] The LSAM shall control cabin pressure to a selectable setpoint between 79 (TBR-001-907) kPa (11.4 psia) to 52 (TBR-001-908) kPa (7.5 psia) with 0.7 (TBR-001-147) kPa (0.1 psia) increments for Lunar Sortie and Lunar Outpost crew missions.

Rationale: This is to facilitate pressure operation from the LSAM to Orion operational pressure to the minimum nominal limit with a 34% oxygen materials limit and 17 kPa (2.5 psia) ppO2 crew limit. This is to have common approach to cabin pressure management across Constellation Architecture.

Draft [CA3062-PO] The LSAM shall limit the maximum oxygen concentration within the pressurized cabin to 34% (TBR-001-038) by volume for Lunar Sortie and Lunar Outpost crew missions.

Rationale: This is to keep the oxygen concentration from exceeding the materials certification limit. This is to have common approach to cabin pressure management across Constellation Architecture.

Draft [CA3107-PO] The LSAM shall maintain the cabin environment at a pressure of no less than 55 kPa (8.0 psia) from an initial nominal cabin pressure with an equivalent cabin hole diameter of 0.64 (TBR-001-2501) cm (0.25 in) to allow the crew time to don suits per CA3058-PO for Lunar Sortie and Lunar Outpost crew missions.

Rationale: This is one of the requirements that define vehicle response to a cabin leak. They will require the time the cabin pressure must me maintained to allow the crew to don suits, the time the cabin pressure must be maintained to prebreathe, suit pressure for depress events, and the number of cabin leak or cabin repress events the vehicle must support for lunar missions This requirement defines the cabin pressure maintenance required to allow time for the crew to don pressure suits. The 0.64 (TBR-001-106) cm (0.25 in) hole is derived from expected leak rates from lost seals on overboard hatches and feed-throughs, and previous spaceflight precedent.

Draft [CA3135-PO] The LSAM shall control cabin oxygen partial pressure to a selectable setpoint between 18 (TBR-001-130) kPa (2.6 psia) ppO2 and 21 (TBR-001-913) kPa (3.1 psia) ppO2 with 0.7 (TBR-001-914) kPa (0.1 psia) increments for Lunar Sortie and Lunar Outpost crew missions.

Rationale: This is to allow oxygen partial pressure selectability to facilitate operations from Orion docking partial pressures to the ppO2 crew limit. This is to have common approach to cabin pressure management across Constellation Architecture.

Draft **[CA3137-PO]** The LSAM shall provide not less than two vestibule pressurization cycles per mission for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The responsibility for vestibule pressurization must be allocated between Orion and LSAM. This requirement allocates responsibility for two pressurization cycles to LSAM. Primary and contingency vestibule pressurization should account for each docking in which the crewed LSAM is the active vehicle. The LSAM will perform the vestibule pressurization when the crewed LSAM docks with the Orion.

Draft **[CA3165-PO]** The LSAM shall provide a habitable environment for a crew of 4 for a minimum of 12 (TBR-001-131) hours beginning at initiation of ascent from the lunar surface through docking with Orion in Lunar Rendezvous Orbit.

Rationale: Defines the duration for which the LSAM will need to support the crew during ascent prior to docking with Orion. Nominal rendezvous durations will be approximately 2 - 4 hours. Rendezvous following a descent abort is anticipated to be up to ~4 hours in duration. However, there are also situations where the LSAM departs from the lunar surface and is not able to complete the rendezvous with Orion, thus, requiring Orion to perform the rendezvous. Some rescue scenarios might have durations as long as ~12 hours. It is expected that the LSAM will be placed in a degraded mode that conserves system resources, yet provides for crew survival, during a rescue scenario.

Draft **[CA3181-PO]** The LSAM shall maintain the cabin environment at a pressure to support prebreathe as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), [HS6091], with an equivalent cabin hole diameter of 0.64 cm (0.25 in) and a suit pressure per CA5659-PO for Lunar Sortie and Lunar Outpost crew missions.

Rationale: This is one of the requirements that define vehicle response to a cabin leak. They will require the time the cabin pressure must me maintained to allow the crew to don suits, the time the cabin pressure must be maintained to prebreathe, suit pressure for depress events, and the number of cabin leak or cabin repress events the vehicle must support for lunar missions This requirement defines the cabin pressure maintenance required allows time for the crew to prebreathe in order to de-nitrify their blood before they go to reduced pressures in the suit. The 0.64 (TBR-001-106) cm (0.25 in) hole is derived from expected leak rates from lost seals on overboard hatches and feed-throughs, and previous spaceflight precedent.

Draft **[CA5385-PO]** The four-crew configuration of the LSAM shall provide a net habitable volume of no less than (TBD-001-603) m3 ((TBD-001-603) ft3) for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The goal for the LSAM is to maximize net habitable volume to comply with unforeseen mission needs without exceeding other design constraints. The operational requirements of the mission including crew size, duration, and mission objectives, will drive the minimum net habitable volume requirement. If the net *habitable volume is minimized or constrained or restricted, operations will be impacted.*

3.7.3.2.15 LSAM Environmental Conditions

Draft **[CA0815-PO]** The LSAM shall meet its requirements during and after exposure to the environments defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, 3.3, and 3.4.

Rationale: The LSAM will be exposed to a variety of natural environments that could make it unable to meet its requirements, potentially in combination with induced environments. This requirement defines the limits of these effects and assures that they will be mitigated by the design. Natural environment effects also need to be considered for the LSAM integrated vehicle configurations: Orion/LSAM, Orion/LSAM/Ares V-EDS, LSAM/Ares V, and LSAM/Ares V/GS.

Draft **[CA5556-PO]** The LSAM shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification .

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design.

Draft **[CA5561-PO]** The LSAM shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification .

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design. Therefore, the production of induced environments must be limited and controlled to allow proper performance and function of other sub-systems and other Systems when operating in mated configurations.

3.7.3.3 Reserved

3.7.3.4 LSAM External Interfaces

[CA0432-PO] The LSAM shall interface with the Orion per CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document .

Rationale: The LSAM and Orion share physical and functional interfaces which are identified in CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document.

Draft **[CA0900-PO]** The LSAM shall interface with the Ares V per CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) -To- Ares V Interface Requirements Document (IRD).

Rationale: The LSAM and Ares V share physical and functional interfaces which are identified in CxP 70109, Constellation Program Lunar Surface Access Module

(LSAM) -To- Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).

Draft **[CA0901-PO]** The LSAM shall interface with Ground Systems per CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -To- Ground Systems Interface Requirements Document (IRD).

Rationale: The LSAM and GS share physical and functional interfaces which are identified in CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -To- Ground Systems Interface Requirements Document (IRD) .

Draft **[CA0902-PO]** The LSAM shall interface with Mission Systems per CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -To- Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: The LSAM and MS share physical and functional interfaces which are identified in CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -To- Mission Systems (MS) Interface Requirements Document (IRD) .

Draft **[CA0903-PO]** The LSAM shall interface with EVA systems per CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -To- Extravehicular Activity (EVA) Interface Requirements Document (IRD) .

Rationale: The LSAM and EVA systems share physical and functional interfaces which are identified in CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -To- Extravehicular Activity (EVA) Interface Requirements Document (IRD) .

Draft **[CA0904-PO]** The LSAM shall interface with the Communication and Tracking Networks per CxP 70118-03, Constellation Program Systems -To- Communications and Tracking Network Interface Requirements Document, Volume 3: Lunar Surface Access Module (LSAM) .

Rationale: The LSAM and C&TN share physical and functional interfaces which are identified in CxP 70118-03, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 3: Lunar Surface Access Module (LSAM).

3.7.3.5 Reserved

3.7.4 Ares V

3.7.4.1 Ares V Description

The Ares V provides the heavy lift capability for the Constellation Program. The Ares V consists of a 5-engine Core Stage, two 5-segment SRBs, and the Earth Departure Stage (EDS), powered by a J2-X engine (same engine as the Ares I upper stage). The EDS serves as the Ares V third stage with a role in injecting the LSAM/EDS stack into the LEO staging orbit where the LSAM/EDS and Orion rendezvous and dock. The EDS performs the Trans-Lunar Injection (TLI) burn for the LSAM and Orion after which it is jettisoned.

3.7.4.2 Ares V Requirements

Draft **[CA3212-PO]** Ares V shall launch an LSAM into a Trans-Lunar trajectory for Lunar Outpost Cargo missions.

Rationale: Defines LSAM as the cargo-delivery vehicle to the Lunar Outpost. NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study showed that an alternate, cargo-only configuration of LSAM on a single Ares V launch is the most effective way to use Constellation Systems to deliver cargo for Lunar Outpost missions. Larger cargo components can be delivered by LSAM by removing the ascent stage used on crew missions and other components.

Draft **[CA3215-PO]** Ares V shall launch cargo into a (TBD-001-565) Earth orbit for Mars missions.

Rationale: Defines functional requirement for Ares V to launch cargo in support of Mars missions. Assembly of Mars cargo systems will be required in Earth orbit prior to departure for Mars.

3.7.4.2.1 Ares V Mission Success

Draft **[CA0486-PO]** Ares V EDS shall limit their contribution to the risk of Loss of Mission (LOM) for Lunar missions to no greater than 1 in 250 (TBR-001-053).

Rationale: The 1 in 250 (TBR-001-053) means a .004 (or .4%) probability of LOM due to the Ares V EDS during any Lunar mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Need, Goals and Objectives, Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

Draft **[CA0487-PO]** Ares V shall limit their contribution to the risk of Loss of Mission (LOM) for Lunar missions to no greater than 1 in 125 (TBR-001-054).

Rationale: The 1 in 125 (TBR-001-054) means a .008 (or .8%) probability of LOM due to the Ares V during any Lunar mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Need, Goals and Objectives, Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

Draft **[CA5930-PO]** Ares V shall be single fault tolerant for critical hazards that do not cause abort or Loss of Mission, except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance must be achieved without the use of emergency operations or emergency systems.

Rationale: Single Fault Tolerance provides for mission critical failures and is dictated by programmatic decision to ensure mission success. The Constellation Program will define levels of fault tolerance that are satisfied by multiple systems and the allocations to those systems. This does not preclude more than the minimum level of fault tolerance.

3.7.4.2.2 ARES V CREW SURVIVAL

Draft **[CA5160-PO]** Ares V shall provide unassisted emergency egress for six (TBR-001-1022) ground crew conducting pre-launch activities within the Ares V during pre-launch pad operations within 2 (TBR-001-1024) minutes starting from the initiation of the egress to the arrival of the last ground crewmember at the Ares V exit point.

Rationale: For contingency situations, the ground crew will need the capability to safely egress the Ares V. This should drive Ares V internal access requirements, design of Ares V interior egress paths, and GSE to allow ground crew conducting pre-launch activities within the Ares V to exit without additional ground crew assistance. This requirement assumes that all Ares V unique GSE required by ground crew for Ares V internal activities is designed and provided by Ares V. The egress time is from the initiation of egress until the last ground crew exits the Ares V. Launch pad egress is covered by Ground Systems.

Draft **[CA5436-PO]** Ares V shall automatically determine the need for an abort.

Rationale: In cases where response time constraints impact crew safety risk requirements, the Ares V should be able to automatically determine the need to abort. Abort determination is based on independent sensor information from the Ares V alone and/or from other systems depending on flight phases. The need to abort by the EDS is required for TLI maneuvers. The need for pad abort is required during launch prior to the SRB ignition.

3.7.4.2.2.1 Ares V Crew Survival Probabilities

Draft **[CA0485-PO]** Ares V EDS shall limit their contribution to the risk of Loss of Crew (LOC) for Lunar missions to no greater than 1 in 37,000 (TBR-001-052).

Rationale: The 1 in 37,000 (TBR-001-052) means a .000027 (or .0027%) probability of LOC due to the EDS during any Lunar mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, Exploration Systems Architecture Study Report. This requirement is driven by CxP 70003-ANX01, Constellation Need, Goals and Objectives, Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.7.4.2.3 Reserved

3.7.4.2.4 Ares V Cargo Delivery

Draft [CA0282-PO] Ares V shall deliver at least 125,000 (TBR-001-220) kg (275,578 lbm) to a (TBD-001-072) Earth orbit for Mars exploration missions.

Rationale: The Mass Delivered requirement is based on analysis. This requirement applies to the Mars exploration missions where a large cargo deployment to (TBD-001-072) Earth orbit is required to meet mission objectives. This requirement may be enveloped by the Ares V crewed Lunar missions requirements CA0847-PO/CA0049-PO or the Ares V Lunar Outpost Cargo mission requirement CA0848-PO.

3.7.4.2.5 Ares V Mission Rates and Durations

Draft [CA0850-PO] Ares V EDS shall meet its requirements after loitering in Low Earth Orbit (LEO) at least (TBD-001-975) days after orbit insertion for crewed lunar missions.

Rationale: The Ares V EDS in the LSAM/Ares V EDS mated configuration, needs to survive on-orbit (e.g., withstand micrometeoroids, maintain orbit and attitude, and preserve propellant) while awaiting the launch of the Orion. The duration of the loiter is based on the interaction between the Orion launch opportunities, the lunar surface landing location, and the operational lighting conditions needed on the lunar surface for the mission. The loiter duration also needs to include time for Orion/LSAM/Ares V EDS RPOD activities and TLI preparations.

[CA6095-PO] Ares V shall perform back to back launches within 45 calendar days, measured from the launch of the first vehicle to the launch of the second vehicle.

Rationale: Ares V must be designed to support a minimum mission interval in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission intervals drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, the minimum interval drives turnaround and maintenance activities for the Constellation systems. This interval is expressed in calendar days.

[CA6095-PO-Objective] Ares V shall provide the capacity to conduct one back to back set of launches per year within 30 days measured from the launch of the first vehicle to the launch of the second vehicle.

Rationale: The capacity of Ares V project to conduct a single set of launches in a 30 day interval per year will allow the capability to maintain manifesting mission success goals in the case of a launch slip.

[CA6097-PO] Ares V shall perform four launches in a year.

Rationale: Ares V must be designed to support a minimum mission frequency which is based on the manifest in order to fulfill the basic requirements of the Ares V Project. Mission frequencies drive infrastructure design, allocation of production *capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Ares V systems. Ares V Lunar missions will consist of one crewed lander and one uncrewed cargo lander for a total of two Ares Vs per lunar mission.*

[CA6097-PO-Objective] Ares V shall perform six launches in a year.

Rationale: Ares V must be designed to support a launch frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Launch frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Ares V systems. Ares V Lunar missions will consist of one crewed lander and one uncrewed cargo lander for a total of two Ares Vs per lunar mission.

[CA6104-PO] Ares V shall provide launch attempts on each of no less than four consecutive days.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. Four days are based on an Ares V-launch-first mission design. The Ares V should be designed so that servicing can be completed for the next day's launch attempt or be designed to last at least four days without servicing.

3.7.4.2.6 Ares V Architecture Definition

Draft **[CA0049-PO]** Ares V shall launch the LSAM from the launch site to the Earth Rendezvous Orbit (ERO) for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: Establishes the Ares V as the launch vehicle to transport the LSAM to the Earth Rendezvous Orbit with sufficient remaining propellant to execute the Trans-Lunar Injection burn. The TLI maneuver takes place after Orion docks with LSAM in the Earth Rendezvous Orbit (ERO). The architecture design solution of launching LSAM on the Ares V separate from the crewed Ares I/Orion launch was a result of NASA-TM-2005-214062, Exploration Systems Architecture Study.

[CA0391-HQ] Ares V shall utilize twin shuttle-derived 5-segment SRBs along with a core stage that employs five modified RS-68 engines for first stage propulsion.

Rationale: The Ares V will take advantage of the flight proven propulsion systems components developed for the Space Shuttle and Evolved Expendable Launch Vehicle (EELV). These launch vehicle components, which have supported over 100 Space Shuttle missions and numerous EELV missions, have extensive test/flight experience databases available for Ares V designers to leverage. In addition, Ares V designers will be able to leverage the ground processing/production facilities, workforce, and tooling already in place to support Space Shuttle operations. The use *of these flight-proven technology and existing ground infrastructure is seen as a significant cost/schedule savings for the Ares V development effort when compared with developing a new design without flight heritage.*

Draft **[CA3217-PO]** Ares V shall provide lift-off clearance between the Ares V integrated stack and the launch facility.

Rationale: The GN&C subsystem and ground structure-launch vehicle physical interface need to be designed such that recontact is an extremely low probability event. Recontact at any point in the vertical rise phase of flight may be catastrophic and could mean loss of launch elements or ground infrastructure. This involves clearances such as Ares V and LSAM access arms, umbilicals, and SRM nozzles. Specific clearance envelopes will be defined in the Ares V/GS and the LSAM/GS IRDs.

Draft **[CA5678-PO]** Ares V shall launch independent of ambient lighting conditions.

Rationale: Use of night time launch windows greatly increases the opportunities for launch to a successful rendezvous orbit. Launch windows to set up for Trans-Lunar Insertion burns frequently fall in darkness.

3.7.4.2.6.1 Ares V Control Mass

Draft **[CA0848-PO]** Ares V shall deliver at least 54,600 (TBR-001-077) kg (120,372 lbm) from the Earth surface to the start of the Trans-Lunar Coast (TLC) for uncrewed Lunar Outpost Cargo missions.

Rationale: This Mass Delivered requirement is based on (TBR-001-910) analysis. This requirement is based on Lunar Outpost Cargo missions. This mass delivered includes the Control Mass of the LSAM-B and Program Mass Reserve. This requirement may be enveloped by the Ares V crewed Lunar missions requirements or the Ares V Mars Cargo mission requirement.

Draft **[CA0847-PO]** Ares V EDS shall deliver at least 66,939 (TBR-001-076) kg (147,266 lbm) from Earth Rendezvous Orbit (ERO) to the start of the Trans-Lunar Coast (TLC) for crewed lunar missions.

Rationale: This Mass Delivered requirement is based on (TBD-001-983) analysis. This Mass Delivered includes the mass of the LSAM/Orion mated configuration, which is the sum of the Control Masses for the LSAM and the Orion, and a Program Mass Reserve. This Mass Delivered requirement combined with the functional requirement defines the required performance of the Ares V for crewed lunar missions. This requirement may be enveloped by the Ares V Lunar Outpost cargo mission requirement or the Ares V Mars Cargo mission requirement.

3.7.4.2.6.2 Ares V Delta-V

Draft **[CA0051-PO]** The Ares V EDS shall provide a minimum translational delta-V of 3,150 (TBR-001-258) m/s (10,335 f/s) for the TLI for crewed lunar missions.

Rationale: The minimum translational delta-V requirement is based on (TBD-001-501) analysis. This includes all delta-V necessary to deliver LSAM and Orion from ERO to the start of the Trans-Lunar Coast (TLC). This delta-V includes necessary allocations for departure windows and other needed allocations. This does not include delta-V for Ares V disposal or attitude control.

3.7.4.2.7 Ares V Safety

Draft **[CA0874-PO]** Ares V shall include a Flight Termination System in accordance with NPR 8715.5, Range Safety Program, Section 3.3.

Rationale: FTS is needed to protect the general population, including ocean and air traffic, from an errant launch vehicle.

Draft **[CA5403-PO]** Ares V shall comply with the requirement in JPR 8080.5, JSC Design and Procedural Standards, Section G-2.

Rationale: Fault tolerance is defeated if a single event can eliminate all modes of tolerance. This requirement mandates separation of redundant systems, subsystems, and elements.

Draft **[CA5432-PO]** Ares V shall generate an indication upon receipt of each Flight Termination command.

Rationale: This requirement provides for the generation of the Orion indication that the FTS has been armed by the Flight Control Officer or that a termination command has been received. This enables functions or actions which may be implemented to facilitate launch abort initiation.

Draft **[CA5433-PO]** Ares V shall provide for FTS inhibit.

Rationale: During ground processing a simple and reliable means of inhibiting is needed to prevent inadvertent activation. Inhibiting makes the FTS not only safe from inadvertent ground, or automatic initiation, but also makes the FTS safe from accidental interface with other mechanical initiation features that might be present. In addition, the EDS FTS will be inhibited during on-orbit mission phases.

Draft **[CA5806-PO]** Ares V shall provide two fault tolerance to catastrophic hazards except for areas approved to use DFMR. The fault tolerance must be achieved without the use of emergency operations or emergency systems.

Rationale: The Ares V shall be designed such that no two failures will have the effect of causing a catastrophic hazard leading to the permanent disability or loss of the crew. The Ares V design, will therefore, provide two fault tolerance protection (or DFMR) to catastrophic hazards, as well as provide protection against catastrophic hazardous effects from failure of any Ares V system or component, regardless if the system or component is necessary for crew survival or mission success. The Constellation Program Office will define levels of fault tolerance that are satisfied by multiple systems and the allocations to those systems. Heritage hardware used to implement Ares V requirements will be assessed against this fault tolerance *requirement. In cases where it is not technically feasible to implement the fault tolerance requirement as written or where added fault tolerance does not result in a reduction of risk, the exception must be documented and brought forward to the program for risk acceptance. The program may then choose to issue a waiver, tailor the requirement or require a redesign.*

[CA5918-PO] Ares V shall be fitted with Flight Termination Systems which will auto initiate (ADS or ISDS) upon inadvertent vehicle separation/break-up for uncrewed launches.

Rationale: Automatic initiation of FTS minimizes time delay in response to breakup, hence minimizing launch area risk, minimizing dispersions, and improving protection of people and property.

[CA5920-PO] Ares V shall be capable of uninstalling or physically disabling devices fitted to the Ares V for automatic initiation of FTS for crewed launches.

Rationale: NASA and the 45th Space Wing acknowledge that time must be maximized to permit crew abort/escape. Therefore auto FTS will be disabled for crewed launches. Uninstalled or physically disabled could mean, e.g. partially uninstalled, or ordnance removed. The preference would be for it to be uninstalled over just "disabled".

3.7.4.2.8 Ares V Command and Control

[CA3113-PO] The Ares V shall accept control of automation.

Rationale: Other Constellation systems will need to select, initiate, inhibit, override, and terminate automation on the Ares V during various operational phases. Reference NPR 8705.2, Human-Rating Requirements for Space Systems, Section 3.2.7 (34445).

Draft **[CA3257-PO]** Ares V shall execute commands valid in the current state.

Rationale: The system will execute commands from other systems in order to perform the specified function or operation. This process includes checking if the command has valid data values and can be executed now based on the current state or mode. Updates to the corresponding Health and Status parameters provide the execution end item result.

[CA3276-PO] Ares V shall execute valid commands which are addressed to the Ares V.

Rationale: The system will execute commands generated internally or from other systems in order to perform the specified function or operation. The ability for Constellation systems to command execution on remote Constellation systems is required per the operations concept where the system, with crew present, may need to command systems without the crew onboard (e.g. LSAM commanding the Orion). In addition, the verification that the command is intended to be executed on the system will support the multi-hop routing capability.

Draft **[CA3292-PO]** Ares V shall provide autonomous lift-off and ascent operations.

Rationale: This requirement provides for independence from external control (i.e. ground control) for nominal operations. Due to the definitions of automated and autonomous, this requirement is needed, in addition to an automated operations requirement, to define automated operation independent of ground control. For ascent phase, vehicle autonomy with onboard authority will reduce the reliance on pre-launch mission design, increase vehicle performance, and improve safety. Additionally, for crewed launch vehicles, autonomous operations for critical functions affecting crew safety are required by NPR 8705.2, Human-Rating Requirements for Space Systems, Section 3.7.1 (34464).

[CA3302-PO] Ares V shall perform automated lift-off and flight operations.

Rationale: This requirement establishes that all of the functions needed to place the EDS and LSAM in the nominal injection orbit be automated. It also applies to EDS functions needed to send Orion and LSAM to LOI. Due to high speed ascent and powered flight control complexity, an automated system will be needed. It is assumed that the lift-off command covers booster ignition and hold down post separation. Flight operations include those for ascent and all EDS flight phases.

Draft **[CA5431-PO]** Ares V shall execute authenticated USAF FCO-initiated FTS command signals.

Rationale: For crewed Ares I or Ares V launch vehicles, FTS activation is limited to range safety initiation by USAF Flight Control Officers, and automated FTS by the launch vehicle via breakwires or other methods is not permitted. For uncrewed Ares I or Ares V launch vehicles, FTS ordnance may be automatically initiated. Automatic FTS initiation will be disabled/inhibited for crewed flights. Breakwire usage is permissible for vehicle health monitoring, and may result in automatic initiation of abort, but is not okay for auto-initiation of FTS events for crewed vehicles.

3.7.4.2.9 Ares V Health and Status

Draft **[CA3124-PO]** The Ares V shall generate Health and Status information.

Rationale: Provides for generation of H&S information on internal operations of the Ares V. Full definition of the specific data is provided in Ares V SRD and multiple Ares V/System IRDs.

Draft **[CA5472-PO]** Ares V shall detect conditions indicating the need to abort.

Rationale: Fault detection enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to detection are further specified by CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD). Crew abort can be initiated by LOC, LOV, or LOM conditions. For EDS, LOC is generally commensurate with LOV, but LOM is quite different. LOM conditions which lead to abort, include early engine shutdowns, TVC failures in null position, RCS failures, etc. This satisfies NPR 8705.2, Human-Rating Requirements for Space Systems, Section 3.5.1 and 3.9.15, which require detection of critical system faults and are not limited by LOC, LOV, or LOM conditions.

Draft **[CA5473-PO]** Ares V shall isolate detected faults to the level required for recovery of function.

Rationale: Fault isolation is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault isolation enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to isolation are further specified by CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle.

The level of recovery is governed by the criticality of systems (Loss of Vehicle).

Draft **[CA5474-PO]** Ares V shall provide recovery from isolated faults.

Rationale: Fault recovery is required for crew safety and mission success by enabling recovery of such critical functions. Faults subject to recovery are further specified by CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD) . FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle.

The level of recovery is governed by the criticality of systems (Loss of Vehicle).

3.7.4.2.10 Ares V Communications and Communications Security

Draft **[CA5044-PO]** The Ares V EDS shall record system-generated digital data received from other Constellation Systems.

Rationale: There are times when the quantity/rate of data recorded at certain times exceeds the capability of that system's downlink to send. Sharing data recording across Constellation systems allow for increased downlink capacity for highly dynamic events. Constellation systems must store data for each other in order to pass that data along the ultimate path it must traverse to make it back to Earth.

Draft **[CA5911-PO]** Ares V shall be able to communicate simultaneously with the LSAM, Mission Systems, and Ground Systems.

Rationale: Simultaneous communications is required so that the Ares V can communicate with both the LSAM via hardline and Ground Systems before launch. Before launch, Mission Systems will be receiving Ares V and LSAM data as well, but it will be via Ground Systems. After launch, the Ares V needs to be able to communicate with the LSAM, Mission Systems, and Ground Systems; some long term engineering telemetry will not be sent to Mission Systems during launch and ascent.

3.7.4.2.11 ARES V GN&C

Draft **[CA0128-PO]** The Ares V EDS shall perform attitude control of the LSAM/Ares V EDS mated configuration prior to Orion docking for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The Ares V EDS will be the system in control of flight after injection into the Ascent Target. This requirement is consistent with the Lunar Sortie and Lunar Outpost Cargo DRMs, specifically, the description of the Ares V EDS/LSAM Operation in LEO in CxP 70007, Constellation Design Reference Missions and Operational Concepts. Ares V EDS controls the LSAM/Ares V EDS mated configuration as the target during RPOD with Orion.

[CA0129-PO] The Ares V EDS shall perform the Trans-Lunar Injection (TLI).

Rationale: The requirement is consistent with Lunar Sortie and Lunar Outpost (crew and cargo) DRMs documented in CxP 70007, Constellation Design Reference Missions and Operational Concepts. The Ares V EDS includes a propulsion system and propellant to perform the TLI maneuver. The requirement is based on the results of NASA TM-2005-214062, Exploration Systems Architecture Study, which indicates that using Ares V EDS rather than the LSAM or the Orion for the TLI balances performance, cost and risk for the Constellation Program.

[CA0183-PO] The Ares V EDS shall perform attitude control of the LSAM/Ares V EDS/Orion mated configuration for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: Ares V EDS will execute the TLI maneuver, so it will provide GN&C functionality for the mated configuration after docking and until hand off of control function to the LSAM, prior to Ares V EDS undocking from the Orion/LSAM.

Draft **[CA3146-PO]** The Ares V shall perform navigation and attitude determination from pre-launch through EDS disposal.

Rationale: Navigation and attitude determination are required to successfully execute ascent, LEO orbit maintenance, LEO rendezvous and docking, and TLI to meet mission objectives. Navigation and attitude determination are required post TLI to successfully deliver EDS to disposal target.

Draft **[CA3186-PO]** Ares V EDS shall change the planned Trans-Lunar Injection (TLI) based on guidance target updates provided prior to TLI.

Rationale: Updated injection targets may be necessary, based on the current orbit, to set up the proper Trans-Lunar Injection of the LSAM/Orion and the LSAM. The knowledge of that target is most accurate if obtained near the injection time. Changing the TLI maneuver, based on updated guidance targets, make it possible to achieve injection within system performance capabilities. Performance margins are based on having accurate targets.

Draft **[CA3216-PO]** Ares V shall meet orbital injection accuracies defined in Table (TBD-001-566).

Rationale: Injection accuracy thresholds are needed to achieve the proper orbit required for the mission. Accuracies for Earth Rendezvous Orbit (ERO), Trans-Lunar Injections (TLI) for both lunar crew and cargo missions, and (TBD-001-072) orbit (for Mars missions) are needed. The allowable deviation from the desired target values is a function of the Ares V maneuvering capability and mission timelines. A large error at injection cutoff might be acceptable if there were sufficient delta-V budget in the Ares V.

Draft **[CA3224-PO]** Ares V shall change the planned ascent trajectory based on design parameter updates provided prior to launch.

Rationale: Performance and load margins may require the capability to update the trajectory design based on launch day environmental conditions.

Draft **[CA3225-PO]** Ares V shall change the planned ascent trajectory based on guidance target updates provided prior to launch.

Rationale: Updated injection targets may be necessary to set up the proper Trans-Lunar Injection of the cargo LSAM and the LSAM/Orion. The knowledge of that target is most accurate if obtained near launch time. Changing the ascent trajectory based on updated guidance targets make it possible to align the Earth Rendezvous Orbit for the Trans-Lunar Injection within system performance capabilities. Performance margins are based on having accurate targets.

[CA5292-PO] Ares V EDS shall perform target vehicle control in the LSAM/Ares V EDS mated configuration during RPODU operations with Orion in LEO.

Rationale: The Ares V EDS is performing guidance, navigation, and control for the LSAM/Ares V EDS mated configuration, so it is natural that it would perform the target vehicle control during RPODU with Orion in ERO. The undocking portion of this requirement protects for the case of Orion undocking from LSAM/Ares V EDS due to an abort of the nominal mission.

3.7.4.2.12 Ares V Reliability and Availability

Draft **[CA0413-PO]** Ares V shall have a probability of launch of not less than (TBD-001-971)%, exclusive of weather, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses Ares V system reliability. System reliability and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements. The value of (TBD-001-971)% in this requirement is driven by the Lunar Campaign needs.

Draft **[CA0414-PO]** Ares V shall have a probability of launch of not less than (TBD-001-972)%, due to natural environments as specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch applies to limitations caused by weather conditions. Abort landing site weather conditions are not included because these limitations are determined by Orion design. The launch vehicle should be capable of operating over a wide range of natural environment conditions (particularly upper level winds) without violating LCC (such as structural or control margins, or exposure to lightning). The percentage of acceptable launches for a given set of climatology data is sometimes referred to as launch probability. The (TBD-001-972) launch probability for Ares V with respect to weather was selected to improve launch probability as much as reasonable over heritage systems as expressed in CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO). The figure is compatible with DSNE launch environment design specifications and was reviewed and approved by the ESAS Requirements Transition Team (ERTT) panel December 20, 2005. The DSNE drives the design of the vehicle to operate within the specified environments. However, the vehicle design must account for variability of day-of-launch conditions. Without this requirement, the vehicle could be in a no-go condition due to natural environments. This requirement is intended to bound the magnitude of the risk of no-go.

Draft **[CA5259-PO]** Ares V shall have a (TBD-001-572) minute launch window per launch opportunity for Lunar Cargo missions.

Rationale: For an Apollo-style orbit insertion and Trans-Lunar Injection, the launch azimuth must change throughout the launch window in order to target the correct location for the Trans-Lunar Injection maneuver. A longer launch window increases the probability of being able to launch within a given launch opportunity. The duration of the window is also limited by range safety considerations. The duration specified increases launch probability while also not imposing an unreasonable reduction in payload capability or causing a problem with range safety.

Draft **[CA5265-PO]** Ares V shall have a (TBD-001-573) minute launch window per launch opportunity for crewed lunar missions.

Rationale: Launch at a different time changes the timing and geometry of the Trans-Lunar Injection opportunity. This may be important for operational considerations. There is no clear need for varying azimuth and yaw steering in this case. A longer launch window increases the probability of being able to launch within a given launch opportunity. The duration of the window is determined by considerations of the impact on lunar mission planning and by the limitations of the vehicle systems.

[CA5533-PO] Ares V/EDS shall be prepared to launch again 4 days prior to the next lunar injection window following a missed window.

Rationale: It is important to provide the capability to recycle the vehicles and mission elements in time to meet the next lunar injection window in the event of a scrubbed launch. The Ares V will be launched at least 1 day prior to the Orion lunar launch, when applicable. The lunar injection windows are typically four days long and occur every 30 (TBR-001-919) days.

[CA6206-PO] Ares V systems failures identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1503)% that would result in a scrubbed launch, shall be maintainable as follows:

a. No less than 30% (TBR-001-1422) can be remedied to support a launch attempt within one day.

b. No less than 45% (TBR-001-1423) can be remedied to support a launch attempt within two days.

c. No less than 50% (TBR-001-1424) can be remedied to support a launch attempt within three days.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses Ares I system maintainability. The intent is to drive a capability to correct those failures discovered (latent defects) after deciding to load cryogenic propellants that will cause a launch scrub in order to maximize the number of launch attempts that are utilized.

The duration for repair time includes the time to establish access, set up, diagnose, perform corrective maintenance, closeout, and complete any retest required in time to make the launch attempt. As this is a design-to requirement, administrative and logistics delay is not included (for example: time searching for a spare part).

The intent of extending through only 50% of failures is to prevent this requirement from driving counterproductive system complexity and increased effort or difficulty for nominal operations and sustainment scenarios. The expectation is that operability assessments should influence the developer's selection of which of the most likely failures to target.

The values used above (30%,45%, and 50%) correspond with the Space Shuttle Program history of times to repair. The intention of this requirement is to inform design with the historical data as a first iteration until the supplier data becomes available. At that time, the analysis will be updated.

3.7.4.2.13 Ares V Maintainability, Supportability, and Logistics

Draft **[CA5804-PO]** Ares V shall use refurbishable elements.

Rationale: Upon arrival back to Earth, the first stage SRB elements of the Ares V will be recovered, refurbished, and reflown utilizing the processes similar to the STS SRBs.

[CA5986-PO] The Ares V project shall produce and deliver Project Verified Engineering Build software and data products to the Constellation Program within the time limits identified in Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Engineering Build is a set of software and data products that contain new requirements (capabilities) and problem fixes. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Engineering Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. Data products contain representative launch geometry values and actual values for other parameters. It has completed Project Level Verification/Validation and has been configured to meet Integrated Build event requirements. Data definitions must be available in time to support generation of data products for the release. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation architecture. Project level activities include: participation in the build content definition, software design, code, and project-level Integration, test and delivery of the Project Verified Engineering Builds to the Program.

TABLE 3.7.4.2.13-1 TIME ALLOCATIONS FOR ENGINEERING BUILDS

Requirement	Threshold	Objective
Ares V	7 months (TBR-001-1062)	2.5 months

[CA5987-PO] The Ares V shall produce and deliver Project Verified Flight Build software and data products to support the mission class within the time limits identified in Time Allocations for Flight Builds Table after the completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Flight Build is a set of software and data products that is based on a Project Verified Engineering Build, has mission specific (launch geometry derived) data and has completed Project Level Verification/Validation. Few software changes are expected. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Flight Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Data parameter values must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without *increasing staff through efficient design of reconfiguration as supported by the Constellation Architecture. Project level activities include: participation in the build content definition, flight specific configuration activity (data reconfiguration), Fast Track activities as required, and delivery of Project Verified Flight Builds. Times are contiguous days.*

TABLE 3.7.4.2.13-2 TIME ALLOCATIONS FOR FLIGHT BUILDS

Requirement	Threshold	Objective
Ares V	14 days	4 days

[CA5988-PO] Ares V shall support day of launch updates for software parameters and data products to configure the systems.

Rationale: A day of launch update is a set of software and data products based on the Program Verified Flight Build and the approved final flight parameter updates for launch day environments (winds), orbit geometry (target tracking), and other I-loads as required.

[CA5989-PO] Ares V shall produce and deliver resolutions for selected non-conformances during the engineering and flight release phases to the discovering organization and the Constellation Program in the time limits identified in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track build process is used for rapid resolution of problems found in the production of Flight Builds and Engineering Builds. The time period starts after documentation of the non-conformance and ends when the resolution is submitted for re-integration into the test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

TABLE 3.7.4.2.13-3 - TIME ALLOCATIONS FOR FAST TRACK PROCESS

Requirement	Threshold	Objective
Ares V	48 hours	12 hours

[CA6009-PO] Ares V shall conduct ground operations for a single Ares V/LSAM mission within the time limits identified in the Ares V Critical Path Allocations for Ares V/LSAM Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by *balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and ground system designs that result in reduced ground operations time and labor without sacrifices to performance or design cost. The critical path constraints levied in Ares V Critical Path Allocations for Ares V/LSAM Ground Operations Table, along with labor-hour constraints defined in CA6009, are intended to drive the design of the flight and ground systems to enable such reductions. The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather, they are intended to be a design target for the system developers.*

In Ares V Critical Path Allocations for Ares V/LSAM Ground Operations Table, the Ares V Ground Operations processing flow is broken down into five sequential time periods between key processing milestones. The sum of the time periods is the overall Ares V Critical Path contribution anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming "single-string" for the integrated operations Ground Systems (i.e., one Ares V Mobile Launcher, one Ares V VAB high bay, one control room for Ares V operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx Ground Operations.

The values identified in Ares V Critical Path Allocations for Ares V/LSAM Ground Operations Table are intended to apply to nominal Ares V operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy ELV systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.7.4.2.13-4 ARES V CRITICAL PATH ALLOCATIONS FOR ARES-V/LSAM GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Start of Ares V Stacking to Ready for LSAM Integration	(TBD-001-1300)	(TBD-001-1301)	Integration of the Ares V on the ML from beginning with stacking of the First Stage Aft Booster Assembly	Ares V, GS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Ready for LSAM Integration to Integrated Stack Ready for Powered Testing	(TBD-001-1302)	(TBD-001-1303)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA
Ready for Powered Testing to Finish of Powered Testing	(TBD-001-1304)	(TBD-001-1305)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares V, LSAM, GS, EVA
Finish of Powered Testing to Pad Connection and Validation Complete	(TBD-001-1306)	(TBD-001-1307)	From the end of powered testing in the VAB until the vehicle is at the launch pad and ready to begin launch preps. Includes vehicle and ground system roll out preparations, roll-out, and ML-Launch pad connections and validations.	GS, Ares V, LSAM
Pad Connection and Validation Complete to Launch	(TBD-001-1308)	(TBD-001-1309)	Begins once pad connections are validated and ends at T-0.	GS, Ares V, LSAM, EVA

3.7.4.2.14 Reserved

3.7.4.2.15 Ares V Environmental Conditions

Draft **[CA5355-PO]** Ares V shall meet its requirements during and after exposure to the environments defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, 3.3, and 3.7.

Rationale: The Ares V will be exposed to a variety of natural environments that could make it unable to meet its requirements, potentially in combination with induced environments. This requirement defines the limits of these effects and assures that they will be mitigated by the design. Natural environment effects also need to be considered for the Ares V integrated vehicle configurations: Ares V/LSAM/GS, Ares V/LSAM, and Ares V/LSAM/Orion.

Draft **[CA5558-PO]** Ares V shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can degrade system performance, shorten system life, and lead to system or mission failure if not properly considered in the design.

Draft **[CA5563-PO]** Ares V shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification .

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design. Therefore, the production of induced environments must be limited and controlled to *allow proper performance and function of other sub-systems and other Systems when operating in mated configurations.*

3.7.4.3 Reserved

3.7.4.4 Ares V External Interfaces

Draft **[CA0905-PO]** Ares V shall interface with the Orion per CxP 70119, Constellation Program Orion -To- Ares V Interface Requirements Document (IRD).

Rationale: The Ares V and Orion share physical and functional interfaces which are identified in CxP 70119, Constellation Program Orion -To- Ares V Interface Requirements Document (IRD).

Draft **[CA0906-PO]** Ares V shall interface with the LSAM per CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) -To- Ares V Interface Requirements Document (IRD).

Rationale: The Ares V and LSAM share physical and functional interfaces which are identified in CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) -To- Ares V Interface Requirements Document (IRD).

Draft **[CA0907-PO]** Ares V shall interface with Ground Systems per CxP 70105, Constellation Program Ares V -To- Ground Systems Interface Requirements Document (IRD).

Rationale: The Ares V and GS share physical and functional interfaces which are identified in CxP 70105, Constellation Program Ares V -To- Ground Systems Interface Requirements Document (IRD).

Draft **[CA0908-PO]** Ares V shall interface with Mission Systems per CxP 70112, Constellation Program Ares V -To- Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: The Ares V and MS share physical and functional interfaces which are identified in CxP 70112, Constellation Program Ares V -To- Mission Systems (MS) Interface Requirements Document (IRD).

Draft **[CA0909-PO]** Ares V shall interface with the Communication and Tracking Networks per CxP 70118-04, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 4: Ares V.

Rationale: The Ares V and C&TN share physical and functional interfaces which are identified in CxP 70118-04, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document (IRD), Volume 4: Ares V.

3.7.4.5 Reserved

3.7.5 Ground Systems (GS)

3.7.5.1 GS Description

Ground Systems provides the launch site ground processing, integrated testing, logistics services, and launch services for Orion, Ares I, Ares V, LSAM, and cargo, post-landing, recovery and deintegration services for the Orion CM, and cargo including search and rescue, and supports Orion refurbishment and maintenance, if required. Ground Systems also provides post-landing and recovery services for the Ares I first stage and Ares V SRBs. Ground Systems include the facilities, equipment, and software required to perform these tasks.

3.7.5.2 GS Requirements

[CA0140-PO] Ground Systems shall provide ground processing for flight systems and cargo.

Rationale: This requirement is a broad parent requirement for ground processing services provided by the Ground Systems for flight elements and cargo (see definition of "Ground Processing" for examples).

[CA0142-PO] Ground Systems shall perform interface and integrated testing on integrated flight systems.

Rationale: Individual Cx Architecture flight systems will arrive and be processed at the launch site. These individual flight systems are mechanically/electrically mated with other flight systems to form the integrated launch vehicle stack or flight vehicle. This requirement covers the testing that will occur after the systems are mated to verify all of the mated interfaces and to validate the integrated systems' functionality and interoperability. This requirement also includes the temporary mating of systems at the launch site that will mate in space for the first time (i.e. MEIT) to form a flight vehicle (e.g. Orion and LSAM).

[CA0145-PO] Ground Systems shall recover the flight crew and recoverable flight elements at designated landing sites.

Rationale: The Ground System is responsible for recovering the crew and recoverable flight systems. Nominal recovery is performed at designated landing sites. This serves as a broad parent requirement for the systems and GSE necessary to safe the Orion Crew Module after landing, egress the flight crew, remove time-critical cargo, and transport the vehicle to a processing site for de-integration. This requirement also covers the systems and GSE needed to locate, safe, retrieve, and transport the Ares I first stage and Ares V boosters.

[CA0858-PO] Ground Systems shall provide ground-based, high-resolution, time-synchronized motion and still imagery during launch preparation, launch operations, ascent, descent, landing, egress, recovery and transport.

Rationale: During critical mission phases (launch preparation, launch operations, ascent, descent, landing, egress, recovery and transport) ground-based imagery provides a means of performing visual assessment of flight systems to assess vehicle viability. This requirement serves as a parent requirement for the ground support equipment and systems necessary to perform this visual assessment. The requirement for ground-based imagery of ascent is limited to imagery obtained at the Launch Site. If necessary, downrange imagery can be obtained by utilizing airborne and/or maritime assets managed by Ground Systems. The requirement for ground-based imagery of descent and landing is limited to nominal, pre-designated landing sites.

[CA4122-PO] Ground Systems shall recover the flight crew within 1 (TBR-001-161) hour after landing at a designated landing site.

Rationale: The Ground System is responsible for recovering the crew. Nominal recovery is performed at designated landing sites. Ground Operations personnel are pre-deployed at the designated landing site to recover the crew post-landing. The driving factor for the 1 (TBR-001-161) hour recovery time is the desire to remove the crew as soon as possible after landing.

[CA4123-PO] Ground Systems shall recover the Orion Crew Module in the event the Orion Crew Module lands at a site other than a designated landing site.

Rationale: In the event that the Orion Crew Module lands at a site, other than a designated landing site Search and Rescue (SAR) operations will be conducted. This requirement serves as the functional parent requirement for the specialized infrastructure and Ground Support Equipment necessary to recover the Orion Crew Module.

[CA5701-PO] Ground Systems shall integrate flight systems and cargo.

Rationale: Individual flight systems will arrive and be processed at the launch site. These individual flight systems are assembled, stacked, mated with other flight systems, and checked out to form the integrated launch vehicle stack. This requirement covers the physical, mechanical, and electrical stacking and mating of the these systems, as well as the installation of cargo into the pressurized flight systems/vehicles (e.g. Orion and LSAM).

3.7.5.2.1 GS Mission Success

3.7.5.2.2 GS Crew Survival

[CA0146-PO] Ground Systems shall locate and rescue the flight crew in the event Orion Crew Module lands at a site other than a designated landing site.

Rationale: The primary objective of this requirement is to provide Search and Rescue (SAR) services to locate and rescue the flight crew.

There are three primary situations which SAR services will be needed:

a. In the event of launch abort (after lift-off and prior to earth orbit insertion)

b. In the event of an early return (after Earth orbit insertion)

c. In the event of an off-nominal landing, not associated with an abort

This requirement serves as the functional parent requirement for the specialized infrastructure and ground support equipment, necessary to perform and coordinate SAR operations.

[CA0151-PO] Ground Systems shall provide safe haven for a maximum of 14 ground personnel and crew at the launch pad.

Rationale: This requirement captures the need to support ground personnel and flight crew evacuation from the launch pad to a safe area.

[CA0306-PO] Ground Systems shall perform rescue and recovery operations independent of ambient lighting conditions.

Rationale: The Ground System is responsible for recovering the crew. Nominal recovery is performed at designated landing sites and may be scheduled at any time of day. Search and Rescue services are needed to locate and retrieve the flight crew if landing occurs at a site other than a designated landing site. Since off-nominal landing may occur at any place on Earth, it may require many hours to reach the landing site which necessitates having the capability to perform both day and night operations.

[CA0336-PO] Ground Systems shall provide unassisted emergency egress for a maximum of six suited crew to a safe haven during pre-launch activities within 2 (TBR-001-134) minutes total starting from last crewmember exits Orion and ending when the last crewmember enters the safe haven.

Rationale: For contingency situations, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons. This should drive design of hatch mechanisms, launch suit, and egress paths in the pre-launch orientations to allow the crew to egress without ground crew assistance.

[CA0337-PO] Ground Systems shall provide a maximum of eight (TBR-001-962) ground crew with the capability for unassisted emergency egress to a safe haven during pre-launch pad activities within 2 (TBR-001-144) minutes.

Rationale: NPR 8705.2, Human-Rating Requirements for Space Systems, requirement 34469, and CA0311-PO establish this requirement. For contingency situations, ground crew will need the capability to egress the launch pad, including vehicles for safety reasons. This will drive design of egress paths to allow ground crew to reach safe haven.

[CA5146-PO] Ground System shall rescue the crew within 24 hrs with a 95% (TBR-001-047) probability of success following a landing at a site other than a designated landing site.

Rationale: Ground Systems will coordinate search and recovery efforts to locate and rescue the crew and flight vehicle. The 95% (TBR-001-047) probability of recovery allows for possibility of a skip entry landing that brings the vehicle and crew down in very remote areas of the Earth (water or land) where recovery would not be possible within 24 hrs. The 95% (TBR-001-047) will be determined by trade study. The target recovery time of 24 hours is designed to allow for search and rescue and recovery organizations to plan for the recovery of the crew and vehicle from remote locations. A 50% margin was applied to the 24 hr recovery period (24 hrs+50% (12 hrs) =36 hrs) to ensure crew survivability in the event of delays in real-time recovery operations. The Orion Crew Module provides for 36 hours of post-landing life support to the crew (CA0194-PO).

[CA5408-PO] The Ground Systems shall control hazards that can lead to catastrophic events with no less than single failure tolerance, except for areas approved to use Design for Minimum Risk. The level of failure tolerance must be determined using the hazard identification and mitigation process described in CxP 70038. The failure tolerance requirement cannot be satisfied by use of emergency operations or emergency systems.

Rationale: The Program has established a minimum of single failure tolerance or DFMR to control catastrophic hazards. NASA-STD-5005, Ground Support Equipment, is the program standard for Ground Support Equipment and meets the program standard for failure tolerance. This does not preclude more than the minimum level of failure tolerance.

[CA5438-PO] Ground Systems shall determine the need for a pad abort.

Rationale: The Ground Systems need to evaluate the Health and Status information obtained from flight and ground systems in order to make a determination to Abort. This requirement, in conjunction with the requirement for Ground Systems to send commands to the flight systems, provides the capability for GS to initiate a pad abort.

3.7.5.2.3 Reserved

3.7.5.2.4 Reserved

3.7.5.2.5 GS Mission Rates and Durations

[CA4121-PO] Ground Systems shall provide for the launch of the Ares I no later than 90 minutes after the launch of the Ares V.

Rationale: Lunar missions involve the simultaneous operations of two flight vehicles. With a 90 minute interval, the Ground System must be able to support pre-launch and launch operations immediately following the launch of the Ares V.

[CA5690-PO] Ground Systems shall provide a daily launch opportunity for no less than seven consecutive days for Ares I missions.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. Seven days is based on an Ares V-launch-first mission design approach and protects for a lunar mission where the Ares V launches on the fourth day of its consecutive launch opportunities. Ground Systems should be designed so that servicing can be completed for the next day's launch attempt or designed to last at least seven days without servicing.

[CA5702-PO] Ground Systems shall provide a daily launch opportunity for no less than 4 consecutive days for Ares V missions.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. Four days is based on an Ares V-launch-first mission design approach. Ground Systems should be designed so that servicing can be completed for the next day's launch attempt or be designed to last at least 4 days without servicing.

[CA6099-PO] Ground Systems shall process and launch four Ares I Integrated Stacks in a year.

Rationale: Ground Systems must be designed to support a minimum mission frequency which is based on the manifest in order to fulfill the basic requirements of the Ground Systems Program. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Ground Systems' systems. Ground Systems should be designed to support 2 missions per year during the ISS phase of the program. Ground Systems should be designed to support 2 ISS and 2 Crewed Lunar Missions per year during the overlapping ISS and Lunar phase of the program.

[CA6099-PO-Objective] Ground Systems shall process and launch six Ares I Integrated Stacks in a year.

Rationale: Ground Systems must be designed to support a mission frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Ground Systems systems. Ground systems should be designed to support 6 ISS missions in a year during the ISS phase of the program. Ground Systems should be designed to support 3 ISS and 3 Crewed Lunar Missions per year during the overlapping ISS and Lunar phase of the program.

[CA6253-PO] Ground Systems shall process and launch four Ares V/LSAM Integrated Stacks in a year.

Rationale: Ground Systems must be designed to support a minimum mission frequency based on the manifest in order to fulfill the basic requirements of the

Constellation Program. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Ground Systems' systems.

[CA6253-PO-Objective] Ground Systems shall process and launch six Ares V/LSAM Integrated Stacks per year.

Rationale: Ground Systems must be designed to support a mission frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Ground Systems systems.

[CA6255-PO] Ground Systems shall conduct back to back launches within 45 calendar days, measured from the launch of the first vehicle to the launch of the second vehicle.

Rationale: Ground Systems must be designed to support a minimum mission interval in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission intervals drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, the minimum interval drives turnaround and maintenance activities for the Constellation systems. This interval is expressed in calendar days.

[CA6255-PO-Objective] Ground Systems shall conduct one back to back set of launches per year within 30 days measured from the launch of the first vehicle to the launch of the second vehicle.

Rationale: Ground Systems must be designed to support a minimum mission interval in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission intervals drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, the minimum interval drives turnaround and maintenance activities for the Orion systems. This interval is expressed in calendar days.

3.7.5.2.6 GS Architecture Definition

[CA0148-PO] Ground Systems shall provide disposal of Earth-based ground and flight assets at the end of their useful life.

Rationale: This requirement specifies the responsibility to Ground Systems for disposition of Constellation flight systems at the end of their useful mission life including transportation, as required. Proper disposition may include abandon in place, excess to other programs or agencies, demolition of equipment and facilities, disposal, or retain for historical value.

[CA0444-PO] Ground Systems shall provide Earth weather services for pre-launch, launch, SRB recovery, Orion CM pad abort recovery, and post landing recovery activities.

Rationale: Earth weather services includes procuring, installing, operating, maintaining, and sustaining the weather infrastructure needed to support landing and recovery operations; and communicating the data to MS and GS weather forecasters and decision makers. Both MS and GS require weather data and forecasts at the landing site(s) for pre-landing, landing, and post-landing / recovery support. Where there is a gap between Constellation Architecture needs and available earth weather capabilities, Ground Systems will generate the necessary data for pre-launch, launch, and post landing recovery activities as well as data measurements needed to support descent, landing and recovery forecasts generated by MS. This includes acquisition (via Ground Systems Earth-based assets) of weather data and communicating the data to both MS and GS operations centers. MS and GS will process both the data they receive from the landing and recovery site, and weather data they acquire from non-Ground Systems external sources. MS and GS will process the data in accordance with their specific operational requirements and for use by the remainder of the Constellation Architecture.

[CA0853-PO] Ground Systems shall receive the flight systems and cargo.

Rationale: The flight systems shall arrive at the launch site via various transportation means such as air, rail or truck. The Ground Systems element has the responsibility of offloading these flight elements and transporting them to a processing facility.

[CA0856-PO] Ground Systems shall de-integrate recoverable flight systems.

Rationale: Upon completion of recovery, recovered flight systems may require operations to remove or disassemble equipment to prepare the flight system for transport to a refurbishment facility or for disposal. This serves as a broad parent requirement for the systems and GSE necessary to remove non-time critical cargo and flight crew equipment from the Orion Crew Module. This requirement also covers the systems and GSE needed to disassemble the Ares I first stage and Ares V boosters in preparation for transport to a refurbishment facility.

3.7.5.2.7 GS Safety (System, Public, and Planetary)

[CA5406-PO] The Ground Systems shall control critical hazards. The hazards must be identified and controlled using the hazard identification and mitigation process described in CxP 70038, Constellation Program Hazard Analyses Methodology. The hazards must be controlled without the use of emergency operations or emergency systems.

Rationale: Control of mission critical failures is dictated by programmatic decision to ensure mission success. NASA-STD-5005,Ground Support Equipment, is the program design standard for Ground Support Equipment and meets the program standard for controlling critical hazards. The Constellation Program will define *hazard controls that may include failure tolerance. The Constellation Program will derive the specific hazard controls and implementation from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.*

3.7.5.2.8 GS Command and Control

[CA3274-PO] Ground Systems shall generate commands.

Rationale: To perform command and control, the ground and automated sequences will need to be able to initiate the sending of commands. These commands could be transmitted to another Constellation system to be received and executed.

3.7.5.2.9 GS Health and Status

[CA3130-PO] Ground Systems shall generate Health and Status information.

Rationale: Provides for generation of H&S information on internal operations of Ground Systems. Full definition of the specific data is provided in Ground Systems SRD and multiple Ground Systems/System IRDs.

[CA5478-PO] Ground Systems shall detect system faults which could result in Loss of Vehicle, Loss of Life and Loss of Mission.

Rationale: Fault detection is required for crew and ground personnel safety and mission success by enabling recovery of such critical functions. Ground Systems will provide fault detection not only for itself, but also for flight systems prior to launch. Faults subject to detection are further specified by CxP 72006, Ground Systems, Systems Requirements Document (SRD) . FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, Loss of Life, and Loss of Mission.

[CA5479-PO] Ground Systems shall isolate detected faults to the level required for recovery of function.

Rationale: Fault isolation is required for crew and ground personnel safety and mission success by enabling recovery of such critical functions. In addition, fault isolation enables crew abort or flight termination (in case of non-recoverable failures). Ground Systems will provide fault isolation not only for itself, but also for flight systems prior to launch. Faults subject to isolation are further specified by CxP 72006, Ground Systems, Systems Requirements Document (SRD) . FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, Loss of Life, and Loss of Mission. The level of recovery is governed by the criticality of systems (Loss of Vehicle, Loss of Life, Loss of Mission).

[CA5480-PO] Ground Systems shall provide recovery from isolated faults.

Rationale: Fault recovery is required for crew safety and mission success by enabling recovery of such critical functions. Ground Systems will provide fault *recovery not only for itself, but also for flight systems prior to launch. Faults subject to recovery are further specified by CxP 72006, Ground Systems, Systems Requirements Document (SRD) . FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, Loss of Life, and Loss of Mission. The level of recovery is governed by the criticality of systems (Loss of Vehicle, Loss of Life, Loss of Mission).*

3.7.5.2.10 GS Communications and Communications Security

[CA5051-PO] *Ground Systems shall record system-generated digital data received from other Constellation Systems.*

Rationale: In order to evaluate historical performance, effectively utilize and benefit from past and current experiences and develop lessons learned, data associated with those experiences must be recorded per CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O40]. Ground Systems must record the data received from other elements in order for ground personnel to trouble-shoot onboard failures, investigate long-term trends and evaluate performance. Recording and archiving are separate functions, and not all recorded data will be archived and kept for the duration of multiple flights. The archival function is assumed to be addressed at the Constellation level in the Data Management Plan.

[CA5907-PO] The Ground Systems shall execute reconfigurable automation sequences valid in the current state.

Rationale: The system will execute reconfigurable automation sequences based on triggers that may be generated internally or from other systems (by means of commands) in order to perform the specified function or operation. This process includes checking if the sequence has valid data values and can be executed now based on the current state or mode. Results of the execution are provided through updates to the sequencing Health and Status parameters.

[CA5908-PO] Ground Systems shall communicate simultaneously with Mission Systems and four other Constellation flight systems during ISS phase operations.

Rationale: During the ISS mission phase, GS communicates with 4 flight systems in addition to MS during launch; CLV, CEV, and two test articles.

[CA6064-PO] Ground Systems shall communicate simultaneously with Mission Systems and six other Constellation flight systems during lunar phase operations.

Rationale: Initial CONOPs assessment for lunar mission phase launch scenarios include GS communications with MS and six additional flight systems, including the CaLV, LSAM, CLV, CEV, and two test articles.

[CA6211-PO] The GS shall process received range safety telemetry and transfer it to the Range within 120 msec (TBR-001-1450) during the launch/ascent phase.

Rationale: Identifies the maximum sub-allocation of end-to-end latency to GS during the launch/ascent phase for range safety telemetry. GS provides connectivity for data from MS between CTN/NISN and the Range. Range safety telemetry latencies are critical to ensuring safe flight and to ensuring compliance with US Eastern Range operational constraints.

3.7.5.2.11 Reserved

3.7.5.2.12 GS Reliability and Availability

[CA3064-PO] Ground Systems shall have a probability of crewed launch of no less than 99 (TBR-001-1412)%, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses system reliability. The value of 99% in this requirement is an allocation from the parent requirement (CA-0123-PO) which, in turn, addresses the "Probability of No Second Launch" which would expire the orbiting EDS/LSAM. The TBR will be closed during the IDAC4 cycle after the (CA-0123-PO) parent requirement TBRs are removed.

[CA6101-PO] The GS shall provide 6 hours (TBR-001-1302) crew support consumables per launch opportunity for (TBD-001-1402) launch opportunities.

Rationale: This requirement defines the amount of consumables that is required to be supplied by Ground Systems to support the crew for each launch attempt not covered by Orion onboard consumables.

[CA6204-PO] Ground System failures, with a likelihood of occurrence greater than (TBD-001-1501)% that would result in a scrubbed crewed launch, shall be maintainable as follows:

a. No less than 60% (TBR-001-1416) can be remedied to support a launch attempt within one day.

b. No less than 70% (TBR-001-1417) can be remedied to support a launch attempt within two days.

c. No less than 80% (TBR-001-1418) can be remedied to support a launch attempt within three days.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses system maintainability. The intent is to ensure those failures with a high likelihood of causing a scrubbed launch can be repaired in order to maximize the number of launch attempts that are utilized. The duration for repair time includes the time to establish access, set up, diagnose, perform corrective maintenance, closeout, and complete any revalidation required in time to *make the launch attempt. As this is a design-to requirement, administrative and logistics delay is not included (for example: time searching for a spare part). The values used above (60%,70%,and 80%) correspond with the Space Shuttle Program Ground Systems history of times to repair. The intention of this requirement is to inform design with the historical data as a first iteration until the supplier data becomes available. At that time, the analysis will be updated.*

[CA6208-PO] Ground Systems shall have a probability of cargo launch of not less than (TBD-001-1505)%, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses system reliability. The value of (TBD-001-1505)% in this requirement is driven by the Lunar Campaign needs.

[CA6209-PO] Ground System failures, identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1506)% that would result in a scrubbed cargo launch, shall be maintainable as follows:

a. No less than 60% (TBR-001-1428) can be remedied to support a launch attempt within one day.

b. No less than 70% (TBR-001-1429) can be remedied to support a launch attempt within two days.

c. No less than 80% (TBR-001-1430) can be remedied to support a launch attempt within three days.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses Ares I system maintainability. The intent is to drive a capability to correct those failures discovered (latent defects) after deciding to load cryogenic propellants that will cause a launch scrub in order to maximize the number of launch attempts that are utilized.

The duration for repair time includes the time to establish access, set up, diagnose, perform corrective maintenance, closeout, and complete any retest required in time to make the launch attempt. As this is a design-to requirement, administrative and logistics delay is not included (for example: time searching for a spare part).

The intent of extending through only 80% of failures is to prevent this requirement from driving counterproductive system complexity and increased effort or difficulty for nominal operations and sustainment scenarios. The expectation is that operability assessments should influence the developer's selection of which of the most likely failures to target.

The values used above (60%,70%, and 80%) correspond with the Space Shuttle Program Ground Systems history of times to repair. The intention of this requirement is to inform design with the historical data as a first iteration until the supplier data becomes available. At that time, the analysis will be updated.

3.7.5.2.13 GS Maintainability, Supportability, and Logistics

[CA5712-PO] Ground Systems shall refurbish the reusable elements of the Ares V.

Rationale: Upon arrival back to Earth, the first stage SRB elements of the Ares V will be recovered, refurbished, and reflown utilizing processes similar to the STS SRBs.

[CA5803-PO] Ground Systems shall refurbish the reusable elements of the Ares I.

Rationale: Upon arrival back to Earth, the first stage SRB element of the Ares I will be recovered, refurbished, and reflown utilizing processes similar to the STS SRBs.

[CA5934-PO] Ground Systems shall provide infrastructure to maintain systems through their operational life cycles.

Rationale: Logistics infrastructure enables the sustainment of safe and efficient operations. Examples of critical infrastructure elements include Inventory Management Systems for tracking program assets on the ground; capabilities to manage and present information necessary to support maintenance operations on ground; and tools and test equipment for maintenance on the ground.

[CA5990-PO] The GS project shall produce and deliver Project Verified Engineering Build software and data products which have been identified as external dependencies to the Constellation Program within the time limits identified in Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Engineering Build is a set of software and data products that contain new requirements (capabilities) and problem fixes. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Engineering Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. Data products contain representative launch geometry values and actual values for other parameters. It has completed Project Level Verification/Validation and has been configured to meet Integrated Build event requirements. Data definitions must be available in time to support generation of data products for the release. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation architecture. Project level activities include: participation in the build content definition, software design, code, and project-level Integration, test and delivery of the Project Verified Engineering Builds to the Program.

TABLE 3.7.5.2.13-1 TIME ALLOCATIONS FOR ENGINEERING BUILDS

Requirement	Threshold	Objective
GS	7 months (TBR-001-1070)	2.5 months

[CA5991-PO] The GS shall produce and deliver Project Verified Flight Build software and data products to support the mission class within the time limits identified in Time Allocations for Flight Builds Table after the completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Flight Build is a set of software and data products that is based on a Project Verified Engineering Build, has mission specific (launch geometry derived) data and has completed Project Level Verification/Validation. Few software changes are expected. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Flight Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Data parameter values must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation Architecture. Project level activities include: participation in the build content definition, flight specific configuration activity (data reconfiguration), Fast Track activities as required, and delivery of Project Verified Flight Builds. Times are contiguous days.

TABLE 3.7.5.2.13-2 - TIME ALLOCATIONS FOR FLIGHT BUILDS

Requirement	Threshold	Objective
GS	14 days	4 days

[CA5992-PO] The GS project shall support day of launch updates for software parameters and data products to configure the systems.

Rationale: A day of launch update is a set of software and data products based on the Program Verified Flight Build and the approved final flight parameter updates for launch day environments (winds), orbit geometry (target tracking), and other I-loads as required.

[CA5993-PO] The GS shall produce and deliver resolutions for selected non-conformances during the engineering and flight release phases to the discovering organization and the Constellation Program in the time limits identified in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track build process is used for rapid resolution of problems found in the production of Flight Builds and Engineering Builds. The time period starts after documentation of the non-conformance and ends when the resolution is submitted for re-integration into the test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

TABLE 3.7.5.2.13-3 TIME ALLOCATIONS FOR FAST TRACK PROCESS

Requirement	Threshold	Objective
GS	48 hours	12 hours

[CA6005-PO] The GS shall conduct ground operations for a single Ares I/Orion mission within the time limits identified in the GS Critical Path Allocations for Ares I/Orion Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and ground system designs that result in reduced ground operations time and labor without sacrifices to performance or design cost. The critical path constraints levied in GS Critical Path Allocations for Ares I/Orion Ground Operations Table, along with labor-hour constraints defined in CA6005, are intended to drive the design of the ground systems to enable such reductions. The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather, they are intended to be a design target for the system developers.

In GS Critical Path Allocations for Ares I/Orion Ground Operations Table, the GS Ground Operations processing flow is broken down into six sequential time periods between key processing milestones. The sum of the six time periods is the overall Critical Path anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming “single-string” for the integrated operations Ground Systems (i.e. one Ares I Mobile Launcher, one Ares I VAB high bay, one control room for Ares I operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx Ground Operations.

The values identified in GS Critical Path Allocations for Ares I/Orion Ground Operations Table are intended to apply to nominal GS operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy ELV systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.7.5.2.13-4 GS CRITICAL PATH ALLOCATIONS FOR ARES-1/ORION GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Start of Ares I Stacking to Ready for Orion Integration	274 (TBR-001-1200)	228 (TBR-001-1201)	Integration of the Ares I on the ML from beginning with stacking of the First Stage Aft Booster Assembly	Ares I, GS
Ready for Orion Integration to Integrated Stack Ready for Powered Testing	53 (TBR-001-1202)	44 (TBR-001-1203)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA
Ready for Powered Testing to Finish of Powered Testing	67 (TBR-001-1204)	56 (TBR-001-1205)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares I, Orion, GS, EVA
Finish of Powered Testing to Pad Connection and Validation Complete	46 (TBR-001-1206)	38 (TBR-001-1207)	From the end of powered testing in the VAB until the vehicle is at the launch pad and ready to begin launch preps. Includes vehicle and ground system roll out preparations, roll-out, and ML-Launch pad connections and validations.	GS, Ares I, Orion
Pad Connection and Validation Complete to Launch	82 (TBR-001-1208)	68 (TBR-001-1209)	Begins once pad connections are validated and ends at T-0.	GS, Ares I, Orion, EVA
Launch to Start of Ares I Stacking	172 (TBR-001-1210)	144 (TBR-001-1211)	Refurbishment activities conducted on the ML and/or at Launch Pad. Includes those activities that must be performed on the ML prior to mating the aft booster assembly to the ML for the next flight.	GS

[CA6010-PO] The GS shall conduct ground operations for a single Ares V/LSAM mission within the time limits identified in the GS Critical Path Allocations for Ares V/LSAM Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and ground system designs that result in reduced ground operations time and labor without sacrifices to performance or design cost. The critical path constraints levied in GS Critical Path Allocations for Ares V/LSAM Ground Operations Table, along with labor-hour constraints defined in CA6010, are intended to drive the design of the ground systems to enable such reductions. The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather, they are intended to be a design target for the system developers.

In GS Critical Path Allocations for Ares V/LSAM Ground Operations Table, the GS Ground Operations processing flow is broken down into six sequential time periods between key processing milestones. The sum of the six time periods is the overall Critical Path anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming "single-string" for the integrated operations Ground Systems (i.e. one Ares V Mobile Launcher, one Ares V VAB high bay, one control room for Ares V operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx Ground Operations.

The values identified in GS Critical Path Allocations for Ares V/LSAM Ground Operations Table are intended to apply to nominal GS operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy ELV systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.7.5.2.13-5 GS CRITICAL PATH ALLOCATIONS FOR ARES-V/LSAM GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Start of Ares V Stacking to Ready for LSAM Integration	(TBD-001-1300)	(TBD-001-1301)	Integration of the Ares V on the ML from beginning with stacking of the First Stage Aft Booster Assembly	Ares V, GS
Ready for LSAM Integration to Integrated Stack Ready for Powered Testing	(TBD-001-1302)	(TBD-001-1303)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA
Ready for Powered Testing to Finish of Powered Testing	(TBD-001-1304)	(TBD-001-1305)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares V, LSAM, GS, EVA
Finish of Powered Testing to Pad Connection and Validation Complete	(TBD-001-1306)	(TBD-001-1307)	From the end of powered testing in the VAB until the vehicle is at the launch pad and ready to begin launch preps. Includes vehicle and ground system roll out preparations, roll-out, and ML-Launch pad connections and validations.	GS, Ares V, LSAM
Pad Connection and Validation Complete to Launch	(TBD-001-1308)	(TBD-001-1309)	Begins once pad connections are validated and ends at T-0.	GS, Ares V, LSAM, EVA
Launch to Start of Ares V Stacking	(TBD-001-1310)	(TBD-001-1311)	Refurbishment activities conducted on the ML and/or at Launch Pad. Includes those activities that must be performed on the ML prior to mating the aft booster assembly to the ML for the next flight.	GS

3.7.5.2.14 Reserved

3.7.5.2.15 GS Environmental Conditions

[CA3018-PO] Ground systems shall provide protection from direct attachment of lightning channels, as described in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Paragraph 3.1.11, to the flight vehicle while on the ground.

Rationale: There is no known technology to prevent lightning strikes from occurring; however, the effects of lightning can be mitigated with appropriate design techniques. However, the lightning protection design of individual elements may be compromised during Ground Operations, thus needing protection. Lightning protection of Ground Systems facilities are governed by National Fire Protection Agency documents and other documentation covering facilities protection.

[CA5112-PO] Ground Systems shall launch the Flight Systems independent of ambient lighting conditions.

Rationale: Use of night time launch windows greatly increases the opportunities for launch to a successful rendezvous orbit. Launch windows to rendezvous with an *object already in space frequently fall in darkness. For example, about 40% of the launch opportunities to the International Space Station occur in darkness when assessed over a one year period. Since Orion launches will involve rendezvous with flight systems previously inserted into orbit, overall mission planning may be severely constrained if night launches are not allowed.*

[CA5360-PO] Ground Systems shall meet its requirements during and after exposure to the environments defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, and 3.7

Rationale: Ground Systems will be exposed to a variety of natural environments that could make it unable to meet its requirements, potentially in combination with induced environments. This requirement defines the limits of these effects and assures that they will be mitigated by the design.

[CA5931-PO] The GS shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification .

Rationale: Induced environments can degrade system performance, shorten system life, and lead to system or mission failure if not properly considered in the design.

[CA5932-PO] The GS shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification .

Rationale: Induced environments can degrade system performance, shorten system life, and lead to system or mission failure if not properly considered in the design. Therefore, the production of induced environments must be limited and controlled to allow proper performance and function of other sub-systems and other Systems when operating in mated configurations.

[CA6071-PO] Ground systems shall monitor and record lightning direct and indirect effects that could result in catastrophic or hazardous failures to flight systems due to direct lightning environments as described in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Paragraph 3.1.11.

Rationale: Lightning direct and indirect effects can be harmful to the vehicle. Monitoring of these effects is necessary in order to determine if the vehicle was affected during a lightning event.

3.7.5.3 Reserved

3.7.5.4 GS External Interfaces

[CA0910-PO] Ground Systems shall interface with Orion per CxP 70028, Constellation Program Orion -To- Ground Systems (GS) Interface Requirements Document (IRD).

Rationale: Ground Systems and Orion share physical and functional interfaces which are identified in CxP 70028, Constellation Program Orion -To- Ground Systems (GS) Interface Requirements Document (IRD).

[CA0911-PO] Ground Systems shall interface with the Ares I per CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD).

Rationale: Ground Systems and Ares I share physical and functional interfaces which are identified in CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD).

[CA0912-PO] Ground Systems shall interface with the LSAM per CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -to- Ground Systems Interface Requirements Document (IRD) .

Rationale: Ground Systems and LSAM share physical and functional interfaces which are identified in CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -to- Ground Systems Interface Requirements Document (IRD) .

Draft [CA0913-PO] Ground Systems shall interface with Ares V per CxP 70105, Constellation Program Ares V -To- Ground Systems Interface Requirements Document (IRD).

Rationale: Ground Systems and Ares V share physical and functional interfaces which are identified in CxP 70105, Constellation Program Ares V -To- Ground Systems Interface Requirements Document (IRD).

[CA0914-PO] Ground Systems shall interface with Mission Systems per CxP 70054, Constellation Program Mission Systems (MS) -to- Ground Systems (GS) Interface Requirements Document (IRD).

Rationale: Ground Systems and Mission Systems share physical and functional interfaces which are identified in CxP 70054, Constellation Program Mission Systems (MS) -to- Ground Systems (GS) Interface Requirements Document (IRD).

[CA0915-PO] Ground Systems shall interface with EVA systems per CxP 70104, Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD).

Rationale: Ground Systems and EVA systems share physical and functional interfaces which are identified in CxP 70104, Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD).

[CA0916-PO] Ground Systems shall interface with the Communication and Tracking Networks per CxP 70118-05, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 5: Ground Systems (GS).

Rationale: The Ground Systems and C&TN share physical and functional interfaces which are identified in CxP 70118-05, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 5: Ground Systems (GS).

3.7.5.5 Reserved

3.7.6 Mission Systems (MS)

3.7.6.1 MS Description

Mission Systems includes the Mission Control Center-Houston (MCC-H) and its interfaces with the flight systems for flight operations, crew and flight controller training facilities, mission planning and flight design tools, and personnel for planning, training, flight ops, and Mission Operations facilities development and maintenance.

3.7.6.2 MS Requirements

[CA0139-PO] Mission Systems shall provide the training system and train the crew, mission controllers, mission planners, and instructors involved in the flight operation of Constellation missions.

Rationale: Training for crew and ground support personnel on flight operations for all vehicles, alone and in concert, must be accomplished in order to successfully execute Constellation missions. This requirement specifies the need for a system that provides Constellation-related training and includes flight crew, mission controllers, mission planners, and instructors.

[CA0152-PO] Mission Systems shall provide Earth-based flight operations for Constellation flight systems.

Rationale: The ability to monitor vehicle and crew activities and mission status promotes safe and effective mission execution; this includes a central Earth-based authority for all flight operations of the flight systems. This does not preclude delegation of that authority to other Constellation elements for particular mission objectives (e.g. science commanding from distributed control centers).

[CA0293-PO] Mission Systems shall provide integrated mission planning and analysis and execution product development for all Constellation Architecture mission phases.

Rationale: This capability is required for integrated pre-mission, mission execution and post-mission analysis, and scheduling for all Constellation Architecture mission phases. This planning information will support analysis and work execution, providing integrated scheduling, resource allocation and tracking. This requirement also includes flight element software and data products (e.g. short term plan, procedure viewers, etc.), as well as ground processing products (e.g. flow scheduling and planning).

[CA5669-PO] Mission Systems shall generate contingency Earth return analysis, plans and procedures.

Rationale: Contingency plans must be available to be sent to the vehicle while it has vehicle-to-Earth communications capabilities to enable the crew to return to Earth without vehicle-to-Earth communications capability. Prior knowledge of the possible contingency scenarios, and the conditions for which specific abort options are available, is required for mission planning, trajectory flight design, training, crew safety, and mission success.

3.7.6.2.1 MS Mission Success

Draft [CA3027-PO] Mission Systems shall limit their contribution to the risk of Loss of Mission (LOM) for a Lunar Outpost Cargo mission to no greater than 1 in (TBD-001-527).

Rationale: The 1 in (TBD-001-527) means a (TBD-001-527) (or (TBD-001-527)%) probability of LOM due to Mission Systems during any Lunar Outpost Cargo mission. This requirement is driven by CxP 70003-ANX01, Constellation Need, Goals and Objectives, Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

Draft [CA3030-PO] Mission Systems shall limit their contribution to the risk of Loss of Mission (LOM) for a Lunar Outpost Crew mission to no greater than 1 in (TBD-001-536).

Rationale: The 1 in (TBD-001-536) means a (TBD-001-536) (or (TBD-001-536)%) probability of LOM due to Mission Systems during any Lunar Outpost Crew mission. This requirement is driven by CxP 70003-ANX01, Constellation Need, Goals and Objectives, Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.7.6.2.2 MS Crew Survival

[CA0163-PO] Mission Systems shall provide updates to the predicted landing footprint to recovery forces within 20 minutes after the declaration of an entry contingency.

Rationale: Nominally the crew will land at the anticipated landing site. To support certain contingency situations (including loss of communications), Mission Systems may need to direct recovery forces to the best estimated location of where the crew *and capsule have landed. This covers both nominal and abort landing timeframes. Recovery forces will be dispatched to this location and begin efforts to acquire the search and rescue signals.*

Draft **[CA3035-PO]** Mission Systems shall limit their contribution to the risk of Loss of Crew (LOC) for a Lunar Outpost Crewed mission to no greater than 1 in (TBD-001-552).

Rationale: The 1 in (TBD-001-552) means a (TBD-001-552) (or (TBD-001-552)%) probability of LOC due to Mission Systems during any Lunar Outpost Crewed mission. This requirement is driven by CxP 70003-ANX01, Constellation Need, Goals and Objectives, Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA5437-PO] Mission Systems shall determine the need for an abort.

Rationale: The MS needs to evaluate the Health and Status information obtained from flight systems in order to make a determination to Abort.

3.7.6.2.3 MS Crew Size

[CA5128-PO] Mission Systems shall provide training of four member crews (each for prime and backup) per lunar mission.

Rationale: The training facility is affected by the size of the crew to be trained in order to scope the size and configuration of the training systems.

[CA5129-PO] Mission Systems shall provide training of six member crews (each for prime and backup) per ISS mission.

Rationale: The training facility is affected by the size of the crew to be trained in order to scope the size and configuration of the training systems.

3.7.6.2.4 Reserved

3.7.6.2.5 MS Mission Rates and Duration

[CA6157-PO] The Mission Systems shall support ISS and Lunar flights of up to 2 ISS and 2 Lunar flights in a year.

Rationale: The Mission Systems must be designed to support a minimum mission frequency which is based on the manifest in order to fulfill the basic requirements of the Constellation Program. This requirement applies to the phase of the Constellation Program when ISS and Lunar missions are overlapping. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of Mission and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Mission Systems' systems. Concurrent ops scenarios are limited to the ISS Crew rotation/Crewed Lunar missions and Crewed Lunar/Uncrewed Lunar missions. A lunar consists of one crewed flight (requiring one Orion/Ares I and one Ares V) plus one uncrewed cargo flight (one Ares V) for a total of one Ares I and two Ares Vs per lunar mission.

[CA6157-PO-Objective] The Mission Systems shall support up to four additional ISS or one additional Lunar flights for a maximum of six flights per year.

Rationale: The Mission Systems must be designed to support a mission frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and Mission personnel proficiency. This requirement applies to the phase of the Constellation Program when ISS and Lunar missions are overlapping. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of Mission and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the Mission Systems' systems. Concurrent ops scenarios are limited to the ISS Crew rotation/Crewed Lunar missions and Crewed Lunar/Uncrewed Lunar missions.

[CA6160-PO] The Mission Systems shall support back to back flights within 45 calendar days, measured from the launch of the first flight to the launch of the second flight.

Rationale: The Mission Systems must be designed to support a minimum mission interval in order to provide a sustainable human exploration program and to maintain acceptable flight crew and Mission personnel proficiency. Mission intervals drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of Mission and mission support systems. In addition, the minimum interval drives turnaround and maintenance activities for the Constellation systems. Intervals are measured from launch to launch of each system.

3.7.6.2.6 MS Architecture Definition

[CA0883-PO] Mission Systems shall provide Earth weather services for post-launch and landing activities.

Rationale: Where there is a gap between Constellation Architecture needs and available Earth weather capabilities, MS shall generate the necessary data for post-launch and landing activities including abort sites. This includes acquisition (via MS Earth-based assets) of weather data, the acquisition of weather data from non-MS external sources, and the necessary processing of that data for use by the Constellation Architecture. MS is responsible for Day of Launch I-Load Update (DOLILU) data calculations and for all weather data generation (e.g. for abort sites, normal landing, etc.) after tower clear.

[CA5125-PO] Mission System shall provide space weather services.

Rationale: Advisories of Solar Particle Events (SPE) are required for crew safety. With sufficient warning, crews can execute procedures to protect themselves from hazardous levels of radiation.

3.7.6.2.7 MS Safety

[CA5405-PO] Mission Systems shall control critical hazards. The hazard must be controlled without the use of EVA, emergency operations or emergency systems.

Rationale: Control of mission critical failures is dictated by programmatic decision to ensure mission success. The Mission Systems will define hazard controls that may include failure tolerance. The Mission Systems will derive the specific hazard controls and implementation from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

[CA5407-PO] Mission Systems shall be a minimum of one failure tolerant for controlling catastrophic hazards, except for areas approved to use Design for Minimum Risk criteria. The level of failure tolerance must be determined using the hazard identification and mitigation process described in CxP 70038. The failure tolerance requirement cannot be satisfied by use of EVA, emergency operations or emergency systems.

Rationale: Constellation has established a minimum of single failure tolerance or DFMR to control catastrophic hazards. However, single failure tolerance may not be adequate in all instances to control catastrophic hazards. Thus, the level of failure tolerance needed is commensurate with the severity of the hazard, and likelihood of occurrence. The Mission Systems will derive the specific level of failure tolerance and implementation (similar or dissimilar redundancy, backup systems) from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

3.7.6.2.8 MS Command and Control

[CA3273-PO] Mission Systems shall generate commands.

Rationale: To perform command and control, the ground and automated sequences will need to be able to initiate the sending of commands. These commands will be either executed internally or transmitted to another Constellation system to be received and executed.

[CA3285-PO] Mission Systems shall concurrently monitor and control in-space vehicles during ISS crew rotation missions as shown in the CxP ISS Concurrent Operations - ISS Crew Rotation Missions Table.

Rationale: Multiple Orion and LSAM vehicles will be operated in space concurrently for ISS and Lunar missions. Active vehicles may include a stack of vehicles (e.g., ISS and docked quiescent mode, Ares V/EDS/Crew LSAM/Orion, Cargo LSAM/Outpost components). Mission Systems infrastructure and resources must allow for ground control to monitor and control multiple vehicles (e.g., multiple active and quiescent vehicles). The need to operate multiple vehicles in space concurrently is based on manifest, flight rate and intervals, overlapping mission classes, and mission durations. It is further assumed that quiescent vehicles can share infrastructure and resources with active vehicles.

TABLE 3.7.6.2.8-1 CxP ISS CONCURRENT OPERATIONS - ISS CREW ROTATION MISSIONS

Maximum Concurrent CxP Operations Support during ISS Crew Rotations		
Scenario	**Active/Station-keeping Orion**	**Quiescent Orion**
1 (TBR-001-1400)	1 (TBR-001-1400)	1 (TBR-001-1400)
2 (TBR-001-1401)	0 (TBR-001-1401)	2 (TBR-001-1401)
3 (TBR-001-1402)	2* (TBR-001-1402)	0 (TBR-001-1402)
Scenario Examples: 1) 1 crew rotation active Orion vehicle and 1 ISS docked quiescent Orion vehicle as the nominal case 2) 2 ISS docked quiescent Orion vehicles 3) * Contingency mission operational scenario - 1 arriving active crew rotation Orion vehicle and the activated and undocked previously quiescent Orion vehicle.		

[CA6200-PO] Mission Systems shall concurrently monitor and control in-space vehicles during the ISS docked crew rotation and early lunar missions as shown in CxP Lunar Sortie Concurrent Operations Table.

Rationale: Orion cargo missions are not considered. ISS crew rotation mission will not occur concurrently with active lunar activities. Mission Systems should be sized for the nominal and inclusive concurrent conditional cases (2 active vehicles). It is prudent not to schedule or conduct 2 critical operations simultaneously during the critical operations periods (i.e. descent to surface or ascent from surface). Mission Systems should be sized for the nominal and inclusive concurrent conditional cases with the expectation that the contingency case is of low probability and monitor and control can be shared within operating margin built into the nominal resources.

TABLE 3.7.6.2.8-2 CxP LUNAR SORTIE CONCURRENT OPERATIONS

Maximum Concurrent CxP Operations Support During ISS Crew Rotations and Early Lunar Missions		
Scenario	**Active/Station-keeping Orion/LLV**	**Quiescent Orion/LLV**
1 (TBR-001-1403)	1 (TBR-001-1403)	2 (TBR-001-1403)
2 (TBR-001-1404)	2 (TBR-001-1404)	1 (TBR-001-1404)
3 (TBR-001-1405)	0 (TBR-001-1405)	2 (TBR-001-1405)
4 (TBR-001-1406)	2* (TBR-001-1406)	1 (TBR-001-1406)

Maximum Concurrent CxP Operations Support During ISS Crew Rotations and Early Lunar Missions		
Scenario	**Active/Station-keeping Orion/LLV**	**Quiescent Orion/LLV**
Scenario Examples: 1) 1 ISS docked quiescent Orion vehicle, 1 quiescent Orion vehicle in LLO, and 1 active LLV as the nominal case 2) 1 ISS docked quiescent Orion vehicle, an active Orion vehicle in LLO and an ascending LLV module as a concurrent conditional case 3) 1 ISS docked quiescent Orion vehicle, 1 quiescent vehicle LLV in LLO 4) * Contingency mission operations scenario –1 ISS activated and undocked previously quiescent Orion vehicle, 1 quiescent Orion vehicle in LLO, and 1 active LLV on the lunar surface		

Draft [CA6201-PO] Mission Systems shall concurrently monitor and control in-space vehicles for lunar outpost missions per the CxP Lunar Outpost Concurrent Operations Table.

Rationale: ISS crew rotation and cargo missions are not considered. Multiple Orion and LLV vehicles will be operated in space concurrently for lunar outpost missions. Concurrent missions similar to 1 Lunar Relay satellite, 1 quiescent Orion vehicle in LLO, 2 active LLV vehicles on the lunar surface, 1 active lunar outpost and lunar surface EVA are the nominal case. Mission systems should be sized for concurrent conditional cases for active Orion vehicles arriving in LLO and LLV descent to the lunar surface with existing active LLV on the lunar surface and the active lunar outpost. A concurrent conditional case could be the ascent of an LLV module to an activated Orion vehicle in LLO while other lunar surface assets continue nominal activities. Concurrent mission phases need to be considered such as the overlay of ongoing lunar vicinity operations with launch, EDS and transit of new moon arrivals or the Earth return transit, landing and search and rescue activities of a previous resident crew. Mission systems should be sized to include multiple use resources for nominal and conditional activities with built in operating margin to accommodate contingencies.

TABLE 3.7.6.2.8-3 CxP LUNAR OUTPOST CONCURRENT OPERATIONS

Maximum Concurrent CxP Operations Support During Early Lunar Missions and Lunar Outpost			
Scenario	**Active Lunar Outpost**	**LLV**	**Quiescent Orion in LLO**
1 (TBR-001-1407)	1 (TBR-001-1407)	2 (TBR-001-1407)	1 (TBR-001-1407)
2 (TBR-001-1408)	1 (TBR-001-1408)	1 (TBR-001-1408)	1 (TBR-001-1408)
3 (TBR-001-1409)	1 (TBR-001-1409)	2 (TBR-001-1409)	0 (TBR-001-1409)
4 (TBR-001-1410)	1 (TBR-001-1410)	0 (TBR-001-1410)	1 (TBR-001-1410)

Maximum Concurrent CxP Operations Support During Early Lunar Missions and Lunar Outpost			
Scenario	**Active Lunar Outpost**	**LLV**	**Quiescent Orion in LLO**
Scenario Examples: 1) 1 Active Lunar Outpost, 2 LLV vehicles on the surface, and 1 quiescent Orion in LLO as the nominal case 2) 1 Active Lunar Outpost, 1 LLV vehicle on the surface, and 1 quiescent Orion in LLO as the nominal case 3) 1 Active Lunar Outpost and 2 LLV vehicles on the surface as the nominal case 4) 1 Active Lunar Outpost and 1 quiescent Orion in LLO as the nominal case			

[CA6215-PO] The MS shall process telemetry destined for Range Safety within 350 msec (TBR-001-1447) during the launch/ascent phase.

Rationale: Establishes the maximum MS sub-allocation of latency for telemetry during the launch/ascent phase. Processing latency for data destined for the US Eastern Range is critical to ensuring safe flight and for meeting the operational constraints of the range. The transmission time from MS to GS is not accounted for in this requirement.

[CA6216-PO] The MS shall process voice within 350 msec (TBR-001-1447) during the launch/ascent phase.

Rationale: Identifies the maximum MS sub-allocation of latency for voice under the verbal abort scenario during the launch/ascent phase. Latencies for crew voice communication are critical to ensure timely crew response to abort commands.

3.7.6.2.9 MS Health and Status

[CA3127-PO] Mission Systems shall generate Health and Status information.

Rationale: Provides for generation of H&S information on internal operations of the Mission Systems. Full definition of the specific data is provided in Mission Systems SRD and multiple Mission Systems/System IRDs.

[CA5475-PO] Mission Systems shall detect system faults which could result in loss of flight vehicle, Loss of Mission, and loss of life.

Rationale: Fault detection is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault detection enables crew abort or flight termination (in case of non-recoverable failures). Mission Systems will provide fault detection not only for itself, but also for systems in flight. Faults subject to detection are further specified by CxP 72136, Mission Systems System Requirements Document. FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, loss of life, and Loss of Mission.

[CA5476-PO] Mission Systems shall isolate detected faults to the level required for recovery of function.

Rationale: Fault isolation is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault isolation enables crew abort or flight termination (in case of non-recoverable failures). Mission Systems will provide fault isolation not only for itself, but also for systems in flight. Faults subject to isolation are further specified by CxP 72136, Mission Systems System Requirements Document. FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, loss of life, and Loss of Mission. The level of recovery is governed by the criticality of systems (Loss of Vehicle, loss of life, Loss of Mission).

[CA5477-PO] Mission Systems shall provide recovery from isolated faults.

Rationale: Fault recovery is required for crew safety and mission success by enabling recovery of such critical functions. Mission Systems will provide fault recovery not only for itself, but also for systems in flight. Faults subject to recovery are further specified by CxP 72136, Mission Systems System Requirements Document. FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the Loss of Vehicle, loss of life, and Loss of Mission. The level of recovery is governed by the criticality of systems (Loss of Vehicle, loss of life, Loss of Mission).

3.7.6.2.10 MS Communications and Communications Security

[CA3128-PO] Mission Systems shall process telemetry.

Rationale: MS processes telemetry to provide for display and mission analysis, as required to operate the mission. Full definition of the specific data is provided in Mission Systems SRD and multiple Mission Systems/System IRDs and Interface Control Documents (ICDs).

[CA4132-PO] Mission Systems shall provide communication services to enable crew and system recovery.

Rationale: Communication services support coordination with recovery forces and to communicate with the crew. Recovery includes both nominal and contingency.

[CA5058-PO] Mission Systems shall record system-generated digital data received from other Constellation Systems.

Rationale: In order to evaluate historical performance, effectively utilize and benefit from past and current experiences, and develop lessons learned, data associated with those experiences must be recorded per CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O40]. Mission Systems must record the data received from other systems in order for ground personnel to trouble-shoot onboard failures, investigate long-term trends, and evaluate performance. Recording and archiving are separate functions, and not all *recorded data will be archived and kept for the duration of multiple flights. The archival function is assumed to be addressed at the Constellation level in the Data Management Plan.*

[CA5071-PO] Mission Systems shall provide connectivity between space originated voice communications and the public communications network.

Rationale: Controlled voice connectivity from space to external networks is required both for public relations and for the support of the crew. NASA has found this service useful on previous, long duration missions. Mission Systems is well suited to provide this function and has done so securely for previous programs.

[CA5903-PO] Mission Systems shall generate reconfigurable automated sequences.

Rationale: Reconfigurable automated sequences need to be uplinked to Orion and LSAM for future onboard execution. They may be uplinked to EDS as well.

3.7.6.2.11 MS GN&C

[CA0158-PO] Mission Systems shall perform navigation for Constellation flight systems during all mission phases including pre-launch.

Rationale: Navigation (e.g. Constellation flight system positions, velocities, and associated navigation parameters) is used to schedule communications and tracking for successful mission planning and execution, and for flight safety. This does not imply continuous availability of downlinked telemetry or tracking data.

Draft **[CA0160-PO]** Mission Systems shall determine stationary element location anywhere on the lunar surface to within (TBD-001-068) meters (TBD-001-068) feet) with 95% probability.

Rationale: Determining the location of stationary, landed elements on the lunar surface is essential to enable surface mobility activities, subsequent precision landings, and to provide a navigational tie between surface landmarks and the lunar reference frame. This requirement pertains to landed elements such as LSAM and DSS and not to subsequently deployed entities such as rovers and EVA crew. Accuracy requirement may be different for landing sites with and without direct line-of-site visibility to the Earth. Trade study TDS 12-2 has been commissioned to determine (TBD-001-068) value (may be a table of values).

[CA0270-PO] Mission Systems shall compute maneuvers for Constellation flight systems during all mission phases including pre-launch.

Rationale: This function enables nominal and contingency mission planning and execution of the ISS and lunar missions. These capabilities are used pre-launch in the mission design process and during real-time flight operations. In situations in which maneuver computations are performed onboard the flight system, the Mission Systems maneuver computations are computed in parallel as a backup.

3.7.6.2.12 MS Reliability and Availability

[CA3065-PO] Mission Systems shall have a probability of launch of no less than 99.9 (TBR-001-1411)%, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses system reliability. System reliability and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements. Due to the high level reliability required of the system, an additional maintainability requirement is not necessary.

[CA5135-PO] Mission Systems shall provide for operations of crewed missions no later than 90 minutes after the launch of the Ares V.

Rationale: Lunar missions involve the simultaneous operations of two flight vehicles. With a 90 minute interval, the Mission System must be able to support pre-launch and launch operations immediately following the launch of the Ares V.

3.7.6.2.13 MS Maintainability, Supportability, and Logistics

[CA5130-PO] Mission Systems shall provide stowage management and planning for delivery of pressurized cargo to the ISS in accordance with the CxP 70031, Constellation Program Orion -To- International Space Station Interface Requirements Document (IRD).

Rationale: The Cx Program Hardware Manifest database will contain hardware properties including mass, volume, and dimensions. The Cx Program will ensure this database is properly populated and is responsible for the prelaunch packing within vehicle constraints. Mission Systems will be responsible for planning the transfer of hardware from Orion to the ISS and ensuring mass, volume, dimensions, and final stowage locations are logged into the Inventory Management System (IMS). IMS data is used to plan on-orbit stowage on both Orion and ISS and to preclude stowing hardware in locations that jeopardize crew safety (e.g., covering fire ports, blocking access to emergency equipment, and blocking crew ingress/egress translational paths).

[CA5131-PO] Mission Systems shall provide stowage management and planning of pressurized cargo going to the lunar surface.

Rationale: The Cx Program Hardware Manifest database will contain hardware properties including mass, volume, and dimensions. The Cx Program will ensure this database is properly populated and is responsible for the prelaunch and descent to lunar surface packing within vehicle constraints. Mission Systems must support the maintenance, inventory and stowage planning for cargo transferred to the lunar surface and ensure mass, volume, dimensions, and final stowage locations are logged into the Inventory Management System (IMS). IMS data is used to plan *cargo stowage on the lunar surface and to preclude stowing hardware in locations that jeopardize crew safety (e.g., covering fire ports, blocking access to emergency equipment, and blocking crew ingress/egress translational paths).*

[CA5132-PO] Mission Systems shall provide stowage management and planning of pressurized cargo returning from the lunar surface.

Rationale: The Cx Program Hardware Manifest database will contain hardware properties including mass, volume, and dimensions. The Cx Program will ensure this database is properly populated and is responsible for the return packing within vehicle constraints. Mission Systems must support the maintenance, inventory and stowage planning for cargo transferred from the lunar surface back to Earth and ensure mass, volume, dimensions, and final stowage locations are logged into the Inventory Management System (IMS). IMS data is used to plan cargo stowage on vehicles returning from the lunar surface and to preclude stowing hardware in locations that jeopardize crew safety (e.g., covering fire ports, blocking access to emergency equipment, and blocking crew ingress/egress translational paths).

[CA5133-PO] Mission Systems shall provide stowage management and planning to allow return of pressurized cargo from the ISS in accordance with the CxP 70031, Constellation Program Orion -To- International Space Station Interface Requirements Document.

Rationale: The Cx Program Hardware Manifest database will contain hardware properties including mass, volume, and dimensions. The Cx Program will ensure this database is properly populated and is responsible for the return packing within vehicle constraints. Mission Systems will be responsible for planning the transfer of hardware from the ISS to Orion and ensuring mass, volume, dimensions, and final stowage locations are logged into the Inventory Management System (IMS). IMS data is used to plan on-orbit stowage on both Orion and ISS vehicles and to preclude stowing hardware in locations that jeopardize crew safety (e.g., covering fire ports, blocking access to emergency equipment, blocking crew ingress/egress translational paths).

[CA5994-PO] Mission Systems shall produce and deliver Project Verified Engineering Build software and data products (excluding project infrastructure products) to the Constellation Program within the time limits identified in Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Engineering Build is a set of software and data products that contain new requirements (capabilities) and problem fixes. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Engineering Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. Data products contain representative launch geometry values and actual values for other parameters. It has completed

Project Level Verification/Validation and has been configured to meet Integrated Build event requirements. Data definitions must be available in time to support generation of data products for the release. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation architecture. Project level activities include: participation in the build content definition, software design, code, and project-level Integration, test and delivery of the Project Verified Engineering Builds to the Program.

TABLE 3.7.6.2.13-1 TIME ALLOCATIONS FOR ENGINEERING BUILDS

Requirement	Threshold	Objective
MS	7 months (TBR-001-1078)	2.5 months

[CA5995-PO] Mission Systems shall produce and deliver Project Verified Flight Build software and data products to support the mission class within the time limits identified in Allocations for Flight Builds Table after the completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Flight Build is a set of software and data products that is based on a Project Verified Engineering Build, has mission specific (launch geometry derived) data and has completed Project Level Verification/Validation. Few software changes are expected. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Flight Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Data parameter values must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation Architecture. Project level activities include: participation in the build content definition, flight specific configuration activity (data reconfiguration), Fast Track activities as required, and delivery of Project Verified Flight Builds. Times are contiguous days.

TABLE 3.7.6.2.13-2 TIME ALLOCATIONS FOR FLIGHT BUILDS

Requirement	Threshold	Objective
MS	14 days	4 days

[CA5996-PO] Mission Systems shall support day of launch updates for software parameters and data products to configure the systems.

Rationale: A day of launch update is a set of software and data products based on the Program Verified Flight Build and the approved final flight parameter updates for launch day environments (winds), orbit geometry (target tracking), and other I-loads as required.

[CA5997-PO] Mission Systems shall produce and deliver resolutions for selected non-conformances during the engineering and flight release phases to the discovering organization and the Constellation Program in the time limits identified in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track build process is used for rapid resolution of problems found in the production of Flight Builds and Engineering Builds. The time period starts after documentation of the non-conformance and ends when the resolution is submitted for re-integration into the test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

TABLE 3.7.6.2.13-3 TIME ALLOCATIONS FOR FAST TRACK PROCESS

Requirement	Threshold	Objective
MS	48 hours	12 hours

[CA6019-PO] Mission Systems shall produce mission integration products for a single mission within the time limits identified in the Mission Integration Production Time Single Mission Constraints - ISS Table and Mission Integration Production Time Single Mission Constraints - Lunar Table.

Rationale: The Mission Integration Production defines an orderly mission production process beginning with the definition of a baselined set of mission requirements and the ensuing flight design, flight software, ground vehicle processing, flight operations documentation development, vehicle configuration, and crew and launch/flight control training activities necessary to support a mission. MS portions of that production effort are in software reconfiguration (CA5964), flight design, flight-specific training, and flight products development. By controlling time and labor expended on these major aspects of the mission integration production process, the CxP recurring operations costs expended on mission unique preparation can be reduced over legacy systems. Days are based on contiguous work days (no weekend or holiday work, 8 hrs/day, 5 days/week)

TABLE 3.7.6.2.13-4 MISSION INTEGRATION PRODUCTION TIME SINGLE MISSION CONSTRAINTS – ISS

Task	System Allocation	Time Threshold (Contiguous Days)	Time Objective (Contiguous Days)
Flight Design	MS	180 (TBR-001-1097)	(TBD-001-1071)
Flight Specific Training	MS	30 (TBR-001-1098)	(TBD-001-1072)
Flight Operations Products	MS	105 (TBR-001-1099)	(TBD-001-1073)

TABLE 3.7.6.2.13-5 MISSION INTEGRATION PRODUCTION TIME SINGLE MISSION CONSTRAINTS – LUNAR

Task	System Allocation	Time Threshold (Contiguous Days)	Time Objective (Contiguous Days)
Flight Design	MS	(TBD-001-1076)	(TBD-001-1077)
Flight Specific Training	MS	(TBD-001-1078)	(TBD-001-1079)
Flight Operations Products	MS	(TBD-001-1080)	(TBD-001-1081)

[CA6036-PO] Mission Systems shall operate each quiescent Orion vehicle at ISS with no more than 2 hours per week contiguous real-time command and control (consisting of 12 man-hours) under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting commanding and MS interaction with a quiescent Orion docked to ISS to specific periods and specific manpower intensity under nominal quiescent operations (i.e. no Orion system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent vehicle would require very little routine command interaction with MS. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). Assumption is that six total operations personnel send commands (e.g. crew uplink messages, state vectors, scripts) during this active command and control period each week. The objective strives to eliminate nominal command and control between ground controllers and a quiescent Orion, hence eliminating need for dedicated flight control teams for a quiescent Orion at ISS under nominal quiescent operations.

[CA6036-PO-Objective] The Mission Systems shall provide no real-time support to Orion during quiescent operations while docked with ISS.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting commanding and MS interaction with a quiescent Orion docked to ISS to specific periods and specific manpower intensity under nominal quiescent operations (i.e. no Orion system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent vehicle would require very little routine *command interaction with MS. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). Assumption is that 6 total operations personnel send commands (e.g. crew uplink messages, state vectors, scripts) during this active command and control period each week. The objective strives to eliminate nominal command and control between ground controllers and a quiescent Orion hence eliminating need for dedicated flight control teams for a quiescent Orion at ISS under nominal quiescent operations.*

[CA6038-PO] Mission Systems shall operate each quiescent vehicle with no more than 2 (TBR-001-1107) hours per week contiguous real-time command and control (consisting of (TBD-001-1086) man-hours) for Lunar missions under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Limiting commanding and MS interaction with each quiescent vehicle (e.g. Orion in LLO, LSAM in LEO, and LSAM on the lunar surface during Outpost stays) to specific periods and specific manpower intensity under nominal operating conditions (i.e. no LSAM or Orion system failures) will contribute to reduced operations life cycle cost. It is expected that a quiescent vehicle would require very little routine command interaction with MS. Managing this interaction within a specific period and to a limited amount of manpower enables reduced life cycle cost through reduced real-time ground control manning (e.g. numbers of shifts and numbers of teams). Assumption is that operations personnel send commands (e.g. crew uplink messages, state vectors, scripts) during this active command and control period each week.

[CA6039-PO] Mission Systems shall monitor each quiescent Orion vehicle without dedicated teams for ISS missions under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Ground active monitoring for a quiescent Orion vehicle is limited by flight system design to specific periods and specific manpower intensity under nominal operating conditions (i.e. no Orion system failures). This requirement does not preclude the fact that Health and Status data from quiescent vehicles will be provided near continuously to MS for fault annunciation and trending. Ground controllers and engineering teams supporting other active vehicles (e.g. ISS) can monitor for trends and fault annunciations as part of the active vehicle routine tasks. Dedicated personnel can be called in to resolve anomalies when needed. This will contribute to reduced operations life cycle cost. It is expected that a quiescent vehicle (e.g. Orion docked to ISS) would require very little routine active telemetry monitoring by engineering teams.

[CA6040-PO] Mission Systems shall monitor a quiescent vehicle without dedicated teams for Lunar missions under nominal quiescent operations.

Rationale: A significant stretch goal is to lower the life cycle cost of mission operations. Ground active monitoring for quiescent Orion and LSAM vehicles is limited by flight system design to specific periods and specific manpower intensity under nominal operating conditions (i.e. no Orion and LSAM system failures). This requirement does not preclude the fact that Health and Status data from quiescent vehicles will be provided near continuously to MS for fault annunciation and trending. Ground controllers and engineering teams supporting other active vehicles (e.g. ISS and Outpost) can monitor for trends and fault annunciations as part of the active vehicle routine tasks. Dedicated personnel can be called in to resolve anomalies when needed. This will contribute to reduced operations life cycle cost. It is expected that a quiescent vehicle (e.g. Orion docked to ISS, Orion in LLO, LSAM in LEO or on the Lunar surface for Outpost stays) would require very little routine active telemetry monitoring by engineering teams.

3.7.6.2.14 Reserved

3.7.6.2.15 Reserved

3.7.6.3 Reserved

3.7.6.4 MS External Interfaces

[CA0917-PO] Mission Systems shall interface with Orion per CxP 70029, Constellation Program Orion -To- Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: Mission Systems and Orion share physical and functional interfaces which are identified in CxP 70029, Constellation Program Orion -To- Mission Systems (MS) Interface Requirements Document (IRD).

[CA0918-PO] Mission Systems shall interface with the Ares I per CxP 70053, Constellation Program Ares I -to- Mission Systems Interface Requirements Document.

Rationale: Mission Systems and Ares I share functional interfaces which are identified in CxP 70053, Constellation Program Ares I -to- Mission Systems Interface Requirements Document.

[CA0919-PO] Mission Systems shall interface with the LSAM per CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -to- Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: Mission Systems and LSAM share physical and functional interfaces which are identified in CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -to- Mission Systems (MS) Interface Requirements Document (IRD).

[CA0920-PO] Mission Systems shall interface with Ares V per CxP 70112, Constellation Program Cargo Launch Vehicle (CaLV) -to- Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: Mission Systems and Ares V share physical and functional interfaces which are identified in CxP 70112, Constellation Program Cargo Launch Vehicle (CaLV) -to- Mission Systems (MS) Interface Requirements Document (IRD).

[CA0921-PO] Mission Systems shall interface with Ground Systems per CxP 70054, Constellation Program Mission Systems (MS) -to- Ground Systems (GS) Interface Requirements Document (IRD).

Rationale: Mission Systems and Ground Systems share physical and functional interfaces which are identified in CxP 70054, Constellation Program Mission Systems (MS) -to- Ground Systems (GS) Interface Requirements Document (IRD).

[CA0922-PO] Mission Systems shall interface with the Communication and Tracking Networks per CxP 70118-06, Constellation Program Systems -to- Communications and Tracking Networks Interface Requirements Document, Volume 6: Mission Systems (MS).

Rationale: Mission Systems and Communication and Tracking Networks share physical and functional interfaces which are identified in CxP 70118-06, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 6: Mission Systems (MS).

3.7.6.5 Reserved

3.7.7 Mars Transfer Vehicle (MTV)

3.7.7.1 MTV Description

3.7.7.2 MTV Requirements

3.7.7.2.1 Reserved

3.7.7.2.2 Reserved

3.7.7.2.3 Reserved

3.7.7.2.4 Reserved

3.7.7.2.5 Reserved

3.7.7.2.6 MTV Architecture Definition

Draft **[CA0862-PO]** The MTV shall provide total delta-V of (TBD-001-012) m/s (f/s) for the Mars Mission.

Rationale: The Program must control the allocation of the responsibility for the propulsive maneuvers in order to allow trades of mass and propulsive capability as the detailed designs of the missions and elements evolve.

3.7.7.2.7 Reserved

3.7.7.2.8 Reserved

3.7.7.2.9 Reserved

3.7.7.2.10 Reserved

3.7.7.2.11 Reserved

3.7.7.2.12 Reserved

3.7.7.2.13 Reserved

3.7.7.2.14 Reserved

3.7.7.2.15 Reserved

3.7.7.3 Reserved

3.7.7.4 Reserved

3.7.7.5 Reserved

3.7.8 Descent/Ascent Vehicle (DAV)

3.7.8.1 DAV Description

3.7.8.2 DAV Requirements

3.7.8.2.1 Reserved

3.7.8.2.2 Reserved

3.7.8.2.3 Reserved

3.7.8.2.4 Reserved

3.7.8.2.5 Reserved

3.7.8.2.6 DAV Architecture Definition

Draft **[CA0863-PO]** The DAV shall provide total delta-V of (TBD-001-012) m/s (f/s) for the Mars Mission.

> *Rationale: The Program must control the allocation of the responsibility for the propulsive maneuvers in order to allow trades of mass and propulsive capability as the detailed designs of the missions and elements evolve.*

3.7.8.2.7 Reserved

3.7.8.2.8 Reserved

3.7.8.2.9 Reserved

3.7.8.2.10 DAV Communications and Communications Security

Draft **[CA3282-PO]** The DAV shall communicate using an independent, dissimilar, voice only system.

Rationale: DAV needs an independent voice communication capability to improve crew safety and mission success. DAV must be able to communicate with others in space systems as well as with Earth when the prime voice system is unavailable.

Draft **[CA3290-PO]** DAV shall communicate simultaneously with Mission Systems and with three (TBR-001-136) other Constellation systems that are within 800 (TBR-001-165) km (432 nmi) of DAV.

Rationale: Simultaneous communication is required between systems on the Martian surface during Martian operations. DAV must communicate with systems on the surface, in Martian orbit, and with MS.

3.7.8.2.11 Reserved

3.7.8.2.12 Reserved

3.7.8.2.13 Reserved

3.7.8.2.14 Reserved

3.7.8.2.15 Reserved

3.7.8.3 Reserved

3.7.8.4 Reserved

3.7.8.5 Reserved

3.7.9 Extravehicular Activities (EVA) System

3.7.9.1 EVA System Description

The EVA System includes the elements necessary to protect crewmembers and allow them to work effectively in the pressure and thermal environments that exceed the human capability during all mission phases. The EVA System include the pressure suits, EVA life support systems, umbilicals, EVA tools and mobility aids, EVA-specific vehicle interfaces, EVA servicing equipment, suit avionics, individual crew survival equipment (e.g. integral to the pressure suit), and ground support systems.

3.7.9.2 EVA System Requirements

[CA4127-PO] The EVA System shall perform at least two (TBR-001-163) microgravity EVA operations of at least 4 (TBR-001-223) hours duration on Lunar missions.

Rationale: In keeping with Constellation Program Need, Goals and Objectives, the EVA System needs to provide an microgravity EVA capability that extends across all practical mission phases and supports EVA tasks on as much of the spacecraft as possible. In practice, this means that the EVA System need to provide a microgravity EVA capability using Orion as an EVA platform that is independent of other vehicles. Programmatic decisions, on the need for this capability were made at the March 29, 2006 Constellation Control Board (CxCB) and documented in the Board minutes. For additional Programmatic discussions and decisions made pertaining to this requirement, refer to the Constellation Operations Panel and Systems Engineering Control Board minutes during the month of March 2006. Two (TBR-001-163) microgravity EVA operations have been scoped to address an unscheduled EVA for mission success prior to decent to lunar surface and a contingency EVA for crew survival to transfer the crew from LSAM to Orion. Four (TBR-001-223) hours is anticipated to be the longest duration microgravity EVA and is consistent with the crew transfer.

[CA6078-PO] The EVA System shall have a control mass of 171.5 kg (378 lbm) in the Orion for lunar missions.

Rationale: The Control Mass for the EVA System in the Orion includes all hardware needed for EVA activities for four crewmembers that are carried on lunar missions by the Orion. This allocation covers pressure suits, suit-integrated crew survival equipment, and IVA umbilicals for each crewmember. The EVA System compliance with the control mass is determined during EVA Design Analysis Cycles. This control mass is needed with the associated program reserve to ensure compatibility with Orion's mass capability and EVA System's ability to meet functional and performance requirements.

[CA6080-PO] The EVA System shall have a control mass of 284.4 kg (627 lbm) in the Orion for ISS missions.

Rationale: The Control Mass for EVA System in the Orion includes all hardware needed for EVA activities for six crewmembers that are carried on ISS missions by the Orion. This allocation covers pressure suits, suit-integrated crew survival equipment, and IVA umbilicals for each crewmember. The EVA System compliance with the control mass is determined during EVA Design Analysis Cycles. This control mass is needed with the associated program reserve to ensure compatibility with Orion's mass capability and EVA System's ability to meet functional and performance requirements.

3.7.9.2.1 EVA System Mission Success

[CA5946-PO] The EVA System shall limit their contribution to the risk of Loss of Mission (LOM) for a Lunar Sortie Mission to no greater than 1 in 600.

Rationale: The 1 in 600 means a .00167 (or .167%) probability of LOM due to the EVA System during any Lunar Sortie Mission. This requirement is driven by CxP 70003-ANX01, Constellation Needs, Goals and Objectives, Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.7.9.2.2 EVA System Crew Survival

[CA3003-PO] The EVA System shall sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 144 hours while receiving consumables from the vehicle.

Rationale: In order to return the crew without permanent disability, the life of the crewmembers needs to be sustained. The 144 hours is associated with the nominal 120 hour expedited return time an unpressurized Orion needs to sustain the life of suited crewmembers during the trip back to Earth with an additional 24 hours of margin. The worst-case would be sustaining the crew for the full time in their suits. The 144 hour clock begins when the crew begins utilizing Orion resources and does not address any time spent on the LSAM. For ISS missions, the amount of time needed to return the crew is assumed to be much less. The EVA System represents the most straightforward solution to crew survival in this contingency situation.

[CA5169-PO] The EVA System shall provide unassisted emergency egress for suited crew to a safe haven during pre-launch activities within 2 (TBR-001-170) minutes total starting from last crewmember exiting Orion to the last crewmember entering the safe haven.

Rationale: Flow down of CA0310. For contingency situations, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons. This should drive the design of seat restraints, crew aids, and space suit mobility components to allow the crew to egress without ground crew assistance. On the launch pad there may be hazardous conditions that preclude return of ground crew to the launch pad in a timely enough fashion to assist the crew in egress, but that do not, in fact, warrant use of the launch abort system, which is in itself a hazardous operation with its own inherent safety risks to crew survival.

[CA5170-PO] The EVA System shall provide for the suited crew to perform an unassisted emergency egress from Orion upon landing within 3 (TBR-001-1023) minutes starting from when the decision to egress Orion is made.

Rationale: For contingency or aborted landings, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons, or to assist in search and rescue operations. This should drive the design of seat restraints, spacecraft aids, and space suit mobility components.

[CA5203-PO] The EVA System shall provide the suited crew with the capability for unassisted emergency egress during pre-launch activities within 2 (TBR-001-173) minutes total starting from initiation of egress to complete crew egress from vehicle.

Rationale: For contingency situations, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons. This should drive the design of seat restraints, hatch mechanisms, launch suit, and egress paths in the pre-launch orientation to allow the crew to egress without ground crew assistance.

[CA6076-PO] The EVA System shall provide the capability to isolate a suited crewmember from the vehicle-provided breathing gas within 5 (TBR-001-1432) minutes in case of an unrecoverable suit depressurization to 15.4 (TBR-001-1431) kPa (2.2 psia).

Rationale: In order to meet the intent of JPR 8080.5A F-22, the system must be capable of isolating a major suit leak such that pressure can be maintained the main suit loop so that the other crewmembers will not perish. It is assumed that a leakage in any one suit will cause the entire suit loop to drop pressure. Per [CA6072-PO], the Constellation Architecture will provide resources to maintain the suit loop pressure at 2.2 psia for up five minutes for a leak rate equivalent to a quarter inch hole at 4.3 psia over vacuum.

3.7.9.2.2.1 EVA System Crew Survival Probabilities

[CA5945-PO] The EVA System shall limit their contribution to the risk of Loss of Crew (LOC) for a Lunar Sortie Mission to no greater than 1 in 800.

Rationale: The 1 in 800 means a .00125 (or .125%) probability of LOC due to EVA System during any Lunar Sortie Mission. This requirement is driven by CxP 70003-ANX01, Constellation Needs, Goals and Objectives, Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.7.9.2.3 Reserved

3.7.9.2.4 Reserved

3.7.9.2.5 EVA System Mission Rates and Duration

[CA6153-PO] The EVA System shall perform ISS and Lunar Flights of up to four ISS and four Lunar Flights in a year.

Rationale: The EVA System must be designed to support a mission frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and Mission personnel proficiency. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of Mission and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the EVA systems. A lunar *mission will consist of one crewed Orion, one crewed LSAM plus one uncrewed LSAM.*

[CA6153-PO-Objective] The EVA Systems shall perform one additional ISS and two additional Lunar flights for a maximum of six flights per year.

Rationale: The EVA System must be designed to support a mission frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and Mission personnel proficiency. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of Mission and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the EVA systems. A lunar mission will consist of one crewed Orion, one crewed LSAM plus one uncrewed LSAM.

[CA6262-PO] The EVA Systems shall perform back to back launches within 45 calendar days, measured from the launch of the first vehicle to the launch of the second vehicle.

Rationale: The EVA System must be designed to support a minimum mission interval in order to provide a sustainable human exploration program and to maintain acceptable flight crew and Mission personnel proficiency. Mission intervals drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of Mission and mission support systems. In addition, the minimum interval drives turnaround and maintenance activities for the Constellation systems. This interval is expressed in calendar days.

[CA6262-PO-Objective] The EVA Systems shall provide the capacity to conduct one back to back set of launches per year within 30 days measured from the launch of the first vehicle to the launch of the second vehicle.

Rationale: The capacity of the EVA Systems to conduct a single set of launches in a 30 day interval per year will allow the capability to maintain manifesting mission success goals in the case of a launch slip.

3.7.9.2.6 Reserved

3.7.9.2.7 EVA System Safety (System, Public, and Planetary)

[CA5400-PO] The EVA System shall comply with the requirement in JPR 8080.5, JSC Design and Procedural Standards, Section G-2.

Rationale: Fault tolerance is defeated if a single event can eliminate all modes of tolerance. This requirement mandates separation of redundant systems, subsystems, and elements.

[CA5409-PO] The EVA System shall control critical hazards. The hazard must be controlled without the use of emergency operations or emergency systems.

Rationale: Control of mission critical failures is dictated by programmatic decision to ensure mission success. The EVA System will define hazard controls that may include failure tolerance. The EVA System will derive the specific hazard controls and implementation from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

[CA5410-PO] The EVA System shall be a minimum of one failure tolerant for controlling catastrophic hazards, except for areas approved to use Design for Minimum Risk criteria. The level of failure tolerance must be determined using the hazard identification and mitigation process described in CxP 70038. The failure tolerance must be achieved without emergency operations or emergency systems.

Rationale: Constellation has established a minimum of single failure tolerance or DFMR to control catastrophic hazards. However, single failure tolerance may not be adequate in all instances to control catastrophic hazards. Thus, the level of failure tolerance needed is commensurate with the severity of the hazard, and likelihood of occurrence. The EVA System will derive the specific level of failure tolerance and implementation (similar or dissimilar redundancy, backup systems) from an integrated design and safety analysis performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology.

3.7.9.2.8 Reserved

3.7.9.2.9 EVA System Health and Status

[CA3121-PO] The EVA System shall generate Health and Status information.

Rationale: Provides for generation of H&S information on internal operations of the EVA System. Full definition of the specific data is provided in EVA SRD and multiple EVA/System IRDs.

[CA3122-PO] The EVA System shall provide Health and Status information to the crew.

Rationale: Provides for processing of H&S information on internal operations of the EVA System for use by the EVA crew.

[CA4125-PO] The EVA System shall provide recovery from isolated faults.

Rationale: Fault recovery is required for crew safety and mission success by enabling recovery of such critical functions. Faults subject to recovery are further specified by the EVA System SRD. FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the loss of EVA System functionality and loss of life. The level of recovery is governed by the criticality of systems (loss of EVA System functionality, loss of life).

[CA5467-PO] The EVA System shall detect system faults which could result in loss of EVA System functionality and loss of life.

Rationale: Fault detection is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault detection enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to detection are further specified by the CxP 72002, EVA Systems Project System Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the loss of EVA system functionality and loss of life.

[CA5468-PO] The EVA System shall isolate detected faults to the level required for recovery of function.

Rationale: Fault isolation is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault isolation enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to isolation are further specified by CxP 72002, EVA Systems Project System Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance. This Level II requirement addresses the loss of EVA System functionality and loss of life. The level of recovery is governed by the criticality of systems (loss of EVA System functionality, loss of life).

3.7.9.2.10 EVA System Communications and Communications Security

Draft **[CA5046-PO]** The EVA System shall provide (TBD-001-221) bytes of digital storage for recording digital data received from other Constellation Systems.

Rationale: Having storage space for other systems' recorded data provides the Constellation Architecture the capability to transfer stored data to ensure that data is available when needed. The recording function is separate from the archival function and is sized on a per mission basis. The archival function is assumed to be addressed at the Constellation level in the Data Management Plan. The amount of space required for each system will change with mission type. The EVA System is encouraged to provide larger than necessary storage space for early missions in preparation for the larger space requirements in later phases of the program. Additional performance details (duration, etc.) will be defined in the EVA System SRD.

Draft **[CA5047-PO]** The EVA System shall (TBD-001-645) record system-generated digital data received from other Constellation Systems.

Rationale: There are times when the quantity/rate of data recorded at certain times exceeds the capability of that system's downlink to send. Sharing data recording across Constellation systems allows for increased downlink capacity for highly dynamic events. Constellation systems must store data for each other in order to pass that data along the ultimate path it must traverse to make it back to Earth.

[CA5909-PO] The EVA System shall communicate simultaneously with four (TBR-001-556) Constellation Systems during a Lunar Sortie mission.

Rationale: Simultaneous communications is required so that a crewmember on EVA can communicate with up to three other crewmembers on EVA and Mission Systems simultaneously. By specifying four Constellation systems, this also covers the case where an EVA crewmember needs to be able to communicate with another EVA crewmember, the LSAM, and Mission Systems simultaneously; this covers the case where a crewmember may be in the LSAM. The TBR will be resolved by working with Advanced Projects Office (APO) to develop a lunar communications architecture based on a lunar surface concept of operations.

[CA5910-PO] The EVA System shall communicate simultaneously with six (TBR-001-557) Constellation Systems during a Lunar Outpost mission.

Rationale: Simultaneous communications is required so that a crewmember on EVA can communicate with other crewmembers on EVA, the Lunar Outpost, an LSAM, and Mission Systems simultaneously. The TBR will be resolved by working with APO to develop a lunar communications architecture based on a lunar surface concept of operations.

3.7.9.2.11 Reserved

3.7.9.2.12 EVA System Reliability and Availability

[CA3063-PO] The EVA System shall have a probability of launch of no less than 99.9 (TBR-001-562)%, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses system reliability. System reliability and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements. Due to the high level reliability required of the system, an additional maintainability requirement is not necessary.

3.7.9.2.13 EVA System Maintainability, Supportability, and Logistics

[CA5182-PO] The EVA System flight hardware shall require no preventive maintenance or repair during a single ISS mission.

Rationale: This requirement addresses the desire to design EVA System hardware such that failures will not occur nor will maintenance be required during a mission. Activities associated with wipe down and cleaning to ensure viability of hardware are not considered within the definition of maintenance for this requirement.

[CA5184-PO] The EVA System flight hardware shall be designed to allow for in-flight maintenance, including replacement and repair of major end items.

Rationale: Past experience has shown that sparing parts versus entire systems is much more logistically efficient for space flight hardware designs, specifically, with *regards to designs that are potentially unique and conformal to each crewmember. The EVA System should be designed to allow for the capability for change out and repair of on-orbit replaceable units.*

[CA5998-PO] The EVA Systems Project shall produce and deliver Project Verified Engineering Build software and data products to the Constellation Program within the time limits identified in Time Allocations for Engineering Builds Table after completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Engineering Build is a set of software and data products that contain new requirements (capabilities) and problem fixes. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Engineering Build to the Constellation Program. Exchanged products are defined in the Product Exchange Matrix. Deliveries are not required unless new content is identified. Data products contain representative launch geometry values and actual values for other parameters. It has completed Project Level Verification/Validation and has been configured to meet Integrated Build event requirements. Data definitions must be available in time to support generation of data products for the release. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation architecture. Project level activities include: participation in the build content definition, software design, code, and project-level Integration, test and delivery of the Project Verified Engineering Builds to the Program.

TABLE 3.7.9.2.13-1 - TIME ALLOCATIONS FOR ENGINEERING BUILDS

Requirement	Threshold	Objective
EVA System	7 months (TBR-001-1086)	2.5 months

[CA5999-PO] The EVA System shall produce and deliver Project Verified Flight Build software and data products software and data products to support the mission class within the time limits identified in Time Allocations for Flight Builds Table after the completion of the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars).

Rationale: A Project Verified Flight Build is a set of software and data products that is based on a Project Verified Engineering Build, has mission specific (launch geometry derived) data and has completed Project Level Verification/Validation. Few software changes are expected. The time period starts when the software content definition is baselined and ends with the delivery of a Project Verified Flight Build to the Constellation Program. Exchanged products are defined in the Product

Exchange Matrix. Data parameter values must be available in time to support generation of data products for the build. Early release of interface configuration data is assumed. Timely integration and verification of solutions reduces the burden on ground and mission systems personnel to develop and maintain temporary workarounds for operational problems. The requirement is to be attained without increasing staff through efficient design of reconfiguration as supported by the Constellation architecture. Project level activities include: participation in the build content definition, flight specific configuration activity (data reconfiguration), Fast Track activities as required, and delivery of Project Verified Flight Builds. Times are contiguous days.

TABLE 3.7.9.2.13-2 - TIME ALLOCATIONS FOR FLIGHT BUILDS

Requirement	Threshold	Objective
EVA System	14 days	4 days

[CA6001-PO] The EVA System shall produce and deliver resolutions for selected non-conformances during the engineering and flight release phases to the discovering organization and the Constellation Program in the time limits identified in Time Allocations for Fast Track Process Table.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track build process is used for rapid resolution of problems found in the production of Flight Builds and Engineering Builds. The time period starts after documentation of the non-conformance and ends when the resolution is submitted for re-integration into the test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

TABLE 3.7.9.2.13-3 - TIME ALLOCATIONS FOR FAST TRACK PROCESS

Requirement	Threshold	Objective
EVA System	48 hours	12 hours

[CA6006-PO] The EVA System shall conduct ground operations for a single Ares I/Orion mission within the time limits identified in EVA Critical Path Allocations for Ares I/Orion Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and *ground system designs that result in reduced ground operations time and labor without sacrifices to performance or design cost. The critical path constraints levied in EVA Critical Path Allocations for Ares I/Orion Ground Operations Table, along with labor-hour constraints defined in CA6006, are intended to drive the design of the flight systems to enable such reductions.*

The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather, they are intended to be a design target for the system developers.

In EVA Critical Path Allocations for Ares I/Orion Ground Operations Table, the EVA Ground Operations processing flow is broken down into three sequential time periods between key EVA ground processing milestones. The sum of the time periods is the overall EVA Critical Path contribution anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming "single-string" for the integrated operations Ground Systems (i.e. one Ares I Mobile Launcher, one Ares I VAB high bay, one control room for Ares I operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx Ground Operations.

The values identified in EVA Critical Path Allocations for Ares I/Orion Ground Operations Table are intended to apply to nominal EVA operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy ELV systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.7.9.2.13-4 EVA CRITICAL PATH ALLOCATIONS FOR ARES-1/ORION GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Ready for Orion Integration to Integrated Stack Ready for Powered Testing	53 (TBR-001-1202)	44 (TBR-001-1203)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Ready for Powered Testing to Finish of Powered Testing	67 (TBR-001-1204)	56 (TBR-001-1205)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares I, Orion, GS, EVA
Pad Connection and Validation Complete to Launch	82 (TBR-001-1208)	68 (TBR-001-1209)	Begins once pad connections are validated and ends at T-0.	GS, Ares I, Orion, EVA

[CA6011-PO] The EVA System shall conduct ground operations for a single Ares V/LSAM mission within the time limits identified in the EVA Critical Path Allocations for Ares V/LSAM Ground Operations Table.

Rationale: Constellation systems require significantly reduced ground processing time, manpower, and infrastructure over legacy manned spaceflight systems to enable a sustainable exploration program. These reductions will be enabled by balancing design cost and performance considerations with the time and labor required for recurring ground operations, along with innovations in the flight and ground system designs that result in reduced ground operations time and labor, without sacrifices to performance or design cost. The critical path constraints levied in EVA Critical Path Allocations for Ares V/LSAM Ground Operations Table, along with labor-hour constraints defined in CA6011, are intended to drive the design of the flight and ground systems to enable such reductions.

The constraints identified in this requirement are not intended to dictate the available resources for conduct of ground processing operations; rather, they are intended to be a design target for the system developers.

In EVA Critical Path Allocations for Ares V/LSAM Ground Operations Table, the EVA Ground Operations processing flow is broken down into three sequential time periods between key processing milestones. The sum of the time periods is the overall EVA Critical Path contribution anticipated for nominal Constellation Ground Operations. The Critical Path allocation reflected in the table is the portion of the critical path, in hours, allocated to each time period. Assuming "single-string" for the integrated operations Ground Systems (i.e. one Ares V Mobile Launcher, one Ares V VAB high bay, one control room for Ares V operations, etc.), the critical path of processing activities that take place on the Mobile Launcher is determined to be the overall critical path for Cx Ground Operations.

The values identified in EVA Critical Path Allocations for Ares V/LSAM Ground Operations Table are intended to apply to nominal EVA operations only. Accordingly, the values do contain time for minor problem resolution activities, but not for resolving significant hardware failures or issues such as those that would drive an LRU replacement, launch scrub, or other off-nominal or contingency operation.

Reductions in ground processing are accomplished by the infusion of technology, simplification of the flight hardware, and streamlining of ground operations and sustaining engineering processes. It is reasonable to assume that efficiency gains for the Constellation Architecture can be achieved over legacy manned spaceflight systems comparable to those achieved by modern commercial launch providers over legacy ELV systems. The threshold and objective values reflected in the table are intended to reflect such efficiency gains over legacy systems.

TABLE 3.7.9.2.13-5 EVA CRITICAL PATH ALLOCATIONS FOR ARES-V/LSAM GROUND OPERATIONS

Time Period	Critical Path Allocation (Hours)		Notes	Allocation
	Threshold	Objective		
Ready for LSAM Integration to Integrated Stack Ready for Powered Testing	(TBD-001-1302)	(TBD-001-1303)	Integration of the Orion to the Ares I, from the time the Ares I is ready for Orion integration until the Ground System and Integrated stack is ready for powered testing	Orion, Ares I, GS, EVA
Ready for Powered Testing to Finish of Powered Testing	(TBD-001-1304)	(TBD-001-1305)	All powered test and checkout of the Ares I and Orion on the Mobile Launcher	Ares V, LSAM, GS, EVA
Pad Connection and Validation Complete to Launch	(TBD-001-1308)	(TBD-001-1309)	Begins once pad connections are validated and ends at T-0.	GS, Ares V, LSAM, EVA

3.7.9.2.14 EVA System Habitability and Human Factors

[CA3058-PO] The EVA System shall provide for suit donning and connection to life support by the full crew within 1 (TBR-001-113) hour.

Rationale: The full crew must get into their suits and connect to vehicle life support while the Orion ECLSS feeds the leak. Per CA3105-PO, the Orion ECLSS must feed the leak for a discrete amount of time in which the crew must be suited and pressurized with confidence (i.e. leak checked). The TBR is associated with the exact time requirement for the EVA System to don the LEA configuration of the suit pressure garment and connect to vehicle life support. This time is driven by the suit donning sequence and umbilical connection between suits and Orion. It may be more appropriate, given the limited Orion volume space available, that suit retrieval and donning will be performed by sets of crewmembers rather than the entire complement of crewmembers simultaneously.

[CA5168-PO] The EVA System shall provide for unassisted donning and doffing of space suit systems.

Rationale: Unassisted don/doff capability is required, in the cases whereby other flight crew are unavailable to assist, either because they are incapacitated or physically cannot provide assistance.

[CA5659-PO] The EVA System shall provide an operational suit pressure of at least 30 (TBR-001-191) kPa (4.3 psid) positive in the event of a non-recoverable cabin depress event.

Rationale: This requirement defines the maximum pressure that the suit will be required to operate. The pressure of 30 (TBR-001-191) kPa (4.3 psid) is based on the operational experience with the Shuttle and ISS Extravehicular Mobility Unit (EMU) and is the pressure recommended in the Explorations Atmospheres Working Group. Definition of this pressure is required to define what the Orion or LSAM response to a cabin leak. This requirement is not intended to define the pressure of the suit for EVA operations (contingency, unscheduled, or scheduled EVAs). The suit pressure in this requirement is primarily driven by the best method to protect the crew from Decompression Sickness given that a long prebreathe will not be possible (due to the vehicle limitations to feed a leak).

3.7.9.2.15 EVA System Environmental Conditions

[CA5188-PO] The EVA System shall meet its requirements during and after exposure to the environments defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.3, 3.4, and 3.7.

Rationale: The EVA System will be exposed to a variety of natural environments that could make it unable to meet its requirements, potentially in combination with induced environments. This requirement defines the limits of these effects and assures that they will be mitigated by the design. Natural environment effects also need to be considered for the EVA System integrated vehicle configurations: Orion/LSAM/EVA, Orion/EVA, and LSAM/EVA.

[CA5559-PO] The EVA System shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design.

[CA5564-PO] The EVA System shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design. Therefore, the production of induced environments must be limited and controlled to allow proper performance and function of other sub-systems and other systems when operating in mated configurations.

3.7.9.3 Reserved

3.7.9.4 EVA System External Interfaces

[CA0923-PO] The EVA System shall interface with Orion per CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document.

Rationale: The EVA System and Orion share physical and functional interfaces, which are identified in the CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document.

[CA0924-PO] The EVA System shall interface with the LSAM per CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD).

Rationale: LSAM and the EVA System share physical and functional interfaces which are identified in CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD).

[CA0925-PO] The EVA System shall interface with GS per CxP 70104, Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD).

Rationale: The EVA System and Ground Systems share physical and functional interfaces, which are identified in CxP 70104, Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD).

3.7.9.5 Reserved

3.7.10 Flight Crew Equipment

3.7.10.1 Reserved

3.7.10.2 Flight Crew Equipment Requirements

[CA6081-PO] The Flight Crew Equipment Office shall have a control mass of 220.4 kg (486 lbm) for Flight Crew Equipment in the Orion for ISS missions

Rationale: The Control Mass for Flight Crew Equipment in the Orion includes all hardware needed for flight crew support for six crewmembers that are carried on ISS missions by the Orion. This value includes food, survival, exercise, medical, hygiene, sleeping, photography, housekeeping, clothing, maintenance, supplies and trash.

[CA6082-PO] The Flight Crew Equipment Office shall have a control mass of 133.8 kg (295 lbm) for Flight Crew Equipment in the Orion for lunar missions

Rationale: The Control Mass for Flight Crew Equipment in the Orion includes all hardware needed for flight crew support for four crewmembers that are carried on lunar missions by the Orion. This value includes food, survival, exercise, medical, *hygiene, sleeping, photography, housekeeping, clothing, maintenance, supplies and trash.*

4.0 VERIFICATION

4.1 RESERVED

4.1.1 Verification Methods

Verification may be accomplished by analysis, demonstration, test, inspection, or any combination thereof. The methods used to accomplish verification are defined below.

a. A - Analysis is a method of verification utilizing techniques and tools such as computer and hardware simulations, analog modeling, similarity assessments, and validation of records to confirm that design requirements to be verified have been satisfied. Analysis is the evaluation of the results of multiple tests and analyses at a lower level as it would apply to a higher level of assembly. Analytical methods selected for verification will be supported by appropriate rationale and be detailed in the applicable documents.

b. D - Demonstration – is a qualitative exhibition of functional performance (i.e., serviceability, accessibility, transportability and human engineering features) usually accomplished with no or minimal instrumentation.

c. T - Test is a method of verification wherein requirements are verified by measurement during or after the controlled application of functional and environmental stimuli. These measurements may require the use of laboratory equipment, recorded data, procedures, test support items, or services. For all verification, qualification, and acceptance test activities, pass or fail test criteria or acceptance tolerance bands (based upon design and performance requirements) shall be specified prior to conducting the test. This will ensure that the actual performance of tested equipment or systems meets or exceeds specifications.

d. I - Inspection is a method of verification of physical characteristics that determines compliance of the item with requirements without the use of special laboratory equipment, procedures, test support items, or services. Inspection uses standard methods such as visuals, gauges, etc., to verify compliance with requirements. Hardware may be inspected for the following:

   1. Construction
   2. Workmanship
   3. Physical condition
   4. Specification and/or drawing compliance

Inspection may be used to confirm that engineering drawings call out proper design and construction features (i.e., materials and processes). Inspection includes Review of Design (ROD). This is typically a review of the as-built drawings to confirm that a design feature has been incorporated into the design (i.e., the Ares I shall use a J2X engine).

Inspection also may be used to determine closure status of verification activities being performed at Level III to support closures at Level II when the data is not analyzed at Level II, but just checked off for closure status.

4.1.2 Design (Qualification) Verification

Unless otherwise specified, all environmental qualification and acceptance testing shall be performed in accordance with the test conditions specified in CxP 70036, Constellation Program Environmental Qualification and Acceptance Testing Requirements (CEQATR).

4.2 CONSTELLATION ARCHITECTURE REQUIREMENTS

[CA0001V-HQ] The capability to deliver crew and cargo to the lunar surface and return to Earth shall be verified by inspection. The inspection shall review lower-level CARD allocated requirements verification closure and Hazard Analysis approval status for a Lunar Design Reference Mission. The verification shall be considered successful when the inspection shows that all lower-level CARD allocated requirements were closed and all the Integrated and System-level hazard reports were approved.

Rationale: Verification of this requirement is a roll-up of verification closures of allocated lower-level requirements, in accordance with the established traceability within the CARD, as well as a review of the Hazard Analysis to be sure it can be done safely.

[CA0003V-HQ] The capability to perform crewed and robotic science activities shall be verified by analysis. The analysis shall consist of a review of the crew time, power, thermal and mass/volume capability to show that they have sufficient performance for the defined allocations for science. The analysis shall review the Lunar missions timeline for crew time allocated to science; the project margins analysis reports for resources allocated to scientific objectives (power, thermal, mass, stowage), and Architecture capabilities (such as communications, surface transportation). The analysis shall be considered successful when it shows that the resource allocation in the CARD 3.7 requirements are met, and there is sufficient crew time to complete the science tasks.

Rationale: Mission resource analysis will confirm sufficient mission resource margins for performing scientific tasks. Architecture capability assessment will confirm that the vehicle will provide all the support services that will be needed for completion of scientific tasks.

[CA0004V-HQ] The capability to perform engineering demonstrations and DTOs shall be verified by analysis. The analysis shall consist of a review of the crew time, power, thermal and mass/volume capability to show that they have sufficient performance for the defined engineering objectives. The analysis shall review the Lunar missions timeline for crew time; the project margins analysis reports for resources (power, thermal, mass, stowage), and Architecture capabilities (such as communications, reconfiguration, surface transportation). The analysis shall be considered successful when it shows that the resource allocation in the CARD 3.7 requirements are met and there is sufficient crew time to complete the DTO/engineering demonstration tasks.

Rationale: Mission resource analysis will confirm sufficient resource margin available for additional items transport to the site of DTO performance and margins for performing specific engineering tasks. Architecture capability analysis will review systems involved in DTO tasks and the capabilities available to support the DTO tasks.

[CA0005V-HQ] The capability to establish and support a permanently habitable outpost on the lunar surface shall be verified by analysis. The analysis shall review the Constellation Architecture lunar cargo delivery capacity and crew time availability on Lunar Sortie missions. The analysis shall be considered successful when it shows that the (TBD-001-322) amount of outpost construction cargo can be delivered to the lunar surface and the crew time is available to perform construction activities.

Rationale: The cargo delivery to the lunar surface and crew time availability analysis will confirm that outpost build can be conducted on Lunar Sortie missions. Mission resources are assumed to be available for any kind of surface activities and not specific to outpost construction.

[CA0006V-HQ] The capability to demonstrate resource extraction and from in situ materials and their utilization during lunar missions shall be verified by analysis. The analysis shall consist of a review of the crew time, power, thermal, and mass/volume capability to show that they have sufficient performance for the defined allocations for resource extraction and utilization demonstrations. The analysis shall review the lunar missions timeline for crew time allocated to resource extraction demonstrations; the project margins analysis reports for resources allocated to resource extraction demonstrations objectives (power, thermal, mass, stowage), and architecture capabilities (such as communications, surface transportation). The analysis shall be considered successful when it shows that the resource allocations in the CARD 3.7 requirements are met and there is sufficient crew time to complete the resource extraction demonstrations tasks.

Rationale: NR

Draft **[CA0011V-HQ]** The capability to perform crewed and robotic science activities shall be verified by analysis. The analysis shall consist of a review of the crew time, power, thermal and mass/volume capability to show that they have sufficient performance for the defined allocations for science. The analysis shall review the Lunar missions timeline for crew time allocated to science; the project margins analysis reports for resources allocated to scientific objectives (power, thermal, mass, stowage), and Architecture capabilities (such as communications, surface transportation). The analysis shall be considered successful when it shows that there is (TBD-001-323) positive margin for each of the resource allocations.

Rationale: Mission resource analysis will confirm sufficient mission resource margins for performing scientific tasks. Architecture capability assessment will confirm that *the vehicle will provide all the support services that will be needed for completion of scientific tasks.*

[CA0013V-HQ] Landing at designated lunar surface locations for Lunar Sortie missions shall be verified by inspection. The inspection shall consist of a review of verification results for child requirements: CA0032, CA0033, CA0046, CA0207, CA0287, CA0529, CA3141, and CA3286. The verification shall be considered successful when the inspection of the verification results shows the Architecture can provide the capability to perform human Lunar Sortie missions to any designated location on the lunar surface.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

Draft **[CA0074V-PO]** (TBD-001-1032)

Rationale: (TBD-001-1032)

[CA0202V-PO] The ability of the Constellation Architecture to perform lunar surface EVAs shall be verified by inspection, analysis, demonstration, and test.

Inspections shall be performed on any appropriate IRDs to ensure compliance with the appropriate verification requirements contained within those documents.

The analysis shall prove that appropriate CA lunar surface systems can provide the following functions:

a. Ability for the crew to depress (external and internal to vehicle) and repress the lunar surface vehicle cabin (internal to vehicle).

b. Compliance to EVA specifications per CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification, Section (TBD-001-703).

c. Provide consumables to support full complement of EVA crewmembers.

d. Egress and ingress paths with pressure suits to and from the lunar surface vehicle.

e. Communication (voice, suit and biomed data).

The demonstration shall consist of the following:

a. Walk back tests subjected to the appropriate mission profile.

b. Interface tests with appropriate mockups and simulators.

c. Interface tests with tools and equipment.

The test shall consist of Constellation Architecture lunar surface EVA systems to show compliance with performance and functional requirements while being subjected to a representative environment.

The verification shall be considered successful when the inspection, analysis, test and demonstration shows that the appropriate Constellation Architecture systems meet functional and performance requirements.

Rationale: Inspections will ensure all children to this requirement, as well, as all appropriate Interface requirements have been successfully verified for compliance.

The analysis will assess all functions required to perform an EVA. It must determine that all of these functions can be successfully performed in the lunar environment without affecting the safety of the crew.

Tests and demonstrations will be performed in a simulated lunar environment and will utilize flight or flight-like hardware. The results of these tests and demos will be used to support and confirm the analysis.

Draft [CA0404V-PO] (TBD-001-1031)

Rationale: (TBD-001-1031)

Draft [CA0889V-PO] The capability to deliver crew to the surface of Mars and return to Earth shall be verified by inspection. The inspection shall review lower-level CARD allocated requirements verification closure and Hazard Analysis approval status for a specific Mars mission. The verification shall be considered successful when the inspection shows that all lower-level CARD allocated requirements were closed and all the integrated and system-level hazard reports were approved.

Rationale: Verification of this requirement is a roll-up of verification closures of allocated lower-level requirements, in accordance with the established traceability within the CARD, as well as a review of the Hazard Analysis to be sure it can be done safely.

[CA0892V-PO] The capability to deliver crew and cargo to the ISS and return to Earth shall be verified by inspection. The inspection shall review lower-level CARD allocated requirements verification closure and Hazard Analysis approval status for an ISS Design Reference Mission. The verification shall be considered successful when the inspection shows that all lower-level CARD allocated requirements were closed and all the Integrated and System-level hazard reports were approved.

Rationale: Verification of this requirement is a roll-up of verification closures of allocated lower-level requirements in accordance with the established traceability within the CARD as well as a review of the Hazard Analysis to be sure it can be done safely.

[CA6077V-PO] The Control Mass requirement for Flight Crew Equipment, EVA System and flight crew shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass.

The verification shall be considered successful when the total predicted mass of these components is less than or equal to the required Control Mass.

Rationale: NR

[CA6079V-PO] The Control Mass requirement for Flight Crew Equipment, EVA System equipment and flight crew shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of these components is less than or equal to the required Control Mass.

Rationale: NR

4.2.1 Mission Success

[CA0033V-HQ] Lunar Sortie LOM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Sortie is not greater than 1 in 20.

Rationale: NR

[CA0095V-PO] ISS Crew LOM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for an ISS Crew mission is no greater than 1 in 200.

Rationale: NR

[CA0097V-PO] ISS Cargo Mission LOM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for an ISS Cargo Mission is no greater than 1 in 200.

Rationale: NR

[CA0099V-PO] Lunar Outpost Crew LOM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows that the calculated mean value of LOM for a Lunar Outpost Crew is no greater than 1 in (TBD-001-034).

Rationale: NR

Draft **[CA3038V-HQ]** The Lunar Outpost Cargo LOM shall be verified by analysis. Analysis shall be performed in accordance with the CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows that the calculated mean value of LOM for a Lunar Outpost Cargo mission is not greater than 1 in (TBD-001-058).

Rationale: NR

Draft **[CA3039V-HQ]** The Mars LOM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Mars mission is not greater than 1 in (TBD-001-050).

Rationale: NR

4.2.2 Crew Survival

[CA0028V-PO] The ability of the Constellation Systems to return the crew to the Earth's surface independent of communications with Mission Systems shall be verified by inspection. The inspection shall consist of a review of verification results for child requirements. The verification shall be considered successful when the inspection of the verification results shows that the Constellation Architecture can return the crew to Earth independent of communications with Mission Systems during all mission phases.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

[CA0107V-HQ] The crew survival through each mission phase shall be verified by analysis. The analysis shall include engineering and safety disciplines, including propulsion, flight control, power, structures, aerothermal, and crew survival to assess potentially catastrophic failure scenarios, and review design features and techniques designated for maximizing the potential for crew survival. The verification shall be considered successful when the analysis shows that the designated crew survival requirements are correctly implemented and verified and the Architecture and System hazard reports capture all potential Loss of Crew scenarios and document the crew survival techniques employed.

Rationale: NR

[CA0172V-PO] The Constellation Architecture performing SAR operations following any day or night contingency landings shall be verified by analysis, test, and demonstration. The analysis shall consist of a review of documentation showing closure of the allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements and the MOU (TBD-001-382) between Cx and search organization(s) to confirm coordination for SAR support. Additional analysis shall consist of a review of CxP 72000, Constellation Program System Requirements for the Orion System for closure of crew survival capability for contingency landing to meet SAR time constraints.

The analysis shall consist of status review of allocated requirements (Orion provide visual aids, Orion provides communication with MS for 36 hours, GS rescues the crew within 24 hours, GS recovers Orion CM other than at designated landing site, GS performs SAR, and GS performs SAR independent of ambient lighting conditions), and MOU (TBD-001-382) between Cx and recovery force(s) to confirm coordination for support. The test shall consist of a drill within the range of Program facilities and utilizing ground recovery assets and personnel. The test will simulate both land and water SAR methods. The demonstration shall consist of exercising procedures in a paper simulation environment for SAR force deployment where the recovery is outside the range of Program facilities and staged ground recovery assets and personnel. This demonstration will utilize the test data as a guideline to perform the paper simulation. Analysis will confirm that agreements are in place and will demonstrate the ability to perform SAR functions. The verification shall be considered successful when the analysis determines that the allocated CxP 72000, Constellation Program System Requirements for the Orion System, CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements are closed, that there is Program agreement with Cx and rescue operation(s), and the test and demonstration results in the Ground Systems ability to perform a rescue following a landing outside of the designated landing sites, independent of ambient lighting conditions.

Rationale: NR

[CA0312V-PO] The capability for safe haven for the crew for at least 36 hours post touchdown on Earth, while awaiting rescue and retrieval shall be verified by inspection. The inspection shall consist of reviews of the children requirements allocated to CxP 72000, Constellation Program System Requirements for the Orion System and review of CxP 72002, EVA Systems Project System Requirements Document (SRD)) and CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document, CxP 70117, Constellation Program System Requirements for the Missions Systems (MS) Element, and CxP 72006, Ground Systems, Systems Requirements Document (SRD) The verification shall be considered successful when the inspection shows that CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document, CxP 72000, Constellation Program System Requirements for the Orion System, CxP 72002, EVA Systems Project System Requirements Document (SRD)), CxP 70117, Constellation Program System Requirements for the Missions Systems (MS) Element, and CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements are closed.

Rationale: NR

[CA6072V-PO] Suit loop pressure preservation during an external pressure leak shall be verified by analysis. The analysis shall use a modeled leak of an equivalent 6.4 (TBR-001-1433) mm (0.25 inch) diameter hole in the suit loop to show that the available gas resources and atmosphere control will maintain the suit loop volume at 15.4 (TBR-001-1431) kPa (2.2 psia) for 5 (TBR-001-1432) minutes. The verification shall be considered successful when the analysis shows that suit loop pressure is maintained at 15.4 (TBR-001-1431) kPa (2.2 psia) for 5 (TBR-001-1432) minutes.

Rationale: NR

[CA6073V-PO] The ability of Constellation Architecture to isolate to a single suit or umbilical from the rest of the suit loop within 5 (TBR-001-1432) minutes shall be verified by inspection. The inspection shall audit the verifications for [CA6074V-PO] and [CA6076V-PO]. The verification shall be considered successful when the inspection shows that the Constellation Architecture is capable of isolating a single suit or umbilical from the rest of the suit loop as specified.

Rationale: NR

4.2.2.1 Crew Survival Probabilities

[CA0032V-HQ] Lunar Sortie LOC shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for a Lunar Sortie is no greater than 1 in 100.

Rationale: NR

[CA0096V-PO] ISS Crew Mission LOC shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for an ISS Crew Mission is no greater than 1 in 1000.

Rationale: NR

[CA0474V-PO] Lunar Outpost Crew LOC shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for a Lunar Outpost Crew mission is no greater than 1 in (TBD-001-036).

Rationale: NR

Draft [CA3037V-HQ] The Mars LOC shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for a Mars mission is not greater than 1 in (TBD-001-054).

Rationale: NR

[CA5818V-HQ] Ascent abort LOC shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC is no greater than 1 in 10.

Rationale: NR

4.2.2.2 Emergency Egress, Aborts, and Early Return for Survivability

[CA0027V-PO] The Constellation abort capability shall be verified by inspection and analysis. The analysis shall include an examination of the integrated performance of the Constellation Architecture system from the Launch Pad to Mission Destination. The analysis shall be considered successful when it shows the Constellation Architecture has abort capability throughout all mission phases. The inspection shall consist of examining the abort verification documentation from the allocated requirements. The inspection shall be considered successful when the subordinate documentation shows that the success criteria for each requirement is met.

Rationale: Inspection is sufficient because the verification activity at the children requirement level is sufficient to verify the requirement. Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0310V-PO] Flight crew capability for unassisted emergency egress to a safe haven during pre-launch activities, within 4 (TBR-001-018) minutes, shall be verified by demonstration and analysis. The demonstration shall consist of performing two runs with two different sets of crewmembers and collecting the task time for crew egress from Orion and continued egress from launch structure to safe area at ground level. Analysis shall consist of performing an integrated examination to verify that the design does not hinder the means for crew or ground personnel to escape and clear the launch pad, in case of an emergency. The analysis will then apply a program approved extrapolation factor, as appropriate, and accounting for all practical anthropometric crew assignments. The verification shall be considered successful when the analysis determines that suited crew can perform an unassisted emergency egress during pre-launch activities, within 4 (TBR-001-018) minutes, starting from the initiation of the egress to the arrival of the last crewmember at the safe haven.

Rationale: NR

[CA0311V-PO] The ability of the Constellation Architecture to provide for eight (TBR-001-962) ground personnel emergency egress to a safe haven from the launch pad within (TBD-001-252) minutes shall be verified by inspection. Inspection shall consist of the review of the allocated 3.7 children requirements. Verification shall be considered successful when the allocated 3.7 children verification requirements are closed and meet eight (TBR-001-962) ground personnel emergency egress to a safe haven from the launch pad within (TBD-001-252) minutes.

Rationale: NR

[CA0352V-HQ] The ability of the Constellation Architecture to return the crew within 132 hours shall be verified by inspection and analysis. The inspection shall consist of examining the abort verification documentation from allocated requirements. The analysis shall assess the start-up and execution of all the necessary LSAM and Orion processes to return the crew to Earth. The inspection shall be considered successful when the subordinate documentation shows that the total time for all system allocations is not greater than 132 hours. The analysis shall be considered successful when the consolidated timeline is no greater than 132 hours.

Rationale: Inspection is needed to verify the children requirement levels are sufficient to meet the requirement. Analysis is needed to assess the integrated timeline.

[CA0530V-PO] The ability of the Constellation Architecture to return the crew without permanent disability to Earth, from every point in the mission in the event of a non-recoverable cabin depressurization, shall be verified by inspection. The inspection shall consist of status review of requirement CA0532-PO, CA4154-PO, CA3108-PO, CA3106-PO, CA3105-PO, CA3140-PO, CA3058-PO, CA3003-PO, CA5659-PO, CA5191-PO, CA5193-PO, CA3194-PO, CA3181-PO, and CA3107-PO. The verification shall be considered successful when the inspection shows that the requirements within CARD Section 3.7.1, 3.7.3, 3.7.9 are closed.

Rationale: This is an overarching architecture (multiple projects) parent requirement that is not reasonably verified by an integrated demonstration. The requirements listed here account for the complete set of flow-down requirements necessary to meet this architecture requirement, so satisfying those parts will satisfy the whole. Verification of the individual flow-down requirements to CARD 3.7 Systems, as specified in the requirement, should verify the systems and the interfaces between those systems have been properly designed to meet this contingency.

[CA3226V-PO] The capability to provide for Earth landing throughout all mission phases shall be verified by inspection. The inspection shall consist of a review of the allocated children requirement verification results. The verification shall be considered successful when the inspection shows closure of all allocated children requirement verifications.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

4.2.3 Crew Size

Draft **[CA0010V-PO]** The capability to transport six (TBR-001-082) crewmembers to the surface of Mars and return them to Earth shall be verified by analysis. The analysis shall include the following functions for all the transport vehicles in the transportation architecture: flight performance/upmass, center of gravity, ECLSS resources, thermal, HSIR verification for anthropometry, cockpit design, the capability to accommodate (physically in terms of space) six (TBR-001-082) crewmembers, plus, reconfiguration capability to cover in-between configurations and (TBD-001-637). Verification shall be considered successful when the analysis shows that Orion can perform the transportation of the specified number of crew within its performance limits.

Rationale: Analysis - The analysis must determine that the vehicle not only has sufficient room to physically accommodate six (TBR-001-082) crewmembers and their supplies (food, water, clothes, etc.) but that the vehicle has the flight performance to transport them to Mars and back; can provide the utilities (power, ECLS, etc.) required to support life; and also provides for the crew's well-being during a 6 month long journey (exercise, communication, recreation, etc.).

[CA0020V-HQ] The Constellation Architecture ability to provide for at least four (TBR-001-010) crewmembers per mission at the lunar outpost shall be verified by analysis. The analysis shall assess the Lunar Outpost design for atmosphere control and quality, potable water, atmosphere temperature, humidity and ventilation, food, body waste, and trash management provide a habitable environment, as specified in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR). The analysis will be supported by component and subsystem tests and analyses. The verification shall be considered successful when the analysis shows the Lunar Outpost provides a habitable environment for 4 (TBR-001-010) crewmembers per mission.

Rationale: Analysis - The analysis must determine that the Lunar Outpost not only has sufficient room to physically accommodate four (TBR-001-010) crewmembers and their supplies (food, water, clothes, etc.) but that the outpost can provide the utilities (power, Environment Control and Life Support [ECLS], etc.) required to support 4 (TBR-001-010) crewmembers; it also provides for the crew's well-being during the rotation period (exercise, communication, recreation, etc.).

[CA0203V-HQ] The capability to deliver crew sizes ranging from two to four to the lunar surface and return to Earth shall be verified by inspection. The inspection shall review lower-level CARD allocated requirements' verification closure and Hazard Analysis approval status for a Lunar Design Reference Mission. The verification shall be considered successful when the inspection shows that all lower-level CARD allocated requirements were closed and the Integrated and System-level hazard reports were approved.

Rationale: NR

[CA0388V-HQ] Constellation Architecture delivery/return crew size requirement shall be verified by inspection. The inspection shall confirm closure of the Orion crew size requirement. The verification shall be considered successful when the inspection shows that the Orion crew size is zero through six.

Rationale: Currently, this Level II verification will require that Orion has and properly closes a Level III crew size requirement of zero through six.

4.2.4 Cargo Delivery and Return

Draft **[CA0002V-HQ]** The Constellation Architecture Mass Delivered requirement to the lunar surface for uncrewed Lunar Outpost Cargo missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the calculated Mass Delivered capability of the Constellation Architecture is equal to or greater than the Mass Delivered requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0209V-HQ] The Constellation Architecture Mass Delivered requirement to the lunar surface for crewed missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when the analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Mass Delivered capability of the Constellation Architecture is equal to or greater than the Mass Delivered requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0211V-HQ] The Constellation Architecture Mass Returned requirement from the lunar surface to the Earth for crewed missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Mass Returned capability of the Constellation Architecture is equal to or greater than the Mass Returned requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA0212V-HQ]** (TBD-001-1033)

Rationale: (TBD-001-1033)

[CA0822V-HQ] The Constellation Architecture capability to provide return cargo volume of at least 0.075 (TBR-001-503) m3 (2.65 ft3) from the lunar surface to the Earth during each crewed lunar mission shall be verified by analysis. Analysis will consist of review of lunar ascent performance and LSAM weight and center of gravity repacking; it will be deemed successful when LSAM lift capability to return at least 0.075 (TBR-001-503) m3 (2.65 ft3) of cargo from the lunar surface to the LLO and Orion performance capability to return at least 0.075 (TBR-001-503) m3 (2.65 ft3) to Earth is confirmed.

Rationale: The analysis must take into consideration the volume in the LSAM available after all return mission objectives and crew requirements are accounted for, the ability to transfer the required volume of payloads from the LSAM to Orion; and the available volume in Orion after the return mission objectives and crew requirements are accounted for.

Draft **[CA0823V-PO]** (TBD-001-1034)

Rationale: (TBD-001-1034)

4.2.5 Mission Rates and Durations

[CA0036V-PO] The ability of the Constellation Architecture to provide a flight rate which will sustain the ISS and Human exploration programs shall be verified by inspection. Inspection shall determine that each individual system of the Constellation Architecture has closed their respective flight rate requirement. Verification shall be considered successful when inspection determines each system has successfully closed its respective flight rate requirement.

Rationale: Analyses will be performed at the System/Project that will determine the ability of the individual pieces of the CxP Program to meet their respective flight rate requirements. The production, assembly, testing, etc of the vehicles along with the capability of the Ground and Mission Systems to integrate, launch, and operate the different mission configurations will be assessed at the appropriate levels. An inspection of the results of the success completion these lower level verification activities will provide sufficient evidence that the CxP complies with this requirement.

Draft **[CA0047V-PO]** (TBD-001-1036)

Rationale: (TBD-001-1036)

Draft **[CA0073V-HQ]** (TBD-001-1035)

Rationale: (TBD-001-1035)

[CA0207V-HQ] Round-trip Lunar Sortie missions with lunar surface duration of 7 days shall be verified by analysis. The analysis shall consist of a review of mission consumables, timeline and system capabilities. The verification shall be considered successful when the analysis shows that the system capabilities, mission timeline, and consumables satisfy round-trip Lunar Sortie mission objectives with lunar surface duration of 7 days.

Rationale: NR

Draft **[CA5289V-PO]** The Constellation Architecture ability to support Lunar Outpost mission for surface durations of at least 210 (TBR-001-039) days shall be verified by analysis. The analysis shall assess the Lunar Outpost design for atmosphere control and quality, potable water, atmosphere temperature, humidity and ventilation, food, body waste, and trash management provide a habitable environment, as specified in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).

The analysis will be supported by component and subsystem tests and analyses. The verification shall be considered successful when the analysis shows the Lunar Outpost provides a habitable environment for the full crew complement for a duration of at least 210 (TBR-001-039) days.

Rationale: This analysis must determine that the Lunar Outpost has sufficient room to physically accommodate crewmembers and their supplies (food, water, clothes, etc.), can provide the required life support utilities (power, ECLS, etc.) and also provides for the crew's well-being (exercise, communication, recreation, etc.) for at least 210 days. This analysis shall be supported by test and analyses performed to verify compliance of the children of this requirement, as well as all appropriate interface requirements.

[CA6102V-PO] The ability for the Constellation Architecture to provide launch opportunities for 4 consecutive days for Ares V missions shall be verified by analysis. The analysis shall assess the Integrated Logistics Support Plan, the Integrated Logistics Support Analysis Report, ground processing plans, Logistics Support Analysis Records (LSAR), and other documents that include launch recycle tasks and activities associated with Ares V missions in order to calculate the time and resources required to perform launch tasks for 4 consecutive days. The verification shall be considered successful when the analysis results show that the Constellation Architecture can provide launch opportunities for at least 4 consecutive days for Ares V missions.

Rationale: Analysis of the various plans and lower-level analysis reports is sufficient for verification work.

4.2.6 Architecture Definition

[CA0021V-PO] The ability of the appropriate Constellation Architecture systems to mitigate the effects of lunar dust shall be verified by analysis and test.

The analysis shall determine a predicted dust environment from certified models. The analysis shall determine the level of dust protection of equipment to preclude dust and to limit the transfer of dust. The analysis shall verify that the equipment meets functional performance requirements in the predicted dust environment.

The test shall verify that components and systems can meet performance requirements when subjected to the predicted dust environment.

Analysis and test shall be considered successful when the appropriate Constellation Architecture systems have shown they meet functional and performance requirements, subjected to lunar dust exposure.

Rationale: Analysis. The analysis must first establish the properties of the lunar dust, (amount, type, etc.) and then assess the ability of the lunar systems to function in the presence of the predicted lunar dust. Tests will simulate the lunar dust, apply the lunar dust environment to the lunar systems, and monitor the lunar systems abilities to perform in the presence of the lunar dust environment.

Draft **[CA0022V-HQ]** (TBD-001-600)

Rationale: (TBD-001-600)

[CA0029V-HQ] The Constellation Architecture's ability to safely dispose of exploration assets shall be verified by inspection. The inspection shall review the verification closure of the lower-level CARD allocated requirement. The verification shall be considered successful when the inspection shows that the lower-level CARD allocated requirement (CA0569-PO) has been closed.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

[CA0039V-HQ] The launch of US assets from within KSC/Eastern Range shall be verified by inspection. The inspection shall consists of reviews of documentation showing closure of the allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD), CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD), CxP 72000, Constellation Program System Requirements for the Orion System, CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD), and CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD)requirements. The verification shall be considered successful when the inspection of the flow-down requirements in CxP 72006, Ground Systems, Systems Requirements Document (SRD) CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD), CxP 72000, Constellation Program System Requirements for the Orion System, CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD), and CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD) shows that these documents are closed.

Rationale: NR

[CA0044V-PO] The capability to land at designated U.S. coastal landing sites shall be verified by inspection of relevant Orion analysis supporting Section 3.7 requirements verification, and Ground Systems analysis supporting CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD) requirements verification. Verification shall be considered successful when inspection shows completion of relevant CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD) verification processes.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

[CA0046V-PO] The ability of the Constellation Architecture to conduct Lunar Sortie missions so that surface stays are conducted during periods of lunar daylight shall be verified by analysis. The analysis shall review mission operation plans, injection window frequencies, launch scrub turnaround times, and element on-orbit lifetime requirements to ensure that Constellation Architecture has the necessary capability, planning, and physical opportunities to utilize lunar daylight. Verification shall be considered successful when the analysis determines that Lunar Sortie missions can be conducted during periods of lunar daylight.

Rationale: The ability of the Lunar Sortie missions to comply with operational lighting constraints will depend on injection window frequencies, launch scrub turnaround times, and element on-orbit lifetime limits. These factors should be accounted for and the sorties implemented, in accordance with the mission operation plans.

[CA0121V-HQ] The Earth Orbit Rendezvous (EOR) - Lunar Orbit Rendezvous (LOR) mission approach shall be verified by inspection. The inspection shall consist of review of the verification results for all children requirements for CA0121V-HQ listed in Appendix C. Verification shall be considered successful when inspection shows the completion of all relevant verification requirement closures.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

[CA0181V-HQ] The ability of the Constellation Architecture to perform Contingency EVA shall be verified by inspection.

The inspection shall consist of review of the following children requirements: Orion Contingency EVA Operation, Orion External EVA Translation Path, LSAM EVA translation paths, Orion lunar contingency capability, Orion ISS contingency capability, Orion Cabin depress, Orion Cabin repress, Orion depress capability external to vehicle, Orion egress path, Orion ingress path, Orion stabilization aids, EVA mobility, EVA Sustain Life, EVA System protect crew from environment, EVA System to provide crew stability, and CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification.

The verification shall be considered successful when the inspection shows that the children requirements referenced in this requirement are closed.

Rationale: This is an overarching architecture (multiple projects) parent requirement that is not reasonably verified by an integrated demonstration, especially considering this is a mission success unscheduled situation. Verification of the individual flow-down requirements, as specified in the requirement, should verify the systems and the interfaces between those systems are sufficient to account for this unscheduled situation.

[CA0281V-HQ] The accomplishment of crewed lunar missions with two launches consisting of one Ares V/LSAM launch and a separate Ares I/Orion launch shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the crewed lunar missions can be accomplished using two launches, one Ares V and one Ares I.

Rationale: For the inspection portion of the verification, the verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

Draft [CA0287V-PO] (TBD-001-651)

Rationale: (TBD-001-651)

[CA0316V-PO] Verification of the docking mechanism shall be by inspection. The inspection shall consist of a review of the final design documentation. Success criteria for this requirement shall be when the review of all of the Level III design documentation shows compliance with design requirements.

Rationale: Level II review of the Level III Design documentation should be sufficient to verify that the docking mechanism has been implemented correctly.

Draft [CA0353V-PO] (TBD-001-1038)

Rationale: (TBD-001-1038)

Draft [CA0405V-HQ] The capability of the Constellation Architecture to support Lunar Outpost crew rotation with one cargo launch shall be verified by analysis. The analysis shall consist of a review of the Constellation Architecture Lunar cargo delivery capacity. The analysis shall be considered successful when the Lunar cargo delivery capacity satisfies the required cargo to support the maximum number of crewmembers.

Rationale: Analysis is required to determine if the mission design can meet this requirement.

Draft [CA0407V-PO] (TBD-001-1039)

Rationale: (TBD-001-1039)

Draft [CA0465V-HQ] (TBD-001-1065)

Rationale: (TBD-001-1065)

[CA3175V-PO] The ability of the Constellation Architecture to perform unscheduled EVA shall be verified by inspection.

The inspection shall consist of review of the following children requirements: CA3140 (Orion depress/repress), CA3166-PO (Orion Lunar EVA Capability), CA4127 (EVA System 2 EVAs), CA3167-PO (compliance with EVA Display and Controls [D&C]), CA5195 (LSAM EVA).

The verification shall be considered successful when the inspection shows that the children requirements referenced in this requirement are closed.

Rationale: This is an overarching architecture (multiple projects) parent requirement that is not reasonably verified by an integrated demonstration, especially considering *this is a mission success unscheduled situation. Verification of the individual flow-down requirements, as specified in the requirement, should verify the systems and the interfaces between those systems are sufficient to account for this unscheduled situation.*

[CA3184V-PO] The delivery of the crew and cargo from the Earth to ISS using the Ares I and Orion shall be verified by inspection. The inspection shall consist of a status review of the child requirement CA3202-PO (The Ares I shall launch the Orion from the launch site to the Ascent Target) and a status review of CA0191-PO (Orion shall perform the orbit transfer from the Ascent Target to ISS). The verification shall be considered successful when the inspection of the analysis results of these requirements show the vehicle successfully achieves the required orbit and satisfies the RPOD requirements of CxP 70031, Constellation Program Orion -to- International Space Station (ISS) Interface Requirements Document (IRD), closing these requirements.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

Draft [CA3211V-PO] The utilization of a direct insertion mission approach for Lunar Cargo Missions shall be verified by inspection. The inspection shall include a review of the mission design and the children requirements listed in Appendix E, Requirements Traceability Matrix (RTM). The verification shall be considered successful when the inspection shows that the Constellation Architecture utilizes a direct insertion mission approach for Lunar Cargo Missions.

Rationale: Verification of this requirement is a roll-up of verification closures of allocated lower-level requirements, in accordance with the established traceability within the CARD.

Draft [CA3214V-PO] The utilization of the Ares V to launch cargo into (TBD-001-368) Earth Orbit for Mars missions shall be verified by inspection. The inspection shall examine the analysis results necessary to verify requirement CA3215-PO (The Ares V shall launch cargo into a (TBD-001-368) Earth orbit for Mars missions). The verification shall be considered successful when the inspection of the analysis results shows the Ares V can successfully deliver the Mars cargo into (TBD-001-368) Earth orbit and the requirement CA3215-PO has been closed.

Rationale: The verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

Draft [CA5247V-PO] (TBD-001-1037)

Rationale: (TBD-001-1037)

4.2.7 Safety (System, Public, and Planetary)

[CA0100V-HQ] Protection of public, personnel and property during ascent and entry phases shall be verified by inspection and analysis. The inspection shall consist of review of the applicable sections of CxP 72000, Constellation Program System Requirements for the Orion System, CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD), CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD), CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD), CxP 70117, Constellation Program System Requirements for the Missions Systems (MS) Element and CxP 72006, Ground Systems, Systems Requirements Document (SRD)The analysis shall consist of an integrated assessment of the generic launch and entry vehicles Expectation of Casualty (Ec) and Probability of Casualty (Pc) to public and personnel and Probability of Impact (Pi) to property during ascent and entry phases. Inspection will be considered successful when verification closures in the CxP 72000, Constellation Program System Requirements for the Orion System , CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD), CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD), CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD), CxP 70117, Constellation Program System Requirements for the Missions Systems (MS) Element and CxP 72006, Ground Systems, Systems Requirements Document (SRD) are closed. Analysis shall be considered successful when:

a. The host ranges' Range Safety Managers, the Agency Range Safety Manager, and the CxP Range Safety Manager have reviewed and approved that the generic integrated launch and flight vehicles designs meet the Preface and sections 1.1-1.2, 1.3.7, 1.4, 2.1, 2.3-2.4, 3.1-3.2, 3.3-3.4, and Appendix A (TBD-001-263) of NPR 8715.5, Range Safety Program, and the host ranges' range safety requirements as tailored for the CxP launch and entry vehicles (e.g., the AFSPCMAN 91-710(T)).

b. All of the Constellation Architecture and each entry range entity interface agreement in accordance with CxP 70159, Constellation Program Support Requirements Document have been satisfied.

Rationale: NPR 8715.5, Range Safety Program, provides risk guidelines, a process and methodology of calculating Expectation of Casualty (Ec), Probability of Casualty (Pc), and Probability of Impact (Pi), and a process for accepting risk levels above the guidelines.

[CA0213V-PO] Control of critical hazards shall be verified by analysis. An integrated hazard analysis shall be performed, in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology, using system level hazard Analyses and FMEA/CIL to show compliance with the approved hazard controls. The verification shall be considered successful when the analysis shows that critical hazards are controlled and all DFMR items approved in the Constellation Hazard Reports.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure mission success.

[CA0214V-PO] Failure tolerance for catastrophic hazards shall be verified by analysis. An Integrated hazard analysis shall be performed, in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology, using system-level hazard analyses and FMEA/CIL to show compliance with the approved level of failure tolerance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled with the approved number of controls and all DFMR items are approved in the Hazard Reports.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

[CA0215V-PO] The separation or protection of redundant systems shall be verified by analysis. The analysis shall review System-level FMEA/CILs for compliance with JPR 8080.5, JSC Design and Procedural Standards, Section G-2. The verification shall be considered successful when the integrated analysis shows that redundant systems are separated or protected.

Rationale: Verification for this requirement will be performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology and CxP 70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology documents. It looks top down and bottoms up at the system level.

[CA0569V-PO] Verification of Constellation disposal of expendable modules and orbital debris shall be by analysis. Analysis shall determine which pieces of Constellation can be considered expendable because they will be destroyed during re-entry and what orbital debris will be generated by the separation of expendable modules. The analysis shall be performed using NASA-accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, drag, heating, and environmental parameters of the various pieces. The simulation shall also model the breakup of the modules and debris and shall estimate the likely ground footprint area within which the debris will fall. Verification shall be successful when analysis shows that Constellation and its expendable modules are designed to separate and be disposed/destroyed in accordance with NPR 8715.6, NASA Procedural Requirements for Limiting Orbital Debris.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5812V-HQ] GPS metric tracking data shall be verified by test and analysis. Testing shall be performed using flight assets, the CxP Ground Systems, Mission Systems, C&TN launch head assets, and USAF range assets prior to first Ares I flight demonstration launch from KSC. Analysis shall be performed using a NASA-accredited simulation for all nominal and off-nominal trajectories, modes, and variable ranges by simulating GPS signal inputs to the flight system. The verification shall be considered successful when the simulated tracking data accurately depicts the simulated GPS location data, and the tracking data received by the MS matches the ground-truth position data provided by independent ground-based radar tracking.

Rationale: Testing this function with flight and range assets provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions.

[CA6041V-PO] The ability of the Constellation Architecture to maintain a safe configuration, without the need for ground and crew interaction for a period of no less than 24 hours during quiescent flight mission phases following a single failure of any safety and mission critical function shall be verified by analysis and test. The analysis shall review the results of the System-level FMEA/CIL for two fault tolerance compliance and the integrated Hazard Reports for necessary controls or mitigations. The test shall be performed on the software and system to show backup capability to correct for single mission and safety critical failures. The verification shall be considered successful when the analysis and test show that catastrophic hazards are controlled by three or more combinations of software and hardware methods without the need for ground and crew action for a period of not less than 24 hours, non-redundant controls have been implemented, and all Design for Minimum Risk (DFMR) items are approved in the Hazard Reports with the supporting design and build data.

Rationale: Verification for this requirement will be performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology and CxP 70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology. These methodologies approach system level failure modes and management top down and bottoms up.

[CA6106V-PO] The recording of essential mission data by the Constellation Architecture for reconstruction of catastrophic events shall be verified by Demonstration. A demonstration shall be performed using flight equivalent units or emulators with flight software under simulated mission conditions over simulated links. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable critical data defined in (TBD-001-1403) document(s) shall be recorded. (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the critical data identified in (TBD-001-1403) document(s) is available for retrieval after experiencing a catastrophic event.

Rationale: A demonstration will show the capability of recording critical data for reconstruction of catastrophic events.

4.2.8 Command and Control

[CA0449V-PO] The capability of the Constellation Architecture to provide command and control per CxP 70072, Constellation Program Management Systems Plan (MSP) shall be verified by Analysis and Demonstration. An analysis of the command and control implementation, as documented in lower level specifications, shall be performed to show that the Constellation Architecture systems can accept and respond to commands from all controlling Constellation elements as identified in the N-squared chart. The analysis shall also provide the number of mission phases and scenarios to be used for the demonstration based on CxP 70007, Constellation Design Reference Missions and Operational Concepts. The demonstration shall consist of the transfer of commands across the integrated system using flight or flight-like components in the DSIL, including representative ground systems, for multiple mission phases and scenarios identified by analysis. The verification shall be considered successful when:

a. The analysis shows that commands transmitted across the Constellation Architecture will be received by the end-point per the N-squared chart and responses will be returned.

b. The demonstration shows that the command and control of systems by appropriate ground systems for all identified mission phases and scenarios using C3I protocols is established.

Rationale: CxP 70072, Constellation Program Management Systems Plan (MSP) is the defining document and will be complied with.

[CA5604V-PO] Performing concurrent operations of multiple vehicles shall be verified by analysis and demonstrations. The demonstrations shall be performed using flight equivalent units or emulators with Flight Software in simulated mission conditions (ISS Crew Rotation, Lunar Sortie and Lunar Outpost). The demonstrations shall utilize an end-to-end data flow that exercises major functionalities of concurrent Constellation vehicles and mission operations. This requires the ability to efficiently manage multiple missions and flight systems concurrently and to uniquely and unambiguously identify and control the individual vehicles. Valid commands to multiple vehicles concurrently including at least some that are safety critical and file uplinks shall be used to verify forward links. Telemetry (H&S), voice, video, and command responses returned from those multiple vehicles concurrently, shall be used to verify the return link. The transmitted and received data as well as commands and applicable responses, shall be examined or compared. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The verification will be considered successful when the demonstration and the analysis of the data shows:

a. That Constellation Architecture is able to manage multiple missions and flight systems concurrently and

b. All transmitted commands, file uplinks, command responses, video, voice, and H&S packets are:

    1. Provided by all applicable Cx systems

    2. Received by the correct system

3. Shown to be correct (contain expected values)
4. Completed for each mission phase

Rationale: Demonstrations that are specific to the system and its characteristic data are needed. Scenarios should reasonably exercise the capability of the demonstrated system. For traffic analysis, the system may be loaded by C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate in order to stress the demonstrated system data transmission and receipt capabilities ("Busy hour scenario"). All data types supported by the demonstration system should be exercised. For systems with communications links, demonstrations should use the C3I interoperability specification. Demonstrations should use the on orbit simulated anticipated transmission latency and noise levels.

4.2.9 Health and Status

[CA0216V-PO] The provision of fault detection, isolation and recovery by the Constellation Architecture shall be verified by Demonstration. The Demonstration shall use integrated Constellation systems in simulated mission conditions. (Exhaustive verification [tests] of lower level fault processing requirements is not required since this will have been accomplished by lower level testing.) These documents will contain a subset of the faults, identified by the Constellation Systems, which have been selected by CxP for verification. The Demonstration shall induce the identified faults and fault scenarios in (TBD-001-268) document(s) for applicable simulated mission phases, states, and modes for each Constellation System involved in that phase. The verification shall be considered successful when the Demonstration shows that applicable faults and fault scenarios identified in (TBD-001-268) document(s) have been:

a. Detected by each affected Constellation system,
b. Isolated by each affected Constellation system,
c. Recovered from by each affected Constellation system.

Rationale: At Constellation Level II, a Demonstration of the provision of fault detection, isolation and recovery:

a. Defined by (TBD-001-268) document(s)

b. By applicable Constellation systems

c. For each mission phase, state and mode

d. Using integrated Constellation systems in simulated mission conditions is sufficient to verify this capability

When the verification begins at the Constellation level, FDIR processing will have been verified at the lower level by detailed test and analysis. A Demonstration that FDIR processing for the integrated system agrees with the documented FDIR *processing specified in (TBD-001-268) document(s) for the Constellation systems is required.*

The (TBD-001-268) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process, which specifies the faults to be detected, isolated, and recovered from.

[CA0217V-PO] The provision of Health and Status data by the Constellation Architecture to Constellation systems and crew shall be verified by Demonstration.

The Demonstration shall use integrated Constellation flight systems in simulated mission conditions. (Exhaustive verification [tests] of each H&S parameter are not required since this will have been accomplished by lower level testing.) The demonstration shall include each mission phase, states, and modes which will be simulated for both nominal and off-nominal conditions.

Health and Status data for each Constellation systems are defined in (TBD-001-372) document(s).

For each mission phase, Health and Status data shall be obtained for and from each Constellation system involved in that mission phase. This shall involve the inclusion of C3I requirements for sending, receiving, and storing data. Crew surrogates in Constellation systems, which will house or carry crew shall observe Health and Status data from each Constellation system involved in that mission phase.

The verification shall be considered successful when the demonstration shows that the Health and Status data identified in (TBD-001-372) document(s):

a. Health and Status is provided for each Constellation system.

b. Health and Status is obtained by each Constellation system.

c. Health and Status is observed by crew surrogates in each Constellation system which will house crew.

d. Health and Status is provided and obtained in each mission phase, state and mode.

e. Health and Status agrees with the actual health and status of the Constellation systems involved in the demonstration.

Rationale: At Constellation Level II, a demonstration of the provision of the Health and Status data:

a. Defined by (TBD-001-372) document(s)

b. For each Constellation system

c. To each Constellation system

d. To crew surrogates in each Constellation system which will house crew *e. For each mission phase, state and mode for both nominal and off-nominal conditions*

f. Using integrated Constellation flight systems in simulated mission conditions is sufficient to verify this capability

When the verification begins at the Constellation level, H&S data will have been verified at the lower level by detailed test and analysis. A demonstration that the H&S data for the integrated system agrees with the actual Health and Status of the Constellation systems is required.

The (TBD-001-372) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the Health and Status parameters for each Constellation system.

[CA6050V-PO] The monitoring of the status of safety inhibits shall be verified by analysis and test. Analysis shall identify the safety inhibits associated with functions whose inadvertent operation has catastrophic hazard potential and determine if each inhibit is designed to be monitored by the Constellation Architecture. Each of these identified safety inhibits shall be tested to show that the correct status of the inhibit can be determined by the Constellation Architecture. Verification shall be considered successful when the analysis determines safety inhibits associated with functions whose inadvertent operation has catastrophic hazard potential are designed to be monitored and testing shows that the status of these safety inhibits can be monitored by the Constellation Architecture.

Rationale: NR

4.2.9.1 Inhibit Monitoring Reliability

[CA6051V-PO] Verification that monitoring the status of a safety inhibit does not reduce the reliability of that inhibit or compromise the safety of the function being monitored shall be by analysis. Analysis shall identify additional failure modes and safety hazards resulting from the monitoring design and operation and then determine their impacts on the reliability of the inhibit and the safety of the function being monitored. Verification shall be considered successful when the analysis determines that neither the reliability of an inhibit is reduced nor the safety of the function is compromised due to monitoring.

Rationale: NR

4.2.10 Communications and Communications Security

[CA0296V-HQ] The communication capabilities of the Constellation Architecture shall be verified by Test and Analysis.

Tests on flight or flight-like components shall be performed under simulated conditions using Systems Integrated Laboratory (SILs) and available flight communications links to show that Point to point and end-to-end communication is possible between all systems with IRDs. Every type and format of data, as expressed in the associated IRD, shall be tested to show that all data are interchanged in accordance with the governing IRD. An analysis of the architecture planned shall be performed for systems that communicate through multiple links. Analysis shall be used to determine appropriate link margins required by mission phase as part of the testing criteria and with data capture tools to show that appropriate communications protocol and data format are being followed. Analysis shall also be used to determine that the full system can meet the data architecture transmission volume requirements.

The verification shall be considered successful when the analysis and testing find that all of the systems can communicate, as required by IRD's in accordance with the C3I specification for the link class.

Rationale: Specifics for communications classes are specified in the C3I compatibility specification. The actual interfaces between any two systems are set forth in separate IRDs. These include hardline and RF communications links. Systems broadcasting as part of the Constellation Architecture shall conform to the broadcasting portion of the C3I specification. It is expected that the communication capabilities might degrade with load on the overall system. The C3I specification covers response to oversubscription by link class. Analysis can be used to aggregate the results of the lower level tests to predict system throughput and simulations can be used to prove those numbers.

[CA0476V-PO] The ability of the Constellation Architecture to support simultaneous communication between at least six systems during ISS phase operations shall be verified by analysis and testing. Analysis of the Constellation Architecture data links shall be performed on a representative configuration of vehicles and Ground Systems. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links. Following the mission timeline, multiple system communications scenarios shall be identified by analysis. Each of these sets of interconnected systems shall be tested using flight or flight-like components with nominal IRD-derived loads of half, maximum, and overload rates to verify that communication among all of the systems can occur simultaneously, as required.

The verification shall be considered a success when:

a. Testing shows the system can simultaneously exchange data at the tested rates of the links in accordance with the operational scenarios without apparent degradation

b. Analysis shows that no degradation is predicted if the test time were indefinite

c. Analysis shows that forward and received link margins are sufficient to support communication at nominal distances for the representative systems

d. Degradation of data transfer is in accordance with the priority policy described in the operational scenario

Rationale: Tests will require development of scenarios that reasonably exercise this capability of the as-built system. The system will need to be loaded with systems transferring information at allocated bandwidth to verify the architecture operation and up to their maximum rate to stress test the architecture in overload conditions (subscription overload). Representative data types will be used to show that all types are supported sufficiently well. Test durations will be typically short (minutes rather than hours) with the exception of overload testing which will exercise buffers. As-built information will be used to load and overload any buffers.

[CA0993V-PO] Recording of Constellation Architecture system-generated digital data shall be verified by Analysis.

An analysis shall be conducted across the Constellation Architecture to determine the sources of data and the provision of recording systems. The analysis shall be conducted for nominal and intermittent data links.

The verification shall be considered successful when the analysis shows that Constellation Architecture system-generated digital data is routed to a recording device on a vehicle or on the ground for nominal and intermittent data links.

Rationale: Data storage using a common standard is critical to support development, test, operation, and maintenance of systems.

[CA3007V-PO] The provision of data reconfiguration by the Constellation Architecture shall be verified by Analysis and Demonstration.

The Analysis shall evaluate mission scenarios and identify at least three mission phase transition activities where data reconfiguration is required. A Demonstration shall be performed by each of the identified reconfiguration activities to show that the configuration can be modified to meet the new mission objectives. The demonstration shall be performed on flight assets in the DSIL. Commanding shall be performed from a system other than the one being changed.

The verification shall be considered successful when the analysis identifies at least three mission scenarios where data reconfiguration is required and when the demonstration shows:

a. Reconfiguration data is transmitted from the non-changed system

b. The changed system accepts and implements the reconfiguration data

c. The new mission objectives are met

d. At least three mission phase transitions are successfully accomplished.

Rationale: Data reconfiguration is a critical tool in providing a robust and adaptable architecture. Demonstration of identified (analyzed) mission phase transition activities will provide additional risk reduction to ensure the architecture is implemented correctly. This verification is supported by lower level verification activities.

[CA3021V-PO] The capability of the Constellation Architecture to provide access to system digital data, as specified in the requirement, shall be verified by demonstration.

The demonstration shall consist of the authorization, transfer, storage, and local retrieval and display of digital data across the integrated system using flight or flight-like components in the DSIL, including representative ground systems, for:

a. Three mission phases

b. Retrieval of stored data from two remote systems by a ground system

c. Voice and video from a simulated lunar mission for at least one hour

d. Simulated data flow between ISS and one Cx system (e.g. Orion) In each case, the demonstration shall include attempts to establish links for the storage and the display of data by authorized and non-authorized users

The verification shall be considered successful when the demonstration shows:

a. Distributed communication between systems for three mission phases is established

b. Data stored on two remote systems is retrieved from a ground system

c. Data stored on one ground system is retrieved from another ground system

d. Voice and motion imagery data from a simulated lunar mission for one hour is received at the ground station

e. Data exchange between ISS and one Cx system is established

f. Access by non-authorized users is not successful

g. Data transfers are established using C3I protocols

Rationale: Access to data across the Constellation Architecture is required to develop, test, operate, and maintain systems. This verification is supported by lower level child requirement verifications and verifications for C3I Specification requirements, which require more rigor.

[CA3043V-PO] The Constellation Architecture end-to-end communications Packet Loss Rate (PLR) of not greater than 1 E-5 (TBR-001-105) given 1500 byte packets shall be verified by analysis. Analysis shall be conducted on the architecture to identify end-to-end links for assessment, and consequently, identifying the individual links for further analysis. Individual link performance characteristics from each identified end-to-end link shall be analyzed, given 1500 byte packets. The individual link performance data shall then be combined to determine the end-to-end PLR for each identified end-to-end link. The verification shall be considered successful when the analysis determines each identified end-to-end link PLR is less than 1 E-5 (TBR-001-105) given 1500 byte packets.

Rationale: Analysis of individual link performance rolled up to provide end-to-end performance is required since testing in flight conditions will not be possible prior to flight.

[CA3051V-PO] Implementation of multi-hop communications among Constellation Architecture Systems shall be verified by Demonstration.

The demonstration of end-to-end communication by systems using retransmission through an intermediate system shall be performed on flight or flight-like systems using simulated space network paths in the DSIL. Valid commands and file uplinks shall be used to test forward links. Telemetry (H&S), voice, video, and command responses returned from the end point, shall be used to test the return link. Test objectives shall be developed using the lower level system IRD(s) to identify valid paths and test data. Test objectives shall include multi-path relay scenarios to and from each system identified as an end-point and through each system required to implement data forwarding. All valid paths and routes shall be demonstrated. For each mission phase, testing shall be performed with every Constellation system involved in that mission phase. This demonstration can be performed in conjunction with the end-to-end verification of the data packets (command, video, etc.) used in the transmissions. Exhaustive testing of packet data content is not required.

Verification will be considered successful when the Demonstration shows all transmitted commands, file uplinks, command responses, video, voice, and H&S packets are:

a. Provided by all Cx systems

b. Routed through all valid routes and paths

c. Received by the correct system

d. Shown to be correct

e. Completed for each mission phase

Rationale: Systems need to intercommunicate even when not directly connected (e.g. the target system for a command may be behind the Moon as viewed from the Earth). This requirement requires systems to use other systems as intermediate relays to establish communications that would otherwise not be possible. DSIL tests will be used to test a wide range of integrated systems. Each system will alternately take the role of a communication end-point and, as required, a data forwarding system in the demonstrations. Multi-hop communication verification is supported by data forwarding and network management verification. When the verification begins at the Constellation level, all uplink and telemetry data will have been verified at the lower level.

[CA5065V-PO] The provision of audio and high resolution motion imagery by the Constellation Architecture to the public shall be verified by analysis and demonstration.

a. An analysis shall be conducted on the Constellation Architecture communications infrastructure, audio implementation, and motion imagery implementation for a comprehensive, representative set of mission scenarios. The analysis shall evaluate the sources and pathways for audio and motion imagery to determine if high definition motion imagery technology is implemented by the architecture to allow the audio and high resolution imagery to be routed to the ground and made available for release to the public.

b. A demonstration using simulated space-originated audio and high resolution motion imagery shall be performed using flight and flight-like equipment for image generation and operational pathways and Ground Systems for transmission. The source signals shall be transmitted to a Ground System portion of the space-to-ground path using Constellation Architecture compliant systems. The source will be either live or recorded signals generated by flight or flight-like equipment. Monitoring of the audio and imagery signals shall be performed at the end-user site or patched to a monitoring system including commercially available consumer high-resolution television monitors.

The verification shall be considered successful when:

a. The analysis shows that the audio and high definition motion imagery is implemented and will be routed to ground for release for all identified mission scenarios.

b. The demonstration shows that the signals are able to be interpreted and viewed as high resolution motion imagery.

Rationale: The full end-to-end system for the entire architecture will not be available for testing before launch, so analysis on mission scenarios will be conduct plus a demonstration on a limited terrestrial configuration will be conducted. This verification is supported by other audio, motion imagery, and communication verifications.

[CA5817V-PO] Ensuring the privacy of all crew Health and Status data shall be verified by analysis and test. They analysis shall consist of a review that the Constellation Architecture vehicles, infrastructure, simulators, and MCCS facilities and facility systems used to ensure the privacy of all crew Health and Status data are built and certified. The testing shall consist of an end-to-end data flow that exercises major functionalities of the tools and systems used to ensure the privacy of all crew Health and Status data. The vehicles, infrastructure, simulators, and MCCS will be identified and characterized in the CxP 70096, Constellation Program System Requirements for the Crew Exploration Vehicle (CEV) Element, CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD), CxP 72136, Mission Systems System Requirements Document, CxP 70118-06, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 6: Mission Systems (MS), CxP 70029, Constellation Program Orion to Missions Systems (MS) Interface Requirements Document (IRD) and CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -to- Mission Systems (MS) Interface Requirements Document (IRD). The verification shall be considered successful when the analysis shows that all of the Constellation Architecture vehicles, infrastructure, simulators, and MCCS facilities, and facility systems are ready to ensure the privacy of all crew Health and Status data.

Rationale: Analysis of the implementation is used to show general compliance to proper handling of private data. Testing is used to show functionality and that access is limited to authorized users.

[CA5820V-PO] The provision of imagery of mission critical and safety related events by the Constellation Architecture shall be verified by analysis and demonstration.

An analysis shall be conducted on the Constellation Architecture for the acquisition and distribution of imagery. The analysis shall evaluate acquisition of imagery for mission critical and safety related events based on system risk evaluation, for at least two flight systems. The analysis shall also evaluate the Constellation Architecture's capability to deliver imagery for identified events to Mission Systems when needed (e.g. real-time, non-real-time). A demonstration shall be performed to evaluate distribution of imagery from at least two flight systems using flight or flight-like assets, to the Mission System, using a simulated Constellation Architecture communication system.

The verification shall be considered successful when:

a. The analysis shows that the acquisition and distribution of imagery for identified mission critical and safety related events to Mission Systems will occur on a timely basis (e.g. in real time for identified time critical events) for at least two flight systems.

b. The demonstration shows that transmitted imagery from at least two flight systems is received by the Mission System and the imagery is recognized to be correct.

Rationale: The full end to end system for the entire architecture will not be available for testing before launch, so analysis will be conducted, plus a demonstration on a limited configuration will be conducted. This verification is supported by other imagery and communication verifications.

[CA5821V-PO] The distribution of mission data by the Constellation Architecture to authorized external entities shall be verified by analysis and demonstration.

An analysis shall be conducted on the Constellation Architecture data distribution services for external user sites. The analysis shall evaluate physical access to mission data by user sites and authorization for access to mission data by external users. A demonstration shall be performed to evaluate access to mission data by a simulated external user. The demonstration shall include attempts to access data by a non-authorized user.

The verification shall be considered successful when the analysis shows that physical access to mission data by external user sites for authorized users is present, and when the demonstration shows that mission data is accessed by authorized users at the simulated external site, and access is not allowed for non-authorized users.

Rationale: Analysis of access is required to show compliance with limited access to authorized users. Demonstration is used to show functionality.

[CA6065V-PO] The ability of the Constellation Architecture to support simultaneous communication between at least (TBD-001-1313) systems during lunar phase operations shall be verified by analysis and testing. Analysis of the Constellation Architecture data links shall be performed on a representative configuration of vehicles and Ground Systems. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links. Following the mission timeline, multiple system communications scenarios shall be identified by analysis. Each of these sets of interconnected systems shall be tested using flight or flight-like components with nominal IRD-derived loads of half, maximum, and overload rates to verify that communication among all of the systems can occur simultaneously, as required. The verification shall be considered a success when:

a. Testing shows the system can simultaneously exchange data at the tested rates of the links in accordance with the operational scenarios without apparent degradation

b. Analysis shows that no degradation is predicted if the test time were indefinite

c. Analysis shows that forward and received link margins are sufficient to support communication at nominal distances for the representative systems

d. Degradation of data transfer is in accordance with the priority policy described in the operational scenario

Rationale: Tests will require development of scenarios that reasonably exercise this capability of the as-built system. The system will need to be loaded with systems transferring information at allocated bandwidth to verify the architecture operation and up to their maximum rate to stress test the architecture in overload conditions (subscription overload). Representative data types will be used to show that all types are supported sufficiently well. Test durations will be typically short (minutes rather than hours) with the exception of overload testing which will exercise buffers. As-built information will be used to load and overload any buffers.

[CA6105V-PO] The capability of CA systems to perform ascent navigation and communications using space-based communications and tracking infrastructure and DoD C-band radars shall be verified by analysis. The analysis shall be accomplished in a NASA-accredited simulation facility that can accurately simulate the navigation and communication interfaces between the space-based communications and tracking infrastructure, DoD C-band radars, and the CA systems. This hardware-in-the-loop simulation shall be done in an integrated avionics testbed using flight or flight-like CA system navigation and communication component hardware, where schedule and cost impacts are appropriate. The analysis shall be considered successful when the performance criteria for navigation and communication capabilities using the space-based communications and tracking infrastructure and DoD C-band radars, as specified in the CA system level SRD’s, have been met.

Rationale: NR

[CA6210V-PO] Verification shall be performed by test and analysis. Verification of each system's allocation of end-to-end latency shall be performed by testing the system under simulated, flight/mission-like conditions. Analysis shall be performed to determine the maximum free-space propagation delay between systems based on selected communications assets and the planned mission trajectories.

Rationale: Testing system performance is a reasonable way to confirm that they are individually meting their allocations. RF propagation delay can only be verified by analysis as each mission profile will have different trajectories and flight paths.

4.2.11 Guidance, Navigation, and Control

[CA0314V-PO] The ability of the Constellation Architecture to perform RPODU independent of lighting conditions shall be verified by inspection. The inspection shall consist of a review of the verification results of the children SRD requirements allocated to Orion and LSAM. The verification shall be considered successful when the inspection review shows the CA can perform RPODU independent of lighting conditions.

Rationale: The work performed at the child requirement level should be complete to verify the requirement. Flight-like interfaces and hardware facilities will be used for the child requirement verification activity, and the results inspected and confirmed.

Draft **[CA0356V-PO]** The Constellation Architecture landing position accuracy on the lunar surface shall be verified by analysis. The analysis shall be accomplished using a NASA-accredited dynamic simulation of the Constellation Architecture systems. The dynamic simulation and analysis shall verify the landing position accuracy on the lunar surface by taking error data from component level navigation sensor testing and processing this data with a dynamic model of the lunar orbit dynamics during descent and landing. The verification shall be considered successful when the analysis and simulation has shown that the accuracy criteria (TBR-001-012) for landing on the lunar surface has been met.

Rationale: NR

Draft **[CA0529V-PO]** The Constellation Architecture landing position accuracy on the lunar surface shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The dynamic simulation and analysis shall verify the landing position accuracy on the lunar surface by taking error data from component level navigation sensor testing and processing this data with a dynamic model of the lunar orbit dynamics during descent and landing. Verification shall be considered successful when analysis and simulation shows a 99.73% probability with a "consumer's risk" of 10% of achieving the required landing position accuracy.

Rationale: NR

Draft **[CA0826V-PO]** The Constellation Architecture EVA crew and rover location accuracy on the lunar surface shall be verified by analysis. The analysis shall be accomplished using a NASA-accredited dynamic simulation of the Constellation Architecture systems. The dynamic simulation and analysis shall verify the EVA crew and rover location accuracy on the lunar surface by taking error data from component level navigation sensor testing and processing this data with a dynamic model of EVA elements and rovers in the lunar surface environment. The verification shall be considered successful when the analysis and simulation has shown that the accuracy criteria (TBD-001-097) and latency criteria (TBD-001-187) for EVA crew and rover location have been met.

Rationale: NR

Draft **[CA3141V-PO]** The Constellation Architecture determination of stationary element location accuracy on the lunar surface shall be verified by analysis. The analysis shall be accomplished using a NASA-accredited dynamic simulation of the Constellation Architecture systems. The dynamic simulation and analysis shall verify the accuracy of stationary element location on the lunar surface by taking error data from component level navigation sensor testing and processing this data with a dynamic model of the landed element. The verification shall be considered successful when the analysis and simulation has shown that the accuracy criteria (TBD-001-068) for stationary element location determination on the lunar surface has been met.

Rationale: NR

[CA5601V-PO] The manual control of flight path, attitude, and attitude rates of the crewed system of the CA shall be verified by inspection. The inspection shall consist of a review of verification activities of child requirements that include manual control activities. The verification shall be considered successful when the inspection results show the crew can perform manual control when the human can operate the system within vehicle margins.

Rationale: The work performed at the child requirement level should be complete to verify the requirement.

[CA5602V-PO] The ability of the Constellation Architecture to perform RPODU independent of ground overflight constraints shall be verified by inspection. The inspection shall consist of a review of the verification results of the allocated children requirements. The verification shall be considered successful when the inspection review shows that the allocated children requirements have been closed.

Rationale: The work performed at the child requirement level should be complete to verify the requirement. Flight-like interfaces and hardware facilities will be used for the child requirement verification activity, and the results inspected and confirmed.

4.2.12 Reliability and Availability

[CA0037V-PO] The ability of Constellation Architecture to be prepared to support launch attempts within six days of a missed TLI window shall be verified by analysis.

Analysis shall assess Level III Logistics Support Plan (LSP), ground processing plans, Logistics Support Analysis Records (LSAR) and other documents that include launch recycle tasks and activities associated with lunar missions and calculate the time and resources required to perform tasks. Analysis shall be updated based upon demonstration of activities as recorded during test flights. Verification shall be considered successful when analysis determines that all work required to recycle the vehicle following a missed window can be completed in time for the next lunar launch window.

Rationale: It is important to be prepared and have plans in place to support this requirement, since this requirement will in part drive the size of the Constellation support Architecture.

[CA0038V-PO] The ability of the Ares I to launch within 90 minutes of the Ares V shall be verified by analysis. Analysis shall assess Level III Logistics Support Plan (LSP), ground processing plans, Logistics Support Analysis Records (LSAR) and other documents that include launch recycle tasks and activities associated with lunar missions and calculate the time and resources required to perform tasks. Analysis shall be updated based upon demonstration of activities as recorded during test flights. Verification shall be considered successful when analysis shows that the fixed and variable resources are adequate to support the launch of the Ares V and the Ares I within 90 minutes of each other.

Rationale: It is important to be prepared and have plans in place to support this requirement, since this requirement will in part drive the size of the Constellation support Architecture.

[CA0040V-PO] The Constellation Architecture capability to launch the flight systems independent of ambient lighting conditions shall be verified by analysis. The analysis shall consist of a review that the facility, facility systems and GSE that will be used to launch flight systems within any ambient lighting conditions are built and certified. These facilities, flight systems and GSE requirements will be identified and characterized in CxP 72006, Ground Systems, Systems Requirements Document (SRD). The verification shall be considered successful when the analysis show that the systems are ready to support flight systems launch for the Constellation Architecture independent of ambient lighting conditions.

Rationale: The requirement is for the Constellation Architecture to provide the capability to launch flight systems independent of ambient lighting conditions. It does not call out, specifically, one project over another. All CARD 3.7 children are being verified in CxP 72006, Ground Systems, Systems Requirements Document (SRD). The push down of the LSAM requirements to the SRD does not affect the CARD 4.7 verification statement. The verification of LSAM will be in the SRD 4.2 and Subsystem Requirements Document (SSRD) 4.7 sections.

[CA0071V-PO] The Constellation Architecture's ability to continuously remain ready to launch throughout the specified readiness period shall be verified by analysis. Analysis will consist of review of vehicle design and Ground Systems servicing for launch readiness during the specified launch readiness period for each mission. The analysis will be deemed successful when the vehicle and Ground Systems are confirmed to be ready for launch throughout the specified readiness period for each mission.

Rationale: NR

[CA0123V-PO] The ability of the Constellation Architecture to have a probability of crew launch of not less than 99 (TBR-001-021)% during the period beginning with the decision to load cryogenic propellants and ending at the expiration of the EDS and Lander LEO loiter shall be verified by analysis and inspection. The verification analysis shall use only R&M Panel approved data sources for Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. The verification analysis shall also address contributing factors to the probability of launch such as duration of delays to perform review, repair, or replacements. The verification shall include inspection of the verification results of launch probability children requirements. Verification shall be considered successful when analysis and inspection shows that the probability of launch per crew launch attempt is not less than 99% (TBR-001-021) with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004) and the inspection confirms that all children requirements have been satisfied.

Rationale: A high probability of launch for the second vehicle in the launch sequence for a crewed lunar mission is critical in order to ensure successful rendezvous of the Lander/EDS and Orion and subsequent TLI. The probability of launch is the cumulative probability that the Ares I can successfully launch over the multiple launch opportunities that are available for a given lunar mission opportunity. This requirement decomposes into other "probability of go" requirements that need to be placed on the separate elements: Orion system ready; Orion abort landing site requirements met; Ares I system ready; Ares I weather related launch constraints, and the ground systems reliability are met. This requirement is inclusive of both the probability of delay and the probable duration of such delay to perform review, repair or replacements in time to meet a specified mission opportunity.

[CA0125V-PO] The ability for the Constellation Architecture to provide launch opportunities for seven consecutive days for crewed missions shall be verified by analysis. The analysis shall assess the Integrated Logistics Support Plan, the Integrated Logistics Support Analysis Report, ground processing plans, Logistics Support Analysis Records (LSAR), and other documents that include launch recycle tasks and activities associated with crewed missions in order to calculate the time and resources required to perform launch tasks for seven consecutive days. The verification shall be considered successful when the analysis results show that the Constellation Architecture can provide launch opportunities for at least seven consecutive days for crewed missions.

Rationale: Analysis of the various plans and lower-level analysis reports is sufficient for verification work.

[CA5600V-PO] The ability of the Constellation Architecture to have a (TBD-001-517)% probability of cargo launch during the period beginning with the decision to load cryogenic propellants and ending 3 days after the initial planned launch attempt shall be verified by analysis. The verification analysis shall use only R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when analysis shows that the probability of launch per uncrewed launch attempt is no less than (TBD-001-517)%, with an uncertainty of not greater than (TBD-001-631)% (TDS# SIG-01-004).

Rationale: CA reliability and availability data, and Ground Operations data will need to be available for the program to verify that the flight hardware will be in a situation that supports the vehicle and Ground Systems to be available to support during the period beginning with the decision to load cryogenic propellants and ending 3 days after the initial planned launch attempt.

4.2.13 Maintainability, Supportability, and Logistics

Draft [CA0550V-PO] The ability of the CA to be maintained during the design reference missions within the mass, volume, and time constraints shall be verified by analysis. Analysis shall assess the maintainability analysis to determine the actions required to maintain the CA and prevent Loss of Mission performed in accordance with CxP 70064, Constellation Program Supportability Plan. These actions shall then be compared to the allocated parameters for each mission phase. Verification shall be considered successful when analysis shows all required CA maintenance actions can be accomplished within the allocated parameters of mass, volume, time, and costs constraints for each mission.

Rationale: It is important to be able to verify the CA ability to be maintainable based upon the data, analysis, and demonstrations by the various CA systems.

[CA3293V-PO] The Constellation Architecture requirement to accept software updates without requiring LRU removal shall be verified by Demonstration.

a. Demonstrations shall be performed using the flight assets (Ares I/Ares V/LSAM) along with associated CxP elements (i.e. Ground Systems and Mission Systems) and Crew under simulated flight conditions.

b. Demonstrations of software updating using the flight/flight-like assets (Ares I/Ares V/LSAM) along with associated CxP elements (i.e. Ground Systems and Mission Systems) and Crew shall be performed during simulation and training exercises.

The verification shall be considered successful when updates through the CxP architecture are:

a. Accepted by the receiving LRU

b. Is accomplished without LRU removal

c. Is confirmed via C3I cross checking (i.e. ack, checksum)

Rationale: Demonstrations using flight quality assets, operational baseline, and C3I infrastructure provides assurance that those participatory CxP elements can perform software updates. A demonstration during simulations and training reduces the risk of being unable to perform the necessary function.

[CA5814V-PO] The ability to perform assembly at the Launch Site without deintegration or reconfiguration of subassemblies shall be verified by analysis and demonstration. The analysis shall examine all assembly tasks, as identified in the Vehicle Assembly Task Analysis. Worksite analysis for each task shall evaluate the need to deintegrate systems for each of the defined tasks. For those tasks requiring two or more personnel, task verification shall be by demonstration using mockups. Verification shall be complete when all assembly tasks can be shown to be accomplishable without deintegration of systems and elements.

Rationale: NR

[CA5815V-PO] The provision for late pad access for time-critical components shall be verified by analysis of the CA design. The analysis will consist of a review of each project (Orion, Ares I, Ares V, LSAM) SRD to Ground Systems allocated SRD requirements and IRDs between Ground Systems and the flight systems allocated requirements. It also will consist of a review that the facility, facility systems and GSE used to support late access operations are built and certified. These facilities, flight systems and GSE requirements will be identified and characterized in the CxP 72006, Ground Systems, Systems Requirements Document (SRD). Verification shall be considered successful when the analysis has shown that late pad access of time-critical components can be accomplished no later than 12 (TBR-001-964) hours prior to scheduled launch.

Rationale: NR

[CA5935V-PO] Verification that the Constellation Architecture includes the required tools for on-orbit maintenance and reconfiguration shall be verified by analysis and inspection. An analysis shall assess the Project Level Maintainability Plans, Supportability Plans, Maintenance Concepts, Logistic Support Analysis Reports (LSARs), and other R&M data sources and identify planned corrective and preventative maintenance and reconfiguration tasks and the tools required to perform these tasks. Inspection shall be performed on (TBD-001-1123) to determine that the CxP has procured the tools required to perform the identified maintenance and reconfiguration tasks. The verification shall be considered successful when the analysis has identified the tools required for on-orbit maintenance and reconfiguration and inspection determines these identified tools have been procured by the CxP.

Rationale: Verification of this requirement is a roll-up of verification closures of allocated lower-level requirements in accordance with the established traceability within the CARD.

[CA5962V-PO] The ability of the Constellation Architecture to remain in an integrated configuration for 100 days without the need for vehicle de-stacking shall be verified by inspection and analysis. The inspection shall consist of a review of allocated requirements closure in the Orion, Ares I, Ares V, LSAM and GS SRDs. The analysis shall consist of review of flight hardware time, age and cycle specification data and a review of the integrated loads analysis data contained in the loads and/or stress data book(s). The inspection shall be considered successful upon closure of the allocated SRD requirements. The analysis shall be considered successful when the review of the flight hardware time, age and cycle specification data, and the integrated loads analysis data show that the Constellation Architecture can remain in an integrated configuration for 100 days without the need for vehicle de-stacking.

Rationale: The work performed at the child requirement level should be complete to help verify the requirement. An analysis will also look at flight hardware time, age, and cycle data, as well as integrated loads analysis data.

[CA5963V-PO] The ability of the Constellation Architecture to withstand cumulative exposure to the natural environments at the launch pad for at least 30 (TBR-001-1108) days shall be verified by inspection and analysis. The inspection shall consist of a review of lower tier allocated requirements closures in the Orion, Ares I, Ares V, LSAM, and GS SRDs. The analysis shall incorporate a review of integrated environment effects on flight system performance and the flight hardware time, age and cycle specification data. The inspection shall be considered successful upon closure of the allocated SRD requirements, and the analysis shall be considered successful when the review of the flight hardware time, age and cycle specification data and integrated flight system performance show full operations capability during and after cumulative exposure to the natural environments (given in CxP 70023, Design Specification for Natural Environments [DSNE]) at the launch pad for at least 30 (TBR-001-1108) days.

Rationale: The work performed at the child requirement level should be complete to help verify the requirement. An analysis will also look at integrated environment effects on flight system performance and the flight hardware time, age, and cycle data.

[CA5964V-PO] The ability of the Constellation Architecture to generate Program Verified Engineering Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Program's capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA5965V-PO] The ability of the Constellation Program to integrate and test Project Verified Engineering Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when assessment of the time used to perform the process indicates the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Program's capability of meeting the high marks required will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA5966V-PO] The ability of the Constellation Architecture to generate Program Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Program's capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA5967V-PO] The ability of the Constellation Program to integrate and test Project Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when assessment of the time used to perform the process indicates the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Program's capability of meeting the high marks required will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA5968V-PO] The ability of the Constellation Architecture to generate day of launch updates shall be verified by demonstration. Demonstration shall be considered successful when day of launch updates have been successfully generated and applied during program verification and validation activities.

Rationale: The intent is to demonstrate that the day of launch update process can be successfully executed.

[CA5969V-PO] The ability of the Constellation Architecture to generate day of launch updates shall be verified by demonstration. Demonstration shall be considered successful when day of launch updates have been successfully generated and applied during program verification and validation activities.

Rationale: The intent is to demonstrate that the day of launch update process can be successfully executed.

[CA5970V-PO] The ability of the Constellation Architecture to provide fixes for selected non-conformances to the discovering organization shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Program's capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA5971V-PO] The ability of the Constellation Architecture to re-integrate of Fast Track non-conformance resolutions shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Program's capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA5972V-PO] The Constellation Architecture activity of integrating, managing the configuration of and distributing data and software shall be verified by test and demonstration. The test shall verify the output products generated by the system. The test shall be considered successful when the system output matches the expected results based on the test input. The demonstration shall examine the output products generated to support development, test, training and mission execution activities. The demonstration will be considered successful when the first orbital flight CoFR has been completed successfully.

Rationale: The test activity addresses the behavior of the tools employed to support the integration, management and distribution. In order to pass CoFR, the process of generating the software and data products has been successfully performed. The first orbital flight was chosen because it involves a representative set of multiple users.

[CA5973V-PO] The ability of the Constellation Architecture to provide the infrastructure to maintain systems through their operational life cycles shall be verified by inspection and analysis. Inspection shall determine that each individual system of the Constellation Architecture has closed their respective infrastructure requirement in support of operational life cycles. Analysis shall include a compilation of metrics that include inventory fill rates, repair turnaround times, and delays in task completion caused by parts/logistics and shall be performed in accordance with the CxP 70064, Constellation Program Supportability Plan. The verification shall be considered successful when the inspection determines each system has successfully closed its respective infrastructure requirement and the analysis shows that the Constellation Architecture provides the infrastructure to maintain systems through their operational life cycles.

Rationale: Infrastructure enables the sustainment of safe and efficient operations. Examples of critical infrastructure elements include Inventory Management Systems for tracking program assets both in-flight and on the ground; capabilities to manage and present information necessary to support maintenance operations on ground and in flight; software and data management tools and tools and test equipment for in-flight maintenance.

[CA6002V-PO] The ability of the Constellation Architecture to conduct ground operations within the constraints levied in Critical Path Allocations for Ares I/Orion Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hour specified therein. The added Objective capability of requirement CA6002-PO will be addressed at Program level design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

[CA6007V-PO] The ability of the Constellation Architecture to conduct ground operations within the constraints levied in Critical Path Allocations for Ares V/LSAM Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6007 will be addressed at Program level design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

[CA6012V-PO] The ability of the Constellation Architecture to produce mission integration products for a single mission within the time limits identified in Mission Integration Production Time Single Mission Constraints - ISS Table and Mission Integration Production Time Single Mission Constraints - Lunar Table shall be verified by analysis. The analysis shall consist of a review of allocated CARD requirements (flight software reconfiguration and ground processing timelines), as well as template and management process document (TBD-001-1084). The verification shall be considered successful when the allocated CARD requirements verifications are closed and when mission integration template plans and management processes meet the mission integration production for a single mission within the time limits identified in Mission Integration Production Time Single Mission Constraints - ISS Table by Initial Operational Capability (IOC) and Mission Integration Production Time Single Mission Constraints - Lunar Table by Lunar Capability with a probability 85% (TBR-001-1094). The added Objective capability of requirement CA6012 will be addressed at Program level design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

[CA6020V-PO] The ability of the Constellation Architecture to operate in any excursion attitude for at least 3 hours without exceeding thermal limits and/or autonomously determine mission attitudes through all flight phases based on flight system constraints and mission reserves shall be verified by demonstration, analysis and inspection. The Demonstration shall use integrated Orion, LSAM and MS systems in simulated mission conditions. (Exhaustive verification [tests] of lower level requirements are not required since this will have been accomplished by lower level project testing.) The analysis shall consist of review of the Orion and LSAM designs, thermal, structural, power generation and communications coverage reports. The inspection shall consist of review of the allocated Orion SRD, LSAM SRD, MS SRD, Orion-LSAM IRD, Missions Systems-Orion (MS-Orion) IRD and MS-LSAM IRD requirements. The demonstration shall be successful when the Orion, LSAM and MS systems show the ability to operate in any excursion attitude for at least 3 hours and/or autonomously determine mission attitudes through all flight phases based on flight system constraints and mission reserves. The inspection shall be successful when the allocated SRD and IRD verification requirements are closed. The analysis shall be successful when the vehicle designs and thermal, structural, power generation and communications coverage analysis reports show that the Constellation Architecture can operate in any excursion attitude for at least 3 hours without exceeding thermal limits and/or autonomously determine mission attitudes through all flight phases based on flight system constraints and mission reserves. The added Objective capability of requirement CA6020 will be addressed at Program level design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

[CA6022V-PO] The ability of the Constellation Architecture to provide for autonomous onboard consumables tracking and management and/or automatic integrated onboard management of consumables, mission timeline, and trajectory planning shall be verified by analysis, inspection, and test. The inspection shall consist of review of verification closures for allocated Orion SRD, LSAM SRD, CEV-LSAM IRD, MS SRD, MS-CEV IRD, and MS-LSAM IRD requirements. An additional analysis shall be performed to identify lunar mission scenarios for developing test objectives. The test shall consist of the execution of simulated lunar mission scenarios where autonomous consumables tracking and management applications and/or automatic integrated onboard management of consumables, mission timeline, and trajectory planning are utilized. The scenarios shall include all vehicles in the logistics supply chain. The inspection shall be considered successful when the allocated SRD and IRD verifications are closed, the analysis shows development test objectives are defined, and the test shows that the Constellation Architecture provides for autonomous onboard consumables tracking and management and/or automatic integrated onboard management of consumables, mission timeline, and trajectory planning for lunar missions. The added Objective capability of requirement CA6022 will be addressed at Program level design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: Inspection is used to ensure linked requirements have been met based on verification closures. Analysis is used to help develop test objectives. Tests are used to create realistic conditions to check function and operations. Analysis of design is not required since testing is performed.

[CA6024V-PO] The ability for the Constellation Architecture to command and control quiescent vehicles during nominal quiescent operations for ISS missions with no more than 2 hours per week contiguous consisting of 12 (TBR-001-1105) man-hours shall be verified by inspection. The inspection shall consist of review of the allocated MS and Orion CARD requirements. The inspection shall be considered successful when the allocated MS and Orion verification requirements are closed and confirm the ability to meet no more than 2 hours per week contiguous consisting of 12 man-hours of real-time command and control during nominal quiescent operations for ISS missions. The added Objective capability of threshold requirement CA6024-PO will be addressed at Program level design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

[CA6026V-PO] The ability for the Constellation Architecture to actively monitor quiescent vehicles during nominal quiescent operations for ISS missions with no more than 1 hour per day contiguous consisting of 10 (TBR-001-1105) man-hours shall be verified by inspection. The inspection shall consist of review of the allocated MS and Orion CARD requirements. The inspection shall be considered successful when the allocated MS and Orion verification requirements are closed and confirm the ability to meet no more than 1 hour per day contiguous consisting of 10 (TBR-001-1105) man-hours of active monitoring during nominal quiescent ISS mission operations.

Rationale: NR

[CA6027V-PO] The ability for the Constellation Architecture to command and control quiescent vehicles during nominal quiescent operations for Lunar missions with no more than 2 (TBR-001-1106) hours per week contiguous consisting of (TBD-001-1085) man-hours shall be verified by inspection. The inspection shall consist of review of the allocated MS, Orion, and LSAM CARD requirements. The inspection shall be considered successful when the allocated MS, Orion and LSAM verification requirements are closed and confirm the ability to meet no more than 2 (TBR-001-1106) hours per week contiguous consisting of (TBD-001-1085) man-hours of real-time command and control during nominal quiescent Lunar mission operations.

Rationale: NR

[CA6028V-PO] The ability for the Constellation Architecture to actively monitor quiescent vehicles during nominal quiescent Lunar mission operations with no more than 1 (TBR-001-1106) hour per day contiguous consisting of (TBD-001-1120) man-hours shall be verified by inspection. The inspection shall consist of review of the allocated MS, Orion, and LSAM CARD requirements. The inspection shall be considered successful when the allocated MS, Orion, and LSAM verification requirements are closed and confirm the ability to meet no more than 1 (TBR-001-1106) hour per day contiguous consisting of (TBD-001-1120) man-hours of active monitoring during nominal Lunar quiescent mission operations.

Rationale: NR

4.2.14 Reserved

4.2.15 Environmental Conditions

[CA0048V-PO] Compliance of the Constellation Architecture with its functional and performance requirements during and after exposure to the DSNE environments shall be verified by inspection and analysis. The inspection shall consist of review of the following:

a. Allocation of the natural environments requirements to the lower tier systems and their verification methods and details

b. The lower tier verification closure data

The analysis shall address interactions of each lower tier system on other systems to include integrated environment effects. The systems shall include the following integrated configurations: Orion/Ares I/GS, Orion/ISS, Orion/Ares I, Orion/Ares V-EDS/LSAM, Orion/LSAM, Ares V/LSAM/GS, and Ares V/LSAM.

The verification shall be considered successful when the inspection and integrated analysis show:

a. The natural environment requirements and verification have been allocated to the lower tier systems in accordance with Section 4 of the DSNE

b. Lower tier verifications have been completed

c. The Constellation Architecture meets its functional and performance requirements during and after exposure to the DSNE environments

Rationale: Verification of functional and performance requirements across the range of natural environments requires a systematic integrated approach to address dependencies on hardware configurations and operational mode. The DSNE Section 4 specifies a standard systems engineering technique for flowing down the natural environment from higher to lower levels using the Natural Environment Requirements Sensitivity and Applicability Matrix (NERSAM) for each mission phase. Lower tier verification close out data, analyses, and models are necessary to support the integrated analysis, but are not sufficient alone to close out the environment requirements from the integrated vehicle configuration.

[CA0991V-PO] The function and performance of the Constellation Architecture during and after exposure to lightning direct and indirect effects shall be verified by test and analysis. The analysis and test shall show compliance to CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document. The verification is considered successful when the test and analysis results show compliance with lightning requirements in the CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document.

Rationale: The CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document will have verification methods and test methodologies for both direct and indirect lightning requirements. The E3

Requirements Document mandates coupon testing of outer mold design materials and identifies a combination of filtering and shielding techniques to be used for lightning protection design.

[CA5552V-PO] Constellation Architecture function and performance during and after exposure to induced environments shall be verified by analysis and inspection. Inspection shall consist of review of lower level analyses and closure reports. The analysis shall consist of a rollup and cross-check of separate systems level analyses for each System. The verification shall be considered successful when the inspection and analysis show that the cumulative induced environments will not exceed the system design specifications for all design reference missions.

Rationale: Induced environments may compromise the performance of the Constellation Architecture. It is important that systems level analyses be performed, including the cumulative environments produced by the Architecture itself, as well as by ISS and other outside agents. A rollup of these analyses must be done to verify the function and performance of the Constellation Architecture against all its induced environments.

4.3 DESIGN AND CONSTRUCTION STANDARDS

4.3.1 Electrical

[CA0817V-PO] The electrical bonding shall be verified by integrated analysis and inspection of the submitted verification reports, verification data, qualification test results. The inspection shall include review of the bonding requirements and review of lower level qualification test, analysis, and drawing inspections. The integrated analysis will focus on analyzing bonding paths between systems. The inspection of lower level compliance data shall verify compliance to NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment. The verification shall be considered successful when two items are complete:

a. The submitted bonding verification data have been approved

b. The analysis shows the integrated vehicle has complied with the CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document and the bonding requirements NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment

Rationale: The Constellation Program must perform an integrated analysis showing that lower assemblies indeed have proper bonding practices according to NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment. The lower assemblies should use testing and inspection to verify bonding.

[CA0990V-PO] The compliance with the Power Quality Specification shall be by inspection. The inspection shall consist of a review of each systems' compliance with the Power Quality Specification. The verification shall be considered successful when the inspection confirms all the requirements of CxP 70050-01, Constellation Program

Electrical Power System Specification, Volume 1: Electrical Power Quality Performance for 28Vdc and CxP 70050-02, Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28Vdc have been satisfied for each System.

Rationale: Detailed verification is performed by each System per the requirements in CxP 70050-01, Constellation Program Electrical Power System Specification, Volume 1: Electrical Power Quality Performance for 28Vdc and CxP 70050-02, Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28Vdc. The CARD 3.7.x.4 Interface Requirements require multi-System integrated testing that will include power interface testing.

4.3.1.1 Electromagnetic Environmental Effects

[CA0554V-PO] Electromagnetic compatibility between Constellation systems shall be verified through test and inspection. The test shall verify that electromagnetic compatibility for all planned simultaneous operations can be performed successfully. The inspection shall verify that all systems comply with CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document. Verification is considered successful when 2 items are satisfied:

a. During the test all systems successfully complete functional and operational performance requirements.

b. Inspection of CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document verification submittal information shows completeness.

Rationale: CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document, mandates compatibility between the various pieces of Constellation Architecture. Prior to integration, each systems electromagnetic signature will be reviewed to verify interface compatibility. Doing a combined electromagnetic analysis is extremely complicated and a test provides the highest level of confidence.

[CA0555V-PO] Compatibility with the external electromagnetic environment shall be verified by test, inspection and analysis. The test shall verify that the integrated systems meet functional and performance requirements without degradation in the presence of the electromagnetic environment as defined in CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document, Section (TBD-001-907). The analysis shall verify that the integrated systems operate without degradation in the presence of the electromagnetic environment as defined in CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document, Section (TBD-001-907) for operational conditions that are impractical to test on ground, such as: ascent, on-orbit and descent. The inspection shall ensure that each system has complied with Constellation E3 requirements. Verification is considered successful when 2 items are satisfied:

a. The analysis and test results verify that the systems are compatible with the external electromagnetic environment.

b. Inspection of the Constellation E3 Requirements Document verification submittal information demonstrates compliance.

Rationale: The question of compatibility will be verified primarily from lower level test data combined with integrated systems level test and analysis. Testing mitigates risk of incompatibilities with the environment in those conditions where testing is practical. Analysis provides risk mitigation, albeit less mitigation, in cases where testing is impractical.

[CA5811V-PO] Electromagnetic compatibility between Constellation Systems and external interfaces shall be verified through test and inspection. The test shall verify that electromagnetic compatibility for all planned simultaneous operations with external interfaces including transportation systems, recovery systems, RF systems (e.g. TDRSS, Range Safety), and other vehicles (e.g. ISS) can be achieved successfully. The inspection shall verify that all Systems comply with CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document. Verification is considered successful when 2 items are satisfied:

a. During the test all systems successfully complete functional and operational performance requirements.

b. Inspection of the CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document verification submittal information demonstrates compliance.

Rationale: The best way to show electromagnetic compatibility at the interface is by test. For some external interfaces, testing may require use of emulators or simulation of interfaces.

4.3.2 Structures and Mechanisms

[CA3004V-PO] Compliance with JSC 62809, Constellation Spacecraft Pyrotechnic Specification, shall be verified by inspection. The inspection shall consist of a review of the NASA certifications addressing the requirements of JSC 62809, Constellation Spacecraft Pyrotechnic Specification for each Constellation system. The verification shall be considered successful when the NASA certifications show that all applicable requirements of JSC 62809, Constellation Spacecraft Pyrotechnic Specification have been met.

Rationale: Detailed verification requirements are contained in JSC 62809, Constellation Spacecraft Pyrotechnic Specification.

[CA3005V-PO] Compliance with NASA-STD-(I)-6016, Standard Materials and Processes Requirements for Spacecraft, shall be verified by inspection. The inspection shall consist of a review of the Materials and Processes Selection, Control, and Implementation Plans for the Level III systems by Level II to verify a consistent implementation of requirements across the program and a review of additional documents from the Level III systems that show approval of the lower level element materials and processes documentation. Verification is considered successful when the Materials and Processes Selection, Control, and Implementation Plans for the Level III systems are approved by Level II and approvals of the other documentation for all lower level elements have been submitted.

Rationale: Each Level III project and Level IV element will be responsible for a Materials and Processes Selection, Control, and Implementation Plan defining the detailed implementation of the NASA-STD-(I)-6016, Standard Materials and Processes Requirements for Spacecraft requirements. The Materials and Processes Selection, Control, and Implementation Plan will identify the degree of conformance to those requirements, and the method of implementation. In addition to the Materials and Processes Selection, Control, and Implementation Plan, the materials and processes documentation will include materials identification and usage lists, materials usage agreements, nondestructive evaluation plans, contamination control plans, analyses, test reports, inspection results and any other materials and processes-related data necessary to qualify flight hardware. This documentation will be prepared at the element level and approved by the element Materials and Processes Control Board. Once approved, these element-level certifications will then be assembled for each system at Level III. These certifications are the materials and processes verifications that will be provided by Level III to Level II. Level II is responsible for verifying that the degree of conformance of the Materials and Processes Selection, Control, and Implementation Plans to NASA-STD-(I)-6016, Standard Material and Process Requirements for Spacecraft, is consistent and acceptable without unreasonable exceptions being approved at Level III or Level IV. Level II is also responsible for auditing materials usage agreements approved by the Level III and Level IV organizations to verify acceptable rationale. All other Level II M&P verifications shall be limited to verification that the M&P documentation has been approved by the responsible Level III/Level IV organization.

[CA3187V-PO] Compliance with CxP 70135, Constellation Program Structural Design and Verification Requirements, shall be verified:

a. For each system by inspection

b. For the integrated systems (for example, Orion integrated with Ares I) by analysis and test

The inspection shall consist of a review of the system Structural Verification Plan and the verification closure packages (a single closure package for each system that addresses each requirement as documented in the approved SVP), for compliance with the agreed to requirements of CxP 70135, Constellation Program Structural Design and Verification Requirements. The verification shall be considered successful when the Project has submitted a Certificate of Compliance for the applicable requirements of CxP 70135, Constellation Program Structural Design and Verification Requirements and Level II has agreed that a sampling review of the verification closure package has shown compliance with CxP 70135, Constellation Program Structural Design and Verification Requirements.

Analysis and test shall be used to verify that the integrated systems (for example, Orion integrated with Ares I) meet the agreed to requirements of CxP 70135, Constellation Program Structural Design and Verification Requirements. The systems shall include the following integrated configurations: Orion/Ares I/GS, Ares I/ISS, Orion/Ares I, Orion/Ares V-EDS/LSAM, Orion/LSAM, Ares V/LSAM/GS, and Ares V/LSAM. Verification that the integrated systems meet the agreed to requirements of CxP 70135, Constellation Program Structural Design and Verification Requirements shall be considered successful when the analyses and test reports show that the objectives in the Level II Structural Verification Plan have been satisfied.

Rationale: Since there are several acceptable verification methods for some of the requirements in CxP 70135, Constellation Program Structural Design and Verification Requirements. the Structural Verification Plan will be a customized list of all the analyses and tests that will be performed to meet the agreed to requirements of CxP 70135, Constellation Program Structural Design and Verification Requirements.

[CA3193V-PO] Compliance with NASA-STD-(I)-5019, Fracture Control Requirements for Spaceflight Hardware shall be verified by inspection. The inspection shall consist of a review of the documents from the Level III systems that show approval of the lower level element fracture control documentation. Verification is considered successful when the fracture control approvals for all lower level elements have been submitted.

Rationale: Each Level IV element will be responsible for identifying the requirements in NASA-STD-(I)-5019, Fracture Control Requirements for Spaceflight Hardware, that apply to their hardware and writing a fracture control plan that defines how those requirements will be satisfied. In addition to the fracture control plan, the fracture control documentation will include analyses, test reports, inspection results and any other fracture-related data necessary to qualify flight hardware. This documentation will be prepared at the element level and submitted for approval to the Fracture Control Board at the NASA Center responsible for each element. Once approved, these element-level certifications will then be assembled for each system at Level III. These certifications are the fracture control verifications that will be provided by Level III to Level II.

[CA3222V-PO] Compliance with JSC 62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications shall be verified by inspection. The inspection shall consist of a review of the NASA certifications addressing the requirements of JSC 62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications for each Constellation system. The verification shall be considered successful when the NASA certifications show that all applicable requirements of JSC 62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications have been met.

Rationale: Detailed verification requirements are contained in JSC 62550, Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications.

[CA3237V-PO] Compliance with Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms, shall be verified:

a. For each system by inspection

b. For the integrated systems (for example, Orion integrated with Ares I) by analysis and test

1. The inspection shall consist of a review of the system Mechanical Systems Verification Plan (MSVP) and the verification closure package (a single closure package for each system that addresses each requirement as documented in the approved MSVP), for compliance with the agreed to requirements of Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms. The verification shall be considered successful when the Project has submitted a Certificate of Compliance for the applicable requirements of Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms, and Level II has agreed that a sampling review of the verification closure package has shown compliance with Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms.
2. Analysis and test shall be used to verify that the integrated systems (for example, Orion integrated with Ares I) meet the agreed to requirements of Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms. The systems shall include the following integrated configurations: Orion/Ares I/GS, Orion/ISS, Orion/Ares I, Orion/Ares V-EDS/LSAM, Orion/LSAM, Ares V/LSAM/GS, and Ares V/LSAM. Verification that the integrated systems meet the agreed to requirements of Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms, shall be considered successful when the analyses and test reports show that the objectives in the Level II MSVP have been satisfied.

Rationale: Since there are several acceptable verification methods for some of the requirements in Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms, the MSVP will be a customized list of all the inspection, analyses and tests that will be performed to meet the agreed to requirements of Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms.

4.3.3 Reserved

4.3.4 Human Engineering

[CA0042V-PO] The compliance with CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), shall be by inspection. The inspection shall consist of a review of each systems' compliance with the Human Systems Integration

Requirements. The verification shall be considered successful when the inspection confirms all the requirements of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR) have been satisfied for each system.

Rationale: NR

4.3.5 Communications Standards

[CA0383V-PO] The protection of systems and information as specified in the CxP 70170, Constellation Program Information Technology (IT) Functional Security Requirements for Program Systems and Elements; Applicability Matrix for Functional Security Requirements, shall be verified by inspection. Verification is considered successful when inspection shows all verification requirements corresponding to the requirements specified for the Constellation Architecture and every System in CxP 70170, Constellation Program Information Technology (IT) Functional Security Requirements, Table 1: Applicability Matrix for Functional Security Requirements, are met.

Rationale: All requirements specified for the Constellation Architecture and every System in CxP 70170, Constellation Program Information Technology (IT) Functional Security Requirements, Table 1: Applicability Matrix for Functional Security Requirements, must be met in order to ensure that the Constellation Architecture is properly secured. Failure to meet any of the requirements levied in CxP 70170, Constellation Program Information Technology (IT) Functional Security Requirements, Table 1: Applicability Matrix for Functional Security Requirements, can result in unacceptable residual security risk. CxP 70170, Constellation Program Information Technology (IT) Functional Security Requirements, Table 1: Applicability Matrix for Functional Security Requirements, is the appropriate place to call out all necessary verification requirements related to functional security requirements of the Constellation Architecture, and thus simple inspection is all that is needed.

[CA5800-PO] Compliance to the CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification, Appendix E, Applicability Matrix shall be by inspection. The inspection shall review closure status of the System level children requirements. The verification shall be considered successful when the inspection confirms that all of the children requirements have been satisfied.

Rationale: To confirm that the Constellation Architecture has complied with the C3I Interoperability Standards Book, an audit of the lower level verification data will be required.

4.3.6 EVA Standards

[CA3167V-PO] The ability of the Constellation Architecture to comply with the requirements in CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification, shall be verified by inspection. The inspection shall consist of a review of each systems' compliance with the Extravehicular Activity Design and

Construction Specification, Appendix B. The verification shall be considered successful when the inspection confirms all the requirements of CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification, have been satisfied for each system.

Rationale: This is an overarching architecture (multiple projects) parent requirement that is verified by review of the individual vehicle flow-down requirements, for Orion, EVA and LSAM. Although the CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification, is specifically intended to levy requirements on vehicles to satisfy EVA requirements, the EVA System also needs to verify that it has implemented a design which is still within the requirements as levied on those vehicles via CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification, Appendix B.

4.3.7 Navigation Standards

[CA3252V-PO] The Constellation Architecture tracking and navigation functional capability conformance with the approved Constellation Program navigation standards shall be verified by inspection. The inspection shall be accomplished by comparing navigation methods and assumptions to those documented in the navigation standards document. The verification shall be considered successful when the inspection shows the navigation functional capability to be in accord with those in CxP 70142, Constellation Program Navigation Standards Specification Document.

Rationale: NR

[CA5618V-PO] The Constellation Architecture functional capability to use continuous reference time scale for the representation and exchange of timing information per the C3I Interoperability Specification , Volume 1 and Volume 4, shall be verified by inspection and demonstration. An inspection shall be performed on the verification closure evidence of lower level requirements linked to this requirement. A demonstration shall be performed of Constellation Systems using flight equivalent units or emulators with flight software under simulated mission conditions over simulated links. Data shall be exchanged for every applicable combination of Systems during the demonstration to verify interoperability of time standards and formats. During the demonstration , the initiating System shall generate time information and provide to the receiving System. The transmitted and received time, and any applicable responses, shall be examined or compared. Receiving Systems shall validate the transmitted time data. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The verification shall be considered successful when the inspection shows the lower level (linked) requirements are met, and the demonstration shows that:

a. Time is transmitted and received for all exchanges tested

b. Both sending and receiving Systems agree that the exchanged time and responses produced by the demonstration contain expected values

Rationale: An inspection is used for compliance of software to the CxP 70022-01, C3I, Volume 1: Interoperability Specification for the use of reference time scale and standards for time representation. A demonstration is used to verify that the selected CxP 70022-01, C3I, Volume 1: Interoperability Specification function's implementation facilitates the correct exchange of time between each of the Systems.

4.3.8 Other Standards

[CA5680V-PO] The requirement for the Constellation Architecture to comply with the provisions of NASA-STD-5005B NASA Standard for the Design and Fabrication of Ground Support Equipment shall be verified by inspection. The inspection shall consist of a review of lower level allocated verification requirements. The inspection shall be considered successful when the lower level allocated verification requirements show closure.

Rationale: NR

4.3.9 Test Standards

[CA4111V-PO] The compliance with the Constellation Environmental Qualification and Acceptance Testing Requirements shall be by analysis. The analysis shall consist of:

a. A review of the compliance of each systems test plans for flow down of the applicable Qualification/Acceptance Tests at levels above the expected environments or the minimum screening level as required in the Constellation Environmental Qualification and Acceptance Testing Requirements

b. Compliance with functional and performance requirements after the testing

The verification shall be considered successful when the analysis shows test plans comply with the requirements of CxP 70036, Constellation Program Environmental Qualification and Acceptance Testing Requirements (CEQATR) Document and results for each of the systems tests have met their functional and performance requirements after the testing.

Rationale: CxP 70036, Constellation Program Environmental Qualification and Acceptance Testing Requirements (CEQATR) Document contains both qualification and acceptance testing requirements for natural and induced environments. Testing is required above and below the expected environments or at a minimum design screening level. The test plans and eventual procedures must reflect that the testing will be done at levels beyond the expected environments. The final success is when the equipment still can perform its functional and performance requirements after exposure to these test environments.

4.4 EXTERNAL INTERFACES

[CA0069V-HQ] The Constellation Architecture interfaces with the Communications and Tracking Network shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by each CxP Project Office and the

Communications and Tracking Network organizations to demonstrate that the interface requirements defined within CxP 70118-02, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 2: Ares I, have been satisfied. Testing shall include integrated testing between the various Constellation Architecture systems and the Communications and Tracking Network via the appropriate Software Integration Laboratories (SILs) in accordance with CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Multi-system testing at the launch site involving integrated launch vehicle stacks (e.g., Orion/Ares I) and flight vehicle stacks that will be assembled for the first time in space (e.g., Orion/LSAM) shall also include integration testing between the various Constellation Architecture systems and the Communications and Tracking Network systems. Verification shall be considered successful when:

a. Analysis confirms that all of the Constellation Architecture and Communications and Tracking Network interfaces defined within CxP 70118-02, Constellation Program Systems –to- Communications and Tracking Network Interface Requirements Document , Volume 2: Ares I, have been satisfied.

b. Integrated multi-system test objectives for the Constellation Architecture and Communications and Tracking Network interfaces established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: The CxPO will evaluate the verification data provided by each CxP Project Office and the Communications and Tracking Network organization to confirm that all of the interfaces requirements specified in the IRD have been satisfied. Integration testing will happen at various stages of evolution for the Constellation Architecture, with initial testing at the Program level occurring via the appropriate SILs, and final testing occurring as flight systems are brought together and integrated at the launch site for the first time. Multi-system testing at the launch site will confirm the integrated operability, functionality, and stability of the various Constellation Architecture and Communications and Tracking Network systems during nominal operation and mode changes.

[CA0077V-HQ] The Constellation Architecture interfaces with the ISS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by each CxP Project Office and the ISS Program to demonstrate that the interface requirements defined within CxP 70031, Constellation Program Orion -to- International Space Station (ISS) Interface Requirements Document (IRD), have been satisfied. Testing shall include integrated testing between the various Constellation Architecture systems and the ISS via the appropriate Constellation Software Integration Laboratories (SILs) and the ISS SIL in accordance with CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Multi-system testing at the launch site involving the Constellation Architecture and the ISS test beds will be performed prior to the first crewed launch of Orion to the ISS to demonstrate integrated functionality and interoperability between the Constellation Architecture and ISS systems. Verification shall be considered successful when:

a. Analysis confirms that all of the Constellation Architecture and ISS interfaces defined within CxP 70031, Constellation Program Orion -to- International Space Station (ISS) Interface Requirements Document (IRD), have been satisfied

b. Integrated multi-system test objectives for the Constellation Architecture and ISS interfaces established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: The CxPO will evaluate the verification data provided by each CxP Project Office and the ISS Program to confirm that all of the interfaces requirements specified in the IRD have been satisfied. Integration testing will happen at various stages of evolution for the Constellation Architecture, with initial testing at the Program level occurring via the appropriate Constellation Program/Project and ISS Program SILs, and final testing occurring as flight systems are brought together and integrated at the launch site for the first time. Multi-system testing at the launch site will confirm the integrated operability, functionality, and stability of the various Constellation Architecture and ISS systems during nominal operation and mode changes.

[CA5750V-PO] The Constellation Architecture interfaces with the ascent entities shall be verified by Inspection, Analysis and Test. The inspection shall consist of review of the verification closure of CA0100V-HQ. The analysis shall consist of a CxP review of the verification data provided by the MS, GS, and each ascent entity. Testing shall include integrated testing between the Mission Operations Project and the ascent entities and between the Ground Operations Project and the ascent entities. Verification shall be considered successful when:

a. Inspection confirms closure of CA0100V-HQ requirement

b. Analysis confirms that all of the Constellation Architecture and each ascent entity interface agreement have been satisfied

c. When integrated multi-system tests between MS and all range entities and between GS and all range entities, satisfy the interface agreements reflected through CA0100V-HQ verification closures.

Rationale: The CxPO will evaluate the verification data provided by CxP Mission Operations Project Office, the Ground Operations Project Office and each ascent entity confirm that all of the interface requirements specified through closure of CA0100V-HQ have been satisfied. Integration testing must be completed prior to operational flights. Incremental verification closure will occur as landing sites and entry range entities are added to the Cx Program and unique agreements are established.

Draft **[CA5940V-PO]** (TBD-001-1059)

Rationale: (TBD-001-1059)

[CA5941V-PO] The Constellation Architecture interfaces with the entry range entities shall be verified by Inspection, Analysis and Test. The inspection shall consist of review of the verification closure of CA0100V-HQ. The analysis shall consist of a CxP review of the verification data provided by the MS, GS, and each entry range entity. Testing shall include integrated testing between the Mission Operations Project and the entry range entities and between the Ground Operations Project and the entry range entities. Verification shall be considered successful when:

a. Inspection confirms closure of CA0100V-HQ requirement

b. Analysis confirms that all of the Constellation Architecture and each entry range entity interface agreement have been satisfied

c. When integrated multi-system tests between MS and all range entities and between GS and all range entities, satisfy the interface agreements reflected through CA0100V-HQ verification closures

Rationale: The CxPO will evaluate the verification data provided by CxP Mission Operations Project Office, the Ground Operations Project Office and each entry range entity confirm that all of the interface requirements specified through closure of CA0100V-HQ have been satisfied. Integration testing must be completed prior to operational flights. Incremental verification closure will occur as landing sites and entry range entities are added to the Cx Program and unique agreements are established.

[CA5942V-PO] The Constellation Architecture compatibility with the Global Positioning System (GPS) interface documented in IS-GPS-200 Rev. D, NAVSTAR Global Positioning System Interface, and the ICD-GPS-705, NAVSTAR GPS Space Segment/User Segment L5 Interfaces, shall be verified by inspection. The inspection shall consist of a review of the closure status of Level III verification requirements associated with the interfaces between the GPS and the applicable Constellation Systems. The verification shall be considered successful when the inspection shows that the status of each Level III verification requirement associated with the interface between the GPS and the applicable Constellation Systems is successfully closed, indicating the Constellation Architecture interface to the GPS is compliant with IS-GPS-200 Rev. D, NAVSTAR Global Positioning System Interface specification, and the ICDGPS-705, NAVSTAR GPS Space Segment/User Segment L5 Interfaces.

Rationale: N/R

[CA6069V-PO] The Constellation Architecture C&T services shall be verified by test, analysis, and inspection. Test and analysis shall be performed jointly between Constellation and SCAN. Inspection shall be performed on the Level III test artifacts provided by SCAN and the Level III projects.

Rationale: SCAN is a program external to Constellation, as such, verification activities must be performed in a joint manner between Constellation and SCAN.

4.5 PHYSICAL CHARACTERISTICS

[CA0023V-PO] The Constellation Architecture adherence to a Control Mass for each flight System, per the CxP 70151, Constellation Program Mass Properties Control Plan, shall be verified by inspection. The inspection shall consist of a review of the verifications performed for the Control Mass and Gross Lift-off Weight requirements for the lower level flight Systems. The verification shall be considered successful when the inspection shows that all flight Systems conform to a Control Mass.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

4.6 RESERVED

4.7 SYSTEMS

4.7.1 Orion

4.7.1.1 Orion Description

4.7.1.2 Orion Requirements

[CA0056V-PO] The requirement for Orion to return crew and cargo from the LRO to the Earth surface for crewed lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Orion vehicle can successfully return the crew and cargo from LRO to the Earth surface for crewed lunar missions.

Rationale: Because of the wide variation of possible inputs and because of lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0091V-PO] The requirement for Orion to deliver crew and cargo from the Earth surface to the Lunar Destination Orbit (LDO) for lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Orion vehicle can successfully deliver crew and cargo from the Earth surface to the Lunar Destination Orbit (LDO) for lunar missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3203V-PO] The ability of Orion to return the crew and pressurized cargo from ISS to Earth surface shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that Orion can return the crew and pressurized cargo from ISS to the Earth surface.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5312V-PO] The ability of Orion to deliver the crew and cargo from the Earth surface to ISS shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that Orion can deliver the crew and cargo from the Earth surface to the ISS and meet the RPOD requirements of the Orion/ISS IRD.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work being used to deliver crew and pressurized cargo from the Earth's surface to the ISS.

[CA5748V-PO] The requirement for the Orion to provide two independent, non-mission specific, electrical power interfaces capable of 1.0 kW of continuous power shall be verified by inspection and test. An inspection of engineering drawings shall verify that the electrical power interfaces are independent. A test shall verify that the electrical interfaces are capable of providing 1.0 kW continuous power to unpressurized cargo. Verification shall be considered successful when the test results and engineering drawings prove that the independent power interfaces are capable of providing the 1.0 kW of power.

Rationale: N/R

[CA5749V-PO] The provision of a standard, redundant, non-flight critical data bus interface for unpressurized cargo by the Orion shall be verified by test. The test shall use a simulation of the unpressurized cargo and the flight Orion or flight equivalent hardware and software in simulated Orion mission conditions. Applicable Orion mission phases, states and modes shall be simulated for both nominal and off nominal conditions at least twice. The Orion shall generate a range of possible commands to the unpressurized Cargo and receive appropriate digital data responses communicating per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification. The verification shall be considered successful when the Test shows that:

a. The Orion generates correctly formatted and valid commands, which are sent to the unpressurized Cargo Interface

b. The Orion receives digital data via the unpressurized Cargo interface

c. The Orion transmits the cargo data to the ground or stores it for later processing

Rationale: Testing is required to ensure that data can be exchanged between the Orion and all unpressurized cargo. Initially, the specific cargo, commands, and digital responses may not be known. Therefore, the requirement is to ensure that the Orion is capable of communicating with potential cargo. Once specific cargo, commands, and digital responses have been identified, another test using flight or flight equivalent hardware and software for both parties is required.

4.7.1.2.1 Orion Mission Success

[CA0088V-PO] Lunar Sortie LOM due to Orion shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Sortie mission due to Orion is no greater than 1 in 50.

Rationale: NR

[CA0399V-PO] ISS Crew LOM due to Orion shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for an ISS Crew mission, due to Orion, is no greater than 1 in 250.

Rationale: NR

[CA3022V-PO] ISS Cargo Mission LOM due to Orion shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for an ISS Cargo Mission, due to Orion, is no greater than 1 in 240 (TBR-001-1303).

Rationale: NR

[CA3023V-PO] Lunar Outpost Crew LOM due to Orion shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Outpost Crew mission due to Orion is not greater than 1 in (TBD-001-515).

Rationale: NR

4.7.1.2.2 Orion Crew Survival

[CA0194V-PO] Orion crew survival following a landing on water shall be verified by analysis.

The analysis shall assess that the Orion design for power, ventilation, and thermal conditioning provides a physical environment that does not lead to crew loss or permanent disability of crew, as specified in CxP 70024, Constellation Human-Systems Integration Requirements (HSIR), for at least 36 hours with the hatch closed following a landing on water, considering relevant contingency and environmental conditions as specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 through 3.5.20 and 3.6.18 through 3.6.20. The analysis shall audit the Orion provision of potable water and emergency supplies for at least 36 hours with the hatch closed following a landing on water.

The verification shall be considered successful when the analysis shows Orion provides for crew survival, without permanent disability, for at least 36 hours with the hatch closed following a landing on water.

Rationale: Analysis is sufficient for verifying ventilation in a contingency situation. The analysis depends upon component and subsystem tests. Seawater preclusion from the ventilation system needs to be verified as part of the requirement for survival in a specified sea state.

[CA0274V-PO] The Orion Emergency Entry mode capabilities shall be verified by Analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% that the relevant software and hardware can successfully achieve a survivable entry and landing for predicted emergency entry modes when applying at least a minimum emergency design margin on subsystems.

Rationale: For the analysis, because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0325V-PO] The capability to provide Earth landing throughout all mission phases shall be verified by analysis. Analysis will cover abort and early return from any point along LEO and Lunar DRM's, and will include performance from SM separation to landing. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a

99.73% probability with a "consumer's risk" of 10% for achieving a survivable Earth landing within appropriate abort targeting constraints.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0493V-PO] Orion habitable environment during an ISS isolation event shall be verified by analysis.

The analysis shall assess that Orion design for power, thermal, atmosphere, and waste management ensures a habitable environment, as specified in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), for the assigned crew for 2 hours while Orion is still docked to the ISS, but the crew is isolated from the ISS.

The analysis shall audit Orion provision of food, water, and emergency supplies for the assigned crew for 2 hours while the crew is isolated from the ISS.

The verification shall be considered successful when the analysis shows Orion provides a habitable environment for the assigned crew for a single event of at least 2 hours in duration while Orion is still docked to the ISS, but the crew is isolated from the ISS.

Rationale: Analysis is sufficient for verifying subsystems in a contingency situation. The analysis depends upon component and subsystem tests. The assigned crew is predetermined for the mission and not intended to cover crew that are assigned to other vehicles.

[CA0532V-PO] The ability of Orion to sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 144 hours shall be verified by analysis. The analysis shall consist of documentation that the Orion System can provide the following simultaneous functions while the Orion habitable volume is depressurized:

a. Breathing gas quantity, flowrates, and scrubbing to the suited crew for 144 hours to meet medical standards, as defined per CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section 3.2.1 Natural and Induced Environments, Atmosphere and Section 3.5.4.3 Environmental Loads, and in accordance with suit pressure defined in CA5659.

b. Thermal conditioning to the suited crew for 144 hours to meet medical standards as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section 3.2.3 Thermal Environment and 3.5.4.3 Environmental Loads.

c. Power to the suited crew for 144 hours per CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document.

d. Nutritional, medical, and hydration needs to the suited crew for 144 hours to meet medical standards as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).

e. Communication (voice, suit and biomed data) with the suited crew for 144 hours as defined in CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document.

f. Seat ingress and harness securing with a pressurized suited crewmember and ability to readjust harness upon re-entry when suit becomes unpressurized.

g. Ability for interfacing Orion systems to operate and remove ammonia/body contaminates in return breathing gas for 144 hours.

The verification shall be considered successful when the analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized for 144 hours.

Rationale: Inspection is needed to verify the children requirement levels are sufficient to meet the requirement. Analysis is needed to assess the integrated timeline.

[CA0983V-PO] The Orion's structural integrity and ability to float shall be verified by analysis. The analysis shall indicate Orion floats and maintains structural integrity after landing on water and exposed to the full range of wind and sea states specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18. The analysis shall show that Orion floats and maintains structural integrity for a minimum of 36 hours and shall also indicate any time beyond the 36-hour minimum in which Orion meets these criteria to establish the maximum floatation duration. The verification shall be considered successful when the analyses indicate that the design precludes structural compromise and floats for a minimum of 36 hours while exposed to the full range of wind and sea states specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18.

Rationale: Including the determination of maximum floatation duration in the analysis will define the length of time within which Orion must be recovered and the limits for post-landing Orion habitation by the crew. The loads induced by the sea state will be specified in the Structural Design Verification Requirements document and satisfaction of those requirements will aid in the closure of this requirement.

[CA0984V-PO] The crew survival during landing touchdown shall be verified by test and analysis. The test shall verify that Orion can withstand the loads associated with landing impact, considering the wind speed, trajectory, and sea conditions. The test shall include instrumentation of the internal Orion elements, including physical crew interfaces. The analysis will combine the lower level test data and other vehicle performance measures to verify the loads transmitted through the vehicle and the essential crew systems, such as ECLSS, shall remain functioning after landing touchdown. The analysis shall verify that the loads within the CxP 70024, Constellation Human-Systems Integration Requirements (HSIR) are not exceeded. The verification shall be considered successful when the test and analyses demonstrate Orion shall assure crew survival during landing touchdown in the wind and sea states as specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), 3.5.18 and 3.6.18.

Rationale: Testing and analysis are required to ensure the vehicle can protect the crew sufficiently from the impact loads associated with landing. The analysis can utilize lower test data to provide an overall analysis and that the HSIR loads are not exceeded.

[CA3108V-PO] The ability of Orion to provide suit stowage such that a suit can be accessed within 2 (TBR-001-157) minutes for donning per crewmember shall be verified by demonstration and analysis.

The demonstration shall consist of 1-g suit donning evaluations using flight or training quality suits in a representative Orion volume mockup, with the suits stowed in the designated Orion stowage location, performed by two different sets of crewmembers (six crewmembers per set) with two runs performed by each set, and collection of task time for suit retrieval per 3108-PO, donning and umbilical connection per 3058-PO, pressurization, leak recovery, and any other tasks required by the crew to complete the suit donning and pressurization process prior to total cabin depressurization. The analysis shall consist of examination of task time collected during the 1-g demonstration, applying a program approved in-space extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments.

The verification will be considered successful when the analysis determines that each suit can be retrieved from stowage within 2 (TBR-001-157) minutes.

Rationale: This demonstration is intended to satisfy several requirements associated with quick suit donning in case of a vehicle leak. It is recognized that the ability of crewmembers to simultaneously retrieve suits is dictated not only by the stowage location, but also by the volume and activities required by the full complement of crewmembers within Orion. Since there are primarily three factors involved (Orion free volume, suit stowage location, and suit design) essential in the ability for the crew to don and connect their suits to life support within the "feed the leak" time, the only seemingly valid approach to confirm is through an integrated demonstration. The analysis will pull together the donning times as collected during the 1-g evaluations, use the best factor available from ISS and SSP history, with regards to additional time required for in-space activities, and verify that those collective times (minus any test artificial time delays, etc.) will allow the crewmembers to retrieve the suits within 2 (TBR-001-157) minutes. Six crewmembers were chosen as the maximum necessary to satisfy overarching Constellation requirements for ISS missions.

[CA3138V-PO] The fire detection and suppression for the pressurized volume shall be verified by analysis, supported by inspection and test. The analysis shall show that Orion detects events indicating fire and limits propagation of a fire in the pressurized volume of Orion. The analysis shall utilize results from Orion children requirements compliance with CxP 72000, Constellation Program System Requirements for the Orion

System fire detection and suppression criteria. An inspection of drawings shall be performed to verify that the fire detection and suppression hardware have been installed in the pressurized volume of Orion. A test of a simulated smoke alarm and vehicle response shall show that an impending fire in the cabin or avionics bay can be detected, suppressed, and the atmosphere restored. The verification shall be considered successful when the analysis, inspection, and test show that a fire in the pressurized volume of Orion can be detected and suppressed before it can propagate.

Rationale: This combination of methods will verify that an appropriate design will be implemented and tested at the vehicle level. Fire detection and suppression is a contingency requirement; prevention will be verified as part of the materials standard and design. The avionics bay, dependent upon design, may present a special case requiring a demonstration for verification.

[CA3259V-PO] Orion visual aids for search and recovery, independent of ambient lighting conditions, shall be verified by inspection. The inspection shall consist of review of allocated requirements from CxP 72000, Constellation Program System Requirements for the Orion System. The verification shall be considered successful when the inspection determines that the Orion System provides SAR visual aids for search and recovery, independent of ambient lighting conditions.

Rationale: This is an overarching Orion project parent verification requirement that can be satisfied once the flow-down requirements to the Orion projects are satisfied. The inspection documentation can be satisfied by the Orion System providing the requirements that address the functions (whether in CxP 72000, Constellation Program System Requirements for the Orion System or CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document).

[CA4154V-PO] The ability of Orion to return the crew to Earth with an unpressurized cabin for at least 144 hours shall be verified by analysis. The analysis shall consist of a review of documentation that the Orion System can provide those critical functions necessary to return Orion and crew back to Earth while the Orion habitable volume is depressurized. The verification shall be considered successful when the analysis confirms the functions can be performed simultaneously when the vehicle is depressurized for at least 144 hours.

Rationale: This is an overarching Orion Project parent verification requirement that can be satisfied once the flow-down requirements to the Orion Project are satisfied. As the next lower level requirements are Level III owned, it is not appropriate to list Level III requirements necessary to satisfy the functions necessary to satisfy this parent. Orion will need to determine what critical functions are required in order to return the vehicle to Earth, and then show by analysis as to how the vehicle design satisfies those functions for 144 hours with an unpressurized cabin.

[CA6074V-PO] The ability of Orion to isolate any suit-umbilical channel shall be verified by inspection. An inspection of the vehicle to EVA System interface shall be performed to ensure the design isolates a suit-umbilical channel upon action to isolate the suit-umbilical from the remaining suit loop. The verification shall be considered successful when the inspection shows Orion is capable of isolating any suit-umbilical channel.

Rationale: NR

[CA6075V-PO] Orion suit loop pressure preservation during an external pressure leak shall be verified by analysis and test. The analysis shall use a modeled leak of an equivalent 6.4 (TBR-001-1433) mm (0.25 inch) diameter hole in the suit to show that the available gas resources and atmosphere control will maintain the crew at a pressure no less than 15.4 (TBR-001-1431) kPa (2.2 psia) for at least 5 (TBR-001-1432) min. A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA System shall show that the suit loop pressure and oxygen partial pressure can be maintained to support prebreathe. A test in the Orion flight article utilizing flight qualified software shall show that the vehicle responds to a simulated suit loop leak event by activating the pressure control components required to maintain pressure and oxygen concentration. The verification shall be considered successful when the analysis and tests show that the Orion can maintain suit loop pressure at a pressure no less than 15.4 (TBR-001-1431) kPa (2.2 psia) for at least 5 (TBR-001-1432) min.

Rationale: NR

4.7.1.2.2.1 Orion Crew Survival Probabilities

[CA0398V-PO] ISS Crew LOC due to Orion shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for an ISS Crew mission due to Orion is no greater than 1 in 1700.

Rationale: NR

[CA0501V-PO] Lunar Sortie LOC due to Orion shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for a Lunar Sortie due to Orion is not greater than 1 in 200.

Rationale: NR

[CA3040V-PO] Lunar Outpost Crew LOC due to Orion shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for a Lunar Outpost Crew mission due to Orion is not greater than 1 in (TBD-001-559).

Rationale: NR

[CA5913V-PO] Ascent abort LOC due to conditions as outlined in Table XXX (TBD-001-1401) or Orion initiated failures shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC due to Orion is no greater than 1 in (TBD-001-947).

Rationale: NR

4.7.1.2.2.2 Orion Emergency Egress, Aborts and Return for Survivability

[CA0170V-PO] This verification shall be satisfied by test and analyses.

a. Tests shall be performed using the flight assets and associated CxP systems (Ground Systems and Mission Systems) under actual flight conditions to validate simulation testing.

b. Abort Determination shall be verified with simulation tests. Simulation tests shall be performed for all nominal and off-nominal profiles, all possible boundaries, modes, variable ranges and accuracy identified in (TBD-001-277) document(s). (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.)

The verification shall be considered successful when:

a. Orion performs the abort determination function(s) through an internal algorithm using internal or external data sources.

b. The CxP Architecture elements receive notification from Orion of the need for an abort through the C3I infrastructure.

c. All possible profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-277) document(s).

Rationale:

a. Flight testing this function provides the best end-to-end verification for this requirement.

b. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.

The (TBD-001-277) documents refer to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

[CA0333V-PO] The Orion abort capability shall be verified by test and analysis. Abort testing shall be conducted in a SIL (or equivalent) for ascent aborts LEO aborts and lunar transit aborts. Ascent abort testing in the SIL shall include models of the launch vehicle and the Orion Launch Abort System (LAS). LEO and transit abort testing shall include aborts to the nominal landing site, as well as other land and water sites. LEO and transit abort testing shall include models of separation dynamics from any attached vehicles (e.g. ISS, LSAM , LSAM /EDS). Transit abort testing shall include the targeting and execution of abort burns from TLI to the mission destination. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 95% probability with a "consumer's risk" of 10% for showing that all test results successfully return the crew to a land or water landing after an abort.

Rationale: Test is required because significant interaction between hardware and software subsystems require a test in an avionics environment driven by a certified flight simulation. Analysis by simulation is also required because of the large number of evaluations that must be performed and the lack of access to the operational environment for test.

[CA0334V-PO] The suited crew capability for unassisted emergency egress from the vehicle during pre-launch activities shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using Orion by performing a minimum of two runs with two different sets of suited crewmembers and collecting the task time for crew egress from Orion. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments. The analysis shall consist of the EVA, Ares I, and Orion system documentation review that meets unobstructed egress for the suited crew through the closure in the allocated CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document requirements. The verification shall be considered successful when the analysis determines the demonstration meets emergency egress within 2 (TBR-001-122) minutes and the allocated children requirements have been closed.

Rationale: This is an overarching Orion project verification requirement that can be satisfied once the flow-down requirements to the Orion projects are satisfied. The inspection documentation can be satisfied by Orion providing the requirements that address the functions (whether in the SRD, ICD or IRD).

[CA0335V-PO] Orion providing two (TBR-001-545) ground crew and six suited flight crew the capability for unassisted emergency egress, during pre-launch activities, shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using two ground crew and six suited flight crew by performing a minimum of two runs with two different sets of crewmembers and collecting the task time for crew egress from Orion. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for practical anthropometric crew assignments. The analysis shall consist of the EVA and Orion system documentation review that meets unobstructed egress for two ground crew and six suited flight crew through the closure in the allocated CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document requirements. The verification shall be considered successful when the analysis determines the demonstration meets emergency egress prior to hatch closure within 2 (TBR-001-202) minutes total starting from initiation of egress to complete ground crew and suited flight crew egress from vehicle and the allocated children requirements have been closed.

Rationale: NR

[CA0416V-PO] The ability of Orion to return the crew to the Earth surface independent of communications with MS during all mission phases shall be verified by analysis. The analysis shall include models of navigation subsystems that impact the ability of the vehicle to navigate independent of MS, and models of systems and elements on which Orion depends to perform this task. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that Orion can return the crew to the Earth surface independent of communications with the MS during all mission phases.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work. In this case, the analysis will require models of all elements on which Orion depends to complete the task, including Ares I, EDS, and LSAM vehicles.

[CA0466V-PO] Orion's capability for unassisted emergency egress for suited crew upon landing shall be verified by demonstration and analysis. The design of seat restraints, capsule orientation at rest, hatch mechanisms and egress paths in the 1 g nominal orientation and worst-case off nominal orientation will allow the crew to egress without ground crew assistance. The demonstration shall consist of evaluations using Orion and performing a minimum of two runs with two different sets of suited crewmembers and collecting the task time for crew egress from Orion. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for practical anthropometric crew assignments. The verification shall be considered successful when the demonstration and analysis shows that Orion supports the capability for unassisted emergency egress for suited crew upon landing.

Rationale: NR

[CA0498V-PO] The ability of Orion to perform aborts without Ares I thrust shall be verified by analysis. The analysis shall show that all ascent aborts can by accomplished without the use of Ares I thrust using a NASA-accredited digital simulation including models of Ares I.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0522V-PO] The verification of Automatic Aborts upon FTS Indication shall be satisfied by test.

Tests shall be performed using the flight assets under simulated flight conditions and certified Ground Systems during integrated ground checkout.

Simulation tests shall be performed for nominal and off-nominal profiles, the boundaries, modes, variable ranges and accuracy identified in (TBD-001-803) document(s). (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.)

This verification shall be considered successful when:

a. Telemetry shows the presence of the FTS indication.

b. That the FTS indication is valid.

c. That Orion automatically initiates the Ascent Abort Sequence.

d. That the abort sequence initiated by Orion is appropriate for the specific mission phase described in (TBD-001-803) document(s).

Rationale: Testing this function provides the best end-to-end verification for this requirement.

Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.

The referenced document refers to the body of engineering source data (i.e. SRDs, IRDs, trade Studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

[CA0579V-PO] The ability of Orion to land outside the Downrange Exclusion Zone during ISS mission shall be verified by analysis. The analysis shall include models of the ascent vehicle and separation dynamics. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 95% probability with a "consumer's risk" of 10% that Orion lands outside the Downrange Exclusion Zone.

Rationale: Analysis by simulation is sufficient because of the large number of evaluations that must be performed and the lack of access to the operational environment for test.

[CA5234V-PO] The ability of Orion to perform abort landings within allowable areas shall be verified by analysis. The analysis shall include models of the ascent vehicle, separation dynamics, and Orion dynamics. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 95% probability with a "consumer's risk" of 10% that Orion lands within the allowable areas.

Rationale: Analysis by simulation is sufficient because of the large number of evaluations that must be performed and the lack of access to the operational environment for test.

[CA5237V-PO] Orion expedited return from lunar orbit capability shall be verified by analysis and test. The testing shall be conducted using a SIL (or equivalent) with models of Orion as well as the LSAM in lunar orbit. The verification shall be considered successful when the test shows that Orion can return the crew from lunar orbit to the Earth surface within 118 (TBR-001-063) hours under nominal conditions. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% for return of Orion from low lunar orbit to the Earth surface within 118 (TBR-001-063) hours in the presence of dispersions.

Rationale: Test is required because significant interaction between hardware and software subsystems require a test in an avionics environment driven by a certified flight simulation. Analysis by simulation is also required because of the large number of evaluations that must be performed and the lack of access to the operational environment for test.

[CA5439V-PO] The verification of Automatic Aborts shall be satisfied by test. Tests shall be performed using the flight assets and associated CxP elements (Ground Systems and Mission Systems) under simulated flight conditions during integrated ground checkout. Simulation tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-795) document(s). (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when:

a. Telemetry shows that the vehicle and associated CxP systems involved with the Automatic Abort function(s) successfully executes the Automatic Aborts modes provided in (TBD-001-795) document(s).

b. The profiles, boundaries, variable ranges and accuracy specified in (TBD-001-795) document(s) are verified.

Rationale: Testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle. The (TBD-001-795) document refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

[CA5947V-PO] The Orion providing two (TBR-001-545) ground crew the capability for unassisted emergency egress, during pre-launch pad activities prior to flight crew ingress, shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using two ground crew performing a minimum of two runs with two different sets of crewmembers and collecting the task time for crew egress from the Orion. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for practical anthropometric crew assignments. The analysis shall consist of the Orion system documentation review that meets unobstructed egress for two ground crew through the closure in the allocated CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD) requirements. The verification shall be considered successful when the analysis determines the demonstration meets emergency egress prior to hatch closure within 2 (TBR-001-1025) minutes total starting from initiation of egress to complete ground crew egress from vehicle and the allocated children requirements have been closed.

4.7.1.2.3 Orion Crew Size

Draft **[CA0347V-PO]** (TBD-001-1040)

Rationale: (TBD-001-1040)

[CA0447V-PO] The capability to transport crews of zero to six into LEO with a single launch shall be verified by analysis. The analysis shall include the following functions: Flight performance/upmass, center of gravity, ECLS System (ECLSS) resources, thermal, CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR) verification for anthropometry, cockpit design, the capability to accommodate (physically in terms of space) minimum and maximum crews, and reconfiguration capability to cover in-between configurations and (TBD-001-637). The analysis shall also include the zero crew case in terms of automated functions, but not the crew accommodations. Verification shall be considered successful when the analysis shows that Orion can perform the transportation of the specified number of crew within its performance limits.

Rationale: NR

4.7.1.2.4 Orion Cargo Delivery and Return

[CA0547V-PO] The capability of the Orion to deliver a contiguous unpressurized cargo volume of at least 0.57 (TBR-001-750) m3 (20 ft3) with 0.83 m (2.72 ft) per side for lunar missions shall be verified by inspection. The inspection shall consist of a review of engineering drawings of the unpressurized portion of the Orion. The verification shall be considered successful when the inspection shows that the Orion is capable of delivering contiguous unpressurized cargo volume of at least 0.57 (TBR-001-750) m3 (20 ft3) with 0.83 m (2.72 ft) per side for lunar missions.

[CA0565V-PO] The ability of Orion to deliver a volume of 10.76 (TBR-001-035) m3 (380 ft3) of pressurized and conditioned delivery to and from the ISS per ISS Cargo mission shall be verified by analysis. The analysis shall consist of a review of cargo bays/stowage locations drawings and a calculation of the volume capability of the cargo bays/stowage locations. The verification shall be considered successful when the analysis confirms the volume calculated is equal to or greater than 10.76 (TBR-001-035) m3 (380 ft3).

Rationale: This VR calculates the volume for cargo by an analysis of the drawings. The deliver/return cargo mass requirement calculates the center of gravity and, therefore, does not need to be repeated here.

[CA0864V-PO] The Orion pressurized Mass Delivered requirement from Earth to ISS for crewed missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% showing that the Mass Delivered capability of Orion is equal to or greater than the Mass Delivered requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0865V-PO] The Orion Mass Returned requirement from ISS to Earth for crewed missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% showing that the calculated Mass Returned capability of Orion is equal to or greater than the Mass Returned requirement.

Rationale: NR

[CA0866V-PO] The Orion pressurized Cargo Mass Delivered requirement from Earth to the ISS for ISS Cargo Missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% showing that the calculated Mass Delivered capability of Orion is at least 2850 kg (6283 lbm) (gross) equal to or greater than the Mass Delivered requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0868V-PO] The Orion Mass Returned requirement from the Lunar Rendezvous Orbit (LRO) to Earth for crewed lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% showing that the calculated Mass Returned capability of Orion is equal to or greater than the Mass Returned requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3182V-PO] The capability of the Orion to deliver cargo from the Earth to ISS in an uncrewed configuration shall be verified shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Orion is capable of delivering cargo from the Earth to ISS in an uncrewed configuration.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5155V-PO] The ability of Orion to return cargo volume from the lunar orbit to the Earth shall be verified by analysis. The Analysis shall consist of a review of cargo bays/stowage locations drawings and a calculation of the volume capability of the cargo bays/stowage locations. The verifications shall be considered successful when the analysis confirms the volume calculated is equal to or greater than the requirement during each crewed mission.

Rationale: This Verification Requirement (VR) calculates the volume for cargo by an analysis of the drawings. The deliver/return cargo mass requirement calculates the center of gravity, and therefore, does not need to be repeated here.

[CA5233V-PO] The Orion mass returned requirement from ISS to Earth for uncrewed cargo missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the calculated mass returned capability of the Orion is equal to or greater than the mass returned requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5950V-PO] The requirement for the Orion to deliver at least 600 (TBR-001-1026) kg (1,322 lbm) of unpressurized mass to the ISS shall be verified by inspection. The inspection shall review the verification results of the Level III mass requirements. The verification shall be considered successful when the inspection reveals that the Orion has the capability to deliver at least 600 (TBR-001-1026) kg (1,322 lbm) of unpressurized cargo to the ISS.

[CA5960V-PO] The capability of Orion to provide an unpressurized cargo volume of 2.92 (TBR-001-1027) m3 (103 ft3) with footprint dimensions of 1.25 (TBR-001-1027) m by 1.16 (TBR-001-1027) m (4.1 ft by 3.8 ft) for ISS missions shall be verified by inspection. An inspection of the engineering drawings of the unpressurized portion of the Orion shall prove that a minimum of 2.92 (TBR-001-1027) m3 (103 ft3) is available for unpressurized cargo. The verification shall be considered successful when the analysis shows the minimum volume of 2.92 (TBR-001-1027) m3 (103 ft3) with footprint dimensions of 1.25 (TBR-001-1027) m by 1.16 (TBR-001-1027) m (4.1 ft by 3.8 ft) for ISS missions is met.

[CA5961V-PO] The requirement for the Orion to deliver at least 382 (TBR-001-1028) kg (841 lbm) of unpressurized mass for lunar missions shall be verified by inspection. The inspection shall review the verification results of the Level III mass requirements. The verification shall be considered successful when the inspection reveals that the Orion has the capability to deliver at least 382 (TBR-001-1028) kg (841 lbm) of unpressurized cargo for lunar missions.

4.7.1.2.5 Orion Mission Rates and Durations

[CA0060V-HQ] The capability of Orion to remain docked to the ISS for at least 210 days shall be verified by inspection and analysis. The inspection shall review CxP 70031, Constellation Program Orion -to- ISS Interface Requirements Document (IRD) requirements and verification closure notices. The analysis shall use a crew timeline model for planned preventive maintenance based on component lifetimes and reliability and include consumable margins for Orion. The verification shall be considered successful when the inspection shows that Orion has complied with the CxP 70031, Constellation Program Orion -to- ISS Interface Requirements Document (IRD) requirements and the analysis shows that:

a. The required Orion maintenance tasks are supported by the crew timeline model.

b. The combined Orion consumable margins are sufficient for Orion to remain docked to the ISS for at least 210 days.

Rationale: NR

[CA0082V-PO] The ability for Orion to loiter uncrewed in LLO for at least 210 (TBR-001-039) days shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include lunar gravity affects and vehicle subsystem models. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, vehicle consumables, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a

99.73% (TBR-001-304) probability with a 90% confidence that Orion can loiter uncrewed in LLO for at least 210 days.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3164V-PO] Orion's provision of a habitable environment for a lunar mission shall be verified by analysis. The analysis shall assess that Orion design for atmosphere control and quality, potable water, atmosphere temperature, humidity and ventilation, food, body waste and trash management provides a habitable environment, as specified in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), for four crew for a minimum of 21.1 days. The analysis will be supported by component and subsystem tests and analyses. The verification shall be considered successful when the analysis shows Orion provides a habitable environment for up to four crew for a minimum of 21.1 days in duration for a lunar mission.

Rationale: Analysis supported by subsystem and component tests and analyses is sufficient to verify that Orion can support a habitable environment for a crew of four for 21.1 days. The analysis will include an audit of consumable supplies.

[CA6084V-PO] The ability of the Orion to provide the capacity to perform two ISS missions in a year shall be verified by analysis. The analysis shall assess the time required to produce, transport, assemble, and test the Orion flight systems and integrate them into mission configuration. The verification shall be considered successful when analysis shows the Orion flight systems can be produced, transported, assembled, tested and integrated into mission configuration in time to meet mission objectives.

[CA6103V-PO] The ability for the Orion to be mission ready for launch attempts on no less than 7 consecutive days for crewed missions shall be verified by analysis. The analysis shall assess the Integrated Logistics Support Plan, the Orion Logistics Support Analysis Report, ground processing plans, Logistics Support Analysis Records (LSAR), and other documents that include launch recycle tasks and activities associated with crewed missions in order to calculate the time and resources required to perform launch tasks for 7 consecutive days. The verification shall be considered successful when the analysis results show that the Orion can be mission ready for launch opportunities on no less than 7 consecutive days for crewed missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA6103V-PO] The ability for the Orion to be mission ready for launch attempts on no less than 7 consecutive days for crewed missions shall be verified by analysis. The analysis shall assess the Integrated Logistics Support Plan, the Orion Logistics Support Analysis Report, ground processing plans, Logistics Support Analysis Records (LSAR), and other documents that include launch recycle tasks and activities associated with crewed missions in order to calculate the time and resources required to perform launch tasks for 7 consecutive days. The verification shall be considered successful when the analysis results show that the Orion can be mission ready for launch opportunities on no less than 7 consecutive days for crewed missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA6258V-PO] The ability of the Orion to provide the capacity to perform two lunar launches in a year shall be verified by analysis. The analysis shall assess the time required to produce, transport, assemble, and test the Orion flight systems and integrate them into mission configuration. The verification shall be considered successful when analysis shows the Orion flight systems can be produced, transported, assembled, tested and integrated into mission configuration in time to meet mission objectives.

[CA6260V-PO] The ability of the Orion to launch on a 45 calendar day interval, measured from the launch of the first mission to the launch of the second mission shall be verified by analysis. The analysis shall the assess the time required to test and integrate the Orion flight systems into mission configuration. Verification shall be considered successful when the analysis determines the Orion can be tested and integrated into mission configuration within 45 calendar days.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide a fully functional vehicle in time to support the mission. An analysis of the timeline considering all aspects involved with processing the vehicle will determine the minimum amount of time to ready the vehicle for the mission. The analysis should also include any reprocessing or refurbishment activities planned. Accurate analysis for a 45 day Orion launch spacing is partially contingent upon the availability of Constellation infrastructure. Therefore, analysis should assume the baselined quantities for all ground systems.

4.7.1.2.6 Orion Architecture Definition

[CA0191V-PO] Orion orbital transfer from the ascent target, defined in the ascent target table in Section 3.7.2.2.6, to ISS requirement shall be verified by analysis. The analysis shall include models of navigation and maneuver targeting subsystems, and models of the systems and elements on which Orion depends to perform the orbit transfer mission phase. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Orion vehicle can successfully perform the orbit transfer from the ascent target to ISS.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0324V-PO] The capability to land at designated U.S. coastal water locations shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall include models of navigation and maneuver targeting subsystems, and models of the systems and elements on which Orion depends to perform the ground landing mission phase and will cover LEO and Lunar DRMs to designated CONUS sites, including performance from SM separation to landing. The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% of achieving a nominal entry and landing at each of the designated sites (as appropriate to the specific DRM) within targeting constraints.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0351V-PO] Orion's capability to launch independent of ambient lighting conditions shall be verified by analysis. The Analysis shall review the Ground Systems operational acceptance test to show that the ground facilities, facility systems and GSE will be able to provide launch capabilities independent of lighting conditions. The analysis shall include a review of vehicle systems, including but not limited to, vehicle tracking, recovery aids and imagery to show that the flight systems, facility, facility systems and GSE that will be used to launch flight systems successful operations and performance determination are independent of ambient lighting conditions are built and certified. These facilities, flight systems and GSE requirements will be identified and characterized in CxP 72000, Constellation Program System Requirements for the Orion System, CxP 72006, Ground Systems, Systems Requirements Document (SRD). The verification shall be considered successful when the analysis shows that the flight and Ground Systems are ready to support flight systems launch for the Orion Architecture independent of ambient lighting conditions.

Rationale: NR

Draft **[CA0373V-PO]** (TBD-001-1041)

Rationale: (TBD-001-1041)

[CA0494V-PO] The capability to perform Earth landing regardless of ambient lighting conditions shall be verified by Analysis. The analysis shall review the performance of Orion software, hardware and operations concepts intended to support Earth landing, assessing potential sensitivity to ambient lighting conditions. The analysis shall be considered successful when it shows that the relevant software, hardware and operations can successfully support entry and landing within design limits, regardless of ambient lighting conditions.

Rationale: A test of the sensors is required for verification because of the potential sensitivity of the hardware to lighting conditions. Simulation would be inadequate, and it is feasible to test the sensors in a facility environment.

[CA3166V-PO] The ability of Orion to perform EVAs on lunar missions at least two (TBR-001-206) EVA operations of at least 4 (TBR-001-207) hours duration each independent of other vehicles shall be verified by analysis, demonstration, and test. The analysis shall prove that the crew can depress the vehicle while external or internal to the vehicle, can repress the vehicle while internal to the vehicle, the hatch can be operated by crewmembers in pressurized EVA system suits, and that the Orion System can provide the following functions while the Orion habitable volume is depressurized:

Supply atmospheric consumables to repress the vehicle two times from 0 psia to standard cabin pressure, as specified in CA0288-PO; provide internal volume to egress and ingress the vehicle with a full complement of six crewmembers; provide translation paths and stabilization for Contingency and Unscheduled EVA tasks; supply consumables to the EVA System to support a total of 16 (TBR-001-538) hours, including 8 (TBR-001-207) hours at vacuum for four crewmembers including oxygen quantity and flow rates, CO_2 and trace contaminant scrubbing, cooling water flow rates and temperatures, power, and communication (voice, suit and biomed data).

The test shall consist of flight-like Orion flight or flight equivalent hardware, primarily ECLSS and power subsystem components, including vehicle interface assembly, and EVA System flight equivalent hardware, including suits, two EVA System umbilicals of 9.1m (TBR-001-409) (30ft) in length, and two EVA System umbilicals of 3m (TBR-001-410) (10ft) in length. The suits will be fully pressurized and receiving all functions from Orion for the following sequences:

The demonstration shall consist of neutral buoyancy evaluations, with the Orion mockups outfitted with the proper internal volume, internal handrails, seats, volumetric mockups of all internal areas, umbilicals, operable hatch, all loose stowage items (which would normally be not stowed away for an EVA), translation path, worksite, simulated EVA tasks, and all external appendages as identified in the Orion drawings, using flight-like EVA suits (pressurized). The demonstration will consist of crewmembers opening and closing the hatch, egressing and ingressing the mockup, evaluation of translation paths between hatch and worksites, worksite stabilization, worksite tasks, and reach and visibility to all vehicle controls necessary during an EVA (depress and repress controls, displays, etc.). The demonstration will be repeated by at least three different sets of crewmembers (for a total of six crewmembers to perform the demonstration). During egress and ingress phases of the demo, there will be at least four suited subjects (or two volumetric representations of suited subjects) located inside Orion.

The test shall consist of Orion flight or flight equivalent hardware with a full complement of EVA System flight or flight equivalent hardware. The suits will be fully pressurized and receiving all functions from Orion at ambient conditions for the following sequences:

a. Four suits (and crewmembers) will be connected to all short umbilical positions with the suits performing simultaneously.

b. Four suits (and crewmembers) will be connected to the two long umbilical locations and two to short umbilical locations. All suits will operate in the sequences of sufficient duration to obtain steady state with the sequence repeated until all suits have been swapped and operated simultaneously at all umbilical locations.

The verification shall be considered successful when:

a. The analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized.

b. The demonstration reflects crew subjective acceptability for Orion ingress, egress, vehicle displays and controls, translations, worksite stability, and worksite tasks as documented in the Crew Consensus report.

c. The test data confirms all Orion and EVA System conform to Orion/EVA IRD specifications of all four suits simultaneously.

Rationale: The analysis portion of this requirement will be satisfied once the flow-down requirements to the Orion Project are satisfied. The analysis of functions will confirm that Orion has levied and closed out the next lower level requirements. The analysis documentation can be satisfied by the Orion System providing the requirements that address the functions (whether in the CxP 72000, Constellation Program System Requirements for the Orion System or CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document), provide evidence as to how Orion has accounted for providing those functions simultaneously with a depressurized cabin, and show that the verification for those requirements has been closed. The 16 (TBR-001-538) hour duration specified assumes 4 hours of EVA, 4 hours of in-suit prebreathe based on a 14.7 psia cabin per CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), requirement (TBD-001-1052) for two EVAs. The distinction has been made between long and short umbilicals to verify that if the length drives closed vs. open loop design implementation, that both types of umbilical lengths can be supplied by Orion simultaneously. Note that the 4 hour prebreathe period may be performed by all four crewmembers on the shorter umbilical length. The demonstration is needed to show that subjectively all the operations required by the crew during suited operations for EVA (egress, ingress, translation, stability, reach and visibility to Orion control, etc.) with a full complement of crewmembers and in the Orion volume are viable. Six crewmembers historically represent the minimum number in order for the Astronaut Office to publish a Crew Consensus Report, which is the favored documentation source to this verification method. The test is necessary as it cannot be assumed at any other point in the Orion or EVA system certification that a full set of suits and Orion have been verified to operate together simultaneously. Four suits were chosen, as this is the defined crew size for lunar missions (currently the contingency and unscheduled EVA is only applicable for lunar missions). Certification hardware can be used for the demonstration, if flight hardware is not available. The swapping of suits to each umbilical outlet will provide a level of confidence that suits can operate in all vehicle locations.

[CA3168V-PO] The ability of Orion to provide an external control to depressurize the cabin that is operable by an EVA crewmember shall be verified by analysis and demonstration.

The analysis shall prove that Orion System can provide the following functions:

a. Ability to depress the vehicle to vacuum through an external method

b. Adherence to CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification, Section (TBD-001-468)

The demonstration shall consist of neutral buoyancy evaluations, with an Orion external mockup outfitted with the external repress mechanism, translation path and all external appendages, as identified in the Orion drawings, using flight-like pressurized EVA suits, to evaluate reach and visibility to external vehicle depress operations by at least six crewmembers.

The verification shall be considered successful when the analysis confirms the functions listed can be performed, and the demonstration reflects acceptable human engineering evaluation for external depressurization reach and access, as documented in the Crew Consensus report.

Rationale: The analysis portion of this requirement will be satisfied once the flow-down requirements to the Orion project are satisfied. As the next lower level requirements are Level III owned, it is not appropriate to list Level III requirements necessary to satisfy the functions necessary to satisfy this parent. The analysis documentation can be satisfied by the Orion System providing the requirements that address the functions (whether in CxP 72000, Constellation Program System Requirements for the Orion System or CxP 70033, Constellation Program Orion -to-EVA Systems Interface Requirements Document), that provide evidence as to how Orion has accounted for providing those functions, and show that the verification for those requirements have been closed. The demonstration is needed to show that all the operations required by the crew to depress the vehicle (with a full complement of crewmembers and in the Orion volume) are properly located for reach and visibility. Six crewmembers historically represent the minimum number in order for the Astronaut Office to publish a Crew Consensus Report, which is the favored documentation source to this verification method.

[CA3204V-PO] Orion orbital transfer from the ascent target, defined in the ascent target table in Section 3.7.2.2.6, to the Earth Rendezvous Orbit (ERO) for crewed lunar missions shall be verified by analysis. The analysis shall include models of navigation and maneuver targeting subsystems, and models of the systems and elements on which Orion depends to perform the orbit transfer mission phase. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Orion vehicle can successfully perform the orbit transfer from the ascent target to ERO for crewed lunar missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3207V-PO] The ability of Orion to perform the orbit transfer from LLO to LRO for crewed lunar missions shall be verified by analysis. The analysis shall include models of navigation and maneuver targeting subsystems, and models of the systems and elements on which Orion depends to perform the orbit transfer mission phase, and shall include multi-body gravity effects. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Orion can perform the orbit transfer from LLO to LRO for crewed lunar missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3209V-PO] The ability of Orion to perform TEI for crewed lunar missions shall be verified by analysis. The analysis shall include models of navigation and maneuver targeting subsystems, and models of the systems and elements on which Orion depends to perform the TEI mission phase, and shall include multi-body gravity effects. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Orion can perform the TEI for crewed lunar missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA4152V-PO] The ability of Orion to provide the infrastructure to perform ISS-based EVAs on ISS missions shall be verified by analysis and demonstration. The analysis shall prove that the Orion System can provide the following functions:

a. The exterior of Orion complies to EVA specifications as invoked per CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification compliance applicability.

b. EVA translation paths as specified per CxP 70033, Constellation Program Orion -to-EVA Systems Interface Requirements Document.

The demonstration shall consist of neutral buoyancy evaluations, with the Orion mockups outfitted with external translation paths, and all external appendages as identified in the Orion drawings, using flight-like EVA suits (pressurized). The demonstration will consist of crewmembers evaluating the translation paths between hatch and worksites. The demonstration will be repeated by at least three different sets of crewmembers (for a total of six crewmembers to perform the demonstration). The verification shall be considered successful when the analysis confirms the functions listed can be performed and the demonstration reflects crew subjective acceptability for Orion translations, as documented in the Crew Consensus report.

Rationale: This is an overarching Orion Project parent verification requirement that can be satisfied once the flow-down requirements to the Orion Project are satisfied. As the next lower level requirements are Level III owned, it is not appropriate to list Level III requirements necessary to satisfy the functions necessary to satisfy this parent. This assumes that any EVA performed for Orion during the ISS mission phases will be performed from the ISS airlock using ISS resources. Thus, the Orion only needs to have the external compliance with the EVA D&C specifications and translation paths. If the Constellation Program determines later that EVA tasks are required for Orion (mission success or contingency EVA for ISS phases), then those will need to be added. The analysis documentation can be satisfied by the Orion System providing the requirements that address the functions (whether in CxP 72000, Constellation Program System Requirements for the Orion System or CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document), that provide evidence as to how Orion has accounted for providing those functions simultaneously with a depressurized cabin, and show that the verification for those requirements has been closed. The demonstration is needed to show that subjectively, translations required by the crew during suited operations for EVA with a full complement of crewmembers, are viable. Six crewmembers historically represent the minimum number in order for the Astronaut Office to publish a Crew Consensus Report, which is the favored documentation source to this verification method.

[CA5148V-PO] The ability of the Orion project to provide the infrastructure necessary to concurrently operate at least three Orion vehicles during ISS phase operations shall be verified by analysis and test. The testing shall consist of an end-to-end data flow that exercises major functionalities of concurrent Mission Operations of at least three Orions in space using flight equivalent units or emulators with Flight Software in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. Analysis consists of a review of the CxP 72000, Constellation Program System Requirements for the Orion System necessary to identify and control specific vehicles (e.g., Orion-1, Orion-2). Verification shall be considered successful when the analysis and test confirm the infrastructure necessary to concurrently operate at least three Orion vehicles during ISS phase operations.

Rationale: This is an overarching Orion project verification requirement that can be satisfied once the flow-down requirements to the Orion projects are satisfied. The analysis can be satisfied by Orion providing the requirements that address the functions (whether in CxP 72000, Constellation Program System Requirements for the Orion System, ICD or IRD).

[CA5240V-PO] The Orion capability to perform orbit transfer from Low Lunar Orbit (LLO) to Lunar Rendezvous Orbit (LRO) in 6 hours (TBR-001-205) or less shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall include models of navigation and maneuver targeting subsystems, and models of the systems and elements on which Orion depends to perform the orbit transfer mission phase, including timing of the orbit transfer maneuver, and translunar and multi-body gravity effects. The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% of successful orbit transfer from LLO to LRO in 6 (TBR-001-205) hours or less.

Rationale: Test is required because significant interaction between hardware and software subsystems require a test in an avionics environment driven by a certified flight simulation. Analysis by simulation is also required because of the large number of evaluations that must be performed and the lack of access to the operational environment for test.

[CA5319V-PO] Orion orbital transfer from the ascent target to a stable low earth orbit (LEO) independent of communications with Mission Systems shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall include models of navigation and maneuver targeting subsystems, and models of the systems and elements on which Orion depends to perform the orbit transfer mission phase, including navigation system performance, specifically in the case where no ground update of state vector is performed. The analysis will review the software's capability to successfully perform this function without updates from MS. The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the vehicle can successfully perform the orbit transfer from ascent target to stable LEO independent of communications with Mission Systems.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work. This assumes that the only possible communication from MS would effect the software's target information, vehicle's position, or commands.

[CA6068V-PO] The ability of the Orion project to provide the infrastructure necessary to concurrently operate at least (TBD-001-1316) Orion vehicles during lunar phase operations shall be verified by analysis and test. The testing shall consist of an end-to-end data flow that exercises major functionalities of concurrent Mission Operations of at least (TBD-001-1316) Orions in space. Analysis consists of a review of the CxP 72000, Constellation Program System Requirements for the Orion System necessary to identify and control specific vehicles (e.g., Orion-1, Orion-2). Verification shall be considered successful when the analysis and test confirm the infrastructure necessary to concurrently operate at least (TBD-001-1316) Orion vehicles during lunar phase operations.

Rationale: This is an overarching Orion project verification requirement that can be satisfied once the flow-down requirements to the Orion projects are satisfied. The analysis can be satisfied by Orion providing the requirements that address the functions (whether in CxP 72000, Constellation Program System Requirements for the Orion System, ICD or IRD).

4.7.1.2.6.1 Orion Control Mass

[CA0827V-PO] The Control Mass requirement of Orion upon arrival at the Ascent Target for Lunar missions, shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worst-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of Orion, upon arrival at the Ascent Target for Lunar Missions, is less than or equal to the required Control Mass.

Rationale: N/R

[CA4134V-PO] The Control Mass requirement of Orion at Lift-Off for Lunar Missions shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worst-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of the Orion at Lift-Off for Lunar Missions is less than or equal to the required Control Mass.

Rationale: NR

[CA4135V-PO] The nominal jettison event times shall be verified by analysis for the Ares I/Orion ascent phase. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% that the vehicle can successfully perform all nominal jettison events within the required amount of time following the Ares I Upper Stage ignition.

Rationale: NR

[CA4139V-PO] The Control Mass requirement of Orion at the time of Ares V rendezvous shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of Orion at the time of Ares V rendezvous is less than or equal to the required Control Mass.

Rationale: NR

[CA4163V-PO] The Control Mass requirement of Orion at Lift-Off for the ISS Mission shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worst-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of Orion at Lift-Off for the ISS Mission is less than or equal to the required Control Mass.

Rationale: NR

[CA4164V-PO] The Control Mass requirement of Orion at the ISS Ascent Target shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worst-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of Orion at the ISS Ascent Target is less than or equal to the required Control Mass.

Rationale: NR

4.7.1.2.6.2 Orion Delta-V

Draft **[CA0406V-PO]** (TBD-001-1042)

Rationale: (TBD-001-1042)

[CA0829V-PO] The Orion translational delta-V requirement shall be verified by analysis. The analysis shall include models of the mass properties, GN&C parameters, engine performance, and systems and elements on which Orion depends to perform translational maneuvers. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-

1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the calculated translational delta-V of Orion is equal to or greater than the translational delta-V requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5948V-PO] The requirement for Orion to provide propellant tanks sized to meet the translational delta-V requirement for lunar missions shall be verified by inspection and analysis. Inspection shall include a ROD of the Orion propellant tanks and flight hardware. The analysis shall include dispersions on mass properties, engine performance, and fuel losses. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The verification shall be considered successful when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Orion propellant tanks are sized for the translational delta-V requirement for lunar missions.

Rationale: (TBD-001-1122)

4.7.1.2.7 Orion Safety (System, Public, and Planetary)

[CA0435V-PO] The control for critical hazard shall be verified by analysis. The analysis shall review the Orion System Hazard Analysis . The verification shall be considered successful when the analysis shows that critical hazards are controlled per CxP 70038, Constellation Program Hazard Analysis Methodology.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

[CA0436V-PO] Failure tolerance for catastrophic hazards shall be verified by analysis. An Integrated hazard analysis shall be performed, using system-level hazard analyses and Failure Modes and Effects Analysis (FMEA) to show compliance with the approved level of failure tolerance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled with the approved number of controls and all DFMR items are approved in the Hazard Reports.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

[CA0437V-PO] The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the Orion System-level FMEA/CILs for compliance with JPR 8080.5, Section G-2. The verification shall be considered successful when the integrated analysis shows that redundant systems are separated or protected.

Rationale: Verification for this requirement will be performed in accordance with the CxP 70038, Constellation Program Hazard Analyses Methodology and CxP 70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology. It looks top down and bottoms up at the system level.

4.7.1.2.8 Orion Command and Control

[CA0134V-PO] The execution of commands by Orion which are valid in the current state shall be verified by Test. The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions. All applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. Each command will be executed separately for each command source path (e.g., crew interface, C&T Networks). All applicable commands defined in (TBD-001-1070) document(s) shall be executed by Orion. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) All safety critical commands shall be executed. The verification shall be considered successful when the Test shows that all of the applicable commands identified in (TBD-001-1070) document(s):

a. The commands are executed by Orion when valid in the current state in every applicable mission phase, state and mode.

b. The commands are rejected by Orion when not valid in the current state in every applicable mission phase, state and mode.

c. The commands and that the effects of the command execution are properly reflected in H&S telemetry and on the crew displays.

Rationale: A Test of the execution of Orion commands defined by (TBD-001-1070) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability. The (TBD-001-1070) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for Orion.

[CA0448V-PO] The capability to control the Orion system by a single crewmember shall be verified by demonstration and analysis. The demonstration shall include crew in the loop testing in a NASA-accredited high fidelity lab and shall verify a single crewmember can monitor and operate all critical functions of Orion from one console. The demonstration shall use these facilities to capture data and analyze manual control performance of the vehicle for all nominal and abort flight phases that are determined appropriate for single human piloting and other critical Orion operations, and shall include system and environment dispersions. The analysis shall utilize the test data to show the single human piloting maneuvers does not violate the Orion structural, thermal or performance margins for all relevant flight phases. The verification shall be considered successful when the demonstration and analysis show that a single crewmember can operate all critical functions of Orion including flight path and attitude control where manual control does not violate structural, thermal or performance margins for all relevant flight phases.

Rationale: A demonstration must be performed with a human subject demonstrating the interactions between the human and avionics to pilot the vehicle under the dynamic conditions of flight. An analysis will validate the demonstration and utilize the demonstration results to show that structural, thermal, or performance margins are not violated.

[CA3110V-PO] The requirement for Orion to Accept Control of Automation shall be verified by test.

a. Tests shall be performed using the flight assets and associated CxP elements (Crew, Ground Systems and Mission Systems) under simulated flight conditions during integrated ground testing.

b. Simulation tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-914) document(s) for which the control of automation will be performed.

The verification shall be considered successful when:

a. The vehicle's running function is halted by the authorized Constellation System assuming vehicle control.

b. When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

c. The applicable vehicle profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-914) document(s).

Rationale: Testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions.

The (TBD-001-914) documents refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

[CA3249V-PO] The Orion crew interface to generate commands shall be verified by Test. The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-750) document(s) shall be generated by crew surrogates. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be generated. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-750) document(s):

a. Commands are generated by crew surrogates in Orion in each applicable mission phase, state and mode.

b. The crew displays reflect the status of the commands.

Rationale: A Test of the generation of Orion commands defined by (TBD-001-750) document(s) on the flight Orion or flight equivalent hardware for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability. The (TBD-001-750) documents will be engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for Orion.

[CA3254V-PO] The generation of commands by Orion shall be verified by Test. The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions. All applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. All applicable commands defined in (TBD-001-742) document(s) shall be generated by Orion. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) All safety critical commands shall be generated. The verification shall be considered successful when the Test shows that all of the applicable commands identified in (TBD-001-742) document(s) are generated by Orion in every applicable mission phase, state and mode.

Rationale: A Test of the generation of Orion commands defined by (TBD-001-742) document(s) for every mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability. The (TBD-001-742) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for Orion.

[CA3255V-PO] The execution of commands by Orion which are addressed to Orion shall be verified by Test. The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-759) document(s) shall be executed by Orion. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be executed. Orion shall be sent every command addressed to it and a subset of all the commands addressed to other systems. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-759) document(s):

a. The commands are executed by Orion when valid in the current state in each applicable mission phase, state and mode and the effect of the command is properly seen to the commanding System.

b. The commands are rejected by Orion when not valid in the current state in each applicable mission phase, state and mode or not properly addressed to Orion.

Rationale: A Test of the execution of Orion commands by the flight Orion or flight equivalent hardware for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability. The (TBD-001-759) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for Orion.

[CA5039V-PO] Orion shall provide a minimum of 20 Gigabytes of digital storage for recording digital data received from other Constellation Systems. The provision of a minimum of 20 Gigabytes of digital storage for recording digital data shall be verified by Inspection and Demonstration.

An inspection shall be conducted on the systems digital storage system implementation. A demonstration shall be performed using flight or similar assets in a SIL (or equivalent) with data received from a simulated "other" system. The receiving system shall record until full.

The verification shall be considered successful when:

a. The inspection shows that a minimum of 20 Gigabytes are allocated for the storage of digital data received from other Constellation Systems.

b. The demonstration shows that the receiving system records at least 20 Gigabytes of "other" system data and an audit of the data shows it to be correct.

Rationale: Inspection of implementation is adequate to ensure allocation. Demonstration of the capability is performed to ensure complete functionality.

[CA5040V-PO] The recording of System-generated digital data received from other Constellation Systems shall be verified by demonstration.

The demonstration shall be conducted in a SIL (or equivalent) using flight or similar assets. Test objectives shall be prepared using IRDs and SRDs to identify source systems for data recording and the data content to be recorded. The source system may be simulated but should be certified. The source data shall be transmitted for no less than 4 hours or for an entire mission phase, if shorter, at least twice.

The verification shall be considered successful when the demonstration shows:

a. Source data is received for an entire mission phase or at least 4 hours

b. Demonstration is performed twice

c. All received data is recorded

d. An audit of the recorded data shows it to be correct.

Rationale: Recording of system-generated digital is critical to support development, test, operation, and maintenance of systems. To confirm interoperability and functionality demonstrations are performed.

4.7.1.2.9 Orion Health and Status

[CA0427V-PO] The provision of Health and Status data by Orion to the crew shall be verified by Test.

The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions.

Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The applicable Health and Status data defined in (TBD-001-287) document(s) shall be observed by crew surrogates. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.)

The verification shall be considered successful when the Test shows that the Health and Status data identified in (TBD-001-287) document(s):

a. Health and Status is observed by crew surrogates in Orion in each applicable mission phase, state and mode.

b. Health and Status agrees with the actual health and status of Orion.

Rationale: A Test of the provision of Orion health and status data by the flight Orion or flight equivalent hardware to crew surrogates in Orion for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-287) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the Health and Status parameters for Orion.

[CA0428V-PO] The generation of Health and Status information by Orion shall be verified by Test.

The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions.

Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The applicable Health and Status data defined in (TBD-001-330) document(s) shall be generated by Orion. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.)

The verification shall be considered successful when the Test shows that the Health and Status data identified in (TBD-001-330) document(s):

a. Health and Status is generated by Orion in each applicable mission phase, state and mode.

b. Health and Status agrees with the actual Health and Status of Orion.

Rationale: A Test of the generation of Orion health and status data by the flight Orion or flight equivalent hardware for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-330) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the Health and Status parameters for Orion.

[CA0438V-PO] The provision of fault detection by Orion shall be verified by Test. The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-906) document(s) for each applicable simulated mission phases, states, and modes for Orion at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-906) document(s) are detected by Orion in every applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by Orion:

a. For the faults and fault scenarios identified by (TBD-001-906) document(s)

b. By the flight Orion or flight equivalent hardware

c. For each mission phase, state and mode

is sufficient to verify this capability.

The (TBD-001-906) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be detected.

[CA5465V-PO] The provision of fault isolation by Orion shall be verified by Test. The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-452) document(s) for applicable simulated mission phases, states, and modes for Orion at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-452) document(s) are isolated by Orion in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by Orion

a. For the faults and fault scenarios identified by (TBD-001-452) document(s)

b. By the flight Orion or flight equivalent hardware

c. For each mission phase, state and mode

is sufficient to verify this capability.

The (TBD-001-452) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be isolated.

[CA5466V-PO] The provision of fault recovery by Orion shall be verified by Test. The Test shall use the flight Orion or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-454) document(s) for applicable simulated mission phases, states, and modes for Orion at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-454) document(s) are recovered from by Orion in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by Orion:

a. for the faults and fault scenarios identified by (TBD-001-454) document(s)

b. by the flight Orion or flight equivalent hardware

c. for each mission phase, state and mode

is sufficient to verify this capability.

The (TBD-001-454) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be recovered from.

4.7.1.2.10 Orion Communications and Communications Security

[CA0344V-PO] The Orion maintaining communications with Mission Systems for at least 36 hours post landing shall be verified by analysis and test. The power budget and transmission power requirement for nominal operation with worst-case reserve for the post-landing period shall be analyzed. The flight unit or similar units shall be tested under simulated communications for the required period of time with sufficient radiated power to maintain communication with the communication infrastructure. Power consumption shall be measured. The flight unit or similar units will be tested with Mission Systems and demonstrated in recovery exercises. The verification shall be considered successful when:

a. Analysis shows that there is sufficient power and reserve based on planned system status after re-entry to maintain communications with Mission Systems for 36 hours of continuous operation.

b. Analysis shows that Mission Systems can maintain communications with the simulated Orion during a worst-case landing location scenario.

c. Testing shows Orion communication with Mission Systems for the 36 hour duration can be maintained in a simulated recovery exercise.

Rationale: Communication coverage is critical to Orion crewmembers both for nominal and off-nominal landing. Simulated testing modeling is used to assess performance in environmental conditions. An analysis of integrated testing of the Mission Systems communication infrastructures is required. Power draw measurement and operation of the actual hardware are necessary to mitigate for of *manufacturing defects. Recovery exercises will show the links necessary are in place and assure environmental factors are understood.*

[CA0470V-PO] The ability of Orion to transmit and receive with an antenna spherical coverage of 90%, excluding non-Orion structural blockage, for all flight phases until SM separation, for the 18 kbps forward/24 kbps return link as defined by the CxP 70118-01, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 1: Orion, Section 3.6.1.2 shall be verified by test and analysis.

The antenna spherical coverage shall be verified with an antenna spherical coverage analysis using a measured antenna pattern and a field test.

First, the antenna types to be used by Orion for the 18 kbps forward/24 kbps return link shall be tested in an anechoic chamber or similar test bed to determine their antenna patterns. This shall be accomplished by rotating the antenna and measuring the signal strength received from a fixed source. The analysis shall use the measured antenna pattern to predict the antenna spherical coverage, for each configuration of Orion antennas used until re-entry, excluding non-Orion structural blockage. If the measured antenna pattern does not include the effects of the relevant CEV structure, those effects shall be modeled in the analysis. The antenna spherical coverage shall take into account the range of motion of any moving structure such as solar panels. For the analysis, antenna spherical coverage shall be considered “available” in a given direction when:

a. The system provides the EIRP specified in CxP 70118-01, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 1: Orion, Section 3.6.1.2 when transmitting in that direction.

b. The system provides the performance given the received power at an isotropic antenna specified in CxP 70118-01, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 1: Orion, Section 3.6.1.2 when receiving in that direction.

Second, an analysis shall be performed to determine the radiated signal strength and received signal strength for the field test. The field test shall be conducted on and installed antenna in a simulated Orion mount [either in an anechoic chamber or in an open area]. Measurements shall be recorded for system signal strength of radiated 24 kbps data. Measurement shall be recorded for received 18 kbps data transmitted with an attenuated test signal as defined by the analysis and transmitted from a representative set of points as determined by analysis. An independent measurement of the transmitted signal strength at a fixed location shall also be recorded as a calibration witness.

The verification shall be considered successful when:

a. The analysis of mounted antenna coverage for 18 kbps forward/24 kbps return link data, excluding non-Orion structural blockage, is shown to be greater than 90%.

b. The field test 24 kbps transmitted signal received signal strength is above the expected analyzed minima for all measured locations.

c. The field test 18 kbps received signal received signal strength is above the expected analyzed minima for all measured locations.

Rationale: While antenna design is a fairly well established field, the interaction of mount and antenna can be profound. It is prudent to verify the analysis with the actual equipment as built. It is expected that the antenna will have more than one element and the set of elements will cover the required solid angle.

[CA0511V-PO] The recording of critical data for reconstruction of catastrophic events by Orion shall be verified by test. The test shall use the flight Orion or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The verification shall be considered successful when the test shows that the critical data is retrievable after the flight hardware has been subjected to the environmental conditions specified in the Orion SRD.

Rationale: A test of the recording of critical data for reconstruction of catastrophic events will be defined by the Orion project for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability. The identification of critical data to be recorded will be developed from multiple engineering sources (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) and documented by the Orion Project.

[CA3280V-PO] The use of a dissimilar voice communication system by Orion as specified in the requirement shall be verified by Analysis and Demonstration. The analysis shall be performed on the Orion voice communication systems. The demonstration shall be performed on the Orion dissimilar voice system. The verification shall be considered successful when:

a. The demonstration verifies that the dissimilar voice system provides system-to-system communication using communication infrastructure paths.

b. The analysis shows the dissimilar system is independent when compared to the prime Orion voice communication system.

Rationale: Analysis shows the system as dissimilar compared to prime voice circuits. Demonstration is used to show functionality. Additional verifications are performed at a lower level.

[CA3287V-PO] Simultaneous communication by Orion with MS and two one other systems in space as specified in the requirement, shall be verified by analysis and testing. Analysis of the specified data links shall be performed. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links running a simulated rendezvous and docking scenario. Signal strength and transmitted data will be simulated. The verification shall be considered a success when:

a. Testing shows the system can simultaneously exchange data throughout the simulation with the specified systems without apparent degradation.

b. Analysis shows that forward and received link margins are sufficient to support communication at 30 km as specified in the requirement. To reflect the desire to test lunar phase requirements during ISS operations as much as is feasible, the analysis will be extended to determine the maximum range at which the link margins are still sufficient to support communications. If testing is needed to verify the greater distances applicable during lunar phase, this will be accomplished by establishing Developmental Test Objectives (DTO).

Rationale: Tests are needed that are specific to the system and its characteristic data are needed. Scenarios shall reasonably exercise the system capability of the as specified system. For load testing, the system under test may be loaded with C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate to stress test the system data transmission and receipt capabilities. All data types supported by the system shall be tested. For systems with communications links, testing needs link testing according to the C3I interoperability specification and demonstration, where possible, with systems expected on-orbit using simulated transmission delays and noise levels.

[CA3288V-PO] Simultaneous communication by Orion with ISS and MS as specified shall be verified by analysis and test.

Analysis of the Orion, ISS, and MS data links shall be performed. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links.

The verification shall be considered a success when:

a. Testing shows the system can simultaneously exchange data through the entire duration of the scenario.

b. Analysis shows that forward and received link margins are support communication at the 30 km specified in the requirement. To reflect the desire to test lunar phase requirements during ISS operations as much as is feasible, the analysis will be extended to determine the maximum range at which the link margins are still sufficient to support communications. If testing is needed to verify the greater distances applicable during lunar phase, this will be accomplished by establishing Developmental Test Objectives (DTO).

Rationale: Tests specific to the system and its characteristic data are needed. Scenarios shall reasonably exercise the system capability of the specified system. All data types for transmission between the involved systems will need to be tested. Testing needs link testing according to the C3I interoperability specification and demonstration, where possible, with systems using simulated transmission delays and noise levels, in this case, the Orion, ISS, and MS.

[CA5901V-PO] Orion capability to reconfigure stored commands, sequences and data shall be verified by demonstration. The demonstration shall use the flight Orion or flight equivalent hardware in simulated mission conditions. Orion shall be preloaded with a set of stored commands, sequences and data. The subset of stored commands, sequences and data identified in (TBD-001-993) documents shall then be reconfigured. (Exhaustive verification of each reconfiguration item is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the stored commands, sequences and data identified in (TBD-001-993) documents have been successfully reconfigured on Orion and that they properly reflect the updated values.

Rationale: A demonstration of Orion capability to reconfigure stored commands, sequences and data is sufficient to verify this capability. The (TBD-001-993) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify what stored commands, sequences and data are subject to reconfiguration and what the range of potential values are.

[CA5904V-PO] Orion capability to execute reconfigurable automation sequences shall be verified by demonstration. The demonstration shall use the flight Orion or flight equivalent hardware in simulated mission conditions. The command sequences identified in (TBD-001-996) documents shall be executed by Orion. In addition, the subset of command sequences identified in (TBD-001-996) documents shall be reconfigured prior to execution. (Exhaustive verification of each automation sequence is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that:

a. The command sequences have been executed without human intervention.

b. The end state of Orion at the end of the sequence execution is the same as if the commands had been executed manually.

c. The reconfigured command sequences execute the updated commands.

d. The sequences are only executed when they are valid in the current state and are rejected otherwise.

Rationale: A demonstration of Orion capability to execute reconfigurable automation sequences is sufficient to verify this capability. The (TBD-001-996) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify which command sequences should be verified and which of those are subject to reconfiguration.

[CA6066V-PO] Simultaneous communication by Orion, LEO operations of lunar phase missions, with MS and (TBD-001-1314) other systems in space, as specified in the requirement, shall be verified by analysis and testing. Analysis of the specified data links shall be performed. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links running a simulated rendezvous and docking scenario. Signal strength and transmitted data will be simulated. The verification shall be considered a success when:

a. Testing shows the system can simultaneously exchange data throughout the simulation with the specified systems without apparent degradation.

b. Analysis shows that forward and received link margins are sufficient to support communication at the distances specified.

Rationale: Tests specific to the system and its characteristic data are needed. Scenarios shall reasonably exercise the system capability of the specified system. For load testing, the system under test may be loaded with C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate to stress test the system data transmission and receipt capabilities. All data types supported by the system shall be tested. For systems with communications links, testing needs link testing according to the C3I interoperability specification and demonstration, where possible, with systems expected on-orbit using simulated transmission delays and noise levels.

[CA6067V-PO] Simultaneous communication by Orion, lunar vicinity operations of lunar phase missions, with MS and (TBD-001-1315) other systems in space, as specified in the requirement, shall be verified by analysis and testing. Analysis of the specified data links shall be performed. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links running a simulated rendezvous and docking scenario. Signal strength and transmitted data will be simulated. The verification shall be considered a success when:

a. Testing shows the system can simultaneously exchange data throughout the simulation with the specified systems without apparent degradation.

b. Analysis shows that forward and received link margins are sufficient to support communication at the distances specified.

Rationale: Tests specific to the system and its characteristic data are needed. Scenarios shall reasonably exercise the system capability of the specified system. For load testing, the system under test may be loaded with C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate to stress test the system data transmission and receipt capabilities. All data types supported by the system shall be tested. For systems with communications links, testing needs link testing according to the C3I interoperability specification and demonstration, where possible, with systems expected on-orbit using simulated transmission delays and noise levels.

[CA6070V-PO] The capability of Orion to communicate with Mission Systems for at least 5 minutes every 3 hours independent of the status of the primary communication system while in LEO shall be verified by analysis and test. Analysis shall be performed on the primary and secondary Constellation and SCaN communication capabilities to determine communications link coverage, availability and visibility. A test shall be performed using flight equivalent units or emulators with flight software involving MS and Orion under simulated mission conditions. Primary and secondary communication systems shall each be operated for a period of no less than 5 minutes. Transmitted and received audio and/or data shall be compared or examined. The verification shall be considered successful when:

a. The analysis shows that Orion to MS can communicate for at least 5 minutes out of every 3 hours with either primary or secondary systems disabled.

b. Both Orion and Mission Systems agree that the audio and/or data exchanged during the test contain expected values.

Rationale: Analysis is required to confirm coverage for LEO. Test is required to ensure interoperability.

[CA6108V-PO] The provision of motion imagery of separation from Ares shall be verified by Analysis. An analysis shall be conducted on the Orion Architecture for the acquisition and distribution of motion imagery of the separation from Ares. The analysis shall evaluate acquisition of imagery, data recording storage capabilities, lighting conditions, vehicle(s) trajectory, camera position and field of view. The analysis shall also evaluate the Orion Architecture's capability to deliver imagery for identified mission critical events when needed. The verification shall be considered successful when the analysis shows that Orion has the capability to record and later distribute an accurate account of it's separation for Ares.

Rationale: An analysis is necessary to ensure that Orion has the capability to provide motion imagery of separation from Ares. This verification is supported by other imagery and communication verifications.

[CA6110V-PO] (TBD-001-1509)

[CA6212V-PO] The processing by Orion of range safety telemetry within 1 second (TBR-001-1440) during the launch/ascent phase shall be verified by test.

The test shall be performed using flight equivalent units or emulators with Flight Software in simulated mission conditions. The test shall time stamp the range safety telemetry upon collection from the Orion sensors and receipt from Ares I and again after processing at the point of transmission (exiting Orion). The test shall be performed on selected points during the flight timeline that cover the full range from launch through ascent. The time stamps shall be analyzed for compliance to the requirement within 95% confidence level. Recording of telemetry entrance and exit times with a packet analyzer or other measurement equipment can be used in place of time stamps.

The verification shall be considered successful when the analysis of the data collected by the test shows that the total time to process the telemetry is within the time specified for all points on the flight timeline.

Rationale: Testing system performance under mission-like conditions is a reasonable way to confirm that they are individually meting their allocations.

[CA6213V-PO] Orion processing voice within 1 second (TBR-001-1441) during the launch/ascent phase shall be verified by test.

The test shall be performed using flight equivalent units or emulators with Flight Software in simulated mission conditions. The external system and communication links may be simulated. The external system shall exchange voice data with Orion for both nominal and dissimilar voice systems. Voice data shall be time stamped, measured, or recorded with a packet analyzer at the end points of the system. The end points for the test shall be defined as:

a. Voice entering or exiting Orion

b. Orion interface to voice creation or reproduction locations (e.g. microphones and speakers)

A representative of each type of path for voice shall be tested. The test shall be repeated for applicable modes and states where voice is exchanged, if applicable. The time measurements or time stamps shall be analyzed for compliance to the requirement.

The verification of Orion processing voice for the launch/ascent phase shall be considered successful when the analysis of the data collected by the test shows that:

a. The total time to process voice is within the time specified

b. Both nominal and dissimilar voice is tested

c. Each voice path type is tested

Rationale: Testing system performance under mission-like conditions is a reasonable way to confirm that they are individually meeting their allocations. A packet analyzer may provide more time resolution and accuracy than time stamps, so is allowed as an option. The requirement does NOT stipulate voice direction or other limitations per the rationale, so the verification is written to cover ALL voice processing by Orion.

4.7.1.2.11 Orion GN&C

[CA0059V-PO] The ability of Orion to actively accomplish rendezvous, proximity operations, dock, and undock with the LSAM /EDS shall be verified by test, demonstration and analysis. Analysis shall be performed for rendezvous, proximity operations, and docking as well as undocking and departure proximity operations. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.86% with a "consumer's risk" of 10%. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without recontact is greater than 99.86% with a "consumer's risk" of 10%.

Rationale: Rationale for docking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all Orion missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Much of the remaining test and analysis depend on the results of this testing.

Rationale for relative navigation sensor tests and demonstrations: The Constellation Architecture will be the first use of many critical relative navigation sensors. Testing the closed loop system with relative navigation sensors and their accompanying intended target hardware will significantly mitigate risk of failure.

Rationale for SIL (or equivalent) tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The docking/undocking test simulation must include models of both maneuvering (Orion) and target (EDS/LSAM) vehicles to model the effects of target vehicle attitude control on docking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

[CA0081V-PO] The ability of the Orion to actively accomplish rendezvous, proximity operations, dock, and undock with the ISS shall be verified by test, demonstration and analysis. Analysis shall be performed for rendezvous, proximity operations, and docking as well as undocking and departure proximity operations. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.86% with a "consumer's risk" of 10%. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without recontact is greater than 99.86% with a "consumer's risk" of 10%.

Rationale: Rationale for docking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all Orion missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Much of the remaining test and analysis depend on the results of this testing.

Rationale for relative navigation sensor tests and demonstrations: The Constellation Architecture will be the first use of many critical relative navigation sensors. Testing the closed loop system with relative navigation sensors and their accompanying intended target hardware will significantly mitigate risk of failure.

Rationale for SIL (or equivalent) tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The docking/undocking test simulation must include models of both maneuvering (Orion) and target (EDS/LSAM) vehicles to model the effects of target vehicle attitude control on docking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

[CA0131V-PO] The ability for Orion to perform target vehicle functions during RPOD with the LSAM shall be verified by inspection, docking mechanism tests, Orion attitude control tests, and Orion attitude control analysis. Orion attitude control analysis shall include models of environmental attitude disturbances, as well as models of the LSAM vehicle, including LSAM thruster plumes. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document is greater than 99.86% with a "consumer's risk" of 10%.

Rationale: Rationale for Inspection: Inspection of the design documentation provides verification that appropriate target hardware has been included in the design and that it is located and oriented to facilitate RPOD operations with LSAM.

Rationale for docking hardware tests: The mechanical docking subsystems are critical to mission success for all Orion missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Much of the remaining test and analysis depend on the results of this testing.

Rationale for SIL tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The undocking test simulation must include models of both maneuvering vehicle (Orion) and separation target (LSAM) vehicles to model the effects of target vehicle attitude control on undocking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

[CA0133V-PO] The ability of Orion to actively accomplish undocking with the LSAM in LLO shall be verified by test, demonstration and analysis. Analysis shall be performed for undocking and departure proximity operations. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall be considered successful when the results show that probability of successful undocking and separation without re-contact is greater than 99.86% with a "consumer's risk" of 10%.

Rationale: Rationale for docking/undocking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all Orion missions. These mechanisms must be characterized and verified to confirm the undocking separation dynamics. Much of the remaining test and analysis depends on the results of this testing.

Rationale for relative navigation sensor tests and demonstrations: The Constellation Architecture will be the first use of many critical relative navigation sensors. Testing the closed loop system with relative navigation sensors and their accompanying intended target hardware will significantly mitigate risk of failure.

Rationale for SIL (or equivalent) tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The undocking test simulation must include models of both maneuvering vehicle (Orion) and separation target (LSAM) vehicles to model the effects of target vehicle attitude control on undocking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

[CA0187V-PO] Orion performance of attitude control of the Orion/LSAM mated configuration after docking in LLO shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document is greater than 99.73% with a "consumer's risk" of 10%.

Rationale: It is assumed that the integrated Orion/LSAM attitude limits will be documented in CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document. Note that this is an integrated performance requirement and may need a new CARD requirement to cover it.

[CA0329V-PO] Guided entry landing accuracy shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). Verification shall be considered successful when analysis of nominal direct and skip entry DRMs with system and environment dispersions shows a 99.73% probability with a "consumer's risk" of 10% of achieving the required landing target accuracy at each of the designated water landing sites (as appropriate to the specific DRM).

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0369V-PO] The ability of Orion to actively accomplish rendezvous, proximity operations, and docking, with the LSAM in LLO shall be verified by test, demonstration and analysis. Analysis shall be performed for rendezvous, proximity operations, and docking and shall include models of both the LSAM and Orion vehicles. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.86% with a "consumer's risk" of 10%.

Rationale: Rationale for docking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all Orion missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Much of the remaining test and analysis depend on the results of this testing.

Rationale for relative navigation sensor tests and demonstrations: The Constellation Architecture will be the first use of many critical relative navigation sensors. Testing the closed loop system with relative navigation sensors and their accompanying intended target hardware will significantly mitigate risk of failure.

Rationale for SIL (or equivalent) tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The docking/undocking test simulation must include models of both maneuvering (Orion) and target (EDS/LSAM) vehicles to model the effects of target vehicle attitude control on docking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

[CA0462V-PO] The ability of Orion to function as a maneuvering vehicle during undocking and departure proximity operations from the target vehicle at any attitude in case of an emergency shall be verified by analysis and test. The analysis shall include models of the Orion, LSAM /Ares V EDS, and the ISS vehicles. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall also include undocking cases initiated prior to and after rigidization of the analysis shows that the probability of successful undocking and departure proximity operations without violation of clearance requirements, as listed in the appropriate IRD, is greater than 99.86% with a 10% "consumer's risk" for the following emergency undocking scenarios:

a. Orion undocking from LSAM /Ares V EDS

b. Orion undocking from LSAM

c. Orion undocking from ISS

The test shall be conducted with the Orion docking interface hardware in conjunction with both LSAM and ISS docking interface hardware. The test shall be conducted with Orion, LSAM, and ISS docking interface hardware in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the Orion, LSAM, Ares V EDS, ISS navigation, guidance and control software. The undocking test shall be conducted with nominal environmental and vehicle conditions. The undocking test shall be conducted with a set of initial attitude and attitude rates that span nominal conditions. The undocking test shall include undocking cases initiated prior to and after rigidization of the docking mechanism is complete. The undocking test shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to Orion and the LSAM or ISS (as appropriate) that are within the specifications of the IRD requirements as appropriate to the vehicle configuration under test. The undocking test shall be conducted for the scenarios:

a. Orion undocking from LSAM/Ares V EDS

b. Orion undocking from LSAM

c. Orion undocking from ISS

Rationale: Rationale for simulation analysis: Simulation-driven analysis enables the examination of a much larger (statistically meaningful) set of cases to be examined including variations to key parameters, conditions, and performance. This set should span the set of expected emergency conditions which would cause Orion undocking.

Rationale for undocking hardware tests: The mechanical docking subsystems are critical to mission success for all Orion missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Because an emergency undocking may occur at any time from soft *capture through mated operations, the undocking tests must incorporate cases after capture but prior to rigidization.*

[CA0463V-PO] The ability for Orion to undock post crew ingress and hatch closure in less than 10 (TBR-001-004) minutes shall be verified by analysis and demonstration. The analysis shall calculate the overall time necessary to power up systems. The demonstration shall use integrated Constellation flight systems in simulated mission conditions. The demonstration shall consist of performing a minimum of four runs using a NASA-accredited simulator with two different sets of crew and collecting the task time for undocking post crew ingress and hatch closure. The verification shall be considered successful when the analysis determines that undocking post crew ingress and hatch closure time required is less than 10 (TBR-001-004) minutes, and demonstration determines that undocking post crew ingress and hatch closure time required is less than 10 (TBR-001-004) minutes for four consecutive runs.

[CA0497V-PO] The capability to manually control Orion when the human pilot can operate the vehicle within predefined limits shall be verified by testing and analysis. The testing shall use a NASA-accredited digital Orion GN&C simulation integrated with a NASA-accredited pilot-in-the-loop test facility, with flight-like hand controllers, displays and out the window scenes. Testing shall use these facilities to capture and analyze manual control performance of the vehicle for all nominal and abort flight phases that are determined appropriate for human piloting, and shall include system and environment dispersions. The verification shall be considered successful when analysis of the results shows that manual control does not violate structural, thermal or performance margins for all relevant flight phases.

Rationale: Pilot-in-the-loop testing is necessary to exercise the man-machine interaction and verify that the crew can, in fact, control the vehicle within predefined limits.

[CA3142V-PO] Orion navigation and attitude determination capability shall be verified by analysis and component testing. The analysis and testing shall be accomplished using flight sensor hardware in a NASA-accredited dynamic hardware-in-the-loop simulation of Orion. The dynamic simulation, analysis, and hardware-in-the-loop tests shall verify the accuracy of Orion navigation and attitude determination capability by taking error data from component level navigation and attitude sensor testing and processing this data with a dynamic model of the orbit and attitude dynamics and disturbances during all mission phases. The verification shall be considered successful when the analysis, simulation, and testing has shown that the criteria as specified in the CxP 72000, Constellation Program System Requirements for the Orion System for the navigation and attitude determination capability has been met.

Rationale: NR

[CA3248V-PO] The Orion maneuver targeting capability shall be verified by analysis. The analysis shall be accomplished using a NASA-accredited dynamic simulation of all the relevant Constellation Architecture flight systems. The dynamic simulation and analysis shall verify the accuracy of the Orion maneuver targeting capability by taking error data from component level navigation sensor testing and processing this data with a dynamic model of the orbit dynamics during all mission phases. The verification shall be considered successful when the analysis and simulation has shown that the criteria for maneuver targeting capability as specified in CxP 72000, Constellation Program System Requirements for the Orion System have been met.

Rationale: NR

[CA4128V-PO] Orion performance of attitude control of the Orion/LSAM mated configuration after Ares V EDS undocking through Orion/LSAM separation in LLO shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document is greater than 99.73% with a 10% "consumer's risk".

Rationale: It is assumed that the integrated Orion/LSAM attitude limits will be documented in CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document.

[CA5286V-PO] The ability of Orion to perform target vehicle functions during undocking and departure proximity operations from LSAM prior to lunar descent shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that Orion can support target vehicle functions during LSAM undock and departure proximity operations.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work. In this case, the verification will demonstrate that the passive Orion vehicle can support the required operations, probably by maintaining an attitude hold relative to the LSAM. The most important aspect of this separation is the avoidance of vehicle collision.

[CA5819V-PO] The ability of Orion to perform TCMs during TLC shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that Orion can perform the TCMs during TLC.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5921V-PO] The ability for Orion to separate from the Ares I shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that Orion can separate from the Ares I.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.1.2.12 Orion Reliability and Availability

[CA0178V-PO] The ability of Orion to have a probability of launch of not less than 98% (TBR-001-937), exclusive of weather, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt, shall be verified by analysis. Analysis shall assess the Orion Level III reliability analysis, maintainability planning, and the Level III Logistics Support Plan (LSP). Verification shall be considered successful when analysis verifies the Orion launch probability of launch of no less than 98%, with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004).

Rationale: The Orion reliability and availability data, along with Ground Operations data that include fixed and variable resources will need to be available for the CA to verify that the flight and ground hardware and other resources will be in a situation that supports the vehicle and Ground Systems to be available to support beginning at the start of cryogenic propellant loading and ending at close of day-of-launch window.

[CA6100V-PO] Provision of adequate consumables to support consecutive launch attempts shall be verified by inspection and analysis. An analysis shall be performed to determine the quantity of consumables required to support 6 (TBR-001-1300) hours per each of (TBD-001-1400) launch attempts, taking credit for corresponding reduction in contingency days allowed by the mission timeline. An inspection shall be performed to confirm the required consumables are included in the vehicle on-board storage. The verification shall be considered successful when the analysis and inspection confirm that adequate consumable resources exist in the vehicle to support the launch attempts as specified.

Rationale: This requirement defines the amount of consumables that is required to be supplied by Orion to support the crew for each launch attempt. If subsequent launch attempts reduce overall mission duration through use of contingency days, this credit may be accounted for in initial consumables loading.

[CA6205V-PO] The ability to remedy the required percentage of Orion system failures identified, after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1502)% that would result in a scrubbed launch within the required time limit, shall be verified by analysis. The analysis shall assess the Orion FMEA, maintenance plan, LSA, and FDIR capabilities to determine the likelihood of occurrence of failures and the percentage of failures that can be remedied within 1 day, 2 days, and 3 days. The verification analysis shall use only Cx R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when the analysis determines:

a. No less than 45% (TBR-001-1419) can be remedied to support a launch attempt within one day

b. No less than 65% (TBR-001-1420) can be remedied to support a launch attempt within two days.

c. No less than 70% (TBR-001-1421) can be remedied to support a launch attempt within three days.

Rationale: The verification analysis requirement is intended to drive a determination of the ability to remedy those failures that are most likely to be identified during the countdown when systems are activated, serviced, and operated. The analysis should sort the set of the most likely failures into those items that can be remedied one day, two days, three days, or more time. Since no location constraint is composed (e.g., nobody said the failure had to be remedied at the pad), a remedy scenario that rolls back, repairs, rolls out to pad, and supports a launch attempt within the time frame is allowed for this sorting. The analysis should consider that the likelihood of a latent defect being present but undetected at the time of a decision to proceed past a given milestone is a variable influenced by the perceptiveness of testing and operations performed before that milestone.

4.7.1.2.13 Orion Maintainability, Supportability, and Logistics

[CA5495V-PO] Verification that Orion can sustain operations, using only onboard equipment and spares, without resupply or support from personnel other than the crew, shall be verified by analysis. The analysis shall assess the Orion Maintenance Concept, the Orion Logistics Support Plan (LSP), related Logistics Support Analysis Records (LSAR), other data from reliability and maintainability analyses conducted in accordance with CxP 70087, Constellation Reliability and Maintainability (R&M) Plan, and shall determine Orion's ability to sustain operations for each Orion mission defined in CxP 70007, Constellation Design Reference Missions and Operational Concepts. The verification shall be considered successful when the analysis shows that the Orion can sustain operations, using only onboard equipment and spares, without resupply or support from personnel other than the crew, to achieve mission success.

Rationale: It will be critical to verify that the vehicle is designed to be self-sustaining and be able to accomplish its mission without need for resupply since resupply of spares will generally be not possible.

[CA5974V-PO] The ability of Orion to generate Project Verified Engineering Builds after the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars) shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA5975V-PO] The ability of the Orion to generate Project Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5976V-PO] The ability of Orion project to generate day of launch updates shall be verified by demonstration. Demonstration shall be considered successful when day of launch updates have been successfully generated and applied during project verification and validation activities.

Rationale: The intent is to demonstrate that the day of launch update process can be successfully executed.

[CA5977V-PO] The ability of Orion to provide fixes for selected non-conformances to the discovering organization shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when inspection determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at

Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA6003V-PO] The ability of the Orion to conduct ground operations within the constraints levied in Orion Critical Path Allocations for Ares I/Orion Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6003 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then updated.

Rationale: NR

[CA6013V-PO] The ability of the Orion architecture to produce cargo engineering products for a single crewed ISS mission within the 90 (TBR-001-1095) days shall be verified by analysis. The analysis shall consist of a review of allocated Orion SRD requirements, as well as template and management process document (TBD-001-1084). The verification shall be considered successful when the allocated Orion SRD requirements verifications are closed and when the cargo engineering products meet development and delivery for a single crewed ISS mission within 90 (TBR-001-1095) days with a probability 85% (TBR-001-1094). The added Objective capability of requirement CA6013 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then updated.

Rationale: NR

[CA6015V-PO] The ability of the Orion architecture to produce cargo engineering products for a single Lunar mission within the (TBD-001-1074) days shall be verified by analysis. The analysis shall consist of a review of allocated Orion SRD requirements, as well as template and management process document (TBD-001-1084). The verification shall be considered successful when the allocated Orion SRD requirements verifications are closed and when the cargo engineering products meet development and delivery for a single Lunar mission within (TBD-001-1074) days with a probability 85% (TBR-001-1094). The added Objective capability of requirement CA6015 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then updated.

Rationale: NR

[CA6029V-PO] The ability for Orion to operate in a quiescent mode at ISS with no more than 2 hours per week contiguous real-time command and control from Mission Systems under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated Orion SRD and MS-CEV IRD requirements. Analysis shall consist of review of the Orion design. The inspection shall be considered successful when the allocated Orion SRD and MS-CEV IRD verification requirements are closed and analysis shall be considered successful when the as-built CEV design confirms the ability to meet no more than 2 hours per week contiguous of real-time command and control from Mission Systems under nominal quiescent operations. The added Objective capability of CA6029-PO will be addressed at design reviews. The Orion's capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then updated.

Rationale: NR

[CA6031V-PO] The ability for the Orion to operate in a quiescent mode for Lunar missions with no more than 2 (TBR-001-1106) hours per week contiguous real-time command and control from Mission Systems under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated Orion SRD and MS-CEV IRD requirements. Analysis shall consist of review of the Orion design. The inspection shall be considered successful when the allocated Orion SRD and MS-CEV IRD verification requirements are closed and analysis shall be considered successful when the as-built Orion design confirms the ability to meet no more than 2 (TBR-001-1106) hours per week contiguous real-time command and control from Mission Systems under nominal quiescent operations.

Rationale: NR

[CA6032V-PO] The ability for the Orion to operate with no more than 1 hour per day contiguous (consisting of 1 (TBR-001-1110) man-hour) monitoring by dedicated Orion engineering team member, while in a quiescent mode for ISS missions under nominal quiescent operations, shall be verified by inspection and analysis. The inspection shall consist of review of the allocated Orion SRD and MS-CEV IRD requirements. Analysis shall consist of review of the Orion design and the engineering team personnel manning and operation plans. The inspection shall be considered successful when the allocated Orion SRD and MS-CEV IRD verification requirements are closed, and analysis shall be considered successful when the as-built Orion design and the Orion engineering personnel manning and operating plans confirm the ability to meet no more than 1 hour per day contiguous (consisting of 1 (TBR-001-1110) man-hour) monitoring by dedicated

Orion engineering team member while in a quiescent mode for ISS missions under nominal quiescent operations.

Rationale: NR

[CA6033V-PO] The ability for the Orion to operate with no more than 1 hour per day contiguous (consisting of 1 (TBR-001-1111) man-hour) monitoring by dedicated Orion engineering team member while in a quiescent mode for Lunar missions under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated Orion SRD and MS-CEV IRD requirements. Analysis shall consist of review of the Orion design and the engineering team personnel manning and operation plans. The inspection shall be considered successful when the allocated Orion SRD and MS-CEV IRD verification requirements are closed and analysis shall be considered successful when the as-built Orion designs and the Orion engineering team personnel manning and operating plans confirm the ability to meet no more than 1 hour per day contiguous (consisting of 1 (TBR-001-1111) man-hour) monitoring by dedicated Orion engineering team member while in a quiescent mode for Lunar missions under nominal quiescent operations.

Rationale: NR

4.7.1.2.14 Orion Habitability and Human Factors

[CA0288V-PO] The control of cabin atmospheric pressure shall be verified by test.

The test shall be performed using a test article with flight-like cabin volume to show that the atmospheric pressure control hardware will maintain cabin pressure within the specified range over the maximum mission duration.

The verification shall be considered successful when the test shows that pressure is successfully controlled by Orion over the range of 103 to 62 kPa (14.9 to 9.0 psia), in 0.7 kPa (0.1 psia) increments.

Rationale: This is to allow Orion to adjust between the primary operating atmospheric pressure setpoints - ISS at 102 kPa (14.8 psia), Orion at 70 kPa (10.2 psia).

[CA0426V-PO] Net habitable volume shall be verified by analysis. The analysis shall review the design of Orion and shall assess the net habitable volume using JSC 63557 (TBR-001-2500), Net Habitable Volume Verification Method, which defines analytical processes to calculate net habitable volume. The verification shall be considered successful when the analysis shows Orion net habitable volume is no less than 10.76 m3 (380 ft3).

Rationale: If the volume is not accurately calculated using a validated process, the verification will not be valid and could result in misrepresentation of the vehicle's net habitable volume impairing the crew's ability to perform critical mission tasks.

[CA0886V-PO] The vestibule pressurization shall be verified by analysis supported by test. The analysis shall determine that gas resources for two vestibule pressurization cycles are available for each mission. Analysis of the Orion Gas Storage and vestibule pressurization shall show that the Orion can store the consumables necessary for and execute two vestibule pressurization cycles. The verification shall be considered successful when the analysis, supported by a qualification test of the pressurization operation, show that the Orion can execute at least two vestibule pressurization cycles per mission.

Rationale: Analysis to calculate the quantity of nitrogen and oxygen, based on the Orion vestibule design and consumable requirements, coupled with the inspection of the storage hardware compliance data is sufficient.

[CA3061V-PO] The oxygen concentration within the pressurized cabin shall be verified by test and analysis.

The test shall be performed using a test article with flight-like cabin volume to show that the atmosphere control system can detect when the oxygen concentration reaches 30% (TBR-001-109). The test shall be performed using a test article with flight-like cabin volume to show that the atmosphere control system can adjust the constituents to maintain the oxygen concentration to 30% (TBR-001-109) maximum. The analysis shall show that the materials selection is certified to meet the 30% (TBR-001-109) oxygen environment.

The verification shall be considered successful when the tests show that the Orion atmosphere control system limits the maximum oxygen concentration within the pressurized cabin to 30% (TBR-001-109) by volume and the analysis of materials shows the materials selection meets the 30% (TBR-001-109) oxygen environment.

Rationale: This verifies the control of the maximum oxygen concentration in the Orion cabin. This also verifies that the materials flammability is not an issue at 30% (TBR-001-109) oxygen concentration.

[CA3105V-PO] Orion cabin pressure preservation to prepare for a total cabin depressurization during an external pressure leak shall be verified by analysis and test. The analysis shall use a modeled leak of an equivalent 0.64 cm (0.25 inch) diameter hole in the cabin to show that the available gas resources and atmosphere control will maintain the crew environment at 55 kPa (8.0 psia) for at least 70 (TBR-001-1301) minutes to prepare for a total cabin depressurization.

A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA suit donning and umbilical connection operations shall show that the cabin pressure and oxygen partial pressure can be maintained during tasks identified for crew suit preparation for a total cabin depressurization.

A test in the Orion flight test article utilizing flight qualified software shall show that the vehicle responds to a simulated rapid decompression event by activating the pressure control components required to maintain pressure and oxygen concentration.

The verification shall be considered successful when the analysis and tests show that Orion can maintain cabin pressure at 55 kPa (8.0 psia) for at least 70 (TBR-001-1301) minutes to prepare for crew survival in a depressurized cabin.

Rationale: This combination of methods will verify that an appropriate design will be implemented and tested at the vehicle level. A cabin leak is a contingency situation; the components will be verified to perform their specified functions, and the vehicle will be verified to activate the components in order to respond to a cabin leak situation.

[CA3106V-PO] The Orion cabin pressure preservation for prebreathe during an external pressure leak shall be verified by analysis and test.

The analysis shall use a modeled leak of an equivalent 0.64 cm (0.25 inch) hole in the cabin to show that the available gas resources and atmosphere control will maintain the crew environment at a sufficient pressure based on suit pressure and HSIR requirement [HS6091] for prebreathe pressure and time.

A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA suit donning and prebreathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained to support prebreathe.

A test in the Orion flight test article utilizing flight qualified software shall show that the vehicle responds to a simulated rapid decompression event by activating the pressure control components required to maintain pressure and oxygen concentration.

The verification shall be considered successful when the analysis and tests show that the Orion can maintain cabin pressure to allow crew prebreathe.

Rationale: This combination of methods will verify that an appropriate design will be implemented and tested at the vehicle level. A cabin leak is a contingency situation; the components will be verified to perform their specified functions, and the vehicle will be verified to activate the components in order to respond to a cabin leak situation.

[CA3133V-PO] The control of oxygen partial pressure shall be verified by test.

The test shall be performed using a test article with flight-like cabin volume to show that the oxygen partial pressure control hardware will maintain oxygen pressure within the specified range over the maximum mission duration.

The verification shall be considered successful when the test shows that oxygen partial pressure is successfully controlled by Orion over the range of 17 to 21 kPa (2.5 to 3.1 psia), in 0.7 kPa (0.1 psia) increments (TBR-001-124).

Rationale: This is to verify Orion will adjust the oxygen partial pressure setpoints to maintain the oxygen concentration within limits established to minimize material flammability concerns.

[CA3140V-PO] The quantity of consumables required for 2 pressure events (TBR-001-127) shall be verified by analysis.

The analysis shall determine the quantity of consumables resources required for the following cases:

a. EVA (for lunar missions only) which includes gas for suit donning, suit purge, prebreathe, cabin depress and cabin repress to 70 kPa (10.2 psia)

b. Contaminated atmosphere event which includes gas for emergency breathing apparatus if applicable, and cabin depress/repress to initial pressure, if applicable

c. Unrecoverable cabin leak which includes gas required to maintain cabin at 55 kPa (8 psia) while crew dons suits, purges suit loop, and performs prebreathe

The analysis shall determine which combination of two cases requires the greatest resources, considering that there can be only one unrecoverable cabin leak event per mission. The analysis shall then determine that those consumables resources are provided by the vehicle consumable gas stowage design.

The verification shall be considered successful when the analysis shows that Orion can provide consumables for two pressure events.

Rationale: Analysis to calculate the quantity of nitrogen and oxygen for the worst two scenarios, based on Orion vehicle design and consumable requirements, coupled with the inspection of the storage hardware compliance data is sufficient to verify this requirement.

[CA5711V-PO] Returning Orion pressurized volume to a habitable environment following a contamination event shall be verified by analysis.

The analysis shall verify that Orion can remove constituents of the contamination to reduced levels below the maximum exposure limits. The analysis model shall incorporate the cabin volume, ventilation system, contaminant removal method and its time-dependent performance.

The verification shall be considered successful when the analysis shows that Orion returns Orion pressurized volume to a habitable environment by reducing starting concentrations of 200 mg CO/m3, 30 mg HCl/m3, and 1,000 mg dichloromethane/m3 by 95% following a contamination event.

Rationale: Analysis is sufficient to verify that the pressurized volume is returned to a habitable environment. Analysis facilitates evaluation of multiple contamination events cases.

4.7.1.2.15 Orion Environmental Conditions

[CA0374V-PO] Compliance of Orion with its functional and performance requirements during and after exposure to the DSNE environments, shall be verified by inspection and analysis. The analysis shall consist of an integrated analysis that includes the following:

a. Development of a Natural Environment Requirements Sensitivity and Applicability Matrices (NERSAMs), defined in section 4 of the DSNE.

b. Allocation of the natural environments requirements to the lower tier elements and their verification methods and details.

The analysis shall include the following integrated configurations: Orion/LSAM, Orion/LSAM/Ares V-EDS, Orion/Ares I, Orion/Ares I/GS, Orion/ISS. The inspection will consist of a review of the lower tier verification closure data. The closure analysis shall utilize lower tier verification closure data and address interactions of each lower tier system on other systems to address integrated environment effects. The verification shall be considered successful when the inspection and integrated analyses show:

a. The NERSAM has been completed in accordance with Section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE).

b. The natural environment requirements and verification have been allocated to the lower tier systems in accordance with Section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE).

c. Lower tier verifications have been completed.

d. Orion meets its functional and performance requirements during and after exposure to CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) environments in all integrated configurations.

Rationale: Verification of functional and performance requirements across the range of natural environments requires a systematic integrated approach to address dependencies on hardware configurations and operational mode. The CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Section 4 specifies a standard systems engineering technique for flowing down the natural environment from higher to lower levels using the Natural Environment Requirements Sensitivity and Applicability Matrix (NERSAM) for each mission phase. Lower tier verification close out data, analyses, and models are necessary to support the integrated analysis, but are not sufficient alone to close out the environment requirements from the integrated vehicle configuration.

[CA5555V-PO] Orion function and performance during and after exposure to induced environments, shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the Orion/System IRD requirements.

b. Review of the induced environment verifications submitted against CxP 72000, Constellation Program System Requirements for the Orion System requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification.

The verification shall be considered successful when the analysis shows that the Orion function and performance requirements are met during and after exposure to CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.

Rationale: Function and performance must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that:

a. The proper induced environments have been considered

b. Sensitivities to these environments

c. Synergistic effects have each been properly addressed for all mission phases

[CA5560V-PO] Orion induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the Orion/System IRD requirements.

b. Review of the induced environment verifications submitted against CxP 72000, Constellation Program System Requirements for the Orion System requirements for DRM total induced environments. The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification.

The verification shall be considered successful when the analysis shows that the Orion peak and cumulative induced environments will not exceed CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.

Rationale: Induced environment contributions must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that:

a. The proper induced environments have been met

b. Sensitivities to these environments

c. Synergistic effects have each been properly addressed for all mission phases.

4.7.1.3 Reserved

4.7.1.4 Orion External Interfaces

[CA0361V-PO] Orion interfaces with the Ares V EDS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Orion Project Office to demonstrate that the Orion-to-Ares V EDS interface requirements defined within the CxP 70119, Constellation Program Orion -to- Ares V Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion and Ares V EDS flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalents) or across distributed SILs (or equivalents) prior to first launch of the Ares V EDS. Testing shall also include a multi-system integrated test of the integrated Orion/LSAM/Ares V EDS vehicle stack prior to first human use of the EDS/LSAM in space to demonstrate integrated functionality and interoperability between the flight systems and between the integrated vehicle stack and the ground support and mission control systems. Verification shall be considered successful when:

a. Analysis confirms that all of the Orion interface verification requirements defined within CxP 70119, Constellation Program Orion -to- Ares V Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Orion Project Office to confirm that all of the Orion-to-EDS interface requirements specified in the IRD have been satisfied. Integrated testing of the Orion and EDS flight avionics and software at, or distributed amongst, the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Since the LSAM will also be part of the integrated Orion/EDS vehicle stack, integrated testing will include configurations with the LSAM. Since the first time the Orion and LSAM/EDS flight systems will be integrated together is in Low Earth Orbit, integrated testing between the flight systems and with the ground support and mission control systems will be performed on the ground at the launch site to confirm integrated operability, functionality, and system stability during/after operational mode changes.

[CA0429V-PO] Orion interfaces with Ares I shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Orion Project Office to demonstrate that the Orion-to-Ares I interface requirements defined within CxP 70026, Constellation Program Orion -to- Ares I Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between Orion and Ares I flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalent) or across distributed SILs (or equivalent) prior to assembly of the integrated launch vehicle stack at the launch site. Testing shall also include a multi-system integrated test of the integrated

Orion/Ares I launch vehicle stack to demonstrate integrated functionality and interoperability between the flight systems and between the integrated launch vehicle stack and the ground support and mission control systems. Verification shall be considered successful when:

a. Analysis confirms that all of the Orion interface verification requirements defined within CxP 70026, Constellation Program Orion -to- Ares I Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Orion Project Office to confirm that all of the Orion-to-Ares I interface requirements specified in CxP 70026, Constellation Program Orion -to- Ares I Interface Requirements Document (IRD) have been satisfied. Integrated testing of the Orion and Ares I flight avionics and software at, or distributed amongst the SILs (or equivalent) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Since the first time the Orion and Ares I flight systems will be integrated together is within the integrated launch vehicle stack, integrated testing between the flight systems within the launch vehicle stack and between the stack and the various ground support and mission control systems will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

[CA0800V-PO] Orion interfaces with the LSAM shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Orion Project Office to demonstrate that the Orion-to-LSAM interface requirements defined within the CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document, have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion and LSAM flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalents) or across distributed SILs (or equivalents) prior to first launch of the LSAM. Testing shall also include a multi-system integrated test of the integrated Orion/LSAM vehicle stack (with and without EDS) prior to first human use of LSAM in space, to demonstrate integrated functionality and interoperability between the flight systems and between the integrated vehicle stack and the ground support and mission control systems. Verification shall be considered successful when:

a. Analysis confirms that all of Orion interface verification requirements defined within CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Orion Project Office to confirm that all of the Orion-to-LSAM interface requirements specified in CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document have been satisfied. Integrated testing of the Orion and LSAM flight avionics and software at or distributed amongst the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Since the EDS will also be part of the integrated Orion/LSAM vehicle stack for part of the lunar transit, integrated testing will include configurations with and without the EDS. Since the first time the Orion and LSAM/EDS flight systems will be integrated together is in Low Earth Orbit, integrated testing between the flight systems and with the ground support and mission control systems will be performed on the ground at the launch site to confirm integrated operability, functionality, and system stability during/after operational mode changes.

[CA0893V-PO] The Orion interfaces with the Ground Systems shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Orion Project Office to demonstrate that the Orion-to-GS interface requirements defined within the CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion avionics and software and the GS via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the GS to confirm interoperability and functionality between the Orion and GS. Verification shall be considered successful when:

a. Analysis confirms that all of the Orion interface verification requirements defined within CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the *verification data provided by the Orion Project Office to confirm that all of the Orion-to-GS interface requirements specified in the IRD have been satisfied. Integrated testing between the Orion avionics and software and the GS via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating GS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.*

[CA0894V-PO] Orion interfaces with the MS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Orion Project Office to demonstrate that the Orion-to-MS interface requirements defined within the CxP 70029, Constellation Program Orion -to- Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion avionics and software and the MS systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the MS to confirm interoperability and functionality between the Orion, GS, and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the Orion interface verification requirements defined within CxP 70029, Constellation Program Orion -to- Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Orion Project Office to confirm that all of the Orion-to-MS interface requirements specified in the IRD have been satisfied. Integrated testing between the Orion avionics and software and the MS via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating MS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0895V-PO] The Orion interfaces with the EVA systems shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Orion Project Office to demonstrate that the Orion-to-EVA interface requirements defined within CxP 70033, Constellation Program Orion -to- EVA Systems Interface

Requirements Document, have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion avionics and software and the EVA systems at a SIL (or equivalent). Multi-system testing performed at the launch site for flight systems shall also incorporate the EVA systems to confirm interoperability and functionality between the Orion, GS, and EVA systems. Verification shall be considered successful when:

a. Analysis confirms that all of Orion interface verification requirements defined within CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Orion Project Office to confirm that all of the Orion-to-EVA interface requirements specified in the IRD have been satisfied. Integrated testing between the Orion avionics and software and the EVA systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating EVA systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0896V-PO] The Orion interfaces with the Communications and Tracking Networks shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Orion Project Office to demonstrate that the Orion interface requirements defined within CxP 70118-01, Constellation Program Systems -to- Communications and Tracking Networks Interface Requirements Document, Volume 1: Orion, have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion avionics and software and the communications and networks systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the Communications and Tracking Network systems to confirm interoperability and functionality between the systems. Verification shall be considered successful when:

a. Analysis confirms that all of the Orion interface verification requirements defined within CxP 70118-01, Constellation Program Systems -to- Communications and Tracking Networks Interface Requirements Document, Volume 1: Orion, have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086,Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Orion Project Office to confirm that all of the Orion-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrated testing between the Orion avionics and software and the communications and network systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating the communication and network systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

4.7.1.5 Orion Physical Characteristics

[CA0386V-HQ] The outer mold line of Orion shall be verified by inspection. The inspection shall consist of the review of Orion configuration drawings for compliance with CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line. The verification shall be considered successful when the inspection shows that the outer mold line of Orion is in compliance with CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line.

Rationale: NR

[CA5933V-PO] The ability of the Orion SM to be configured as a standalone Element shall be verified by inspection. Inspection shall consist of a review of the SM drawings to ensure that Orion has the capability, at a conceptual level, to be augmented to carry any required equipment (e.g., avionics, power, thermal, GN&C, C&T), in a mission specific kit, to allow the SM to operate as a standalone Element. Verification shall be considered successful when inspection of the drawings has verified that SM provides the necessary interfaces enabling it to be augmented with a mission specific kit that allows the SM to operate as a standalone element.

Rationale: Analysis will confirm sufficient mission resources and margins for performing the desired missions. Orion capability assessment will confirm that the vehicle will provide the support services that are needed for completion of the mission.

4.7.2 Ares I

4.7.2.1 Ares I Description

4.7.2.2 Ares I Requirements

4.7.2.2.1 Ares I Mission Success

[CA1065V-PO] Loss of Ares I mission shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for an Ares I mission is not greater than 1 in 500.

Rationale: NR

[CA5805V-PO] Failure tolerance for catastrophic hazards shall be verified by analysis. An integrated hazard analysis shall be performed, in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology, using Ares Element Hazard Analysis and FMEA/CIL to show compliance with the approved level of failure tolerance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled with the approved number of controls and all DFMR items approved in the Ares I Hazard Reports.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

[CA5916V-PO] Control of critical hazards shall be verified by analysis. An integrated hazard analysis shall be performed, in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology, using Ares Element Hazard Analysis and FMEA/CIL to show compliance with the approved hazard controls. The verification shall be considered successful when the analysis shows that critical hazards are controlled and all DFMR items approved in the Ares I Hazard Reports.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure mission success.

4.7.2.2.2 Ares I Crew Survival

[CA0258V-PO] The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the Ares I System-level FMEA/CILs for compliance with JPR 8080.5, JSC Design and Procedural Standards, section G-2. The verification shall be considered successful when the integrated analysis shows that redundant systems are separated or protected.

Rationale: Verification of this requirement will be performed in accordance with the CxP 70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology document.

[CA5435V-PO] This verification shall be satisfied by test and analyses.

a. Tests shall be performed using the flight assets and associated CxP elements (Ground Systems and Mission Systems) under actual flight conditions to validate simulation testing.

b. Abort Determination shall be verified with simulation tests.

Simulation tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-783) document(s). (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing).

The verification shall be considered successful when:

a. The Ares I performs the abort determination function(s) through an internal algorithm using internal or external data sources.

b. The CxP Architecture elements receive notification from the Ares I of the need for an abort through the C3I infrastructure.

c. The profiles, boundaries, modes, variable ranges and accuracy specified in (TBD-001-783) document(s) are verified.

Rationale: Testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle. The (TBD-001-783) document refers to the body of engineering source data (i.e. SRDs, IRDs, Trade Studies, Analyses, Flight Procedures, Flight Rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

4.7.2.2.2.1 Ares I Crew Survival Probabilities

[CA5914V-PO] The probability of exceeding Ascent abort conditions as outlined in Table XXX (TBD-001-1401) due to Ares I shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of exceeding the ascent abort conditions due to Ares I is no greater than 1 in (TBD-001-948).

Rationale: NR

4.7.2.2.2.2 Ares I Emergency Egress, Aborts and Return for Survivability

[CA5159V-PO] The unassisted emergency egress for six (TBR-001-211) ground crew from internal Ares I during pre-launch pad activities within 2 (TBR-001-168) minutes shall be verified by demonstration and analysis. The demonstration shall consist of performing a minimum of two runs with two different sets of ground crewmembers and collecting the task time for ground crew egress from initiation of the egress event to the last person being external to Ares I. Analysis shall consist of performing an integrated examination to verify that the design does not hinder the means for ground personnel to escape the internal Ares I case of an emergency. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for all practical anthropometric ground crew assignments. The verification shall be considered successful when the analysis determines that six (TBR-001-211) ground crew can perform an unassisted emergency egress from internal Ares I during pre-launch pad activities within 2 (TBR-001-168) minutes starting from the initiation of the egress to the arrival of the last ground crewmember at the Ares I exit point.

Rationale: NR

4.7.2.2.3 Reserved

4.7.2.2.4 Reserved

4.7.2.2.5 Ares I Mission Rates and Durations

[CA6087V-PO] The ability of Ares I to provide the capacity to perform four launches in a year shall be verified by analysis. The analysis shall assess the time required to produce, transport, assemble, and test the Ares I flight systems and integrate them into mission configuration. The verification shall be considered successful when analysis shows the Ares I flight systems can be produced, transported, assembled, tested and integrated into mission configuration in time to meet mission objectives.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide a fully functional vehicle in time to support the mission. An analysis of the timeline considering all aspects involved with processing the vehicle will determine the minimum amount of time to ready the vehicle for the mission. The analysis should also include any reprocessing or refurbishment activities planned.

[CA6089V-PO] The ability of Ares I to conduct back to back launches within 45 calendar days measured from the launch of the first integrated stack and ending with the launch of the second integrated stack shall be verified by analysis. The analysis shall the assess the time required to test and integrate the Ares I flight systems into mission configuration. Verification shall be considered successful when the analysis determines the Ares I can be tested and integrated into mission configuration within 45 calendar days.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide a fully functional vehicle in time to support the mission. An analysis of the timeline considering all aspects involved with processing the vehicle will determine the minimum amount of time to ready the vehicle for the mission. The analysis should also include any reprocessing or refurbishment activities planned.

4.7.2.2.6 Ares I Architecture Definition

[CA0389V-HQ] The incorporation of the a single 5-segment Solid Rocket Booster modified from the Space Shuttle Solid Rocket Booster (SSRB) for first stage propulsion and a single modified Apollo J-2X engine for second stage propulsion in the Ares I design shall be verified by inspection. The inspection shall consist of the review of Ares I configuration drawings. The verification shall be considered successful when the inspection shows that shuttle-derived 5-segment SRB and a modified Apollo J-2X engine are utilized in the Ares I design.

Rationale: The incorporation of the a single 5-segment Solid Rocket Booster modified from the Space Shuttle Solid Rocket Booster (SSRB) for first stage propulsion and a single modified Apollo J-2X engine for second stage propulsion in the Ares I design shall be verified by inspection. The inspection shall consist of the review of Ares I configuration drawings. The verification shall be considered successful when the inspection shows that shuttle-derived 5-segment SRB and a modified Apollo J-2X engine are utilized in the Ares I design.

[CA1023V-PO] The liftoff clearance between the Ares I integrated stack vehicle and the launch facility shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares I integrated stack vehicle can maintain liftoff clearance with the launch facility as defined in the CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD).

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3202V-PO] The delivery of Orion from the launch site to Ascent Target shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% that Orion can achieve the Ascent Target.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3221V-PO] The ability of the Ares I to change the planned ascent trajectory based on design parameter updates prior to launch shall be verified by test. The test shall be performed using Ares I flight hardware and a certified flight-like communication system.

The verification shall be considered successful when test results show the Ares I can accurately change ascent trajectory based on design parameter updates.

Rationale: Data exchange between the Ares I flight computer and the operations environment can reasonably be tested with hardware and the communication system before flight, and is the highest fidelity of verification for the requirement. Design parameter (I-loads) may include pitch/yaw/roll profile, etc.

[CA3223V-PO] The ability of the Ares I to change the planned ascent trajectory based on guidance target updates provided prior to launch shall be verified by test. The test shall be performed using Ares I flight hardware and a certified flight-like communication system. The verification shall be considered successful when test results show the Ares I can accurately change ascent trajectory based on updates provided prior to launch.

Rationale: Data exchange between the Ares I flight computer and the operations environment can reasonably be tested with hardware and the communication system before flight, and is the highest fidelity of verification for the requirement.

[CA5677V-PO] The Ares I capability to launch independent of ambient lighting conditions shall be verified by analysis. The Analysis shall review the Ground Systems operational acceptance test to show that the ground facilities, facility systems and GSE will be able to provide launch capabilities independent of lighting conditions. The analysis shall include a review of vehicle systems, including but not limited to, vehicle tracking, recovery aids and imagery, to show that the flight systems, facility, facility systems and GSE that will be used to launch flight systems successful operations and performance determination are independent of ambient lighting conditions are built and certified. These facilities, flight systems and GSE requirements will be identified and characterized in the CxP 72034, Crew Launch Vehicle (CLV) Systems Requirements Document (SRD), CxP 72006, Ground Systems, Systems Requirements Document (SRD). The verification shall be considered successful when the analysis show that the flight and ground systems are ready to support flight systems launch for the Ares I Architecture independent of ambient lighting conditions.

4.7.2.2.6.1 Ares I Control Mass

[CA1000V-PO] The Ares I Mass Delivered requirement from Earth to the Ascent Target for ISS missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the mass delivered requirement can be met during the worst performing month.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA1005V-PO] The Ares I Mass Delivered requirement from Earth to the Ascent Target for crewed lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the mass delivered requirement can be met during the worst performing month.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA4138V-PO] The capability of the Ares I to accommodate the Gross Lift Off Weight of Orion shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that Ares I can accommodate the Gross List Off Weight of Orion.

Rationale: NR

[CA4165V-PO] The capability of Ares I to accommodate the Gross Lift Off weight of Orion for the ISS missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares I can accommodate the Gross Lift Off Weight of Orion for the ISS missions.

Rationale: NR

4.7.2.2.6.2 Reserved

4.7.2.2.7 Ares I Safety (System, Public, and Planetary)

[CA0566V-PO] The Ares I FTS usage, in accordance with NPR 8715.5, Range Safety Program, Section 3.3, shall be verified by inspection. The inspection shall examine the Level III acceptance data packages for inclusion of certified FTS. The verification shall be considered successful when the acceptance data package confirms the FTS is in the design and that it has met the design and test requirements of NPR 8715.5, Range Safety Program, Section 3.3 using AFSPCMAN 91-710, Range Safety User Requirements, Columns 2, 3 and 4, as tailored for the Constellation Program.

Rationale: Every delivered booster and upper stage must have a FTS that will be confirmed via the acceptance data package.

[CA1053V-PO] The Ares I execution of authenticated USAF FCO FTS commands shall be verified by Test.

a. The test shall be performed using actual CxP flight vehicles and Ground Systems along with the USAF Range Safety organization during ground testing.

b. Authenticated FTS Command testing shall be performed with simulations. Simulation testing shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-852) document(s) for which the FTS Commands are sent. (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.)

This verification shall be considered successful when the test results prove that the FTS is initiated upon the receipt of a valid USAF FCO-initiated command.

Rationale: Testing is considered the best means for requirement verification. Joint party FTS testing is the established precedence for verification. The USAF Range Safety is identified in this VR as they are an external interface to CxP. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.

The (TBD-001-852) document refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

[CA1054V-PO] This verification shall be satisfied by test.

a. The test shall be performed using CxP flight assets and certified Ground Systems during integrated ground checkout.

b. Vehicle generation of indication upon receipt of each Flight Termination command shall be verified during simulation tests. These tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-343) document(s) for which the Flight Termination and vehicle signals apply. (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing.)

This verification will be considered successful when:

a. Telemetry shows that the (Ares I) generated an indication upon each FTS command.

b. The telemetry shows that the indication of each FTS command was received by the CxP destination (i.e. Orion).

c. That the combined environments will not induce a false indication from the Ares I.

Rationale: Testing is considered the best means for requirement verification. FTS testing is the established precedence for verification. Simulation testing is *necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.*

The (TBD-001-343) document refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

[CA1055V-PO] A delay between the Fire command and FTS ordnance detonation is required to ensure crew survival. NPR 8705.2, Human-Rating Requirements for Space Systems, states: "Flight termination shall include features that allow sufficient time for abort or escape prior to activation of the destruct system." The delay between Fire and actual detonation will be determined by relative motion analysis using digital simulation. The FTS actuation delay shall be verified by test. The test shall be conducted using Ares I flight or flight-equivalent avionics hardware, and shall include a method to determine the elapsed time between the command receipt and the detonation of the FTS ordinance. The verification shall be considered successful when the test results show the time delay from command receipt to FTS ordinance detonation is (TBD-001-344) seconds.

Rationale: The measurement of the time delay from command to detonation can be measured within a test facility, and will produce a quantitative measure. So the test method is selected. While analysis will need to be performed to validate the delay time is correct, it is not explicitly needed to verify the requirement, as stated, is correct.

[CA1056V-PO] FTS Inhibit shall be verified by Demonstration. The FTS Inhibit shall be demonstrated with the Flight and Ground Systems. The demonstration shall exercise the FTS Inhibit function on flight vehicle hardware throughout vehicle processing until launch and during recovery operations. Verification shall be considered successful when objective evidence (FTS telemetry/visual indicators) shows that Ground Systems is able to access and inhibit the FTS function in the applicable usage scenarios.

Rationale: Demonstrations during the certification, training and rehearsal of Ground Systems usage of the FTS, in a flight fidelity setting, is the valid setting to verify this integrated requirement.

[CA5825V-PO] The ability of the Ares I to automatically shutdown Ares I elements for detected faults that lead to catastrophic conditions that will occur in 2 seconds shall be verified by analysis. The analysis shall be performed using a NASA-accredited digital simulation that can simulate catastrophic conditions to allow the Ares I elements to detect the faults. The verification shall be considered successful when the analysis shows that the Ares I can detect the faults that lead to catastrophic conditions that will occur in 2 seconds and the required Ares I elements shutdown automatically.

Rationale: Analysis is required to simulate conditions present during catastrophic conditions that would not be possible in ground or atmospheric tests.

[CA5917V-PO] The auto initiate capability of the Ares I Flight Termination Systems shall be verified by demonstration. The demonstration shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. The simulated mission conditions shall be those that could result in vehicle separation/break-up. (Exhaustive verification of all conditions is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the Ares I Flight Termination Systems initiate upon vehicle separation/break-up in the absence of a signal from range safety.

Rationale: A demonstration is sufficient to verify the auto initiate capability of the Ares I Flight Termination Systems. The Flight Termination Systems used in the demonstration must be flight or flight equivalent hardware but do not have to be physically installed on the Ares I. They may be attached to and destroy dummy hardware as long as the Ares I hardware and software used to determine vehicle separation/break up are flight or flight equivalent. Alternatively, a non-destructive demonstration may be performed that shows that the destruct mechanism works (i.e. signal reaches ordinance, fuse is lit, etc.) without actually destroying the vehicle.

[CA5919V-PO] The disabling of the auto initiate capability of the Ares I Flight Termination Systems shall be verified by inspection and demonstration. The inspection shall examine the ground procedures for uninstalling or disabling the auto initiate capability of the Ares I Flight Termination Systems. The verification shall be considered successful when the inspection conclusively shows that the Ares I cannot be launched with crew, when the auto initiate capability of the Ares I Flight Termination Systems is installed or enabled. The demonstration shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. The simulated mission conditions shall be those that could result in vehicle separation/break-up. (Exhaustive verification of all conditions is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the Ares I Flight Termination Systems do not initiate upon vehicle separation/break-up when disabled or uninstalled.

Rationale: A demonstration is sufficient to verify the disabling of the auto initiate capability of the Ares I Flight Termination Systems.

4.7.2.2.8 Ares I Command and Control

[CA1028V-PO] The Automated Ares I Lift-Off and Ascent Operations requirement verification shall be satisfied by test.

a. Tests shall be performed using the flight assets under simulated flight conditions with the applicable CxP elements (Crew, Mission Systems, and/or Ground Systems) during integrated ground testing.

b. Simulation tests shall be performed for the nominal and off-nominal profiles, the boundaries, modes, variable ranges and accuracy identified in (TBD-001-649) document(s) for which the automated lift-off and ascent/flight function must operate.

(Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing).

The verification shall be considered successful when:

a. The applicable automated lift-off and ascent/flight functions identified in (TBD-001-649) Document(s) are tested.

b. The monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow-on task.

c. The applicable profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-649) document(s).

Rationale: Testing this function provides the best end-to-end verification for this requirement. The associated CxP elements are either active participants or passively monitored by the specific automated function(s). Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.

The referenced documents refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

[CA1029V-PO] The Ares I Autonomous Lift-Off and Ascent Operations requirement verification shall be satisfied by demonstration.

a. Demonstrations shall be performed using the flight (Ares I) assets and Crew Surrogates under simulated flight conditions during integrated ground exercises.

b. Demonstrations using the flight/flight-like assets (Ares I) and crew of the automated and autonomous lift-off and ascent operations shall be performed during simulation and training exercises.

The verification shall be considered successful when:

a. Demonstrated autonomous operation is accomplished.

b. Additional adjustments are not required.

c. External intervention was not necessary.

Rationale: Demonstrations using Flight Assets and the CxP Architecture provide the best environment to demonstrate autonomous functions. Demonstrations during simulations and training exercises are necessary to reduce the risk of being unable to perform the autonomous operation during flight.

[CA3112V-PO] The requirement for the Ares I to Accept Control of Automation shall be verified by test.

a. Tests shall be performed using the flight assets and associated CxP elements (Crew, Ground Systems and Mission Systems) under simulated flight conditions during integrated ground testing.

b. Simulation tests shall be performed for the nominal and off-nominal profiles, the boundaries, modes, variable ranges and accuracy identified in (TBD-001-729) document(s) for which the control of automation will be performed.

The verification shall be considered successful when:

a. The vehicle's running function is halted by the authorized Constellation System assuming vehicle control.

b. The monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

c. The applicable vehicle profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-729) document(s).

Rationale: Testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle. The (TBD-001-729) document refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process.

[CA3256V-PO] The execution of commands by the Ares I, which are valid in the current state, shall be verified by Test. The Test shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-734) document(s) shall be executed by the Ares I. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be executed. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-734) document(s):

a. Commands are executed by the Ares I when valid in the current state in each applicable mission phase, state and mode.

b. Commands are rejected by the Ares I when not valid in the current state in each applicable mission phase, state and mode.

Rationale: A Test of the execution of Ares I commands defined by (TBD-001-734) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability. The (TBD-001-734) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules etc.) generated throughout the design process which specifies the commands for the Ares I.

[CA3275V-PO] The execution of commands by the Ares I which are addressed to the Ares I shall be verified by Test.

The Test shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-763) document(s) shall be executed by the Ares I. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be executed. The Ares I shall be sent each command addressed to it and a subset of the commands addressed to other systems.

The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-763) document(s):

a. Commands are executed by the Ares I when addressed to the Ares I.

b. Commands are processed by the Ares I according to C3I network protocols (e.g., immediately routed, stored and forwarded later, dropped, etc., including that the appropriate notifications are sent) when not addressed to the Ares I.

Rationale: A Test of the execution of Ares I commands defined by (TBD-001-763) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability. The (TBD-001-763) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for the Ares I.

4.7.2.2.9 Ares I Health and Status

[CA1084V-PO] The provision of fault detection by the Ares I shall be verified by Test. The Test shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified abort faults and fault scenarios in (TBD-001-346) document(s) for all applicable simulated mission phases, states, and modes for the Ares I at least twice. The verification shall be considered successful when the Test shows that the abort faults and fault scenarios identified in (TBD-001-346) document(s) are detected by the Ares I in every applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the Ares I for the faults and fault scenarios identified by (TBD-001-346) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-346) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be detected.

[CA1085V-PO] The provision of fault isolation by the Ares I shall be verified by Test. The Test shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-424) document(s) for all applicable simulated mission phases, states, and modes for the Ares I at least twice. The verification shall be considered successful when the Test shows that the applicable fault and fault scenarios identified in (TBD-001-424) document(s) are isolated by the Ares I in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the Ares I for the faults and fault scenarios identified by (TBD-001-424) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-424) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be isolated.

[CA1086V-PO] The provision of fault recovery by the Ares I shall be verified by Test. The Test shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-347) document(s) for the applicable simulated mission phases, states, and modes for the Ares I at least twice. The verification shall be considered successful when the Test shows that the applicable fault and fault scenarios identified in (TBD-001-347) document(s) are recovered from by the Ares I in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the Ares I for the faults and fault scenarios identified by (TBD-001-347) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-347) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be recovered from.

[CA3118V-PO] The generation of Health and Status information by the Ares I shall be verified by Test. The Test shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable Health and Status data defined in (TBD-001-708) document(s) shall be generated by the Ares I. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the Test shows that the Health and Status data identified in (TBD-001-708) document(s):

a. Health and Status data generated by the Ares I in each applicable mission phase, state and mode.

b. Health and Status data agrees with the actual health and status of the Ares I.

Rationale: A Test of the generation of Ares I health and status data defined by (TBD-001-708) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-708) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the Health and Status parameters for the Ares I.

[CA5816V-PO] The provision of fault detection by the Ares I shall be verified by Test.

The Test shall use the flight Ares I or flight equivalent hardware in simulated mission conditions.

The Test shall induce the identified faults and fault scenarios in (TBD-001-1008) document(s) for each applicable simulated mission phase, state, and mode for the Ares I at least twice.

The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-1008) document(s) are detected by the Ares I in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the Ares I for the faults and fault scenarios identified by (TBD-001-1008) document(s) for each mission phase, state and mode are sufficient to verify this capability. The (TBD-001-1008) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be detected.

[CA6107V-PO] Requirement shall be verified by analysis and test. Analysis of the specified data path shall be performed. The analysis shall include environmental factors for nominal and off-nominal mission operation scenarios. The test shall consist of simulations of the communications for nominal and off-nominal mission operations including pre-launch communication activities and shall be conducted at least twice each for nominal and maximum data rates. The test shall be conducted on flight or flight-like systems and simulated systems over simulated nominal space links.

The verification shall be considered successful when:

a. Testing shows the Constellation mission element can send data to Mission Systems, and Ground Systems correctly and without apparent degradation for both nominal and maximum data rates at least twice.

b. Analysis shows that data links, including forward and reverse margins, provide necessary bandwidth to support communication during nominal and off-nominal operations.

Rationale: Analysis is used to verify that communication links will remain operational during the specified mission scenarios and environmental conditions. Testing is used to load the system to stress levels. Test results must be repeatable and consistent.

4.7.2.2.10 Ares I Communications and Communications Security

[CA5906V-PO] The Ares I capability to reconfigure stored commands, sequences and data shall be verified by demonstration. The demonstration shall use the flight Ares I or flight equivalent hardware in simulated mission conditions. The Ares I shall be preloaded with a set of stored commands, sequences and data. The subset of stored commands, sequences and data identified in (TBD-001-998) documents shall then be reconfigured. (Exhaustive verification of each reconfiguration item is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the stored commands, sequences and data identified in (TBD-001-998) documents have been successfully reconfigured on the Ares I and that they properly reflect the updated values.

Rationale: A demonstration of the Ares I capability to reconfigure stored commands, sequences and data is sufficient to verify this capability. The (TBD-001-998) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify what stored commands, sequences and data are subject to reconfiguration and what the range of potential values are.

[CA5912V-PO] Simultaneous communication by the Ares I with Orion, Mission Systems, and Ground Systems shall be verified by analysis and test.

Analysis of the specified data links shall be performed. The analysis shall include environmental factors for nominal and off-nominal Ares I launch operation scenarios. The test shall consist of simulations of the communications for nominal and off-nominal Ares I launch operations including pre-launch communication activities and shall be conducted at least twice each for nominal and maximum data rates. The test shall be conducted on flight or flight-like systems and simulated systems over simulated nominal space links.

The verification shall be considered successful when:

a. Testing shows the Ares I can simultaneously exchange data with Orion, Mission Systems, and Ground Systems for Ares I pre-launch and launch operations correctly and without apparent degradation for both nominal and maximum data rates for each scenario at least twice.

b. Analysis shows that hardline, networked, and RF data links, including forward and reverse margins, provide necessary bandwidth to support communication during nominal and off-nominal Ares I launch operations.

Rationale: Analysis is used to verify that RF communication links will remain operational during the specified mission scenarios and environmental conditions. Testing is used to load the system to stress levels. Test results must be repeatable and consistent.

[CA6214V-PO] The processing by Ares I of telemetry destined for range safety within 250 msec (TBR-001-1439) during the launch/ascent phase shall be verified by test.

The test shall be performed using flight equivalent units or emulators with Flight Software in simulated mission conditions. The test shall time stamp the range safety telemetry upon collection from the sensors and again after processing at the point of transmission (exiting Ares I). The test shall be performed on selected points during the flight timeline that cover the full range from launch through ascent. The time stamps shall be analyzed for compliance to the requirement within 95% confidence level. Recording of telemetry entrance and exit times with a packet analyzer or other measurement equipment can be used in place of time stamps.

The verification shall be considered successful when the analysis of the data collected by the test shows that the total time to process the telemetry is within the time specified for all points on the flight timeline.

Rationale: Testing system performance under mission-like conditions is a reasonable way to confirm that they are individually meeting their allocations. 95% confidence could be met with 20 points along the flight timeline where only 1 point does not meet the requirement. A packet analyzer may provide more time resolution and accuracy than time stamps, so is allowed as an option.

4.7.2.2.11 Ares I GN&C

[CA3143V-PO] The Ares I navigation and attitude determination capability shall be verified by analysis and component testing. The analysis and testing shall be accomplished using flight sensor hardware in a NASA-accredited dynamic hardware-in-the-loop simulation of the Ares I. The dynamic simulation, analysis, and hardware-in-the-loop tests shall verify the accuracy of the Ares I navigation and attitude determination capability by taking error data from component level navigation and attitude sensor testing, and processing this data with a dynamic model of the orbit and attitude dynamics and disturbances during ascent. The verification shall be considered successful when the analysis, simulation, and testing has shown that the criteria as specified in CxP 72034, Crew Launch Vehicle (CLV) Systems Requirements Document (SRD) for the navigation and attitude determination capability from pre-launch through Ares I upper stage separation from Orion has been met.

Rationale: NR

4.7.2.2.12 Ares I Reliability and Availability

[CA0072V-PO] The requirement for the Ares I to have a 10 minute planar launch window per crewed launch opportunity for ISS missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares I can launch (planar) within a 10 minute window for ISS missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA1008V-PO] The ability for the Ares I to provide launch opportunities for 7 consecutive days for crewed missions shall be verified by analysis. The analysis shall assess the Integrated Logistics Support Plan, the Ares I Logistics Support Analysis Report, ground processing plans, Logistics Support Analysis Records (LSAR), and other documents that include launch recycle tasks and activities associated with crewed missions in order to calculate the time and resources required to perform launch tasks for 7 consecutive days. The verification shall be considered successful when the analysis results show that the Ares I can provide launch opportunities for at least 7 consecutive days for crewed missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work

[CA1066V-PO] The ability of the Ares I have a probability of launch of not less than 98 (TBR-001-939)% on the initial attempt, exclusive of weather, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt, shall be verified by analysis. The verification analysis shall use only R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when analysis shows that the probability of launch per crew launch attempt is not less than 98 (TBR-001-939)% with an uncertainty of not greater than (TBD-001-345)% (TDS# SIG-01-004).

Rationale: The Ares I reliability and availability data, along with Ground Operations data that include fixed and variable resources will need to be available for the CA to verify that the flight and ground hardware and other resources will be in a situation that supports the vehicle and Ground Systems to be available to support during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

[CA1068V-PO] The ability of the Ares I to a meet a 95% (TBR-001-940) launch probability with respect to the natural environment shall be verified by analysis. The analysis shall examine the data submitted for verification of the requirements based on the Design Specification for Natural Environments (DSNE) specifications, monthly climatological statistics, and the Induced Environments Design Specification. The envelope defining the extents of the compiled data from these sources should then be defined as the weather constraints for launch probability assessments. The defined weather constraints shall subsequently be analyzed against weather conditions for each month and determine that the Ares I can launch with 95% (TBR-001-940) probability within these conditions with no more than (TBD-001-345)% uncertainty. The verification shall be considered successful when the analysis concludes that the Ares I has a launch probability of 95% (TBR-001-940), with an uncertainty of not greater than (TBD-001-345)% (TDS# SIG-01-004), with respect to the natural environment.

Rationale: The assessment of the launch probability with respect to the natural environment must consider associated induced effects of the launch configuration e.g. pad clearances that are dependent upon the winds. The only way to determine this overall probability is analysis.

[CA5323V-PO] The requirement for the Ares I to have a 90 min planar launch window per crewed launch opportunity for Lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares I can launch within at least a 90 min planar launch window for crewed Lunar missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA6203V-PO] The ability to remedy the required percentages of Ares I system failures identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1500)% that would result in a scrubbed launch within the required time limit, shall be verified by analysis. The analysis shall assess the Ares I FMEA, maintenance plan, LSA, and FDIR capabilities to determine the likelihood of occurrence of failures and the percentage of failures that can be remedied within 1 day, 2 days, and 3 days. The verification analysis shall use only Cx R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when the analysis determines, with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004) that:

a. No less than 45% (TBR-001-1413) can be remedied to support a launch attempt within one day.

b. No less than 65% (TBR-001-1414) can be remedied to support a launch attempt within two days.

c. No less than 70% (TBR-001-1415) can be remedied to support a launch attempt within three days.

Rationale: The verification analysis requirement is intended to drive a determination of the ability to remedy those failures that are most likely to be identified during the countdown when systems are activated, serviced, and operated. The analysis should sort the set of the most likely failures into those items that can be remedied one day, two days, three days, or more time. Since no location constraint is composed (e.g. nobody said the failure had to be remedied at the pad), a remedy scenario that rolls back, repairs, rolls out to pad, and supports a launch attempt *within the time frame is allowed for this sorting. The analysis should consider that the likelihood of a latent defect being present but undetected at the time of a decision to proceed past a given milestone is a variable influenced by the perceptiveness of testing and operations performed before that milestone.*

4.7.2.2.13 Ares I Maintainability, Supportability, and Logistics

[CA5713V-PO] The ability of the reusable elements of the Ares I to be refurbished shall be verified by analysis. The analysis shall be performed on the requirements for the flight elements to be refurbished in the facility and facility systems and GSE provided by the Ground System used to support refurbishment of flight elements. The analysis shall compare the Ares I refurbishable elements design to the GS design for compatibility. The verification shall be considered successful when the analysis shows that the reusable elements of the Ares I can be refurbished in the GS facilities, facility systems and GSE that support refurbishment as attested by the design certification review.

[CA5978V-PO] The ability of Ares I to generate Project Verified Engineering Builds after the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars) shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA5979V-PO] The ability of the Ares I to generate Project Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5980V-PO] The ability of Ares I to generate day of launch updates shall be verified by demonstration. Demonstration shall be considered successful when day of launch updates have been successfully generated and applied during project verification and validation activities.

Rationale: The intent is to demonstrate that the day of launch update process can be successfully executed.

[CA5981V-PO] The ability of Ares I to provide fixes for selected non-conformances to the discovering organization shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when inspection determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA6004V-PO] The ability of the Ares I to conduct ground operations within the constraints levied in Ares I Critical Path Allocations for Ares I/Orion Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6003 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

4.7.2.2.14 Reserved

4.7.2.2.15 Ares I Environmental Conditions

[CA1069V-PO] Compliance of the Ares I with its functional and performance requirements during and after exposure to the DSNE environments shall be verified by inspection and analysis. The inspection shall consist of review of the following:

a. Allocation of the natural environments requirements to the lower tier systems and their verification methods and details

b. The lower tier verification closure data

The analysis shall address interactions of each lower tier system on other systems to include integrated environment effects.

The systems shall include the following integrated configurations: Orion/Ares I/GS, Orion/Ares I, and Ares I/GS.

The verification shall be considered successful when the inspection and integrated analysis show:

a. The natural environment requirements and verification have been allocated to the lower tier systems in accordance Section 4 of the DSNE

b. Lower tier verifications have been completed

c. The Ares I meets its functional and performance requirements during and after exposure to the DSNE environments

Rationale: Verification of functional and performance requirements across the range of natural environments requires a systematic integrated approach to address dependencies on hardware configurations and operational mode. The DSNE Section 4 specifies a standard systems engineering technique for flowing down the natural environment from higher to lower levels using the Natural Environment Requirements Sensitivity and Applicability Matrix (NERSAM) for each mission phase. Lower tier verification close out data, analyses, and models are necessary to support the integrated analysis, but are not sufficient alone to close out the environment requirements from the integrated vehicle configuration.

[CA5557V-PO] Ares I function and performance during and after exposure to induced environments shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the Ares I/System IRD requirements.

b. Review of the induced environment verifications submitted against CxP 72034, Crew Launch Vehicle (CLV) Systems Requirements Document (SRD) requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification. The verification shall be considered successful when the analysis shows that the Ares I function and performance requirements are met during and after exposure to CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.

Rationale: Function and performance must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that;

a. The proper induced environments have been considered

b. Sensitivities to these environments

c. Synergistic effects have each been properly addressed for all mission phases

[CA5562V-PO] Ares I induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the Ares I/System IRD requirements.

b. Review of the induced environment verifications submitted against CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD) requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification.

The verification shall be considered successful when the analysis shows that the Ares I peak and cumulative induced environments will not exceed CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.

Rationale: Induced environment contributions must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that:

a. The proper induced environments have been met

b. Sensitivities to these environments

c. Synergistic effects have each been properly addressed for all mission phases

4.7.2.3 Reserved

4.7.2.4 ARES I EXTERNAL INTERFACES

[CA0430V-PO] The Ares I interfaces with the Orion shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the Ares I-to-Orion interface requirements defined within the CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program

Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares I and Orion flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalent) or across distributed SILs (or equivalents) prior to assembly of the integrated launch vehicle stack at the launch site. Testing shall also include a multi-system integrated test of the integrated Ares I/Orion launch vehicle stack to demonstrate integrated functionality and interoperability between the flight systems and between the integrated launch vehicle stack and the ground support and mission control systems. Verification shall be considered successful when:

a. Analysis confirms that all of the Orion interface verification requirements defined within CxP 70026, Constellation Program Orion -to- Ares I Interface Requirements Document (IRD) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Ares Project Office to confirm that all of the Ares I-to-Orion interface requirements specified in CxP 70026, Constellation Program Orion -to- Ares I Interface Requirements Document (IRD) have been satisfied. Integrated testing of the Ares I and Orion flight avionics and software at or distributed amongst the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Since the first time the Ares I and Orion flight systems will be integrated together is within the integrated launch vehicle stack, integrated testing between the flight systems within the launch vehicle stack and between the stack and the various ground support and mission control systems will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

[CA0897V-PO] The Ares I interfaces with the GS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the Ares I-to-GS interface requirements defined within the CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP

70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares I avionics and software and the GS via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the GS to confirm interoperability and functionality between the Ares I and GS. Verification shall be considered successful when:

a. Analysis confirms that all of the Ares I interface verification requirements defined within CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Ares Project Office to confirm that all of the Ares I-to-GS interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares I avionics and software and the GS via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating GS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

[CA0898V-PO] The Ares I interfaces with MS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the Ares I-to-MS interface requirements defined within the CxP 70053, Constellation Program Ares I -to- Mission Systems Interface Requirements Document, have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares I avionics and software and MS via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate MS to confirm interoperability and functionality between the Ares I, GS, and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the Ares I interface verification requirements defined within CxP 70053, Constellation Program Ares I -to- Mission Systems Interface Requirements Document, have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Ares Project Office to confirm that all of the Ares I-to-MS interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares I avionics and software and the MS via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating MS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

[CA0899V-PO] The Ares I interfaces with the Communications and Tracking Networks shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the Ares I interface requirements defined within the CxP 70118-02, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 2: Ares I, have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares I avionics and software and the communications and networks systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the communications and tracking network systems to confirm interoperability and functionality between the systems. Verification shall be considered successful when:

a. Analysis confirms that all of the Ares I interface verification requirements defined within CxP 70118-02, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 2: Ares I, have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Ares Project Office to confirm that all of the Ares I-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares I avionics and software and the communications and network systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating the communication and network *systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.*

4.7.2.5 Reserved

4.7.3 Lunar Surface Access Module (LSAM)

4.7.3.1 LSAM Description

4.7.3.2 LSAM Requirements

[CA3213V-PO] The ability for the LSAM to deliver cargo to the lunar surface for Lunar Outpost Cargo Missions shall be verified by analysis. The simulation tools and analysis methodology, including assumed non-ideal model behavior and design data used in the analysis, shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the LSAM can deliver cargo to the lunar surface for Lunar Outpost Cargo Missions.

Rationale: The requirement specifies a design approach, and the inspection is considered a Review of Design (ROD). Verification of specific elements of the design approach will be performed at other verification levels.

4.7.3.2.1 LSAM Mission Success

Draft [CA0504V-PO] Lunar Sortie LOM due to the LSAM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Sortie mission due to the LSAM is no greater than 1 in 75 (TBR-001-060).

Rationale: NR

Draft [CA3036V-PO] Lunar Outpost Crew LOM due to the LSAM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Outpost Crew mission due to LSAM is not greater than 1 in (TBD-001-557).

Rationale: NR

Draft [CA3042V-PO] Lunar Outpost Cargo LOM due to the LSAM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Outpost Cargo mission due to LSAM is not greater than 1 in (TBD-001-561).

Rationale: NR

4.7.3.2.2 LSAM Crew Survival

Draft [CA3139V-PO] The fire detection and suppression for the pressurized volume shall be verified by analysis, supported by inspection and test. The analysis shall show that the LSAM detects events indicating fire and limits propagation of a fire in the pressurized volume of the LSAM. The analysis shall utilize results from LSAM children requirements compliance with CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD) fire detection and suppression criteria. An inspection of drawings shall be performed to verify that the fire detection and suppression hardware has been installed in the pressurized volume of the LSAM. A test of a simulated smoke alarm and vehicle response shall show that an impending fire in the cabin or avionics bay can be detected, suppressed, and atmosphere restored. The verification shall be considered successful when the analysis, inspection, and test show that a fire in the pressurized volume of the LSAM can be detected and suppressed before it can propagate.

Rationale: This combination of methods will verify that an appropriate design will be implemented and tested at the vehicle level. Fire detection and suppression is a contingency requirement; prevention will be verified as part of the materials standard and design. The avionics bay, dependent upon design, may present a special case requiring a demonstration for verification.

Draft [CA5191V-PO] The ability of the LSAM to sustain life of the suited crew without permanent disability in an unpressurized cabin for up to 7 (TBR-001-214) hours shall be verified by analysis. The analysis shall prove that the LSAM System can provide the following simultaneous functions while the LSAM habitable volume is depressurized for 4 crewmembers:

a. EVA System oxygen quantity for 7 (TBR-001-214) hours

b. EVA System oxygen flow rates for 7 (TBR-001-214) hours

c. EVA System breathing gas scrubbing for 7 (TBR-001-214) hours

d. EVA System fluid flow rates and temperatures for 7 (TBR-001-214) hours

e. EVA System power for 7 (TBR-001-214) hours

f. EVA System nutritional, medical, and hydration needs for 7 (TBR-001-214) hours

g. Communication (voice, suit and biomed data) with EVA System for 7 (TBR-001-214) hours

h. Seat ingress and harness securing with a pressurized suit for lunar ascent and Orion docking (if required)

i. Ability for interfacing Orion systems to operate and remove ammonia/body contaminates in return breathing gas for 7 (TBR-001-214) hours.

The verification shall be considered successful when the analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized for 7 (TBR-001-214) hours for four crewmembers.

Rationale: NR

Draft [CA5193V-PO] The ability of the LSAM to perform the functions necessary to return to LRO within 3 (TBR-001-171) hours with an unpressurized cabin shall be verified by analysis. The analysis shall prove that the LSAM System can provide the following simultaneous functions while the LSAM habitable volume is depressurized:

a. LSAM minimum system operation with an unpressurized cabin for 3 (TBR-001-171) hours

b. LSAM launch off lunar surface and rendezvous with Orion

c. LSAM ECLSS cooling to all minimum systems with an unpressurized cabin for 3 (TBR-001-171) hours

d. LSAM alarm annunciation to crew inside pressure suit

e. Any necessary LSAM vehicle maintainability required during the return trip designed per suited standards, not just vehicle interfaces but also IVA tools necessary for those tasks)

f. (TBD-001-945) Others

g. CA5195-PO

The verification shall be considered successful when the analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized

Rationale: NR

Draft [CA5194V-PO] The ability of the LSAM to provide suit stowage such that a suit can be accessed within 2 (TBR-001-172) minutes for donning shall be verified by demonstration and analysis. The demonstration shall consist of 1-g suit donning evaluations using flight or training quality suits in a representative LSAM volume mockup, with the suits stowed in the designated LSAM stowage location, performed by two different sets of crewmembers (six crewmembers per set) with two runs performed by each set, and collection of task time for suit retrieval, donning, pressurization, and any other tasks required by the crew to complete the suit donning and pressurization process. The analysis shall consist of examination of task time collected during the 1-g demonstration, applying a program approved microgravity extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments. The verification will be considered successful when the analysis determines that each suit can be retrieved from stowage within 2 (TBR-001-172) minutes.

Rationale: NR

4.7.3.2.2.1 LSAM Crew Survival Probabilities

Draft **[CA0503V-PO]** Lunar Sortie LOC due to the LSAM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for a Lunar Sortie mission due to the LSAM is no greater than 1 in 250 (TBR-001-059).

Rationale: NR

Draft **[CA3041V-PO]** Lunar Outpost Crew LOC due to the LSAM shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for a Lunar Outpost Crew mission due to the LSAM is not greater than 1 in (TBD-001-560).

Rationale: NR

4.7.3.2.2.2 LSAM Emergency Egress, Aborts, and Return for Survivability

[CA5236V-PO] The ability of the LSAM to provide abort capability from TLI until the mission destination shall be verified by analysis and test. The analysis shall consist of abort trajectory analysis and lunar descent abort analysis. The trajectory analysis shall determine the amount of LSAM propellant required to return the Orion/LSAM vehicle to a safe CM entry point from any point between TLI and Orion/LSAM separation. The lunar descent analysis shall be performed on aborts during lunar descent using simulation tools and analysis methodology, including any assumed non-ideal model behavior and design data used, shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The digital simulation and analysis shall include models of the LSAM stage separation as well as Orion in lunar orbit. The testing shall be conducted within a SIL (or equivalent) facility and shall include testing of LSAM abort trajectory maneuvers with the Orion/LSAM vehicle, testing of Ascent stage abort maneuvers during LSAM descent, and testing of the LSAM capability to separate and stabilize the Orion/LSAM vehicle while mated to the Ares V, including the TLI maneuver phase. The trajectory analysis verification shall be considered successful when the analysis shows that LSAM propellant is sufficient to return Orion/LSAM to a safe CM entry point. The lunar descent abort analysis shall be considered successful when the results show that the probability of successful ascent stage re-docks with Orion is not less than 99.73% with a "consumer's risk" of 10%.The abort trajectory maneuver testing shall be considered successful when the results show that the LSAM hardware and software can perform all rotational and translational maneuvers required to return the mated Orion/LSAM to a safe CM entry point. The lunar descent abort testing shall be considered successful when the results show that the LSAM ascent stage can successfully separate from the descent stag and rendezvous and dock with Orion. The LSAM/Ares V separation testing shall be considered successful when the results show that the LSAM can separate from the Ares V without recontact and stabilize the mated Orion/LSAM.

Rationale: Test is required because significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a certified flight simulation. Analysis by simulation is also required because of the large number of evaluations that must be performed and the lack of access to the operational environment for test.

Draft **[CA5238V-PO]** The LSAM expedited return from lunar surface to docking with Ares I LRO shall be verified by analysis and test. The testing shall be conducted using a SIL (or equivalent) with models of the LSAM ascent stage as well as Orion in lunar orbit. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the LSAM can return the crew from the surface of the moon to docking with Orion in the Lunar Rendezvous Orbit in 12 (TBR-001-179) hours or less for Lunar Sortie and Lunar Outpost crew missions.

Rationale: Test is required because significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a certified flight simulation. Analysis by simulation is also required because of the large number of evaluations that must be performed and the lack of access to the operational environment for test.

[CA5316V-PO] The ability of the LSAM to return the crew to Orion independent of communications with MS shall be verified by analysis. The analysis shall be performed using simulation tools and analysis methodology, including any assumed non-ideal model behavior or design data used, shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508) and include models of LSAM and Orion navigation subsystems that impact the ability of the vehicle to navigate independent of MS. The analysis shall include Monte Carlo dispersion on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis shows a probability of not less than 99.86% with a "consumer's risk" of 10% that the LSAM can return the crew to Orion independent of communications with MS.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.3.2.3 LSAM Maintainability, Supportability, and Logistics

4.7.3.2.4 LSAM Cargo Delivery and Return

Draft **[CA0062V-PO]** The LSAM Mass Returned requirement from the lunar surface to LRO during each crewed mission shall be verified by analysis. This analysis shall be performed using simulation tools and analysis methodology, including assumed non-ideal model behavior and design data used, shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508) The analysis shall include Monte

Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows that the probability of the LSAM's Return Mass Capability exceeding or equaling the Return Mass requirement is 99.86% with a "consumer's risk "of 10%.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA0090V-PO]** The LSAM Mass Delivered requirement from the Lunar Destination Orbit to the lunar surface for crewed missions shall be verified by analysis. This analysis shall be performed using simulation tools and analysis methodology, including assumed non-ideal model behavior and design data, in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall include dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows probability of the LSAM's Calculated Mass Delivered capability will equal or exceed the Mass Delivered requirement is 99.86% with a10% "Consumer's Risk".

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA0137V-PO]** The LSAM Mass Delivered requirement from the Lunar Destination Orbit to the lunar surface for uncrewed missions shall be verified by analysis. This analysis shall be performed using simulation tools and analysis methodology, including assumed non-ideal model behavior and design data used, in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows probability of the LSAM's Calculated Mass Delivered capability will equal or exceed the Mass Delivered requirement is 99.86% with a 10% "Consumer's Risk".

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA4140V-PO] The LSAM Mass Delivered requirement during the TLC and the LOI shall be verified by analysis. This analysis shall be performed using simulation tools and analysis methodology, including assumed non-ideal model behavior and design data used, in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows the probability that the LSAM's Calculated Mass

Delivered capability will equal or exceed the Mass Delivered requirement is 99.86% with a 10% "Consumer's Risk".

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA5156V-PO]** The ability of the LSAM to return cargo from the moon shall be verified by analysis. Analysis consists of documentation that the Mission System can provide the following simultaneous functions for LSAM:

a. LSAM provisions for returning cargo volume of at least (TBR-001-167) from the lunar orbit to Earth for Lunar Sortie missions

b. LSAM provisions for returning cargo volume of at least (TBR-001-167) from the lunar orbit to Earth for Lunar Outpost missions

The verifications shall be considered successful when the analysis confirms the functions listed can be performed by the LSAM for each crewed lunar mission.

Rationale: This is an overarching LSAM project verification requirement that can be satisfied once the flow-down requirements to the LSAM projects are satisfied. The analysis can be satisfied by the LSAM providing the requirements that address the functions (whether in the SRD, ICD or IRD).

4.7.3.2.5 LSAM Mission Rates and Durations

Draft **[CA0839V-PO]** The ability for the LSAM to loiter in LEO at least (TBD-001-975) days after orbit insertion shall be verified by simulation and analysis. This analysis shall be performed using simulation tools and analysis methodology, including assumed non-ideal model behavior and design data, in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and vehicle consumables and high-order earth gravity effects. The verification shall be considered successful when the analysis results show there is a 99.86% probability with a 10% "consumer's risk" that the LSAM can loiter for at least (TBD- 001-975) days after orbit insertion.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA0842V-PO]** LSAM operating without a crew on the lunar surface for at least 210 (TBR-001-039) days shall be verified by analysis. The analysis shall consist of assessment of environmental considerations, the consumables to support a 210 (TBR-001-039) day loiter plus crew return, reliability assessment to ensure the system remains operable, engine performance, vehicle consumables, and navigation factors. This is not meant to support a crew for the entire 210 (TBR-001-039) days. The verification shall be considered successful when the analysis shows that the LSAM can loiter without a crew on the lunar surface for 210 (TBR-001-039) days.

Rationale: NR

Draft [CA4150V-PO] The ability of the LSAM to sustain crews on the lunar surface for at least 7 days during a lunar sortie mission shall be verified by analysis. The analysis shall assess the lunar surface habitat vehicle design for atmosphere control and quality, potable water, atmosphere temperature, humidity and ventilation, food, body waste and trash management provides a habitable environment, as specified in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR). The analysis will be supported by component and subsystem tests and analyses. The verification shall be considered successful when the analysis shows the Lunar sortie vehicle provides a habitable environment for the full crew complement for a duration of at least 7 days.

Rationale: NR

[CA6091V-PO] The ability of the LSAM to provide the capacity to perform four ISS launches in a year shall be verified by analysis. The analysis shall assess the time required to produce, transport, assemble, and test the LSAM flight systems and integrate them into mission configuration. The verification shall be considered successful when analysis shows the LSAM flight systems can be produced, transported, assembled, tested and integrated into mission configuration in time to meet mission objectives.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide a fully functional vehicle in time to support the mission. An analysis of the timeline considering all aspects involved with processing the vehicle will determine the minimum amount of time to ready the vehicle for the mission. The analysis should also include any reprocessing or refurbishment activities planned.

[CA6093V-PO] The ability of the LSAM to launch on a 45 calendar day interval, measured from the launch of the first mission to the launch of the second mission shall be verified by analysis. The analysis shall the assess the time required to test and integrate the LSAM flight systems into mission configuration. Verification shall be considered successful when the analysis determines the LSAM can be tested and integrated into mission configuration within 45 calendar days.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide a fully functional vehicle in time to support the mission. An analysis of the timeline considering all aspects involved with processing the vehicle will determine the minimum amount of time to ready the vehicle for the mission. The analysis should also include any reprocessing or refurbishment activities planned.

[CA6202V-PO] The ability for the LSAM to be mission ready for launch attempts on no less than 4 consecutive days for Ares V missions shall be verified by analysis. The analysis shall assess the Integrated Logistics Support Plan, the LSAM Logistics Support Analysis Report, ground processing plans, Logistics Support Analysis Records (LSAR), and other documents that include launch recycle tasks and activities associated with Ares V missions in order to calculate the time and resources required to perform launch tasks for 4 consecutive days. The verification shall be considered successful when the analysis results show that the LSAM can be mission ready for launch opportunities on no less than 4 consecutive days for crewed missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.3.2.6 LSAM Architecture Definition

[CA0394V-PO] The LSAM design inclusion of a crew airlock shall be verified by inspection. The inspection shall review the design drawing to ensure the airlock is included. Verification is considered successful when the Inspection shows that an airlock is included in the design.

Rationale: Inspection of the design drawings will be sufficient to determine whether or not an airlock has been included in the design of the LSAM. This requirement does not address the detailed requirements that the airlock has to meet, merely that an airlock is included in the design. As such, an inspection of the design drawings should be sufficient.

[CA0397V-HQ] The restart function of the LSAM liquid hydrogen/liquid oxygen descent stage propulsion system shall be verified by analysis and test. The analysis shall be performed using simulation tools and analysis methodology, including assumed non-ideal model behavior and design data, in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall simulate the propulsion system under the operational environment, including dynamic and environmental conditions experienced by the system during restart. The verification shall be considered successful when the analysis shows the probability of system restart is 99.73% with a "consumer's confidence" of 10% and that probability of achieving the minimum steady-state thrust and Isp (TBD-001-1010) after restart is 99.865% with a "consumer's confidence" of 10%. The restart test shall use a propulsion test facility to examine restart operation of the engine hardware in a live test environment. The test will utilize a range of operational environments as defined in (TBD-001-1011) Test Plan. The verification shall be considered successful when the test shows that the minimum steady-state thrust and Isp after restart is (TBD-001-1010).

Rationale: Analysis is required to simulate environmental conditions present during restart that would not be possible in ground or atmospheric tests. Tests provide the necessary quantitative data that confirms the propulsion system performs as required.

[CA3200V-PO] The throttle function of the LSAM liquid hydrogen/liquid oxygen descent stage propulsion system shall be verified by analysis and test. The analysis shall use a NASA-accredited digital simulation and shall simulate the propulsion system under the operational environment, including dynamic and environmental conditions, experienced by the system during throttling. The verification shall be considered successful when the analysis shows the propulsion system can be throttled to (TBD-001-364) and that the system maintains expected thrust after throttle. The throttle test shall use a propulsion test facility to examine throttle operation of the engine hardware in a live test environment. The test will utilize a range of operational environments as defined in (TBD-001-365) Test Plan. The verification shall be considered successful when the test shows that the propulsion system can be throttled to (TBD-001-364) and that the system maintains expected thrust after throttle.

Rationale: Analysis is required to simulate environmental conditions present during restart that would not be possible in ground or atmospheric tests. Test provides the necessary quantitative data that confirms the propulsion system performs as required.

[CA3206V-PO] The ability of the LSAM to deliver the crew and cargo from LDO to the lunar surface shall be verified by analysis. The analysis shall be performed using simulation tools and analysis methodology, including assumed non-ideal model behavior and design data, in accordance with the 6-step verification process defined in (TBD-001-1508) The analysis performed shall include lunar gravity effects and a model of the lunar surface. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a 99.86% probability with a 10% "Consumer's Risk" that the LSAM can successfully deliver the crew and cargo from LDO to the lunar surface.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3208V-PO] The ability of the LSAM to deliver the crew and cargo from the lunar surface to the LRO shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the LSAM can deliver the crew and cargo from the lunar surface to LRO.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA3286V-PO]** The capability for LSAM to perform Lunar Sortie missions without the aid of pre-deployed lunar surface infrastructure shall be verified by analysis. The analysis shall consist of a review of the LSAM design to navigate, land, perform lunar ascent, and sustain crew life support for lunar sortie missions. The verification shall be considered successful when the analysis shows that the LSAM systems can perform Lunar Sortie missions without the aid of pre-deployed lunar surface infrastructure.

Rationale: This is an overarching architecture (multi-project) parent requirement that drives the LSAM system to plan/design to perform Lunar Sortie missions without the aid of pre-deployed lunar surface infrastructure. The requirement listed here accounts for the complete set of flow-down requirements necessary to meet this overarching architecture requirement, so satisfying those parts will satisfy the whole. Verification of the individual flow-down requirements to CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD as specified in the requirement should verify the systems and the interfaces between those systems have been properly designed to meet the architecture requirement.

[CA5149V-PO] The ability of LSAM project to provide the infrastructure necessary to concurrently operate at least two (TBR-001-218) LSAM vehicles shall be verified by analysis and test. The testing shall consist of an end-to-end data flow that exercises major functionalities of concurrent mission operations of at least two (TBR-001-218) LSAMs in space. Analysis consists of a review of the CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD) and IRDs which describe LSAM infrastructure necessary to identify and control specific vehicles (e.g. LSAM-1, LSAM-2). Verification shall be considered successful when the analysis and test confirms the infrastructure necessary to concurrently operate at least two (TBR-001-218) LSAM vehicles.

Rationale: This is an overarching LSAM project verification requirement that can be satisfied once the flow-down requirements to the LSAM projects are satisfied. The analysis can be satisfied by the LSAM providing the requirements that address the functions (whether in CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD), ICD or IRD).

[CA5195V-PO] The ability of the LSAM to perform at least 1 (TBR-001-217) microgravity EVA of 4 (TBR-001-244) hours duration independent of other vehicles shall be verified by analysis, demonstration, and test.

The analysis shall prove that the LSAM system can provide the following functions while the LSAM habitable volume is depressurized. The following functions are in addition to those functions necessary to support the planned number of EVAs for the lunar surface sorties. The vehicle cabin reference is that portion of the habitable volume used for lunar ascent and Orion docking.

a. Ability for the crew to depress the vehicle cabin

b. Compliance to EVA specifications per CxP 70130, Constellation Program Extravehicular Activity Design and Construction Specification

c. Internal volume to egress and ingress the vehicle with a full complement of crewmember

d. Provide consumables to support 4 crewmembers for 1 EVA (4 (TBR-001-244) hours per EVA)

e. Translation paths to and stabilization for Contingency and Unscheduled EVA tasks

f. Hatch operable with pressure suits

g. Egress and ingress paths with pressure suits

The analysis shall prove that the LSAM System can provide the following functions for 8 (TBR-001-528) hours for four crewmembers while the LSAM habitable volume is depressurized:

a. EVA System oxygen quantity and flow rates

b. EVA System breathing gas scrubbing

c. EVA System fluid flow rates and temperatures

d. EVA System power

e. Communication (voice, suit and biomed data) with EVA System

f. Provide the functions simultaneously during the 4 hour EVA for two EVA crewmembers with an umbilical length of 9.1 m (TBR-001-409) (30 ft) and two EVA crewmembers with an umbilical length of 3 m (TBR-001-410) (10 ft)

The demonstration shall consist of neutral buoyancy evaluations, with the LSAM mockups outfitted with the proper internal volume, internal handrails, seats, volumetric mockups of all internal areas, umbilicals, operable hatch, all loose stowage items (which would normally be not stowed away for an EVA), translation path, worksite, simulated EVA tasks, and all external appendages as identified in the LSAM drawings, using flight-like EVA suits (pressurized). The demonstration will consist of crewmembers opening and closing the hatch, egressing and ingressing the mockup, evaluation of translation paths between hatch and worksites, worksite stabilization, worksite tasks, and reach and visibility to all vehicle controls necessary during an EVA (depress and repress controls, displays, etc.). The demonstration will be repeated by at least three different sets of crewmembers (for a total of six crewmembers to perform the demonstration). During egress and ingress phases of the demo, there will be at least four suited subjects (or two volumetric representations of suited subjects) located inside the LSAM.

The test shall consist of LSAM flight or flight equivalent hardware with a full complement of EVA System flight or flight equivalent hardware. The suits will be fully pressurized and receiving all functions from the LSAM at ambient conditions for the following sequences.

a. Four suits (and crewmembers) will be connected to all short umbilical positions with the suits performing simultaneously.

b. Four suits (and crewmembers) will be connected to the two long umbilical locations and two to short umbilical locations.

All suits will operate in the sequences of sufficient duration to obtain steady state with the sequence repeated until all suits have been swapped and operated simultaneously at all umbilical locations.

The verification shall be considered successful when:

a. The analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized and can be performed for 8 (TBR-001-528) hours (4 hours of prebreathe, 4 hours of EVA)

b. The demonstration reflects crew subjective acceptability for LSAM ingress, egress, vehicle displays and controls, translations, worksite stability, and worksite tasks as documented in the Crew Consensus report.

c. The test data confirms all LSAM and EVA System conform to CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD) specifications of all four suits simultaneously.

Rationale: In keeping with CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), LSAM needs to have its own EVA capability. In practice, this means that LSAM needs to not only have the functional capabilities required to conduct an EVA (e.g. depress/repress) but also the necessary consumables and stowage of equipment as well (e.g. EVA umbilicals). The 1 (TBR-001-217) microgravity EVA operation is based on the Contingency EVA transfer of the crew from LSAM to Orion.

[CA5303V-PO] The requirement for the LSAM to land on the lunar surface under certain lighting conditions shall be verified by Test and analysis. The Test shall be performed in a facility that can replicate the lighting conditions defined in the requirement, and which can simulate vehicle motion. LSAM navigation sensors will be tested in this environment. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% that the selected navigation sensors can operate within expected lighting conditions, and the LSAM shall land on the lunar surface under the lighting conditions specified in Table (TBD-001-460).

Rationale: The ability of sensor hardware to operate in specific lighting conditions can be tested on the ground before flight, using 6-DOF test facilities. This is required to ensure that they will operate properly during the mission. For analysis, because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.3.2.6.1 LSAM Control Mass

Draft **[CA0836V-PO]** The Control Mass requirement of the LSAM shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worst-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the LSAM total predicted mass is less than or equal to the required Control Mass.

Rationale: NR

Draft **[CA5231V-PO]** The Control Mass requirement of the LSAM shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worst-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the LSAM total predicted mass is less than or equal to the required Control Mass.

Rationale: NR

4.7.3.2.6.2 LSAM Delta-V

[CA0837V-PO] The LSAM translational Delta-V requirement for the LSAM/Orion mated configuration shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the calculated Delta-V of the LSAM for the LSAM/Orion mated configuration is greater than or equal to the translational Delta-V requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA4141V-PO] The LSAM translational delta-V requirement for the descent from the Lunar Destination Orbit (LDO) to the lunar surface shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the calculated translational delta-V of the LSAM is equal to or greater than the delta-V requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA4143V-PO] The LSAM translational delta-V requirement for its ascent from the lunar surface to the Lunar Rendezvous Orbit (LRO) shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the calculated translational delta-V of the LSAM is equal to or greater than the translational delta-V requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA4145V-PO] The LSAM translational delta-V requirement for the Lunar Outpost cargo missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the calculated translational delta-V of the LSAM is equal to or greater than the delta-V requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.3.2.7 LSAM Safety

Draft [CA0890V-PO] The control for critical hazard shall be verified by analysis. The analysis shall review the LSAM System Hazard Analysis . The verification shall be considered successful when the analysis shows that critical hazards are controlled per CxP 70038, Constellation Program Hazard Analysis Methodology.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

Draft [CA0891V-PO] Failure tolerance for catastrophic hazards shall be verified by analysis. An Integrated hazard analysis shall be performed, using system-level hazard analyses and FMEA to show compliance with the approved level of failure tolerance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled with the approved number of controls and all DFMR items are approved in the Hazard Reports.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

Draft [CA5399V-PO] The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the LSAM System-level FMEA/CILs for compliance with JPR 8080.5, JSC Design and Procedural Standards, Section G-2. The verification shall be considered successful when the integrated analysis shows that redundant systems are separated or protected.

Rationale: Verification for this requirement will be performed in accordance with CxP 70038, Constellation Program Hazard Analyses Methodology, and CxP 70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology. It looks top down and bottom up at the system level.

4.7.3.2.8 LSAM Command and Control

Draft **[CA3111V-PO]** The requirement for the LSAM to Accept Control of Automation shall be verified by test.

a. Tests shall be performed using the flight assets and associated CxP elements (Crew, Ground and Mission Systems) under simulated flight conditions during integrated ground testing.

b. Simulation tests shall be performed for the nominal and off-nominal profiles, the boundaries, modes, variable ranges and accuracy identified in (TBD-001-727) document(s) for which the control of automation will be performed.

The verification shall be considered successful when:

a. The vehicle's running function is halted by the authorized Constellation System assuming vehicle control.

b. When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

c. The applicable vehicle profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-727) document(s).

Rationale: Testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle. The (TBD-001-727) document refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

Draft **[CA3250V-PO]** The LSAM crew interface to generate commands shall be verified by Test. The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-755) document(s) shall be generated by crew surrogates. (Exhaustive verification [test] of each H&S command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be generated. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-755) document(s) are generated by crew surrogates in the LSAM in each applicable mission phase, state and mode.

Rationale: A Test of the generation of LSAM commands defined by (TBD-001-755) document(s) by crew surrogates in the LSAM on the flight LSAM or flight equivalent hardware for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-755) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for the LSAM.

Draft **[CA3258V-PO]** The execution of commands by the LSAM which are valid in the current state shall be verified by Test. The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-738) document(s) shall be executed by the LSAM. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be executed. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-738) document(s):

a. Commands are executed by the LSAM when valid in the current state in each applicable mission phase, state and mode.

b. Commands are rejected by the LSAM when not valid in the current state in each applicable mission phase, state and mode.

Rationale: A Test of the execution of LSAM commands defined by (TBD-001-738) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-738) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for the LSAM.

Draft **[CA3272V-PO]** The generation of commands by the LSAM shall be verified by Test.

The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions.

Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The applicable commands defined in (TBD-001-640) document(s) shall be generated by the LSAM. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be generated.

The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-640) document(s) are generated by the LSAM in each applicable mission phase, state and mode.

Rationale: A Test of the generation of LSAM commands defined by (TBD-001-640) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-640) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for the Ares V.

Draft **[CA3277V-PO]** The execution of commands by the LSAM which are addressed to the LSAM shall be verified by Test.

The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-772) document(s) shall be executed by the LSAM. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be executed. The LSAM shall be sent each command addressed to it and a subset of the commands addressed to other systems.

The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-772) document(s):

a. Commands are executed by the LSAM when addressed to the LSAM

b. Commands are processed by the LSAM according to C3I network protocols (e.g., immediately routed, stored and forwarded later, dropped, etc., including that the appropriate notifications are sent) when not addressed to the LSAM.

Rationale: A Test of the execution of Ares V commands defined by (TBD-001-772) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-772) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for the LSAM.

[CA5434V-PO] This verification shall be satisfied by test and analyses.

a. Tests shall be performed using the flight assets and associated CxP elements (Ground Systems and Mission Systems) under actual flight conditions to validate simulation testing.

b. Abort Determination shall be verified with simulation tests. Simulation tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-780) document(s). (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.)

The verification shall be considered successful when:

a. The LSAM performs the abort determination function(s) through an internal algorithm using internal or external data sources.

b. The CxP Architecture elements receive notification from the LSAM of the need for an abort through the C3I infrastructure.

c. The profiles, boundaries, modes, variable ranges and accuracy within the specified (TBD-001-780) document(s) are verified.

Rationale: Flight testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.

The (TBD-001-780) documents refer to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

Draft **[CA5440V-PO]** This verification shall be satisfied by test.

a. Tests shall be performed using the flight assets and associated CxP elements (Ground Systems and Mission Systems) under actual flight conditions to validate simulation testing.

b. Automatic Aborts shall be verified with simulation tests. Simulation tests shall be performed for all nominal and off-nominal profiles, all possible boundaries, modes, variable ranges and accuracy identified in (TBD-001-799) document(s). (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.)

The verification shall be considered successful when:

a. Flight telemetry/simulation data proves that the vehicle and associated CxP systems involved with the Automatic Abort function(s) successfully executes all Automatic Aborts modes provided in (TBD-001-799) document(s).

b. All possible profiles, boundaries, variable ranges and accuracy are verified within the specified (TBD-001-799) document(s).

Rationale: Flight testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.

The (TBD-001-799) document refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

[CA5801V-PO] The capability to control the LSAM system by a single crewmember shall be verified by demonstration and analysis. The demonstration shall include crew in the loop testing in a NASA-accredited high fidelity lab and shall verify a single crewmember can monitor and operate all critical functions of the LSAM from one console. The demonstration shall use these facilities to capture and analyze manual control performance of the vehicle for all nominal and abort flight phases that are determined appropriate for single human piloting and other critical LSAM operations, and shall include system and environment dispersions. The analysis shall utilize the test data to show the single human piloting maneuvers do not violate the LSAM structural, thermal or performance margins for all relevant flight phases. The verification shall be considered successful when the demonstration and analysis show that a single crewmember can operate all critical functions of the LSAM including flight path and attitude control where manual control does not violate structural, thermal or performance margins for all relevant flight phases.

Rationale: A demonstration must be performed with a human subject demonstrating the interactions between the human and avionics to pilot the vehicle to a Lunar landing under the dynamic conditions of landing.

4.7.3.2.9 LSAM Health and Status

Draft **[CA0431V-PO]** The generation of Health and Status information by the LSAM shall be verified by Test. The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable Health and Status data defined in (TBD-001-331) document(s) shall be generated by the LSAM. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the Test shows that the Health and Status data identified in (TBD-001-331) document(s):

a. Health and Status data is generated by the LSAM in each applicable mission phase, state and mode.

b. Health and Status agrees with the actual health and status of the LSAM.

Rationale: A Test of the generation of LSAM Health and Status data defined by (TBD-001-331) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-331) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the Health and Status parameters for the LSAM.

Draft **[CA3115V-PO]** The provision of Health and Status data by the LSAM to the crew shall be verified by Test. The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable Health and Status data defined in (TBD-001-625) document(s) shall be observed by crew surrogates. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the Test shows that the Health and Status data identified in (TBD-001-625) document(s):

a. Health and Status data is observed by crew surrogates in the LSAM in each applicable mission phase, state and mode.

b. Health and Status data agrees with the actual health and status of the LSAM.

Rationale: A Test of the provision of LSAM Health and Status data defined by (TBD-001-625) document(s) by the flight LSAM or flight equivalent hardware to crew surrogates in the LSAM for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-625) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the Health and Status parameters for the LSAM.

Draft **[CA5469V-PO]** The provision of fault detection by the LSAM shall be verified by Test. The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-459) document(s) for applicable simulated mission phases, states, and modes for the LSAM at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-459) document(s) are detected by the LSAM in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the LSAM

a. For the faults and fault scenarios identified by (TBD-001-459) document(s)

b. By the flight LSAM or flight equivalent hardware

c. For each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-459) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be detected.

Draft **[CA5470V-PO]** The provision of fault isolation by the LSAM shall be verified by Test. The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-1016) document(s) for applicable simulated mission phases, states, and modes for the LSAM at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-1016) document(s) are isolated by the LSAM in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the LSAM

a. For the faults and fault scenarios identified by (TBD-001-1016) document(s) *b. By the flight LSAM or flight equivalent hardware*

c. For each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-1016) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be isolated.

Draft **[CA5471V-PO]** The provision of fault recovery by the LSAM shall be verified by Test. The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-461) document(s) for applicable simulated mission phases, states, and modes for the LSAM at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-461) document(s) are recovered from by the LSAM in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the LSAM

a. For the faults and fault scenarios identified by (TBD-001-461) document(s)

b. By the flight LSAM or flight equivalent hardware

c. For each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-461) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be recovered from.

4.7.3.2.10 LSAM Communications and Communications Security

[CA0887V-PO] The ability of the LSAM to transmit and receive with geometric antenna coverage of 90% (TBR-001-755) for low rate data shall be verified by test and analysis. The antenna to be used by the LSAM shall be tested in an anechoic chamber or similar test bed to determine its innate geometric transmission and reception characteristics. This shall be accomplished by rotating the antenna and measuring the signal strength received from a fixed source. The analysis shall use the tested geometric characteristics of the antenna to predict the coverage of the antenna, for all attitudes, as mounted on the LSAM. The analysis shall also determine the needed signal strength and quality to provide 90% (TBR-001-755) coverage. A field test shall be conducted on an installed antenna in a simulated LSAM mount, either in an anechoic chamber or in an open area. Measurements shall be recorded for system signal strength and quality of radiated low rate data. Measurement shall be recorded for received low rate data transmitted with an attenuated test signal as defined by the analysis and transmitted from a representative set of points as determined by analysis. An independent measurement of the transmitted signal strength at a fixed location shall also be recorded as a calibration witness.

The verification shall be considered successful when:

a. The analysis of mounted antenna coverage for low rate data is shown to be greater than 90% (TBR-001-755) of all attitudes.

b. The field tests of the mounted antenna measured against transmissions from the representative points show antenna gain in accord with the analysis for that set of points.

c. The transmitted signal is received with sufficient strength and quality above the expected analyzed minima for all measured locations.

Rationale: While antenna design is a fairly well established field, the interaction of mount and antenna can be profound. It is prudent to verify the analysis with the actual equipment as built. It is expected that the antenna will have more than one element and the set of elements will cover the required solid angle.

Draft **[CA0517V-PO]** The recording of critical data for reconstruction of catastrophic events by the LSAM shall be verified by Test.

The Test shall use the flight LSAM or flight equivalent hardware in simulated mission conditions.

Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The applicable critical data defined in (TBD-001-336) document(s) shall be recorded by the LSAM. (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.)

The verification shall be considered successful when the Test shows that the applicable critical data identified in (TBD-001-336) document(s):

a. Critical data is recorded by the LSAM in each applicable mission phase, state and mode.

b. Critical data is available for retrieval after catastrophic events.

Rationale: A Test of the recording of critical data for reconstruction of catastrophic events defined by (TBD-001-336) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-336) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the critical data to be recorded.

[CA3289V-PO] Simultaneous communication by LSAM with MS and 2 (TBR-001-129) other systems as specified shall be verified by analysis and testing. Analysis of the specified data links shall be performed. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links using operational scenarios. The verification shall be considered a success when:

a. Testing shows the system can simultaneously exchange data with the specified systems without loss or apparent degradation.

b. Analysis shows that forward and received link margins are sufficient to support communication at the distances specified.

Rationale: Tests specific to the system and its characteristic data are needed. Scenarios shall reasonably exercise the system capability of the as specified system. For load testing, the system under test may be loaded with C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate to stress test the system data transmission and receipt capabilities. All data types supported by the system shall be tested. For systems with communications links, testing needs link testing according to the C3I interoperability specification and demonstration, where possible, with systems expected on-orbit using simulated transmission delays and noise levels.

Draft **[CA5054V-PO]** LSAM shall record System-generated digital data received from other Constellation Systems. The recording of System-generated digital data received from other Constellation Systems shall be verified by demonstration.

The demonstration shall be conducted in SIL (or equivalent) using flight or similar assets. Test objectives shall be prepared using IRDs and SRDs to identify source systems for data recording and the data content to be recorded. The source system may be simulated but should be certified. The source data shall be transmitted for no less than 4 hours or for an entire mission phase, if shorter, at least twice.

The verification shall be considered successful when the demonstration shows:

a. Source data is received for an entire mission phase or at least 4 hours

b. Demonstration is performed twice

c. All received data is recorded

d. An audit of the recorded data shows it to be correct

Rationale: Recording of System-generated digital is critical to support development, test, operation, and maintenance of systems. To confirm interoperability and functionality demonstrations are performed.

[CA5902V-PO] The LSAM capability to reconfigure stored commands, sequences and data shall be verified by demonstration. The demonstration shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. The LSAM shall be preloaded with a set of stored commands, sequences and data. The subset of stored commands, sequences and data identified in (TBD-001-994) documents shall then be reconfigured. (Exhaustive verification of each reconfiguration item is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the stored commands, sequences and data identified in (TBD-001-994) documents have been successfully reconfigured on the LSAM and that they properly reflect the updated values.

Rationale: A demonstration of the LSAM capability to reconfigure stored commands, sequences and data is sufficient to verify this capability. The (TBD-001-994) *documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify what stored commands, sequences and data are subject to reconfiguration and what the range of potential values are.*

[CA5905V-PO] The LSAM capability to execute reconfigurable automation sequences shall be verified by demonstration. The demonstration shall use the flight LSAM or flight equivalent hardware in simulated mission conditions. The command sequences identified in (TBD-001-997) documents shall be executed by the LSAM. In addition, the subset of command sequences identified in (TBD-001-997) documents shall be reconfigured prior to execution. (Exhaustive verification of each automation sequence is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that:

a. The command sequences have been executed without human intervention.

b. The end state of the LSAM at the end of the sequence execution is the same as if the commands had been executed manually.

c. The reconfigured command sequences execute the updated commands.

d. Sequences are only executed when they are valid in the current state and are rejected otherwise.

Rationale: A demonstration of the LSAM capability to execute reconfigurable automation sequences is sufficient to verify this capability. The (TBD-001-997) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify which command sequences should be verified and which of those are subject to reconfiguration.

[CA6109V-PO] The provision of integrated audio and high resolution motion imagery by LSAM in real-time post-orbit insertion shall be verified by Test.

Tests shall be performed using flight equivalent units or emulators with flight software under simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. Tests using simulated space-originated audio and high resolution motion imagery shall be performed using flight or flight-like equipment for image generation and operational pathways for transmission. The source will be either live or recorded signals simulating LSAM in real-time post-orbit insertion. The output data shall be captured at the point where it exits the vehicle. The verification shall be considered successful when:

a. The test shows that the signals are able to be interpreted and viewed as high resolution motion imagery.

b. Audio is integrated with the motion imagery.

c. LSAM confirms that a comparison of the audio and motion imagery produced by the test and the output data captured contain expected values.

Rationale: A test is necessary to ensure that the generation of integrated audio and high definition motion imagery is functioning correctly using flight equipment or equivalent

4.7.3.2.11 LSAM GN&C

[CA0135V-PO] The ability of the LSAM to actively accomplish rendezvous, proximity operations, and docking, with Orion in LRO shall be verified by test, demonstration and analysis. The rendezvous, proximity operations and docking analysis shall be conducted using simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% for successful rendezvous and docking.

Rationale: Rationale for docking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all Orion missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Much of the remaining test and analysis depend on the results of this testing.

Rationale for relative navigation sensor tests and demonstrations: The Constellation Architecture will be the first use of many critical relative navigation sensors. Testing the closed loop system with relative navigation sensors and their accompanying intended target hardware will significantly mitigate risk of failure.

Rationale for SIL (or equivalent) tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The docking test simulation must include models of both maneuvering (Orion) and target (EDS/LSAM) vehicles to model the effects of target vehicle attitude control on docking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

Draft **[CA0284V-PO]** The capability of the LSAM to land within 1 (TBR-001-044) km (0.54 nmi) of a pre-selected landing point on the lunar surface independent of surface aids shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% that the LSAM can land within 1 (TBR-001-044) km (0.54 nmi) of a pre-selected landing point on the lunar surface independent of landing aids.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA0418V-PO]** The capability of the LSAM to land within 100 (TBR-001-012) m (328 ft) of a pre-selected landing point on the lunar surface using lunar vicinity landing aids shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% that the LSAM can land within 100 (TBR-001-012) m (328 ft) of a pre-selected landing point on the lunar surface using lunar vicinity landing aids.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0461V-PO] The capability of the LSAM to perform the LOI into LDO for lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the LSAM can perform the LOI into LDO for lunar missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA3144V-PO]** The LSAM navigation and attitude determination capability shall be verified by analysis and component testing. The analysis and testing shall be accomplished using flight sensor hardware in a NASA-accredited dynamic hardware-in-the-loop simulation of the LSAM. The dynamic simulation, analysis, and hardware-in-the-loop tests shall verify the accuracy of the LSAM navigation and attitude determination capability by taking error data from component level navigation and attitude sensor testing, and processing this data with a dynamic model of the orbit and attitude dynamics and disturbances during all mission phases. The verification shall be considered successful when the analysis, simulation, and testing has shown that the criteria as specified in the LSAM SRD (CxP TBD-001-946) for the navigation and attitude determination capability has been met.

Rationale: NR

Draft **[CA3145V-PO]** The LSAM DOI maneuver computation capability shall be verified by analysis. The analysis shall be accomplished using a comprehensive dynamic simulation of the LSAM. The dynamic simulation and analysis shall verify the accuracy of the maneuver computation capability by taking error data from component level navigation sensor testing and processing this data with a dynamic model of the orbit dynamics. The verification shall be considered successful when the analysis and simulation has shown that the criteria as specified in the LSAM Verification document (TBD-001-946) has been met.

Rationale: NR

[CA3205V-PO] The ability of the LSAM to perform TCMs during TLC shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall include trans-lunar and multi-body gravity effects. The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the LSAM can perform the TCMs during TLC.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA3251V-PO]** The LSAM rendezvous maneuver computation capability shall be verified by analysis. The analysis shall be accomplished using a NASA-accredited dynamic simulation of all the relevant Constellation Architecture flight systems. The dynamic simulation and analysis shall verify the accuracy of the maneuver computation capability by taking error data from component level navigation sensor testing and processing this data with a dynamic model of the orbit dynamics. The verification shall be considered successful when the analysis and simulation has shown that the criteria as specified in CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD) have been met.

Rationale: NR

[CA5275V-PO] The ability for the LSAM to function as the target vehicle during RPOD with Orion in LLO prior to crew transfer back to Orion shall be verified by test and analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The LSAM attitude control analysis shall include models of environmental attitude disturbances, as well as models of the Orion vehicle, including Orion thruster plumes. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document is greater than 99.86% with a "consumer's risk" of 10%.

Rationale: Rationale for SIL tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The undocking test simulation must include models of both maneuvering vehicle (Orion) and separation target (LSAM) vehicles to model the effects of target vehicle attitude control on undocking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

[CA5278V-PO] The capability to manually control the LSAM when the human pilot can operate the vehicle within predefined limits shall be verified by testing and analysis. The testing shall use a NASA-accredited digital LSAM GN&C simulation integrated with a NASA-accredited pilot-in-the-loop test facility, with flight-like hand controllers, displays and out the window scenes. Testing shall use these facilities to capture and analyze manual control performance of the vehicle for all nominal and abort flight phases that are determined appropriate for human piloting, and shall include system and environment dispersions. The verification shall be considered successful when analysis of the results shows that manual control does not violate structural, thermal or performance margins for all relevant flight phases.

Rationale: Pilot-in-the-loop testing is necessary to exercise the man-machine interaction and verify that the crew can in fact control the vehicle within predefined limits.

[CA5284V-PO] The ability for the LSAM to perform target vehicle functions during undocking with Orion shall be verified by inspection, docking mechanism tests, LSAM attitude control tests, and LSAM attitude control analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The simulation shall include models of environmental attitude disturbances, as well as models of the Orion vehicle, including Orion thruster plumes. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document during LSAM undocking and separation is greater than 99.73% with a "consumer's risk" of 10%.

Rationale: Rationale for Inspection: Inspection of the design documentation provides verification that appropriate target hardware has been included in the design and that it is located and oriented to facilitate RPOD operations with Orion.

Rationale for docking hardware tests: The mechanical docking subsystems are critical to mission success for all LSAM missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation *dynamics. Much of the remaining test and analysis depend on the results of this testing.*

Rationale for SIL (or equivalent) tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The undocking test simulation must include models of both maneuvering vehicle (Orion) and separation target (LSAM) vehicle to model the effects of target vehicle attitude control on undocking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

[CA5285V-PO] The ability of the LSAM to actively accomplish undocking with Orion prior to lunar descent shall be verified by test, demonstration and analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability of successful undocking and separation without re-contact with a "consumer's risk" of 10%.

Rationale: Rationale for undocking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success. These mechanisms must be characterized and verified to confirm the undocking separation dynamics. Much of the remaining test and analysis depend on the results of this testing.

Rationale for relative navigation sensor tests and demonstrations: The Constellation Architecture will be the first use of many critical relative navigation sensors. Testing the closed loop system with relative navigation sensors and their accompanying intended target hardware will significantly mitigate risk of failure.

Rationale SIL (or equivalent) tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The undocking test simulation must include models of both maneuvering vehicle and separation target vehicles to model the effects of target vehicle attitude control on undocking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

[CA5290V-PO] The LSAM's performance of attitude control of the Orion/LSAM mated configuration after separating from the Ares V EDS shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the

6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% that the Orion/LSAM mated configuration will remain within the attitude limits specified by CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5293V-PO] The requirement for LSAM to provide target vehicle interfaces in the LSAM/Ares V EDS mated configuration during Orion RPODU in LEO shall be verified by inspection and test. Orion design documentation shall be inspected to show that any LSAM hardware required for proper functioning of the Orion sensors or navigation system is present and mounted in accordance with CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document.

The docking and undocking hardware testing shall consist of ground tests, using flight-equivalent docking adaptors for Orion and LSAM in a 6-DOF test facility. The docking and undocking tests shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to Orion and LSAM that are within the specifications of CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document requirements.

Rationale: Rationale for Inspection: Inspection of the design documentation provides verification that appropriate target hardware has been included in the design and that it is located and oriented to facilitate RPOD operations with Orion.

Rationale for docking hardware tests: The mechanical docking subsystems are critical to mission success for all LSAM missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Much of the remaining test and analysis depend on the results of this testing.

4.7.3.2.12 LSAM Reliability and Availability

Draft **[CA5532V-PO]** The capability of the LSAM to launch again 4 (TBR-001-183) days prior to the next lunar injection window following a missed window shall be verified by analysis. The analysis shall include an assessment of access capabilities per the CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -to- Ground Systems Interface Requirements Document (IRD) the tasks and activities required to reprocess and ready the LSAM to launch after a missed launch attempt, and an assessment of the reliability of the LSAM systems to hold in a "ready to launch" configuration. The verification shall be considered successful when the analysis shows that all LSAM systems that require maintenance or service during reprocessing have the access and interfaces required and the LSAM can be reprocessed, and be prepared to launch again 4 (TBR-001-183) days prior to the next lunar injection window following a missed window.

Rationale: Processing flows, schedules, and launch manifest will be needed to determine whether LSAM can be launched as often as required.

Draft [CA5605V-PO] The ability of the LSAM to have a probability of launch of not less than (TBD-001-064)% on the initial attempt during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt shall be verified by analysis. The verification analysis shall use only Reliability and Maintainability (R&M) Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when analysis shows that the probability of the initial launch attempt is not less than (TBD-001-064)% with an uncertainty of not greater than (TBD-001-1009)% (TDS# SIG-01-004).

Rationale: CA reliability and availability data, and Ground Operations data will need to be available for the program to verify that the flight hardware will be in a situation that supports the vehicle and Ground Systems to be available to support during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

[CA6207V-PO] The ability to remedy the required percentage of LSAM system failures identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1504)% that would result in a scrubbed launch within the required time limit, shall be verified by analysis. The analysis shall assess the LSAM FMEA, maintenance plan, LSA, and FDIR capabilities to determine the likelihood of occurrence of failures and the percentage of failures that can be remedied within 1 day, 2 days, and 3 days. The verification analysis shall use only Cx R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when the analysis determines, with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004) that:

a. No less than 30% (TBR-001-1425) can be remedied to support a launch attempt within one day.

b. No less than 45% (TBR-001-1426) can be remedied to support a launch attempt within two days.

c. No less than 50% (TBR-001-1427) can be remedied to support a launch attempt within three days.

Rationale: The verification analysis requirement is intended to drive a determination of the ability to remedy those failures that are most likely to be identified during the countdown when systems are activated, serviced, and operated. The analysis should sort the set of the most likely failures into those items that can be remedied one day, two days, three days, or more time. Since no location constraint is composed (e.g. nobody said the failure had to be remedied at the pad), a remedy scenario that rolls back, repairs, rolls out to pad, and supports a launch attempt *within the time frame is allowed for this sorting. The analysis should consider that the likelihood of a latent defect being present but undetected at the time of a decision to proceed past a given milestone is a variable influenced by the perceptiveness of testing and operations performed before that milestone.*

4.7.3.2.13 LSAM Maintainability, Supportability, and Logistics

[CA5505V-PO] Verification that LSAM can sustain operations, using only onboard equipment and spares, without resupply or support from personnel other than the crew, shall be verified by analysis. The analysis shall assess the LSAM Maintenance Concept, the LSAM Logistics Support Plan (LSP), related Logistics Support Analysis Records (LSAR), other data from reliability and maintainability analyses conducted in accordance with CxP 70087, Constellation Reliability and Maintainability (R&M) Plan, and shall determine the LSAM's ability to sustain operations for each LSAM mission defined in CxP 70007, Constellation Design Reference Missions and Operational Concepts. The verification shall be considered successful when the analysis shows that the LSAM can sustain operations, using only onboard equipment and spares, without resupply or support from personnel other than the crew, to achieve mission success.

Rationale: It will be critical to verify that the vehicle is designed to be self-sustaining since resupply of spares will generally be not possible.

[CA5982V-PO] The ability of the LSAM to generate Project Verified Engineering Builds after the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars) shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5983V-PO] The ability of the LSAM to generate Project Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be *re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).*

[CA5985V-PO] The ability of the LSAM to provide fixes for selected non-conformances to the discovering organization shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when inspection determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc).

[CA6008V-PO] The ability of the LSAM to conduct ground operations within the constraints levied in LSAM Critical Path Allocations for Ares V/LSAM Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6008 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will be then updated.

Rationale: NR

[CA6017V-PO] The ability of the LSAM architecture to produce cargo engineering products for a single Lunar mission within the (TBD-001-1074) days shall be verified by analysis. The analysis shall consist of a review of allocated LSAM SRD requirements as well as LSAM template and management process document (TBD-001-1084). The verification shall be considered successful when the allocated LSAM SRD requirements verifications are closed and when the cargo engineering products meet development and delivery for a single Lunar mission within (TBD-001-1074) days with a probability 85% (TBR-001-1094). The added Objective capability of requirement CA6017 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

[CA6034V-PO] The ability for the LSAM to operate in a quiescent mode for Lunar missions with no more than 2 (TBR-001-1106) hours per week contiguous real-time command and control from Mission Systems under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated LSAM SRD and MS-LSAM IRD requirements. Analysis shall consist of review of the LSAM design. The inspection shall be considered successful when the allocated LSAM SRD and MS-LSAM IRD verification requirements are closed and analysis shall be considered successful when the as-built LSAM design confirms the ability to meet no more than 2 (TBR-001-1106) hours per week contiguous real-time command and control from Mission Systems under nominal quiescent operations.

Rationale: NR

[CA6035V-PO] The ability for the LSAM to operate with no more than 1 (TBR-001-1107) hour per day contiguous (consisting of (TBD-001-1086) man-hours) monitoring by dedicated LSAM engineering teams while in a quiescent mode for Lunar missions under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated LSAM SRD and MS-LSAM IRD requirements. Analysis shall consist of review of the LSAM design and the engineering team personnel manning and operation plans. The inspection shall be considered successful when the allocated LSAM SRD and MS-LSAM IRD verification requirements are closed and analysis shall be considered successful when the as-built LSAM designs and the LSAM engineering team personnel manning and operating plans confirm the ability to meet no more than 1 hour per day contiguous (consisting of (TBD-001-1086) man-hours) monitoring by dedicated LSAM engineering teams while in a quiescent mode for Lunar missions under nominal quiescent operations.

Rationale: NR

4.7.3.2.14 LSAM Habitability and Human Factors

Draft **[CA0813V-PO]** The LSAM's provision of a habitable environment for a lunar mission shall be verified by analysis. The analysis shall assess that the LSAM design for atmosphere control and quality, potable water, atmosphere temperature, humidity and ventilation, food, body waste and trash management provides a habitable environment, as specified in CxP 70024, Constellation Human-Systems Integration Requirements, for four crew for a minimum of 180 (TBR-001-033) hours. The analysis will be supported by component and subsystem tests and analyses. The verification shall be considered successful when the analysis shows the LSAM provides a habitable environment for up to four crew for a minimum of 180 (TBR-001-033) hours in duration for a lunar mission.

Rationale: Analysis supported by subsystem and component tests and analyses is sufficient to verify that the LSAM can support a habitable environment for a crew of four for 180 (TBR-001-033) hours. The analysis will include an audit of consumable supplies.

Draft [CA0814V-PO] The control of cabin atmospheric pressure shall be verified by test.

The test shall be performed using a test article with flight-like cabin volume to show that the atmospheric pressure control hardware will maintain cabin pressure within the specified range over the maximum mission duration.

The verification shall be considered successful when the test shows that pressure is successfully controlled by the LSAM over the range of 79 (TBR-001-907) to 52 (TBR-001-908) kPa (11.4 to 7.5 psia), in 0.7 (TBR-001-147) kPa (0.1 psia) increments.

Rationale: This is to allow the LSAM to adjust between the primary operating atmospheric pressure setpoints - Orion at 70 kPa (10.2 psia), LSAM at 55 kPa (8.0 psia).

Draft [CA3062V-PO] The oxygen concentration within the pressurized cabin shall be verified by test and analysis.

The test shall be performed using a test article with flight-like cabin volume to show that the atmosphere control system can detect when the oxygen concentration reaches 34%. The test shall be performed using a test article with flight-like cabin volume to show that the atmosphere control system can adjust the constituents to maintain the oxygen concentration to 34% maximum. The analysis shall show that the materials selection is certified to meet the 34% oxygen environment.

The verification shall be considered successful when the tests show that the LSAM atmosphere control system limits the maximum oxygen concentration within the pressurized cabin to 34% by volume and the analysis of materials shows the materials selection meets the 34% oxygen environment.

Rationale: This verifies the control of the maximum oxygen concentration in the LSAM cabin. This also verifies that the materials flammability is not an issue at 34% oxygen concentration.

Draft [CA3107V-PO] The LSAM cabin pressure preservation for suit donning during an external pressure leak shall be verified by analysis and test.

The analysis shall use a modeled leak of an equivalent 0.64 (TBR-001-106) cm (0.25 inch) diameter hole in the cabin to show that the available gas resources and atmosphere control will maintain the crew environment at 55 kPa (8.0 psia) for the time defined to don suits in CA3058-PO.

A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA suit donning and prebreathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained during suit donning.

A test in the LSAM flight test article utilizing flight qualified software shall show that the vehicle responds to a simulated rapid decompression event by activating the pressure control components required to maintain pressure and oxygen concentration.

The verification shall be considered successful when the analysis and tests show that the LSAM can maintain cabin pressure at 55 kPa (8.0 psia) for the time defined to don suits in CA3058-PO.

Rationale: This combination of methods will verify that an appropriate design will be implemented and tested at the vehicle level. A cabin leak is a contingency situation; the components will be verified to perform their specified functions, and the vehicle will be verified to activate the components in order to respond to a cabin leak situation.

Draft [CA3135V-PO] The control of oxygen partial pressure shall be verified by test.

The test shall be performed using a test article with flight-like cabin volume to show that the oxygen partial pressure control hardware will maintain oxygen pressure within the specified range over the maximum mission duration.

The verification shall be considered successful when the test shows that oxygen partial pressure is successfully controlled by the LSAM over the range of 18 (TBR-001-130) to 21 (TBR-001-913) kPa (2.6 to 3.1 psia), in 0.7 (TBR-001-914) kPa (0.1 psia) increments.

Rationale: This is to verify the LSAM will adjust the oxygen partial pressure setpoints to maintain the oxygen concentration within limits established to minimize material flammability concerns.

Draft [CA3137V-PO] The vestibule pressurization shall be verified by analysis supported by test. The analysis shall determine that gas resources for two vestibule pressurization cycles are available for each mission. Analysis of the LSAM Gas Storage and vestibule pressurization shall show that the LSAM can store the consumables necessary for and execute two vestibule pressurization cycles. The verification shall be considered successful when the analysis, supported by a qualification test of the pressurization operation show that the LSAM can execute at least two vestibule pressurization cycles per mission.

Rationale: Analysis to calculate the quantity of nitrogen and oxygen, based on the LSAM vestibule design and consumable requirements, coupled with the inspection of the storage hardware compliance data is sufficient.

Draft [CA3165V-PO] The LSAM provision of a habitable environment during ascent shall be verified by analysis. The analysis shall assess that the LSAM design for atmosphere control and quality, potable water, atmosphere temperature, humidity and ventilation, provides a habitable environment, as specified in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), for four crew for a minimum of 12 (TBR-001-131) hours. The analysis will be supported by component and subsystem tests and analyses. The verification shall be considered successful when the analysis shows the LSAM provides a habitable environment for up to four crew for a minimum of 12 (TBR-001-131) hours in duration for ascent from the lunar surface.

Rationale: Analysis supported by subsystem and component tests and analyses is sufficient to verify that the LSAM can support a habitable environment for a crew of four for 12 (TBR-001-131) hours. The analysis will include an audit of consumable supplies.

Draft [CA3181V-PO] The LSAM cabin pressure preservation for pre-breathe during an external pressure leak shall be verified by analysis and test.

The analysis shall use a modeled leak of an equivalent 0.64 (TBR-001-106) cm (0.25 in) diameter hole in the cabin to show that the available gas resources and atmosphere control will maintain the crew environment at a sufficient pressure based on suit pressure and HSIR requirements for prebreathe pressure and time.

A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA suit donning and prebreathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained to support prebreathe.

A test in the LSAM flight test article utilizing flight qualified software shall show that the vehicle responds to a simulated rapid decompression event by activating the pressure control components required to maintain pressure and oxygen concentration.

The verification shall be considered successful when the analysis and tests show that the LSAM can maintain cabin pressure to allow crew prebreathe.

A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA suit donning and prebreathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained to support prebreathe.

A test in the LSAM flight article utilizing flight qualified software shall show that the vehicle responds to a simulated rapid decompression event by activating the pressure control components required to maintain pressure and oxygen concentration.

The verification shall be considered successful when the analysis and test show that the LSAM can maintain cabin pressure conditions.

Rationale: This combination of methods will verify that an appropriate design will be implemented and tested at the vehicle level. A cabin leak is a contingency situation; the components will be verified to perform their specified functions, and the vehicle will be verified to activate the components in order to respond to a cabin leak situation.

Draft [CA5385V-PO] The LSAM net habitable volume shall be verified by analysis. The analysis shall review the design of the LSAM and shall assess the net habitable volume using JSC 63557 (TBR-001-1500), Net Habitable Volume Verification Method, which defines analytical processes to calculate net habitable volume. The verification shall be considered successful when the analysis shows the LSAM net habitable volume is no less than (TBD-001-603) m3 ((TBD-001-603) ft3).

Rationale: If the volume is not accurately calculated using a validated process, the verification will not be valid and could result in misrepresentation of the vehicle's net habitable volume impairing the crew's ability to perform critical mission tasks.

4.7.3.2.15 LSAM Environmental Conditions

Draft **[CA0815V-PO]** Compliance of the LSAM with its functional and performance requirements during and after exposure to the DSNE environments shall be verified by inspection and analysis. The analysis shall consist of an integrated analysis that includes the following:

a. Development of a Natural Environment Requirements Sensitivity and Applicability Matrices (NERSAMs), defined in Section 4 of the DSNE

b. Allocation of the natural environments requirements to the lower tier elements and their verification methods and details

The analysis shall include the following integrated configurations: Orion/LSAM, Orion/LSAM/Ares V-EDS, LSAM/Ares V, LSAM/Ares V/GS. The inspection will consist of a review of the lower tier verification closure data. The closure analysis shall utilize lower tier verification closure data and address interactions of each lower tier system on other systems to address integrated environment effects. The verification shall be considered successful when the inspection and integrated analyses show:

a. The NERSAM has been completed in accordance with Section 4 of the DSNE.

b. The natural environment requirements and verification have been allocated to the lower tier systems in accordance Section 4 of the DSNE.

c. Lower tier verifications have been completed.

d. The LSAM meets its functional and performance requirements during and after exposure to the DSNE environments in all integrated configurations.

Rationale: Verification of functional and performance requirements across the range of natural environments requires a systematic integrated approach to address dependencies on hardware configurations and operational mode. The DSNE Section 4 specifies a standard systems engineering technique for flowing down the natural environment from higher to lower levels using the Natural Environment Requirements Sensitivity and Applicability Matrix (NERSAM) for each mission phase. Lower tier verification close out data, analyses, and models are necessary to support the integrated analysis, but are not sufficient alone to close out the environment requirements from the integrated vehicle configuration.

Draft **[CA5556V-PO]** LSAM function and performance during and after exposure to induced environments shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the LSAM/System IRD requirements

b. Review of the induced environment verifications submitted against CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD) requirements for DRM total induced environments

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification.

The verification shall be considered successful when the analysis shows that the LSAM function and performance requirements are met during and after exposure to the Induced Environment Design Specifications (IEDS)-specified induced environments for each DRM.

Rationale: Function and performance must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of the IEDS can provide verification including assurance that:

a. The proper induced environments have been considered

b. Sensitivities to these environments

c. Synergistic effects have each been properly addressed for all mission phases

Draft **[CA5561V-PO]** LSAM induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the LSAM/System IRD requirements

b. Review of the induced environment verifications submitted against CxP 72001, Lunar Surface Access Module (LSAM) Systems Requirements Document (SRD) requirements for DRM total induced environments

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification. The verification shall be considered successful when the analysis shows that the LSAM peak and cumulative induced environments will not exceed CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.

Rationale: Induced environment contributions must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that:

a. The proper induced environments have been met

b. Sensitivities to these environments *c. Synergistic effects have each been properly addressed for all mission phases*

4.7.3.3 Reserved

4.7.3.4 LSAM External Interfaces

[CA0432V-PO] The LSAM interfaces with Orion shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the LSAM Project Office to demonstrate that the LSAM-to-Orion interface requirements defined within the CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM and Orion flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalent) or across distributed SILs (or equivalents) prior to first launch of the LSAM. Testing shall also include a multi-system integrated test of the integrated Orion/LSAM vehicle stack (with and without EDS) prior to first human use of LSAM in space to demonstrate integrated functionality and interoperability between the flight systems and between the integrated vehicle stack and the ground support and mission control systems. Verification shall be considered successful when:

a. Analysis confirms that all of the LSAM interface verification requirements defined within CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document, have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the LSAM Project Office to confirm that all of the LSAM-to-Orion interface requirements specified in CxP 70034, Constellation Program Orion -to- LSAM Interface Requirements Document have been satisfied. Integrated testing of the LSAM and Orion flight avionics and software at or distributed amongst the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Since the EDS will also be part of the integrated LSAM/Orion vehicle stack for part of the lunar transit, integrated testing will include configurations with and without the EDS. Since the first time the LSAM and Orion flight systems will be integrated together is in Low Earth Orbit, integrated testing between the flight systems and with the ground support and mission control systems will be performed on the ground at the launch site to confirm integrated operability, functionality, and system stability during/after operational mode changes.

Draft **[CA0900V-PO]** The LSAM interfaces with the Ares V shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the LSAM Project Office to demonstrate that the LSAM-to-Ares V interface requirements defined within CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) -to- Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD) , have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM and Ares V (including EDS) flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalent) or across distributed SILs (or equivalents) prior to first launch of the LSAM. Testing shall also include a multi-system integrated test of the Ares V/LSAM launch vehicle stack to demonstrate integrated functionality and interoperability between the flight systems and between the integrated launch vehicle stack and the ground support and mission control systems. Verification shall be considered successful when:

a. Analysis confirms that all of the LSAM interface verification requirements defined within CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) -to- Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the LSAM Project Office to confirm that all of the LSAM-to-Ares V interface requirements (including EDS) specified in the IRD have been satisfied. Integrated testing of the LSAM and Ares V flight avionics and software at or distributed amongst the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Since the first time the LSAM and Ares V flight systems will be integrated together is within the integrated launch vehicle stack, integrated testing between the flight systems within the launch vehicle stack and between the stack and the various ground support and mission control systems will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

Draft **[CA0901V-PO]** The LSAM interfaces with GS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the LSAM Project Office to demonstrate that the LSAM-to-GS interface requirements defined within the CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -to- Ground Systems Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM avionics and software and GS via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate GS to confirm interoperability and functionality between the LSAM and GS. Verification shall be considered successful when:

a. Analysis confirms that all of the LSAM interface verification requirements defined within CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -to- Ground Systems Interface Requirements Document (IRD) (have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the LSAM Project Office to confirm that all of the LSAM-to-GS interface requirements specified in the IRD have been satisfied. Integrated testing between the LSAM avionics and software and GS via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating GS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

Draft **[CA0902V-PO]** The LSAM interfaces with MS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the LSAM Project Office to demonstrate that the LSAM-to-MS interface requirements defined within the CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -to- Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM avionics and software and MS via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the MS to confirm interoperability and functionality between the LSAM, GS, and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the LSAM interface verification requirements defined within CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -to- Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the LSAM Project Office to confirm that all of the LSAM-to-MS interface requirements specified in the IRD have been satisfied. Integrated testing between the LSAM avionics and software and the MS via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating MS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

Draft **[CA0903V-PO]** The LSAM interfaces with the EVA systems shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the LSAM Project Office to demonstrate that the LSAM-to-EVA interface requirements defined within CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM avionics and software and the EVA systems at a SIL (or equivalent. Multi-system testing performed at the launch site for flight systems shall also incorporate the EVA systems to confirm interoperability and functionality between the LSAM, GO, and EVA systems. Verification shall be considered successful when:

a. Analysis confirms that all of the LSAM interface verification requirements defined within CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the LSAM Project Office to confirm that all of the LSAM-to-EVA interface requirements specified in the IRD have been satisfied. Integrated testing between the LSAM avionics and software and the EVA systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating EVA systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

Draft **[CA0904V-PO]** The LSAM interfaces with the Communications and Tracking Networks shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the LSAM Project Office to demonstrate that the Ares I interface requirements defined within the CxP 70118-03, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 3: Lunar Surface Access Module (LSAM) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares I avionics and software and the communications and networks systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the communications and tracking network systems to confirm interoperability and functionality between the systems. Verification shall be considered successful when:

a. Analysis confirms that all of the LSAM interface verification requirements defined within CxP 70118-03, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 3: Lunar Surface Access Module (LSAM), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the LSAM Project Office to confirm that all of the LSAM-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrated testing between the LSAM avionics and software and the communications and network systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating the communication and network systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

4.7.3.5 Reserved

4.7.4 Ares V

4.7.4.1 Ares V Description

4.7.4.2 Ares V Requirements

Draft **[CA3212V-PO]** The LSAM's performance of attitude control of the Orion/LSAM mated configuration after separating from the Ares V EDS shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares V can successfully deliver the LSAM into a Trans-Lunar trajectory for Lunar Outpost missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft [CA3215V-PO] The Ares V cargo launch into (TBD-001-565) Earth orbit for Mars missions requirement shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares V can successfully deliver cargo into (TBD-001-565) Earth orbit.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.4.2.1 Ares V Mission Success

Draft [CA0486V-PO] Lunar mission LOM due to the Ares V EDS shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar mission due to the Ares V EDS is no greater than 1 in 250 (TBR-001-053).

Rationale: NR

Draft [CA0487V-PO] Lunar mission LOM due to the Ares V shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for Lunar missions due to the Ares V is not greater than 1 in 125 (TBR-001-054).

Rationale: NR

Draft [CA5930V-PO] The Ares V single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the Ares V System Hazard Analysis and FMEA/CIL for single fault tolerance compliance. The verification shall be considered successful when the analysis shows that critical hazards are controlled by two or more methods and all DFMR items are approved in the Hazard Reports.

Rationale: Verification for this requirement will be performed in accordance with the Cx Hazard Analysis Methodology and the CxP FMEA/CIL Methodology documents. It looks top down and bottoms up at the system level.

4.7.4.2.2 ARES V CREW SURVIVAL

Draft **[CA5160V-PO]** Ares V providing ground crew capability for unassisted emergency egress during pre-launch activities shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using ground crew and launch support structure and performing a minimum of two runs with two different sets of ground crewmembers and collecting the task time for ground crew egress to ground level. The analysis shall consist of the Ground System, EVA, Ares V and Orion system documentation review that meets unobstructed egress for the suited crew through the closure in the allocated GS-EVA IRD, GS-Ares V IRD, GS-Orion IRD, Orion-EVA IRD, and Ground Operations Plan requirements. The verification shall be considered successful when the analysis determines the demonstration meets emergency egress within 2 (TBR-001-169) minutes and the allocated children requirements have been closed.

Rationale: NR

Draft **[CA5436V-PO]** This verification shall be satisfied by test and analyses.

a. Tests shall be performed using the flight assets and associated CxP elements (Ground Systems and Mission Systems) under actual flight conditions to validate simulation testing.

b. Abort Determination shall be verified with simulation tests. Simulation tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-786) document(s). (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.)

The verification shall be considered successful when:

a. The Ares V performs the abort determination function(s) through an internal algorithm using internal or external data sources.

b. The CxP Architecture elements receive notification from the Ares V of the need for an abort through the C3I infrastructure.

c. The profiles, boundaries, modes, variable ranges and accuracy specified in (TBD-001-786) document(s) are verified.

Rationale:

a. Flight testing this function provides the best end-to-end verification for this requirement.

b. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle. The (TBD-001-786) *documents refer to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.*

4.7.4.2.2.1 Ares V Crew Survival Probabilities

Draft [CA0485V-PO] Lunar mission LOC due to the Ares V EDS shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for Lunar missions due to the Ares V EDS is not greater than 1 in 37,000 (TBR-001-052).

Rationale: NR

4.7.4.2.3 Reserved

4.7.4.2.4 Ares V Cargo Delivery

Draft [CA0282V-PO] The Ares V Mass Delivered from the Earth surface to LEO for Mars exploration missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Mass Delivered capability of the Ares V is equal to or greater than the Mass Delivered requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.4.2.5 Ares V Mission Rates and Durations

Draft [CA0850V-PO] The ability for the Ares V EDS to loiter in LEO at least (TBD-001-975) days after orbit insertion shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares V EDS can loiter for at least (TBD-001-975) days after orbit insertion.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA6095V-PO] The ability of Ares V to launch on a 45 calendar day interval measured from the launch of the first mission to the launch of the second mission shall be verified by analysis. The analysis shall assess the time required to test and integrate the Ares V flight systems into mission configuration. Verification shall be considered successful when the analysis determines the Ares V can be tested and integrated into mission configuration within 45 calendar days.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide a fully functional vehicle in time to support the mission. An analysis of the timeline considering all aspects involved with processing the vehicle will determine the minimum amount of time to ready the vehicle for the mission. The analysis should also include any reprocessing or refurbishment activities planned.

[CA6097V-PO] The ability of Ares V to provide the capacity to perform two missions in a year shall be verified by analysis. The analysis shall assess the time required to produce, transport, assemble, and test the Ares V flight systems and integrate them into mission configuration. The verification shall be considered successful when analysis shows the Ares V flight systems can be produced, transported, assembled, tested and integrated into mission configuration in time to meet mission objectives.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide a fully functional vehicle in time to support the mission. An analysis of the timeline considering all aspects involved with processing the vehicle will determine the minimum amount of time to ready the vehicle for the mission. The analysis should also include any reprocessing or refurbishment activities planned.

[CA6104V-PO] The ability for the Ares V to provide launch opportunities for 4 consecutive days for crewed missions shall be verified by analysis. The analysis shall assess the Integrated Logistics Support Plan, the Ares V Logistics Support Analysis Report, ground processing plans, Logistics Support Analysis Records (LSAR), and other documents that include launch recycle tasks and activities associated with crewed missions in order to calculate the time and resources required to perform launch tasks for 4 consecutive days. The verification shall be considered successful when the analysis results show that the Ares V can provide launch opportunities for at least 4 consecutive days for crewed missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.4.2.6 Ares V Architecture Definition

Draft **[CA0049V-PO]** The delivery of the LSAM from the launch site to the ERO shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the LSAM reaches ERO.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0391V-HQ] The incorporation of the shuttle-derived 5-segment SRBs and RS-68 engines in the Ares V design shall be verified by inspection. The inspection shall consist of the review of Ares V configuration drawings. The verification shall be considered successful when the inspection shows that shuttle-derived 5-segment SRBs and RS-68s are utilized in the Ares V design.

Rationale: The incorporation of the shuttle-derived 5-segment SRBs and RS-68 engines in the Ares V design shall be verified by inspection. The inspection shall consist of the review of Ares V configuration drawings. The verification shall be considered successful when the inspection shows that shuttle-derived 5-segment SRBs and RS-68s are utilized in the Ares V design.

Draft [CA3217V-PO] The liftoff clearance between the Ares V integrated stack vehicle and the launch facility shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall be performed using digital flight simulations of the integrated stack dynamics and the launch facility. The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares V integrated stack can maintain the (TBD-001-371) liftoff clearance with respect to the launch facility.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft [CA5678V-PO] The Ares V+EDS capability to launch independent of ambient lighting conditions shall be verified by test and analysis. Ground Systems will perform an operational acceptance test to show that the ground facilities, facility systems and GSE will be able to provide launch capabilities independent of lighting conditions. The analysis shall include a review of vehicle systems, including but not limited to, vehicle tracking, recovery aids and imagery, to show that the flight systems, facility, facility systems and GSE that will be used to launch flight systems successful operations and performance determination are independent of ambient lighting conditions are built and certified. These facilities, flight systems and GSE requirements will be identified and characterized in CxP 70103, Constellation Program System Requirements for the Cargo Launch Vehicle (CaLV) Element, CxP 72006, Ground Systems, Systems Requirements Document (SRD). The verification shall be considered successful when the demonstration and analysis show that the flight and ground systems are ready to support flight systems launch for the Constellation Architecture independent of ambient lighting conditions.

Rationale: NR

4.7.4.2.6.1 Ares V Control Mass

Draft **[CA0848V-PO]** The Ares V Mass Delivered from the Earth surface to the start of the Trans-Lunar Coast (TLC) for uncrewed lunar Cargo Outpost missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Mass Delivered capability of the Ares V is equal to or greater than the Mass Delivered requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA0847V-PO]** The Ares V EDS Mass Delivered from Earth Rendezvous Orbit (ERO) to the start of the Trans-Lunar Coast (TLC) for crewed Lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Mass Delivered capability of the Ares V EDS is equal to or greater than the Mass Delivered requirement.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.4.2.6.2 Ares V Delta-V

Draft **[CA0051V-PO]** The Ares V EDS translational delta-V requirement for the TLI for crewed Lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the calculated translational delta-V of the Ares V EDS is equal to or greater than the translational delta-V requirement.

Rationale: Establishes the Ares V as the launch vehicle to transport the LSAM to the Earth Rendezvous Orbit with sufficient remaining propellant to execute the Trans-Lunar Injection burn. The TLI maneuver takes place after Orion docks with LSAM in the Earth Rendezvous Orbit (ERO).

4.7.4.2.7 Ares V Safety

Draft **[CA0874V-PO]** The Ares V FTS usage in accordance with NPR 8715.5, Range Safety Program, Section 3.3 shall be verified by inspection. The inspection shall examine the Level III acceptance data packages for inclusion of certified FTS. The verification shall be considered successful when the acceptance data package confirms the FTS is in the design.

Rationale: Every delivered booster must have an FTS that will be confirmed via the acceptance data package.

Draft **[CA5403V-PO]** The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the Ares V System-level FMEA/CILs for compliance with JPR 8080.5, Section G-2. The verification shall be considered successful when the integrated analysis shows that redundant systems are separated or protected.

Rationale: Verification of this requirement will be performed in accordance with the CxP FMEA/CIL methodology document.

Draft **[CA5432V-PO]** This verification shall be satisfied by test.

a. The test shall be performed using CxP flight test vehicles and certified Ground Systems during ground checkout.

b. Vehicle generation upon receipt of each Flight Termination command shall be verified during simulation tests. These tests shall be performed for the nominal and off-nominal profiles, the boundaries, modes, variable ranges and accuracy identified in (TBD-001-634) Document(s) for which the Flight Termination and vehicle signals apply. (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing).

This verification will be considered successful when:

a. Telemetry shows that the Ares V generated an indication upon each FTS command.

b. The telemetry shows that the indication of each FTS command was received by the CxP destination (i.e. Orion).

c. That the combined environments will not induce a false indication from the Ares V.

Rationale: Testing is considered the best means for requirement verification. FTS testing is the established precedence for verification. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.

The (TBD-001-634) documents refer to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

Draft **[CA5433V-PO]** FTS inhibit shall be verified by demonstration. The FTS Inhibit shall be demonstrated with the Flight, Ground and Mission Systems. The demonstration shall exercise the FTS Inhibit function on flight vehicle hardware through out vehicle processing until launch and during recovery operations.

Verification shall be considered successful when objective evidence (FTS telemetry/visual indicators) shows that Ground and Mission Systems are able to access and inhibit the FTS function in the usage scenarios identified in (TBD-001-423) document(s).

Rationale: Demonstrations during the certification, training and rehearsal of Ground and Mission Systems usage of the FTS in a flight fidelity setting is the valid setting to verify this integrated requirement.

The (TBD-001-423) documents refer to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

Draft **[CA5806V-PO]** The two fault tolerance for catastrophic hazard shall be verified by analysis. The analysis shall review the results of the Ares V System Hazard Analysis, and FMEA/CIL for two fault tolerance compliance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled by three or more methods and all DFMR items are approved in the Hazard Reports.

Rationale: Verification for this requirement will be performed in accordance with the CxP 70038, Constellation Program Hazard Analyses Methodology and the CxP 70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology. It looks top down and bottoms up at the system level.

[CA5918V-PO] The auto initiate capability of the Ares V Flight Termination Systems shall be verified by demonstration. The demonstration shall use the flight Ares V or flight equivalent hardware in simulated mission conditions. The simulated mission conditions shall be those that could result in vehicle separation/break-up. (Exhaustive verification of all conditions is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the Ares V Flight Termination Systems initiate upon vehicle separation/break-up in the absence of a signal from range safety.

Rationale: A demonstration is sufficient to verify the auto initiate capability of the Ares V Flight Termination Systems. The Flight Termination Systems used in the demonstration must be flight or flight equivalent hardware but do not have to be physically installed on the Ares V. They may be attached to and destroy dummy hardware as long as the Ares V hardware and software used to determine vehicle separation/break up are flight or flight equivalent. Alternatively, a non-destructive demonstration may be performed that shows that the destruct mechanism works *(i.e., signal reaches ordinance, fuse is lit, etc.) without actually destroying the vehicle.*

[CA5920V-PO] The disabling of the auto initiate capability of the Ares V Flight Termination Systems shall be verified by inspection and demonstration. The inspection shall examine the ground procedures for uninstalling or disabling the auto initiate capability of the Ares V Flight Termination Systems. The verification shall be considered successful when the inspection conclusively shows that the Ares V cannot be launched with crew when the auto initiate capability of the Ares V Flight Termination Systems is installed or enabled. The demonstration shall use the flight Ares V or flight equivalent hardware in simulated mission conditions. The simulated mission conditions shall be those that could result in vehicle separation/break-up. (Exhaustive verification of all conditions is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the Ares V Flight Termination Systems do not initiate upon vehicle separation/break-up when disabled or uninstalled.

Rationale: A demonstration is sufficient to verify the disabling of the auto initiate capability of the Ares V Flight Termination Systems.

4.7.4.2.8 Ares V Command and Control

[CA3113V-PO] The requirement for the Ares V to Accept Control of Automation shall be verified by test.

a. Tests shall be performed using the flight assets and associated CxP elements (Crew, Ground Systems and Mission Systems) under simulated flight conditions during integrated ground testing.

b. Simulation tests shall be performed for the nominal and off-nominal profiles, the boundaries, modes, variable ranges and accuracy identified in (TBD-001-732) document(s) for which the control of automation will be performed.

The verification shall be considered successful when:

a. The vehicle's running function is halted by the authorized Constellation System assuming vehicle control.

b. When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

c. The applicable vehicle profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-732) Document(s).

Rationale: Testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle.

The (TBD-001-732) document refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process.

Draft **[CA3257V-PO]** The execution of commands by the Ares V which are valid in the current state shall be verified by Test.

The Test shall use the flight Ares V or flight equivalent hardware in simulated mission conditions.

Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The applicable commands defined in (TBD-001-426) document(s) shall be executed by the Ares V. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be executed.

The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-426) document(s):

a. Commands are executed by the Ares V when valid in the current state in each applicable mission phase, state and mode.

b. Commands are rejected by the Ares V when not valid in the current state in each applicable mission phase, state and mode.

Rationale: A Test of the execution of Ares V commands defined by (TBD-001-426) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-426) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for the Ares V.

[CA3276V-PO] The execution of commands by the Ares V which are addressed to the Ares V shall be verified by Test.

The Test shall use the flight Ares V or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-768) document(s) shall be executed by the Ares V. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be executed. The Ares V shall be sent each command addressed to it and a subset of the commands addressed to other systems.

The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-768) document(s):

a. Commands are executed by the Ares V when addressed to the Ares V.

b. Commands are processed by the Ares V according to C3I network protocols (e.g., immediately routed, stored and forwarded later, dropped, etc., including that the appropriate notifications are sent) when not addressed to the Ares V.

Rationale: A Test of the execution of Ares V commands defined by (TBD-001-768) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the commands for the Ares V.

Draft [CA3292V-PO] The Ares V Autonomous Lift-off and Ascent Operations requirement shall be verified by demonstration.

a. Demonstrations shall be performed using the flight (Ares V) assets and Crew Surrogates under simulated flight conditions during integrated ground testing.

b. Demonstrations using the flight/flight-like assets (Ares V) and Crew of the automated and autonomous lift-off and ascent operations shall be performed during simulation and training exercises.

The verification shall be considered successful when:

a. Demonstrated autonomous operation is accomplished.

b. Additional adjustments are not required.

c. External intervention was not necessary.

Rationale: Demonstrations using Flight Equivalent Assets and actual CxP architecture provide the best environment to demonstrate autonomous functions. Demonstrations during simulations and training exercises are necessary to reduce the risk of being unable to perform the autonomous operation during flight.

[CA3302V-PO] The Ares V Automated Lift-Off and Flight Operations requirement verification shall be satisfied by Test.

a. Tests shall be performed using the flight (Ares V) assets under simulated flight conditions with the applicable CxP elements (Crew, Mission Systems, and/or Ground Systems) during integrated ground testing.

b. Simulation tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-414) document(s) for which the automated lift-off and ascent/flight function must operate. (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing).

The verification shall be considered successful when:

a. The automated lift-off and ascent/flight functions identified in (TBD-001-414) document(s) are tested.

b. When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

c. The profiles, boundaries, modes, variable ranges and accuracy are verified as specified in the (TBD-001-414) document(s).

Rationale: Testing this function provides the best end-to-end verification for this requirement. The associated CxP elements are either active participants or passively monitored by the specific automated function(s). Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle. The (TBD-001-414) document refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

Draft **[CA5431V-PO]** The Ares V execution of authenticated USAF FCO FTS commands shall be verified by test.

a. The test shall be performed using actual CxP flight vehicles and Ground Systems along with the USAF Range Safety organization during ground testing.

b. Authenticated FTS Command testing shall be performed with simulations. Simulation testing shall be performed for the nominal and off-nominal profiles, the applicable boundaries, modes, variable ranges and accuracy identified in (TBD-001-742) document(s) for which the FTS Commands are sent. (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.)

This verification shall be considered successful when the test results prove that the FTS is initiated upon the receipt of a valid USAF FCO-initiated command.

Rationale: Testing is considered the best means for requirement verification. Joint party FTS testing is the established precedence for verification. The USAF Range Safety is identified in this VR as they are an external interface to CxP. Simulation testing is necessary because it is not feasible to flight test all possible conditions anticipated in the CxP life cycle. The (TBD-001-755) documents refer to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

4.7.4.2.9 Ares V Health and Status

Draft **[CA3124V-PO]** The generation of Health and Status information by the Ares V shall be verified by Test. The Test shall use the flight Ares V or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable Health and Status data defined in (TBD-001-711) document(s) shall be generated by the Ares V. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the Test shows that the Health and Status data identified in (TBD-001-711) document(s):

a. Health and Status is generated by the Ares V in each applicable mission phase, state and mode.

b. Health and Status agrees with the actual health and status of the Ares V.

Rationale: A Test of the generation of Ares V Health and Status data defined by (TBD-001-711) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-711) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the Health and Status parameters for the Ares V.

Draft **[CA5472V-PO]** The provision of fault detection by the Ares V shall be verified by Test. The Test shall use the flight Ares V or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-432) document(s) for applicable simulated mission phases, states, and modes for the Ares V at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-432) document(s) are detected by the Ares V in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the Ares V for the faults and fault scenarios identified by (TBD-001-432) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-432) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be detected.

Draft **[CA5473V-PO]** The provision of fault isolation by the Ares V shall be verified by Test. The Test shall use the flight Ares V or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-435) document(s) for applicable simulated mission phases, states, and modes for the Ares V at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-435) document(s) are isolated by the Ares V in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the Ares V for the faults and fault scenarios identified by (TBD-001-435) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-435) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be isolated.

Draft **[CA5474V-PO]** The provision of fault recovery by the Ares V shall be verified by Test. The Test shall use the flight Ares V or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-438) document(s) for applicable simulated mission phases, states, and modes for the Ares V at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-438) document(s) are recovered from by the Ares V in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the Ares V for the faults and fault scenarios identified by (TBD-001-438) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-438) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specifies the faults to be recovered from.

4.7.4.2.10 Ares V Communications and Communications Security

Draft **[CA5044V-PO]** Ares V shall record System-generated digital data received from other Constellation Systems. The recording of System-generated digital data received from other Constellation Systems shall be verified by Demonstration.

The demonstration shall be conducted in a SIL (or equivalent) using flight or similar assets. Test objectives shall be prepared using IRDs and SRDs to identify source systems for data recording and the data content to be recorded. The source system may be simulated but should be certified. The source data shall be transmitted for no less than 4 hours or for an entire mission phase, if shorter, at least twice.

The verification shall be considered successful when the demonstration shows:

a. Source data is received for an entire mission phase or at least 4 hours.

b. Demonstration is performed twice.

c. All received data is recorded.

d. An audit of the recorded data shows it to be correct.

Rationale: Recording of System-generated digital is critical to support development, test, operation, and maintenance of systems. To confirm interoperability and functionality demonstrations are performed.

Draft **[CA5911V-PO]** Simultaneous communication by the Ares V with the LSAM, Mission Systems, and Ground Systems shall be verified by analysis and test.

Analysis of the specified data links shall be performed. The analysis shall include environmental factors for nominal and off-nominal Ares V launch operation scenarios. The test shall consist of simulations of the communications for nominal and off-nominal Ares V launch operations including pre-launch communication activities and shall be conducted at least twice each for nominal and maximum data rates. The test shall be conducted on flight or flight-like systems and simulated systems over simulated nominal space links.

The verification shall be considered successful when:

a. Testing shows the Ares V can simultaneously exchange data with the LSAM, Mission Systems, and Ground Systems for Ares V pre-launch and launch operations correctly and without apparent degradation for both nominal and maximum data rates for each scenario at least twice.

b. Analysis shows that hardline, networked, and RF data links, including forward and reverse margins, provide necessary bandwidth to support communication during nominal and off-nominal Ares V launch operations.

Rationale: Analysis is used to verify that RF communication links will remain operational during the specified mission scenarios and environmental conditions. Testing is used to load the system to stress levels. Test results must be repeatable and consistent.

4.7.4.2.11 ARES V GN&C

Draft **[CA0128V-PO]** The Ares V EDS performance of attitude control of the LSAM/Ares V EDS mated configuration prior to Orion docking shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) -to- Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD) is greater than 99.73% with a "consumer's risk" of 10%.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0129V-PO] The use of the Ares V EDS to perform TLI shall be verified by inspection and analysis. The inspection shall review verification results for CA0051-PO. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares V EDS can perform the TLI burn.

Rationale: The ability of the hardware to perform the delta-V is verified in another requirement, and inspected here. The analysis is required to ensure the integrated vehicle can successfully accomplish all the tasks required for the TLI burn, including attitude control, thrust maintenance, etc.

[CA0183V-PO] The Ares V EDS performance of attitude control of the LSAM/Ares V EDS/Orion mated configuration shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP (TBD-001-1053), Constellation Program Lunar Lander -to- Ares V -to- Orion Interface Requirements Document (IRD) is greater than 99.73% with a "consumer's risk" of 10%.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA3146V-PO]** The Ares V navigation and attitude determination capability shall be verified by analysis and component testing. The analysis and testing shall be accomplished using flight sensor hardware in a comprehensive dynamic hardware-in-the-loop simulation of the Ares V. The dynamic simulation, analysis, and hardware-in-the-loop tests shall verify the accuracy of the Ares V navigation and attitude determination capability by taking error data from component level navigation and attitude sensor testing, and processing this data with a dynamic model of the orbit and attitude dynamics and disturbances during ascent. The verification shall be considered successful when the analysis, simulation, and testing has shown that the criteria as specified in the Ares V Verification document (TBD-001-943) navigation capability has been met.

Rationale: NR

Draft **[CA3186V-PO]** The ability of the Ares V EDS to change the planned Trans-Lunar Injection based on guidance target updates provided prior to TLI shall be verified by test. The test shall be performed using Ares V EDS flight hardware and a certified flight-like communication system. The verification shall be considered successful when test results show the Ares V EDS can accurately change TLI based on updates prior to launch.

Rationale: Data exchange between the Ares V EDS flight computer and the operations environment can reasonably be tested with hardware and the communication system before flight, and is the highest fidelity of verification for the requirement.

Draft **[CA3216-PO]** The ability of the Ares V to meet orbital injection accuracies shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.73% probability with a "consumer's risk" of 10% that the Ares V can achieve the orbital injection accuracies defined in Table (TBD-001-566).

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA3224V-PO]** The ability of the Ares V to change the planned ascent trajectory design parameter updates prior to launch shall be verified by test. The test shall be performed using Ares V flight hardware and a certified flight-like communication system. The verification shall be considered successful when test results show the Ares V can accurately change ascent trajectory prior to launch.

Rationale: Data exchange between the Ares V flight computer and the operations environment can reasonably be tested with hardware and the communication system before flight, and is the highest fidelity of verification for the requirement.

Draft **[CA3225V-PO]** The ability of the Ares V to change the planned ascent trajectory based on guidance target updates provided prior to launch shall be verified by test. The test shall be performed using Ares V flight hardware and a certified flight-like communication system. The verification shall be considered successful when test results show the Ares V can accurately change ascent trajectory based on updates provided prior to launch.

Rationale: Data exchange between the Ares V flight computer and the operations environment can reasonably be tested with hardware and the communication system before flight, and is the highest fidelity of verification for the requirement.

[CA5292V-PO] The capability of the Ares V EDS to provide attitude control of the mated Ares V EDS/LSAM vehicle during Orion RPODU shall be verified by test and analysis. The Ares V EDS attitude hold tests shall be conducted within a SIL (or equivalent). The SIL (or equivalent) shall include models of environmental attitude disturbances, as well as models of the LSAM and Orion vehicles, including Orion thruster plumes. One or more tests shall be conducted for all nominal Orion RPODU trajectories. The attitude hold tests shall be considered successful when the results show that Ares V attitude errors and angular rate errors remain within the limits specified by CxP 70119, Constellation Program Orion –to- Ares V Interface Requirements Document (IRD). The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The simulation shall include models of environmental attitude disturbances, as well as models of the LSAM and Orion vehicles, including Orion thruster plumes. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70119, Constellation Program Orion –to- Ares V Interface Requirements Document (IRD), during Orion RPODU is greater than 99.73% with a "consumer's risk" of 10%.

Rationale: Rationale for SIL tests: Significant interaction between hardware and software subsystems requires a test in an avionics environment driven by a NASA-accredited digital simulation. The test simulation must include models of both maneuvering vehicle and target vehicle to model the effects of target vehicle attitude control on docking/undocking dynamics. These tests will include relative sensor hardware to the maximum extent practicable in the ground test environment.

Rationale for simulation analysis: Analysis by simulation is required because of the large number of evaluations that must be performed, the large amount of time required to perform tests in real time, and the capability to modify parameters in simulation that cannot be controlled in the operational environment.

4.7.4.2.12 Ares V Reliability and Availability

Draft **[CA0413V-PO]** The ability of the Ares V to have a probability of launch of not less than (TBD-001-971)% on the initial attempt, exclusive of weather, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt shall be verified by analysis. The verification analysis shall use only R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when analysis shows that the probability of the initial launch attempt is not less than (TBD-001-971)% with an uncertainty of not greater than (TBD-001-407)% (TDS# SIG-01-004).

Rationale: Level III vehicle reliability and availability data, and Ground Operations data will need to be available for the program to verify that the flight hardware will be in a situation that supports the vehicle and Ground Systems to be available to support during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.

Draft **[CA0414V-PO]** The ability of the Ares V to a meet a (TBD-001-972)% launch probability with respect to the natural environment shall be verified by analysis. The analysis shall examine the data submitted for verification of the requirements based on the Design Specification for Natural Environments (DSNE) specifications, monthly climatological statistics, and the Induced Environments Design Specification. The envelope defining the extents of the compiled data from these sources should then be defined as the weather constraints for launch probability assessments. The defined weather constraints shall subsequently be analyzed against the weather conditions for a given launch window and determine that the Ares V can launch within these conditions. The verification shall be considered successful when the analysis concludes that the Ares V has a launch probability of (TBD-001-972)%, with an uncertainty of not greater than (TBD-001-1018)% (TDS# SIG-01-004), with respect to the natural environment.

Rationale: The assessment of the launch probability with respect to the natural environment must consider associated induced effects of the launch configuration, i.e., Orion constraints and loads, the current sea states over the ground path, Ground Systems constraints, and other factors. The only way to determine this overall probability is analysis.

Draft **[CA5259-PO]** The requirement for the Ares V to have a (TBD-001-572) minute launch window per cargo launch opportunity for Lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that Ares V can launch within at least a (TBD-001-572) minute window for cargo Lunar missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

Draft **[CA5265-PO]** The requirement for the Ares V to have a (TBD-001-573) minute launch window per crewed launch opportunity for Lunar missions shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The requirement shall be considered satisfied when analysis results show there is at least a 99.86% probability with a "consumer's risk" of 10% that the Ares V can launch within at least a (TBD-001-573) minute window for crewed Lunar missions.

Rationale: Because of the wide variation of possible inputs and because of the lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5533V-PO] The capability of the Ares V/EDS to launch again 4 (TBR-001-183) days prior to the next lunar injection window following a missed window shall be verified by analysis. The analysis shall include an assessment of access capabilities per the CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) -to- Ground Systems Interface Requirements Document (IRD), the tasks and activities required to reprocess and ready the Ares V/EDS to launch after a missed launch attempt, and an assessment of the reliability of the Ares V/EDS systems to hold in a "ready to launch" configuration. The verification shall be considered successful when the analysis shows that all Ares V/EDS systems that require maintenance or service during reprocessing have the access and interfaces required and the Ares V/EDS can be reprocessed, and be prepared to launch again 4 (TBR-001-183) days prior to the next lunar injection window following a missed window.

Rationale: Processing flows, schedules, and launch manifest will be needed to determine whether Ares V/EDS can be launched as often as required.

[CA6206V-PO] The ability to remedy the required percentage of Ares V system failures identified after decision to load cryogenic propellants with a likelihood of occurrence greater than (TBD-001-1503)% that would result in a scrubbed launch within the required time limit, shall be verified by analysis. The analysis shall assess the Ares V FMEA, maintenance plan, LSA, and FDIR capabilities to determine the likelihood of occurrence of failures and the percentage of failures that can be remedied within 1 day, 2 days, and 3 days. The verification analysis shall use only Cx R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan.

Verification shall be considered successful when the analysis determines, with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004) that:

a. No less than 30% (TBR-001-1422) can be remedied to support a launch attempt within one day.

b. No less than 45% (TBR-001-1423) can be remedied to support a launch attempt within two days.

b. No less than 50% (TBR-001-1424) can be remedied to support a launch attempt within three days.

Rationale: The probability of launch for the Constellation Architecture consists of a combination of system reliability, maintainability, and weather constraints. This requirement primarily addresses Ares I system maintainability. The intent is to drive a capability to correct those failures discovered (latent defects) after deciding to load cryogenic propellants that will cause a launch scrub in order to maximize the number of launch attempts that are utilized. The duration for repair time includes the time to establish access, set up, diagnose, perform corrective maintenance, closeout, and complete any retest required in time to make the launch attempt. As this is a design-to requirement, administrative and logistics delay is not included (for example: time searching for a spare part). The intent of extending through only 70% of failures is to prevent this requirement from driving counterproductive system complexity and increased effort or difficulty for nominal operations and sustainment scenarios. The expectation is that operability assessments should influence the developer's selection of which of the most likely failures to target.

4.7.4.2.13 Ares V Maintainability, Supportability, and Logistics

Draft [CA5804V-PO] The ability of the reusable elements of the Ares V to be refurbished by Ground System shall be verified by analysis. The analysis shall be performed on the requirements for the flight elements to refurbished in the facility and facility systems and GSE provided by the Ground System used to support refurbishment of flight elements. The analysis shall compare the Ares V refurbishable elements design to the GS design for compatibility. The verification shall be considered successful when the analysis shows that the reusable elements of the Ares V can be refurbished in the GS facilities, facility systems and GSE that support refurbishment as attested by the design certification review.

Rationale: NR

[CA5986V-PO] The ability of the Ares V to generate Project Verified Engineering Builds after the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars) shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The

Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5987V-PO] The ability of the Ares V to generate Project Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5988V-PO] The ability of the Ares V to generate day of launch updates shall be verified by demonstration. Demonstration shall be considered successful when day of launch updates have been successfully generated and applied during project verification and validation activities.

Rationale: The intent is to demonstrate that the day of launch update process can be successfully executed.

[CA5989V-PO] The ability of the Ares V to provide fixes for selected non-conformances to the discovering organization shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when inspection determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA6009V-PO] The ability of the Ares V to conduct ground operations within the constraints levied in Ares V Critical Path Allocations for Ares V/LSAM Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6009 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will be then updated.

Rationale: NR

4.7.4.2.14 Reserved

4.7.4.2.15 Ares V Environmental Conditions

Draft [CA5355V-PO] Compliance of the Ares V with its functional and performance requirements during and after exposure to the DSNE environments shall be verified by inspection and analysis. The inspection shall consist of review of the following:

a. Allocation of the natural environments requirements to the lower tier systems and their verification methods and details

b. The lower tier verification closure data.

The analysis shall address interactions of each lower tier system on other systems to include integrated environment effects. The systems shall include the following integrated configurations: Orion/LSAM/Ares V-EDS/GS, Orion/LSAM/Ares V-EDS, Orion/LSAM/Ares V/GS, Orion/LSAM/Ares V, LSAM/Ares V/GS and LSAM/Ares V.

The verification shall be considered successful when the inspection and integrated analysis show:

a. The natural environment requirements and verification have been allocated to the lower tier systems in accordance Section 4 of the DSNE.

b. Lower tier verifications have been completed.

c. The Ares V meets its functional and performance requirements during and after exposure to the DSNE environments.

Rationale: Verification of functional and performance requirements across the range of natural environments requires a systematic integrated approach to address dependencies on hardware configurations and operational mode. The DSNE Section 4 specifies a standard systems engineering technique for flowing down the natural environment from higher to lower levels for each mission phase. Lower tier verification close out data, analyses, and models are necessary to support the *integrated analysis, but are not sufficient alone to close out the environment requirements from the integrated vehicle configuration.*

Draft [CA5558V-PO] Ares V function and performance during and after exposure to induced environments shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the Ares V/System IRD requirements.

b. Review of the induced environment verifications submitted against CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD) requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification.

The verification shall be considered successful when the analysis shows that the Ares V function and performance requirements are met during and after exposure to the IEDS-specified induced environments for each DRM.

Rationale: Function and performance must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of the IEDS can provide verification including assurance that:

a. The proper induced environments have been considered.

b. Sensitivities to these environments.

c. Synergistic effects have each been properly addressed for all mission phases.

Draft [CA5563V-PO] Ares V induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the Ares V/System IRD requirements.

b. Review of the induced environment verifications submitted against Ares V/System SRD requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of the CxP 70143, Constellation Program Induced Environment Design Specification. The verification shall be considered successful when the analysis shows that the Ares V peak and cumulative induced environments will not exceed the IEDS-specified induced environments for each DRM.

Rationale: Induced environment contributions must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of the IEDS can provide verification including assurance that:

a. The proper induced environments have been met.

b. Sensitivities to these environments

c. Synergistic effects have each been properly addressed for all mission phases.

4.7.4.3 Reserved

4.7.4.4 Ares V External Interfaces

Draft **[CA0905V-PO]** The Ares V EDS interfaces with Orion shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the Ares V EDS-to-Orion interface requirements defined within the CxP 70119, Constellation Program Orion -to- Ares V Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares V EDS and Orion flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalent) or across distributed SILs (or equivalents) prior to first launch of the Ares V EDS. Testing shall also include a multi-system integrated test of the integrated Orion/LSAM/Ares V EDS vehicle stack prior to first human use of the EDS/LSAM in space to demonstrate integrated functionality and interoperability between the flight systems and between the integrated vehicle stack and the ground support and mission control systems.

Verification shall be considered successful when:

a. Analysis confirms that all of the Ares V interface verification requirements defined within CxP 70119, Constellation Program Orion -to- Ares V Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Orion Project Office to confirm that all of the Ares V EDS-to-Orion interface requirements specified in the IRD have been satisfied. Integrated testing of the EDS and Ares V flight avionics and software at or distributed amongst the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Since the LSAM will also be part of the integrated Orion/EDS vehicle stack, integrated testing will include configurations with the LSAM. Since the first time Orion and LSAM/EDS flight systems will be integrated together is in Low Earth Orbit, integrated testing between the flight systems and with the ground support and mission control systems will be performed on the ground at the launch site to confirm integrated operability, functionality, and system stability during/after operational mode changes.

Draft **[CA0906V-PO]** The Ares V interfaces with the LSAM shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the LSAM-to-Ares V interface requirements defined within CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) -to- Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD) , have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares V (including EDS) and LSAM flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalent) or across distributed SILs (or equivalents) prior to first launch of the LSAM. Testing shall also include a multi-system integrated test of the Ares V/LSAM launch vehicle stack to demonstrate integrated functionality and interoperability between the flight systems and between the integrated launch vehicle stack and the ground support and mission control systems.

Verification shall be considered successful when:

a. Analysis confirms that all of the Ares V interface verification requirements defined within CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) -to- Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Ares Project Office to confirm that all of the Ares V-to-LSAM interface requirements (including EDS) specified in the IRD have been satisfied. Integrated testing of the LSAM and Ares V flight avionics and software at or distributed amongst the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Since the first time the Ares V and LSAM flight systems will be integrated together is within the integrated launch vehicle stack, integrated testing between the flight systems within the launch vehicle stack and between the stack and the various ground support and mission control systems will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

Draft **[CA0907V-PO]** The Ares V interfaces with the GO shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the CLV-to-GO interface requirements defined within CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) -to- Ground Systems Interface Requirements Document (IRD) , have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares V avionics and software and the GO systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the GO systems to confirm interoperability and functionality between the Ares V and GO systems. Verification shall be considered successful when:

a. Analysis confirms that all of the Ares V interface verification requirements defined within CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) -to- Ground Systems Interface Requirements Document (IRD) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Ares Project Office to confirm that all of the Ares V-to-GO interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares V avionics and software and the GO systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating GO systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

Draft **[CA0908V-PO]** The Ares V interfaces with the MS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the Ares V-to-MS interface requirements defined within CxP 70112, Constellation Program Cargo Launch Vehicle (CaLV) –to- Mission Systems (MS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares V avionics and software and the Mission Systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the Mission Systems to confirm interoperability and functionality between the Ares V, GS, and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the Ares V interface verification requirements defined within CxP 70112, Constellation Program Ares V -to- Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Ares Project Office to confirm that all of the Ares V-to-MS interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares V avionics and software and the Mission Systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating MS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.

Draft [CA0909V-PO] The Ares V interfaces with the Communications and Tracking Networks shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the Ares V interface requirements defined within CxP 70118-04, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 4: Cargo Launch Vehicle (CaLV), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares V avionics and software and the Communications and Tracking Networks systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the communications and tracking network systems to confirm interoperability and functionality between the systems.

Verification shall be considered successful when:

a. Analysis confirms that all of the Ares V interface verification requirements defined within CxP 70118-04, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 4: Cargo Launch Vehicle (CaLV), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the Ares Project Office to confirm that all of the Ares V-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares V avionics and software and the communications and network systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating the communication and network systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after *operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators was adequate.*

4.7.4.5 Reserved

4.7.5 Ground Systems (GS)

4.7.5.1 GS Description

4.7.5.2 GS Requirements

[CA0140V-PO] Ground Systems to provide ground processing for flight systems and cargo shall be verified by analysis and inspection. The analysis shall be performed on the requirements for delivery of facility, facility systems and GSE that will be used to support ground processing for flight systems and cargo. These facility, facility systems and GSE requirements will be identified and characterized in CxP 72006, Ground Systems, Systems Requirements Document (SRD). An inspection shall be on the lower level requirements to verify that the facility, facility systems and GSE will be able to successfully process flight systems and cargo for the purpose of preparing these flight systems and cargo for launch. The verification for analysis shall be considered successful when the analysis shows that CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the performance the ground processing of flight elements and cargo have been satisfied per the design certification review. The verification for the inspection shall be considered successful when the inspection of the lower level requirements shows that all of the ground side flight-to-ground interfaces meet ICD specifications and that all of the appropriate environmental conditions; mechanical handling equipment; tools and platforms/structures and electrical; fluid and data processing services are fully functional and operational.

Rationale: NR

[CA0142V-PO] The provision of Ground Systems to perform interface and integration testing on integrated Cx Architecture flight systems shall be verified by analysis and test. The analysis shall be performed on the requirements for delivery of facility, facility systems and GSE that will be used to support the nominal assembly and interface checkout per the assembly plans, integration testing of the flight systems being assembled into a launch vehicle stack for the first time (i.e. FEIT), or that will meet for the first time in space (i.e. MEIT). These facility, facility systems and GSE requirements will be identified and characterized in the CxP 72006, Ground Systems, Systems Requirements Document (SRD). An operational acceptance test shall be performed to demonstrate that the facility, facility systems and GSE will be able to successfully mate, power and operate an integrated launch vehicle stack or in-space flight vehicle for the purpose of performing nominal assembly and interface checkout per the assembly plans, Flight Element Integration Testing (FEIT) or a Multi-Element Integration Test (MEIT). The verification for analysis shall be considered successful when the analysis shows that the CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the performance of interface and integration testing of fight systems have been satisfied per the design certification review. The verification for test shall be considered successful when the operational acceptance test shows that a simulated integrated launch vehicle or flight vehicle has been successfully mated, powered and operated.

Rationale: NR

[CA0145V-PO] Ground Systems to provide recovery services for recoverable flight elements and the flight crew at designated landing sites shall be verified by analysis. The analysis shall be performed on the requirements for delivery of facility, facility systems and GSE that will be used to safe the Orion Crew Module after landing, egress the flight crew, remove time-critical cargo, and transport the vehicle to a processing site for de-integration. These facility, facility systems and GSE requirements will be identified and characterized in the CxP 72006, Ground Systems, Systems Requirements Document (SRD). The verification for analysis shall be considered successful when the analysis shows that the CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that are needed to locate, safe, retrieve, and transport the Ares I first stage and Ares V boosters of flight elements and flight crew at designated landing sites have been satisfied per the design certification review.

Rationale: NR

[CA0858V-PO] Ground-based imagery of the Constellation flight elements shall be verified by analysis. The analysis shall consist of a review that the facility and facility systems and GSE that will be used to provide ground based imagery of flight elements are built and certified. These facility, facility systems and GSE requirements will be identified and characterized in the GS-SRD and GS-SSRD. The verification shall be considered successful when the analysis shows that the systems are ready to support ground-based imagery of the Constellation flight elements.

Rationale: NR

[CA4122V-PO] Ground Systems to provide recovery of the flight crew within 1(TBR-001-161) hr after landing at a designated landing site shall be verified by test and analysis. An operational acceptance test shall be performed to demonstrate that the personnel, facilities, facilities systems and GSE will be able to successfully recovery the flight crew within 1 (TBR-001-161) hr after landing at the designated landing site. The analysis shall be performed on the requirements for the facility and facility systems and GSE to support the recovery. These facility, facility systems and GSE requirements will be identified and characterized in the CxP 72006, Ground Systems, Systems Requirements Document (SRD). The verification shall be considered successful when the test and analysis shows that the personnel, CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that support recovering the crew within 1 (TBR-001-161) hr after landing have been satisfied per the design certification review.

Rationale: NR

[CA4123V-PO] Ground Systems recovery of the Orion Crew Module in the event Orion lands outside the designated landing site shall be verified by analysis, test and demonstration. The analysis shall consist of a review of documentation showing closure of the allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) , requirements and the MOU (TBD-001-382) between Cx and search organization(s) to confirm coordination for SAR support. Additional analysis shall consist of a review of CxP 72000, Constellation Program System Requirements for the Orion System, for closure of crew survival capability for contingency landing to meet SAR time constraints. The analysis shall consist of status review of allocated requirements (Orion provide visual aids and GS perform SAR) and MOU (TBD-001-382) between Cx and rescue operation(s) to confirm coordination for support. The test shall consist of a drill within the range of Program facilities and utilizing ground recovery assets and personnel. The test will simulate both land and water SAR methods. The demonstration shall consist of exercising procedures in a paper simulation environment for SAR force deployment where the recovery is outside the range of Program facilities and staged ground recovery assets and personnel. This demonstration will utilize the test data as a guideline to perform the paper simulation. Analysis will confirm that agreements are in place and will demonstrate the ability to perform SAR functions. The verification shall be considered successful when the analysis determines that the allocated CxP 72000, Constellation Program System Requirements for the Orion System, CxP 72006, Ground Systems, Systems Requirements Document (SRD)requirements are closed, that there is Program agreement with Cx and rescue operation(s), and the test and demonstration results in the Ground Systems ability to perform a rescue following a landing outside of the designated landing sites, independent of ambient lighting conditions.

Rationale: NR

[CA5701V-PO] The provision of Ground Systems to integrate flight systems and cargo shall be verified by analysis, demonstration and test. The analysis shall be performed on the requirements for delivery of facility, facility systems and GSE that will be used to support the assembly, stacking, mating, and checkout of flight systems and for the installation of cargo into a pressurized flight system. These facility, facility systems and GSE requirements will be identified and characterized in the CxP 72006, Ground Systems, Systems Requirements Document (SRD) . The physical demonstration shall be performed by lifting a dummy load of similar size, weight, center of gravity and of similar attach mechanism design of the flight systems and simulating a stacking/mating operation. An operational acceptance test shall be performed by powering and checking out the facility, facility systems, and GSE in preparation for a nominal interface and integration test or a Flight Element Integration Testing (FEIT).

The verification for analysis shall be considered successful when the analysis shows that the CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the performance of integrated launch vehicle stacking and mating operations and installation of cargo into flight systems have been satisfied per the Critical Design Review. The verification for demonstration shall be considered successful when the demonstration shows that the cranes, lifting slings, dollies and platform structures, all validate the stacking and mating operations without exceeding any design or operations constraints or performance measures. The verification for mechanical/electrical testing shall be considered successful when the operational acceptance test shows that Ground Systems equipment/interfaces perform the required functions and meet ICD specifications.

Rationale: NR

4.7.5.2.1 GS Mission Success

4.7.5.2.2 GS Crew Survival

[CA0146V-PO] Ground Systems rescue of the flight crew in the event Orion lands outside the designated landing sites shall be verified by analysis, test and demonstration. The analysis shall consist of a review of documentation showing closure of the allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) , MOU (TBD-001-382) between Cx and search organization(s) to confirm coordination for SAR support. Additional analysis shall consist of a review of the allocated sections of CxP 72000, Constellation Program System Requirements for the Orion System for closure of crew survival capability for contingency landing to meet SAR time constraints. The test shall consist of an Orion mock-up drill within the range of Program facilities and will utilize ground recovery assets and personnel. The test will simulate both land and water SAR methods. The demonstration shall consist of exercising procedures in a paper simulation environment for SAR force deployment where the recovery is outside the range of Program facilities and staged ground recovery assets and personnel. This demonstration shall utilize the test data as a guideline to perform the paper simulation. The verification shall be considered successful when the analysis determines that the allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) is closed, that there is Program agreement with Cx and recovery force(s), and the test and demonstration results in the Ground Systems ability to perform a rescue of the Flight Crew.

Rationale: This is an overarching Ground System project parent verification requirement that can be satisfied once the flow-down requirements to the Ground Operation projects are satisfied. The analysis documentation can be satisfied by the Ground System providing the requirements that address the functions (whether in the SRD or SSRD) and by the Orion project providing the requirements that address the functions within CxP 72000, Constellation Program System Requirements for the Orion System.

[CA0151V-PO] Ground Systems to provide safe haven for 14 ground personnel and crew at the launch pad shall be verified by analysis. The analysis shall be performed on the requirements for delivery of facility and facility systems and GSE used to support safe haven capability. These facility, facility systems and GSE requirements will be identified and characterized in CxP 72006, Ground Systems, Systems Requirements Document (SRD) . The verification shall be considered successful when the analysis shows that the CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that support safe haven for 14 ground personnel and crew at the launch pad have been satisfied per the design certification review.

Rationale: NR

[CA0306V-PO] Ground Systems capability to perform rescue and recovery operations independent of ambient lighting conditions shall be verified by test and analysis. Ground Systems will perform an operational acceptance test to show that the ground facilities, facility systems and GSE will be able to provide rescue and recovery operations independent of lighting conditions. The analysis shall include a review of ground systems, including but not limited to, vehicle tracking, recovery aids and imagery, to show that the facility, facility systems and GSE that will be used for rescue and recover of flight elements independent of ambient lighting conditions are built and certified. These facilities, flight systems and GSE requirements will be identified and characterized in the CxP 72006, Ground Systems, Systems Requirements Document (SRD) The verification shall be considered successful when the test and analysis show that the flight and ground systems are ready to support the rescue and recovery of flight elements independent of ambient lighting conditions.

Rationale: NR

[CA0336V-PO] The suited crew capability for unassisted emergency egress to a safe haven during pre-launch activities shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using Orion and launch support structure by performing a minimum of two runs with two different sets of suited crewmembers and collecting the task time for crew egress from Orion to a safe haven at ground level. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments. The analysis shall consist of the Ground System, EVA, Ares I, and Orion system documentation review that meets unobstructed egress for the suited crew through the closure in the allocated CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD), CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document, and CxP 72120, Ground Operations Project Plan requirements. The verification shall be considered successful when the analysis determines the demonstration meets emergency egress within 2 (TBR-001-134) minutes and the allocated children requirements have been closed.

Rationale: This is an overarching Ground Ops project verification requirement that can be satisfied once the flow-down requirements to the Ground Ops projects are *satisfied. The analysis can be satisfied by the Ground Ops System providing the requirements that address the functions (whether in the SRR, ICD or IRD).*

[CA0337V-PO] Capability of the Ground Systems to provide for a maximum of eight (TBR-001-962) ground crew unassisted emergency egress to a safe haven during pre-launch pad activities within (TBD-001-252) minutes shall be verified by demonstration and analysis. The demonstration shall consist of performing a minimum of two runs with two different sets of eight ground crewmembers and collecting the task time for ground crew egress from the Orion and continued egress from launch structure to safe area at ground level. Analysis shall consist of performing an integrated examination to verify that the design does not hinder the means for ground personnel to escape and clear the launch pad in case of an emergency. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for all practical anthropometric ground crew assignments. The verification shall be considered successful when the analysis and demonstration determine that eight (TBR-001-962) ground crew can perform an unassisted emergency egress during pre-launch activities within (TBD-001-252) minutes starting from the initiation of the egress to arrival of the last ground crewmember at the safe haven.

Rationale: NR

[CA5146V-PO] Ground Systems rescue of the crew within 24 hours with a 95% (TBR-001-047) probability of success after landing outside the designated landing site shall be verified by analysis, test and demonstration. The analysis shall consist of a review of documentation showing closure of the allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements and the MOU (TBD-001-382) between Cx and search organization(s) to confirm coordination for SAR support. Additional analysis shall consist of a review of CxP 72000, Constellation Program System Requirements for the Orion System for closure of crew survival capability for contingency landing to meet SAR time constraints. The analysis shall also consist of status review of allocated requirements (Orion provide visual aids and GS perform SAR) and MOU (TBD-001-382) between Cx and rescue operation(s) to confirm coordination for support. The test shall consist of a drill within the range of Program facilities and utilizing ground recovery assets and personnel. The test will simulate both land and water SAR methods. The demonstration shall consist of exercising procedures in a paper simulation environment for SAR force deployment where the recovery is outside the range of Program facilities and staged ground recovery assets and personnel. This demonstration will utilize the test data as a guideline to perform the paper simulation. Analysis will confirm that agreements are in place and will demonstrate the ability to perform SAR functions. The verification shall be considered successful when the analysis determines that the allocated CxP 72000, Constellation Program System Requirements for the Orion System, CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements are closed and that there is Program agreement with Cx and rescue operation(s), and the test and demonstration results in the Ground Systems ability to perform a rescue within 24 hours following a landing outside of the designated landing sites.

Rationale: NR

[CA5408V-PO] Failure tolerance for catastrophic hazards shall be verified by analysis. The analysis shall review the results of the element-level hazard analyses, FMEA/CILs, and the integrated architecture Hazard Analysis for failure tolerance compliance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled with the approved number of controls and all DFMR items are approved in the Hazard Reports per CxP 70038, Constellation Program Hazard Analyses Methodology.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

[CA5438V-PO] The requirement that the GS determine the need for a pad abort shall be satisfied by Analysis and Test.

a. Tests shall be performed using the flight assets and associated CxP elements (Ground Systems and Mission Systems) under actual flight conditions to validate simulation testing.

b. Abort Determination shall be verified with simulation tests. Simulation tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-792) Document(s). (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing).

The verification shall be considered successful when:

a. The Ground Systems performs the abort determination function(s) through an internal algorithm using internal or external data sources.

b. The CxP Architecture Systems receive notification from the Ground Systems of the need for an abort through the C3I infrastructure.

c. The profiles, boundaries, modes, variable ranges and accuracy specified in (TBD-001-792) Document(s) are verified.

Rationale: Testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle. The (TBD-001-792) documents refer to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

4.7.5.2.3 Reserved

4.7.5.2.4 Reserved

4.7.5.2.5 GS Mission Rates and Durations

[CA4121V-PO] Ground Systems to support operation of the Ares I no later than a 90 minute interval after the launch of Ares V shall be verified by analysis. The analysis shall be performed on the requirements for delivery of facility and facility systems and GSE used to perform launch capability. These facility, facility systems and GSE requirements will be identified and characterized in the CxP 72006, Ground Systems, Systems Requirements Document (SRD) . The verification shall be considered successful when the analysis shows that the CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that support operation of the Ares I no later than a 90 minute interval after the launch of Ares V have been satisfied per the design certification review.

Rationale: NR

[CA5690V-PO] The ability for the Ground Systems to provide a daily launch opportunity for not less than 7 consecutive days for Ares I missions shall be verified by inspection. The inspection shall consist of examining the allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) children requirement verification results and the Logistics Support Analysis. The verification shall be considered successful when the inspection of allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) children requirement verifications determines they are closed and the LSA shows that the Ground Systems can provide a daily launch opportunity for not less than 7 consecutive days for Ares I missions.

Rationale: The work performed at the child requirement level should be complete to verify the requirement.

[CA5702V-PO] The ability for the Ground Systems to provide a daily launch opportunity for not less than 4 consecutive days for Ares V missions shall be verified by inspection. The inspection shall consist of examining the allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) children requirement verification results and the Logistics Support Analysis. The verification shall be considered successful when the inspection of allocated CxP 72006, Ground Systems, Systems Requirements Document (SRD) children requirement verifications determines they are closed and the LSA shows that the Ground Systems can provide a daily launch opportunity for not less than 4 consecutive days for Ares V missions.

Rationale: Verification requirements will be satisfied by work at child requirement level, so an inspection of those results is sufficient. No additional work is needed at this level.

[CA6099V-PO] The ability of Ground Systems to launch and process four Ares I Integrated Stacks in a year shall be verified by analysis. Analysis shall assess:

a. The time required to integrate the flight systems into mission configurations, and

b. The availability of Constellation launch facilities. Verification shall be considered successful when analysis determines the scheduled usage of the launch facilities can accommodate scheduled flight rates.

Rationale: The capacity to perform the required mission rates depends upon the time required for the Ground Systems to integrate the different flight systems into the specified mission configuration and the availability of the required launch facilities (launch pad, mobile launcher, etc.). An analysis of the timeline considering all aspects involved with integrating the flight systems will determine the minimum amount of time to ready them for the mission. Additional availability analysis will assess the predicted reliability and maintainability of the launch facilities as well as an examination of their actual scheduled usage. The analysis should also include any reprocessing or refurbishment activities needed to prepare the launch facilities for the next mission.

[CA6253V-PO] The ability of Ground Systems to process and launch four Ares V/LSAM Integrated Stacks in a year shall be verified by analysis. Analysis shall assess:

a. The time required to integrate the flight systems into mission configurations

b. The availability of Constellation launch facilities.

Verification shall be considered successful when analysis determines the scheduled usage of the launch facilities can accommodate scheduled flight rates.

Rationale: The capacity to perform the required mission rates depends upon the time required for the Ground Systems to integrate the different flight systems into the specified mission configuration and the availability of the required launch facilities (launch pad, mobile launcher, etc.). An analysis of the timeline considering all aspects involved with integrating the flight systems will determine the minimum amount of time to ready them for the mission. Additional availability analysis will assess the predicted reliability and maintainability of the launch facilities as well as an examination of their actual scheduled usage. The analysis should also include any reprocessing or refurbishment activities needed to prepare the launch facilities for the next mission.

[CA6255V-PO] The ability of Ground Systems to launch on a 45 calendar day interval, measured from the launch of the first mission to the launch of the second mission shall be verified by analysis. The analysis shall the assess:

a. The time required to integrate the flight systems into mission configurations

b. The availability of Constellation launch facilities.

Verification shall be considered successful when analysis determines the scheduled usage of the launch facilities can accommodate scheduled flight rates within 45 calendar days

Rationale: The capacity to perform the required mission rates depends upon the time required for the Ground Systems to integrate the different flight systems into the specified mission configuration and the availability of the required launch facilities (launch pad, mobile launcher, etc.). An analysis of the timeline considering all aspects involved with integrating the flight systems will determine the minimum amount of time to ready them for the mission. Additional availability analysis will assess the predicted reliability and maintainability of the launch facilities as well as an examination of their actual scheduled usage. The analysis should also include any reprocessing or refurbishment activities needed to prepare the launch facilities for the next mission.

4.7.5.2.6 GS Architecture Definition

[CA0148V-PO] Ground Systems disposal of Earth-based ground and flight assets at the end of their useful life shall be verified by inspection and analysis. The analysis shall consist of a review of the disposal plans for hardware, software, records and other documentation including Configuration Management and Quality records. Analysis of disposal plans shall include at least transportation, storage and archives, abandon in place, re-allocation and re-use within the Agency, donation to outside organizations such as museums and educational institutions, demolition, implementation of government excess procedures, and other methods planned to disposition and dispose of the assets. The inspection shall consist of verifications that Configuration Control Board Directive (CCBD) actions are implemented and environmental and safety considerations are in compliance with environmental impact statements. The verification shall be considered successful when the analysis shows that plans incorporate all requirements for the disposition of the assets and required inspections are complete.

Rationale: NR

[CA0444V-PO] Ground Systems Earth weather services for pre-launch, launch, SRB recovery, Orion CM pad abort recovery, and post landing recovery activities shall be verified by analysis. The analysis shall consist of a review that the facility and facility systems and GSE that will be used to support the weather services are built and certified. These facility, facility systems and GSE requirements will be identified and characterized in CxP 72006, Ground Systems, Systems Requirements Document (SRD) . The verification shall be considered successful when the analysis shows that the systems are ready to support Earth weather service operations for the Constellation Architecture.

Rationale: NR

[CA0853V-PO] Ground Systems to receive flight systems and cargo shall be verified by analysis and demonstration. The analysis shall be performed on the requirements for delivery of facility, facility systems and GSE that will be used to support the receipt of flight systems and cargo. These facility, facility systems and GSE requirements will be identified and characterized in CxP 72006, Ground Systems, Systems Requirements

Document (SRD) . The demonstration shall be performed by lifting a dummy load of similar size, weight, center of gravity and of similar attach mechanism design of the flight systems/cargo containers and transporting them to a processing facility and then offloading the simulated flight systems/cargo containers. The verification for analysis shall be considered successful when the analysis shows that CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the performance offloading and transporting the flight elements and cargo to their respective processing facilities have been satisfied per the design certification review. The verification for demonstration shall be considered successful when the demonstration shows that the cranes, lifting slings, dollies, transportation vehicles and receiving structures, all validate receiving operations without exceeding any design or operations constraints or performance measures.

Rationale: NR

[CA0856V-PO] Ground Systems to de-integrate the recoverable flight systems shall be verified by analysis. The analysis shall be performed on the requirements to remove or disassemble equipment and prepare the flight system for delivery of a refurbishment facility. The analysis will also include the evaluation of facility systems and GSE used to de-integrate flight systems. These facility, facility systems and GSE requirements will be identified and characterized in CxP 72006, Ground Systems, Systems Requirements Document (SRD) . The verification shall be considered successful when the analysis shows that CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that support de-integration of flight systems have been satisfied per the critical design review.

Rationale: NR

4.7.5.2.7 GS Safety (System, Public, and Planetary)

[CA5406V-PO] Control of critical hazards shall be verified by analysis. The analysis shall review the results of the element-level hazard analyses, FMEA/CILs, and the integrated architecture Hazard Analysis to show compliance with the approved hazard controls. The verification shall be considered successful when the analysis shows that critical hazards are controlled and all DFMR items approved in the Constellation Hazard Reports per CxP 70038, Constellation Program Hazard Analyses Methodology.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

4.7.5.2.8 GS Command and Control

[CA3274V-PO] The generation of commands by the Ground Systems shall be verified by Test.

The Test shall use the operational Ground Systems hardware and software in simulated mission conditions.

Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice.

The applicable commands defined in (TBD-001-641) document(s) shall be generated by the Ground Systems. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be generated.

The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-641) document(s) are generated by the Ground Systems in each applicable mission phase, state and mode.

Rationale: A Test of the generation of Ground Systems commands defined by (TBD-001-641) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-641) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the commands for the Ground Systems.

4.7.5.2.9 GS Health and Status

[CA3130V-PO] The generation of health and status information by the Ground Systems shall be verified by Test. The Test shall use the operational Ground Systems hardware and software in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable health and status data defined in (TBD-001-718) document(s) shall be generated by the Ground Systems. (Exhaustive verification (tests) of each H&S parameter is not required since this will have been accomplished by lower level testing). The verification shall be considered successful when the Test shows that the health and status data identified in (TBD-001-718) document(s):

a. Health and Status is generated by the Ground Systems in each applicable mission phase, state and mode.

b. Health and Status agrees with the actual health and status of the Ground Systems.

Rationale: A Test of the generation of Ground Systems Health and Status data defined by (TBD-001-718) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-718) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the health and status parameters for the Ground Systems.

[CA5478V-PO] The provision of fault detection by the Ground Systems shall be verified by Test. The Test shall use the operational Ground Systems hardware and software in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-465) document(s) for applicable simulated mission phases, states, and modes for the Ground Systems at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-465) document(s) are detected by the Ground Systems in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the Ground Systems for the faults and fault scenarios identified by (TBD-001-465) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The(TBD-001-465) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be detected.

[CA5479V-PO] The provision of fault isolation by the Ground Systems shall be verified by Test. The Test shall use the operational Ground Systems hardware and software in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-466) document(s) for applicable simulated mission phases, states, and modes for the Ground Systems at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-466) document(s) are isolated by the Ground Systems in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the Ground Systems for the faults and fault scenarios identified by (TBD-001-466) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-466) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be isolated.

[CA5480V-PO] The provision of fault recovery by the Ground Systems shall be verified by Test. The Test shall use the operational Ground Systems hardware and software in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-467) document(s) for applicable simulated mission phases, states, and modes for the Ground Systems at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-467) document(s) are recovered from by the Ground Systems in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the Ground Systems for the faults and fault scenarios identified by (TBD-001-467) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-467) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be recovered from.

4.7.5.2.10 GS Communications and Communications Security

[CA5051V-PO] Ground Systems shall record System-generated digital data received from other Constellation Systems. The recording of System-generated digital data received from other Constellation Systems shall be verified by Demonstration.

The demonstration shall be conducted in SIL (or equivalent) using flight or similar assets. Test objectives shall be prepared using IRDs and SRDs to identify source systems for data recording and the data content to be recorded. The source system may be simulated but should be certified. The source data shall be transmitted for no less than 4 hours or for an entire mission phase, if shorter, at least twice.

The verification shall be considered successful when the Demonstration shows:

a. Source data is received for an entire mission phase or at least 4 hours.

b. Demonstration is performed twice.

c. All received data is recorded.

d. An audit of the recorded data shows it to be correct.

Rationale: Recording of System-generated digital is critical to support development, test, operation, and maintenance of systems. To confirm interoperability and functionality demonstrations are performed.

[CA5907V-PO] The GS capability to execute reconfigurable automated sequences shall be verified by demonstration. The demonstration shall use the operational GS hardware and software in simulated mission conditions. The command sequences identified in (TBD-001-999) documents shall be received by GS. (Exhaustive verification of each automation sequence is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that:

a. The reconfigurable automated sequences have been successfully received and the reconfiguration product generated.

b. The reconfigurable automated sequences contain data and commands valid for use by other Constellation Systems.

c. All reconfigurable automated sequences are within expected ranges.

Rationale: A demonstration of MS capability to generate reconfigurable automation sequences is sufficient to verify this capability. The (TBD-001-999) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the reconfigurable automated sequences for each Constellation System.

[CA5908V-PO] The ability of the Ground System to communicate simultaneously with Mission Systems and four other Constellation flight systems during ISS phase operations, shall be verified by analysis and test.

Analysis of the mission phases and data links shall be performed. The analysis shall include nominal and off-nominal scenarios for each phase. Simulations of the communications for nominal and off-nominal operations, including pre-launch communication activities and all other planned mission phases shall be conducted and repeated as needed for nominal and maximum data rates. Testing shall be conducted using four flight, flight-like systems, or simulated systems over simulated nominal, including simulated noise, space links with bidirectional data flowing simultaneously at specified nominal and maximum data rates between Ground System and all of the four systems. Testing shall similarly be conducted for each known flight or pre-flight configuration including those with hard-line, networked, or RF data links.

The verification shall be considered successful when:

a. Testing shows the Ground System can, in every case, simultaneously exchange data with:

   1. Four generic simulated Constellation flight elements

   2. All tested pre-launch and launch operations configurations. All data must be received correctly and without apparent degradation for both nominal and maximum data rates for each scenario.

b. Analysis shows that hard-line, networked, and RF data links, (including forward and reverse margins,) provide necessary bandwidth to support communication during nominal and off-nominal Ares I launch operations

c. All results from the series of test are consistent.

Rationale: We are interested first in the simultaneous communicating across and among interfaces during each of the phases. Communicating with four generic systems will test the simultaneous nature of the transmissions. Analysis is used to verify that RF communication links will remain operational during all expected mission scenarios and environmental conditions. Testing all configurations will add the complexity of going across various interfaces simultaneously. Testing is also used to load the system to stress levels. Test results must be repeatable and consistent. There may be phases without four other elements available, so we will test for up to four. Some phases may utilize different interfaces (e.g. hard-line, or RF links) so each configuration expected will be tested. Communications could be through an umbilical at the launch pad, RF via the Communications and Tracking Network, or through the IP network (NASA Integrated Services Network [NISN]).

[CA6064V-PO] The ability of the Ground System to communicate simultaneously with Mission Systems and six other Constellation flight systems during lunar phase operations shall be verified by analysis and test. Analysis of the mission phases and data links shall be performed. The analysis shall include nominal and off-nominal scenarios for each phase. Simulations of the communications for nominal and off-nominal operations, including pre-launch communication activities and all other planned mission phases shall be conducted and repeated as needed for nominal and maximum data rates. Testing shall be conducted using six flight, flight-like systems, or simulated systems over simulated nominal, including simulated noise, space links with bidirectional data flowing simultaneously at specified nominal and maximum data rates between Ground System and all of the six systems. Testing shall similarly be conducted for each known flight or pre-flight configuration including those with hardline, networked, or RF data links. The verification shall be considered successful when:

a. Testing shows the Ground System can, in every case, simultaneously exchange data with:

   1. Six generic simulated Constellation flight elements.

   2. All tested pre-launch and launch operations configurations.

   All data must be received correctly and without apparent degradation for both nominal and maximum data rates for each scenario.

b. Analysis shows that hardline, networked, and RF data links, (including forward and reverse margins,) provide necessary bandwidth to support communication during nominal and off-nominal Ares I and Ares V launch operations.

c. All results from the series of test are consistent.

Rationale: We are interested first in the simultaneous communicating across and among interfaces during each of the phases. Communicating with six generic systems will test the simultaneous nature of the transmissions. Analysis is used to verify that RF communication links will remain operational during all expected mission scenarios and environmental conditions. Testing all configurations will add the complexity of going across various interfaces simultaneously. Testing is also used to load the system to stress levels. Test results must be repeatable and consistent. There may be phases without six other elements available, so we will test for up to six. Some phases may utilize different interfaces (e.g., hardline, or RF links) so each configuration expected will be tested. Communications could be through an umbilical at the launch pad, RF via the Communications and Tracking Network, or through the IP network (NASA Integrated Services Network [NISN]).

[CA6211V-PO] The processing by GS of received range safety telemetry and transfer to the Range within 120 msec (TBR-001-1450) during the launch/ascent phase shall be verified by test.

The test shall be performed using operational equivalent units or emulators with Operational Software in simulated mission conditions. The Range may be simulated. The latency in the actual link between GS and the Range must be accounted for in the test (transfer to Range). The test shall time stamp the range safety telemetry upon receipt at the GS, and again after processing at the point of transmission to the Range (exiting GS), and finally upon receipt at the Range. The test shall be performed on selected points during the flight timeline that cover the full range from launch through ascent. The time stamps shall be analyzed for compliance to the requirement within 95% confidence level. Recording of telemetry entrance and exit times with a packet analyzer or other measurement equipment can be used in place of time stamps.

The verification shall be considered successful when the analysis of the data collected by the test shows that the total time to process and transfer the telemetry is within the time specified for all points on the flight timeline.

Rationale: Testing system performance under mission-like conditions is a reasonable way to confirm that they are individually meeting their allocations. 95% confidence could be met with 20 points along the flight timeline where only 1 point does not meet the requirement. A packet analyzer may provide more time resolution and accuracy than time stamps, so is allowed as an option.

4.7.5.2.11 Reserved

4.7.5.2.12 GS Reliability and Availability

[CA3064V-PO] The ability of the Ground Systems to meet a probability of crewed launch of no less than 99 (TBR-001-1412)% during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt, shall be verified by analysis. The verification analysis shall use only R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when analysis shows that the probability of launch on the initial attempt is not less than 99 (TBR-001-1412)%, with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004).

Rationale: Ground Systems will be responsible for verifying that all fixed and variable resources needed to support during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt will be available and ready.

[CA6101V-PO] Provision of adequate consumables to support consecutive launch attempts shall be verified by inspection and analysis. An analysis shall be performed to determine the quantity of consumables required to support 6 (TBR-001-1302) hours per each of (TBR-001-1402) launch attempts. An inspection shall be performed to confirm the required consumables are provided by Ground Systems at the launch pad. The verification shall be considered successful when the analysis and inspection confirm that adequate consumable resources are provided by ground systems to support the launch attempts as specified.

Rationale: This requirement defines the amount of consumables that is required to be supplied by Ground Systems to support the crew for each launch attempt not covered by Orion onboard consumables.

[CA6204V-PO] The ability to remedy Ground System failures with a likelihood of occurrence greater than (TBD-001-1501)% that would result in a scrubbed launch shall be verified by analysis. The analysis shall assess the Ground System FMEA, maintenance plan, LSA, and FDIR capabilities to determine the likelihood of occurrence of failures and the percentage of failures that can be remedied within 1 day, 2 days, and

3 days. The verification analysis shall use only Cx R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when the analysis determines, with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004) that:

a. No less than 60% (TBR-001-1416) can be remedied to support a launch attempt within one day.

b. No less than 70% (TBR-001-1417) can be remedied to support a launch attempt within two days.

c. No less than 80% (TBR-001-1418) can be remedied to support a launch attempt within three days.

Rationale: NR

[CA6208V-PO] The ability of the Ground Systems to meet a probability of cargo launch of no less than (TBD-001-1505)% during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt. The verification analysis shall use only R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when analysis shows that the probability of launch on the initial attempt is not less than (TBD-001-1505)%, with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004).

Rationale: NR

[CA6209V-PO] The ability to remedy the required percentage of Ground System failures identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1506)% that would result in a scrubbed cargo launch within the required time limit, shall be verified by analysis. The analysis shall assess the Ground System FMEA, maintenance plan, LSA, and FDIR capabilities to determine the likelihood of occurrence of failures and the percentage of failures that can be remedied within 1 day, 2 days, and 3 days. The verification analysis shall use only Cx R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when the analysis determines, with an uncertainty of not greater than (TBD-001-927)% (TDS# SIG-01-004) that:

a. No less than 60% (TBR) can be remedied to support a launch attempt within one day.

b. No less than 70% (TBR) can be remedied to support a launch attempt within two days.

c. No less than 80% (TBR) can be remedied to support a launch attempt within three days.

Rationale: The verification analysis requirement is intended to drive a determination of the ability to remedy those failures that are most likely to be identified during the countdown when systems are activated, serviced, and operated. The analysis should sort the set of the most likely failures into those items that can be remedied one day, two days, three days, or more time. Since no location constraint is composed (e.g. nobody said the failure had to be remedied at the pad), a remedy scenario that rolls back, repairs, rolls out to pad, and supports a launch attempt within the time frame is allowed for this sorting. The analysis should consider that the likelihood of a latent defect being present but undetected at the time of a decision to proceed past a given milestone is a variable influenced by the perceptiveness of testing and operations performed before that milestone.

4.7.5.2.13 GS Maintainability, Supportability, and Logistics

[CA5712V-PO] Ground Systems to provide refurbishment of the reusable elements of the Ares V shall be verified by analysis. The analysis shall be performed on the requirements for delivery of facility and facility systems and GSE used to support refurbishment of flight elements identified and characterized in the CxP 72006, Ground Systems, Systems Requirements Document (SRD)). The analysis shall compare the Ares V refurbishable elements design to the GS design for compatibility. The verification shall be considered successful when the analysis shows that the CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that support refurbishment of the reusable elements of the Ares V have been satisfied per the design certification review.

Rationale: NR

[CA5803V-PO] The ability of the reusable elements of the Ares I to be refurbished by Ground System shall be verified by analysis. The analysis shall be performed on the requirements for the flight elements to refurbished in the facility and facility systems and GSE provided by the Ground System, used to support refurbishment of flight elements identified and characterized in the CxP 72006, Ground Systems, System Requirements Document (SRD). The analysis shall compare the Ares I refurbishable elements design to the GS design for compatibility. The verification shall be considered successful when the analysis shows that the CxP 72006, Ground Systems, System Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that support refurbishment of the reusable elements of the Ares I have been satisfied per the design certification review.

Rationale: NR

[CA5934V-PO] The ability of the Ground Systems to provide the infrastructure to maintain systems through their operational life cycles shall be verified by inspection and analysis. Inspection shall determine that each individual system of the Grounds Systems has closed their respective infrastructure requirement in support of operational life cycles. Analysis shall include a compilation of metrics that include inventory fill rates, repair turnaround times, and delays in task completion caused by parts/logistics and shall be performed in accordance with the CxP 70064, Constellation Program Supportability Plan. The verification shall be considered successful when the inspection determines each system has successfully closed its respective infrastructure requirement and the analysis shows that the Ground Systems provides the infrastructure to maintain systems through their operational life cycles.

[CA5990V-PO] The ability of the GS to generate Project Verified Engineering Builds after the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars) shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5991V-PO] The ability of the GS to generate Project Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5992V-PO] The ability of the GS project to generate day of launch updates shall be verified by demonstration. Demonstration shall be considered successful when day of launch updates have been successfully generated and applied during project verification and validation activities.

Rationale: The intent is to demonstrate that the day of launch update process can be successfully executed.

[CA5993V-PO] The ability of the GS to provide fixes for selected non-conformances to the discovering organization shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when inspection determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA6005V-PO] The ability of the GS to conduct ground operations within the constraints levied in GS Critical Path Allocations for Ares I/Orion Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6005 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will be then updated.

Rationale: NR

[CA6010V-PO] The ability of the GS to conduct ground operations within the constraints levied in GS Critical Path Allocations for Ares V/LSAM Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6010 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will be then updated.

Rationale: NR

4.7.5.2.14 Reserved

4.7.5.2.15 GS Environmental Conditions

[CA3018V-PO] The protection from direct attachment of lightning channels to the flight vehicle while on the ground shall be verified by test and analysis. The verification is considered successful when the test and analysis results show that Constellation systems are protected from direct lightning attachment during Ground Operations, shipping and transportation, refurbishment, and/or other related operations.

Rationale: NR

[CA5112V-PO] The Ground Systems capability to launch the Flight Systems independent of ambient lighting conditions shall be verified by demonstration and analysis. The demonstration shall consist of the facility, facility systems and GSE providing launch operations independent of lighting conditions. The analysis shall consist of a review that the facility, facility systems and GSE that will be used to launch Flight Systems within any ambient lighting conditions are built and certified. These facilities, Flight Systems and GSE requirements will be identified and characterized in CxP 72006, Ground Systems, Systems Requirements Document (SRD) . The verification shall be considered successful when the analysis and demonstration show that the Ground Systems are ready to support Flight Systems launch independent of ambient lighting conditions.

Rationale: NR

[CA5360V-PO] Compliance of the GS with its functional and performance requirements during and after exposure to CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) environments shall be verified by inspection and analysis. The inspection shall consist of review of the following:

a. Allocation of the natural environments requirements to the lower tier systems and their verification methods and details

b. The lower tier verification closure data

The analysis shall address interactions of each lower tier system on other systems to include integrated environment effects. The verification shall be considered successful when the inspection and integrated analysis show:

a. The natural environment requirements and verification have been allocated to the lower tier systems in accordance Section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE).

b. Lower tier verifications have been completed.

c. The GS meets its functional and performance requirements during and after exposure to CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) environments.

Rationale: Verification of functional and performance requirements across the range of natural environments require a systematic integrated approach to address dependencies on hardware configurations and operational mode. CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) Section 4 specifies a standard systems engineering technique for flowing down the natural environment from higher to lower levels for each mission phase. Lower tier verification close out data, analyses, and models are necessary to support the integrated analysis, but are not sufficient alone to close out the environment requirements from the integrated vehicle configuration.

[CA5931V-PO] GS function and performance during and after exposure to the combined natural and induced environments shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the GS/System IRD requirements.

b. Review of the induced environment verifications submitted against CxP 72006, Ground Systems, Systems Requirements Document (SRD) requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification. The verification shall be considered successful when the analysis shows that the GS function and performance requirements are met during and after exposure to CxP 70143, Constellation Program Induced Environment Design Specification combined natural and induced environments for each DRM.

Rationale: Function and performance must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification, including assurance that:

a. The proper combined natural and induced environments have been considered.

b. Sensitivities to these environments.

c. Synergistic effects have each been properly addressed for all mission phases.

[CA5932V-PO] GS induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the GS/System IRD requirements.

b. Review of the induced environment verifications submitted against CxP 72006, Ground Systems, Systems Requirements Document (SRD)) requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification. The verification shall be considered successful when the analysis shows that the GS peak and cumulative induced environments will not exceed CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.

Rationale: Induced environment contributions must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that:

a. The proper induced environments have been met.

b. Sensitivities to these environments.

c. Synergistic effects have each been properly addressed for all mission phases.

[CA6071V-PO] The lightning monitoring and recording shall be verified by test. The verification is considered successful when the test results show that Ground systems will monitor and record lightning direct and indirect effects that could result in catastrophic or hazardous failures from direct lightning attachment, and that this monitoring is provided during Ground Operations, shipping and transportation, refurbishment, and/or other related operations.

Rationale: NR

4.7.5.3 Reserved

4.7.5.4 GS External Interfaces

[CA0910V-PO] The GS interfaces with Orion shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the GS Project Office to demonstrate that the Orion-to-GS interface requirements defined within CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion avionics and software and the Ground Systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the Ground Systems to confirm interoperability and functionality between Orion and Ground Systems. Verification shall be considered successful when:

a. Analysis confirms that all of the GS interface verification requirements defined within CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the GS Project Office to confirm that all of the GS-to-Orion interface requirements specified in the IRD have been satisfied. Integrated testing between the Orion avionics and software and the GS via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating Ground Systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0911V-PO] The GS interfaces with the Ares I shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the GS Project Office to demonstrate that the GS-to-Ares I interface requirements defined within CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares I avionics and software and the Ground Systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the Ground Systems to confirm interoperability and functionality between the Ares I and Ground Systems. Verification shall be considered successful when:

a. Analysis confirms that all of the GS interface verification requirements defined within CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the GS Project Office to confirm that all of the GS-to-Ares I interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares I avionics and software and the GS via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating GS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0912V-PO] The GS interfaces with the LSAM shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the LSAM Project Office to demonstrate that the GS-to-LSAM interface requirements defined within CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -to- Ground Systems Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM avionics and software and the Ground Systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the Ground Systems to confirm interoperability and functionality between the LSAM and Ground Systems. Verification shall be considered successful when:

a. Analysis confirms that all of the GS interface verification requirements defined within CxP 70106, Constellation Program Lunar Surface Access Module (LSAM) -to- Ground Systems Interface Requirements Document (IRD) , have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the LSAM Project Office to confirm that all of the LSAM-to-GS interface requirements specified in the IRD have been satisfied. Integrated testing between the LSAM avionics and software and the Ground Systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating Ground Systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational *mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.*

Draft **[CA0913V-PO]** The GS interfaces with the Ares V shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the Ares Project Office to demonstrate that the GS-to-Ares V interface requirements defined within CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) -to- Ground Systems Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares V avionics and software and the GS systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the GS systems to confirm interoperability and functionality between the Ares and GS systems. Verification shall be considered successful when:

a. Analysis confirms that all of the GS interface verification requirements defined within CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) -to- Ground Systems Interface Requirements Document (IRD) , have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the GS Project Office to confirm that all of the GS-to-Ares V interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares V avionics and software and the GS systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating GS systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0914V-PO] The GS interfaces with MS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the GS Project Office to demonstrate that the GS-to-MS interface requirements defined within CxP 70054, Constellation Program Mission Systems (MS) -to- Ground Systems (GS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Multi-system testing performed at the launch site for flight systems shall also incorporate the MS and GS systems to confirm interoperability and functionality between the GS and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the GS interface verification requirements defined within CxP 70054, Constellation Program Mission Systems (MS) -to- Ground Systems (GS) Interface Requirements Document (IRD) , have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the GS Project Office to confirm that all of the GS-to-MS interface requirements specified in the IRD have been satisfied. Integrating GS and MS systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes.

[CA0915V-PO] The GS interfaces with the EVA systems shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the GS Project Office to demonstrate that the GS-to-EVA interface requirements defined within CxP 70104, Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Multi-system testing performed at the launch site for flight systems shall also incorporate the EVA systems to confirm interoperability and functionality between the GS and EVA systems. Verification shall be considered successful when:

a. Analysis confirms that all of the GS interface verification requirements defined within CxP 70104, Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the GS Project Office to confirm that all of the GS-to-EVA interface requirements specified in the IRD have been satisfied. Integrating EVA systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes.

[CA0916V-PO] The GS interfaces with the Communications and Tracking Networks shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the GS Project Office to demonstrate that the GS interface requirements defined within the CxP 70118-05, Constellation Program Systems to Communications and Tracking Network Interface Requirements Document, Volume 5:

Ground Systems (GS) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Multi-system testing performed at the launch site for flight systems shall also incorporate the communications and tracking network systems to confirm interoperability and functionality between the GS and communications and tracking network systems. Verification shall be considered successful when:

a. Analysis confirms that all of the GS interface verification requirements defined within CxP 70118-05, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document, Volume 5: Ground Systems (GS) , have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the GS Project Office to confirm that all of the GS-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrating the communication and network systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

4.7.5.5 Reserved

4.7.6 Mission Systems (MS)

4.7.6.1 MS Description

4.7.6.2 MS Requirements

[CA0139V-PO] The training system and process shall be verified by analysis and test. The testing shall consist of simulations which exercise mission classes (e.g., ISS, Lunar Sortie, Lunar Outpost) designed to meet training objectives. The analysis shall consist of a review of the preliminary generic and flight specific crew and ground personnel training curriculum, certification plans and generic training certification process documentation. Additional analysis shall include review of the documentation that the simulators are built and certified to satisfy the Element requirements for each of those systems. The verification shall be considered successful when testing and analysis show that the training systems and process meet Constellation missions class objectives for flight crew, mission controllers, mission planners, and instructors involved in the operation of Constellation missions.

Rationale: NR

[CA0152V-PO] The Earth-based flight operations for the Constellation systems shall be verified by analysis and test. The testing shall consist of an End-to-End data flow that exercises the functionalities required for successful mission operations. The analysis shall consist of a review that the as-built simulators and Mission Control Center Systems satisfy the Level IV requirements for that system. The verification shall be considered successful when testing and analysis show that the control systems are ready to support Earth-based flight operations for the Constellation systems.

Rationale: NR

[CA0293V-PO] The integrated mission planning and analysis and execution product development shall be verified by analysis and test. The analysis shall consist of a review that the mission planning and analysis tools and facilities (e.g. Planning system, flight design analysis, procedure development tool, procedure and timeline viewer tools and procedures production and fabrication facility) satisfy the Level IV requirements for each of those systems. The testing shall consist of an End-to-End data flow that exercises major functionalities of the tools and facilities used to perform mission analysis and to develop and view execution products. The verification shall be considered successful when analysis shows that the planning and analysis tools and facilities satisfy the Element requirements and the test shows that the tools and facilities are ready to support mission analysis and execution product development and viewing.

Rationale: NR

[CA5669V-PO] The capability of the Mission System to generate contingency Earth return analysis, plans and procedures shall be verified by analysis. The analysis shall confirm that all the steps required by CxP 70076, Constellation Program Modeling and Simulation Management Requirements - Level II, to achieve a NASA-accredited tool for developing and generating analysis, plans and procedures have been performed. The verification shall be considered successful when the analysis confirms that Mission Systems which has the capability to generate contingency Earth return analysis, plans and procedures has been accredited per CxP 70076, Constellation Program Modeling and Simulation Management Requirements - Level II.

Rationale: Analysis of the various lower-level analysis requirements results is sufficient for verifying this requirement.

4.7.6.2.1 MS Mission Success

Draft **[CA3027V-PO]** Lunar Outpost Cargo LOM due to the Mission Systems shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Outpost Cargo mission due to Mission Systems is not greater than 1 in (TBD-001-527).

Rationale: NR

Draft **[CA3030V-PO]** Lunar Outpost Crew LOM due to the Mission Systems shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Outpost Crew mission due to Mission Systems is not greater than 1 in (TBD-001-536).

Rationale: NR

4.7.6.2.2 MS Crew Survival

[CA0163V-PO] Mission Systems landing footprint location services for Orion shall be verified by test and analysis. The analysis shall be accomplished using a NASA-accredited dynamic simulation of the Constellation Architecture systems. The dynamic simulation and analysis shall verify the accuracy of the landing footprint location by taking error data from component level navigation sensor testing and processing this data with a dynamic model of Orion during Earth descent and landing. The tests shall be accomplished in a test facility that can accurately simulate the interfaces to the Constellation Architecture systems. The test facility shall verify the accuracy of the landing footprint location by taking simulated data, such as from tracking stations or onboard navigation sensor measurements, and processing this data with trajectory planning and maneuver targeting algorithms to be used during flight. In addition, estimation of vehicle landing footprint in the absence of tracking data or in the presence of suboptimal vehicle control performance will also be verified. The system will include actual flight hardware and MS ground hardware in the loop, where appropriate, in terms of cost and availability. The verification shall be considered successful when the tests and analysis have shown that the performance criteria on Orion landing footprint location, as specified in the CxP 70117, Constellation Program System Requirements for the Mission Systems (MS) Element, has been met within 20 minutes after the declaration of an entry contingency.

Rationale: NR

Draft **[CA3035V-PO]** Lunar Outpost Crew LOC due to Mission Systems shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOC for a Lunar Outpost Crew mission due to Mission Systems is not greater than 1 in (TBD-001-552).

Rationale: NR

[CA5437V-PO] The requirement that the MS determine the need for an abort shall be verified by Test.

a. Tests shall be performed using the flight assets and associated CxP elements (Ground Systems and Mission Systems) under actual flight conditions to validate simulation testing.

b. Abort Determination shall be verified with simulation tests. Simulation tests shall be performed for all nominal and off-nominal profiles, all possible boundaries, modes, variable ranges and accuracy identified in (TBD-001-789) Document(s). (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing)

The verification shall be considered successful when:

a. The Mission Systems performs the abort determination function(s) through an internal algorithm using internal or external data sources.

b. The CxP Architecture Systems receive notification from the Mission Systems of the need for an abort through the C3I infrastructure.

c. All possible profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-789) Document(s).

Rationale: Testing this function provides the best end-to-end verification for this requirement. Simulation testing is necessary because it is not feasible to flight test all of the possible conditions anticipated in the CxP life cycle. The (TBD-001-789) documents refers to the body of engineering source data (i.e. SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process. The source data will contain the agreed upon parameters which are presently undefined.

4.7.6.2.3 MS Crew Size

[CA5128V-PO] Training for four member crews (each for prime and backup) per Lunar Sortie mission shall be verified by analysis. The analysis shall consist of a formal review that the training curriculum, as-built simulators, training systems (Part Task Trainers [PTTs], Mock-ups, etc.), facilities and Mission Control Center Systems satisfy the requirements to train four member crews (each for prime and backup) for Lunar Sortie missions. The verification shall be considered successful when analysis show that the training curriculum, as-built simulators, training systems (PTTs, Mock-ups, etc.), facilities and Mission Control Center Systems meet Lunar Sortie mission related training objectives for four member crews (each for prime and backup).

Rationale: NR

[CA5129V-PO] Training for six member crews (each for prime and backup) per ISS mission shall be verified by analysis. The analysis shall consist of a formal review that the training curriculum, as-built simulators, training systems (PTTs, Mock-ups, etc.), facilities and Mission Control Center Systems satisfy the requirements to train six member crews (each for prime and backup) for ISS missions. The verification shall be considered successful when the analysis shows that the training curriculum, as-built simulators, training systems (PTTs, Mock-ups, etc.), facilities and Mission Control Center Systems meet ISS missions related training objectives for six member crews (each for prime and backup).

Rationale: NR

4.7.6.2.4 Reserved

4.7.6.2.5 MS Mission Rates and Duration

[CA6157V-PO] The ability of the Mission Systems to provide the capacity to perform ISS and Lunar Missions of up to two ISS and two Lunar Missions in a year shall be verified by analysis. Analysis shall assess the availability of Constellation mission control facilities. Verification shall be considered successful when analysis determines the scheduled usage of the mission control facilities can accommodate scheduled flight rates.

Rationale: The capacity to perform the required mission rates depends upon the availability of the required mission control facilities. An availability analysis will assess the predicted reliability and maintainability of the mission control facilities as well as an examination of their actual scheduled usage. The analysis should also include any reprocessing or refurbishment activities needed to prepare the mission control facilities for the next mission.

[CA6160V-PO] The ability of the Mission Systems to provide the capacity to support launches on a 45 calendar day interval, measured from the first launch of the first mission to the first launch of the second mission shall be verified by analysis. Analysis shall assess:

a. The time required to prepare for missions

b. The availability of Constellation mission control facilities.

Verification shall be considered successful when analysis determines the scheduled usage of the mission control facilities can accommodate scheduled flight rates.

Rationale: The capacity to perform the required mission rates depends upon the availability of the required mission control facilities. An availability analysis will assess the predicted reliability and maintainability of the mission control facilities as well as an examination of their actual scheduled usage. The analysis should also include any reprocessing or refurbishment activities needed to prepare the mission control facilities for the next mission.

4.7.6.2.6 MS Architecture Definition

[CA0883V-PO] Earth weather services for post-launch and landing activities for all Constellation Architecture elements shall be verified by analysis. The analysis shall consist of a review that the MS facility and facility systems used to generate the weather services are built, operational, and certified. The verification shall be considered successful when the analysis shows that all of the MS facility and facility systems are ready to support Earth weather services operations for post-launch and landing activities for all Constellation Architecture elements.

Rationale: NR

[CA5125V-PO] Space weather services for all mission phases for all flight systems shall be verified by inspection. The inspection shall consist of a review of documentation provided by MS showing closure of MOU (TBD-001-409) with National Oceanic and Atmospheric Administration (NOAA) providing space weather services and the MS facility and facility systems used to generate the weather services are built and certified. The verification shall be considered successful when the inspection shows closure that there is an agreement with Constellation Program and NOAA on the fulfillment of the MOU and that all of the MS facility and facility systems are ready to support space weather services operations during all mission phases for all flight systems.

Rationale: NR

4.7.6.2.7 MS Safety

[CA5405V-PO] The control for critical hazard shall be verified by analysis. The analysis shall review the Mission Systems System Hazard Analysis . The verification shall be considered successful when the analysis shows that critical hazards are controlled per CxP 70038, Constellation Program Hazard Analysis Methodology.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

[CA5407V-PO] Failure tolerance for catastrophic hazards shall be verified by analysis. An Integrated hazard analysis shall be performed, using system-level hazard analyses and FMEA to show compliance with the approved level of failure tolerance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled with the approved number of controls and all DFMR items are approved in the Hazard Reports.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

4.7.6.2.8 MS Command and Control

[CA3273V-PO] The generation of commands by the Mission Systems shall be verified by Test. The Test shall use the operational Mission Systems hardware and software in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-746) document(s) shall be generated by the Mission Systems. (Exhaustive verification [test] of each command is not required since this will have been accomplished by lower level testing.) Each safety critical command shall be generated. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-746) document(s) are generated by the Mission Systems in each applicable mission phase, state and mode.

Rationale: A Test of the generation of Mission Systems commands defined by (TBD-001-746) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-746) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the commands for the Mission Systems.

[CA3285V-PO] Concurrently monitoring and controlling in-space vehicles per the 6 test cases listed in CxP ISS Concurrent Operations – ISS Crew Rotation Missions Table shall be verified by test. The testing shall consist of an End-to-End data flow that exercises command, health and status monitoring, file transfers, voice and video services of concurrent mission operations using flight equivalent units or emulators with Flight Software or simulated flight vehicles in simulated mission conditions. Scenarios that are described in the table shall be exercised for both nominal and off-nominal conditions. The verification shall be considered successful when test shows that the Mission Operations is ready to concurrently monitor and control in-space vehicles per the 6 test cases in CxP ISS Concurrent Operations – ISS Crew Rotation Missions Table.

Rationale: While all interface standards (C3I, etc.) have already been verified, this test ensures that multiple vehicles can be operated concurrently per normal and contingency flight conditions and in different appropriate mission phases. Scenarios shall reasonably exercise the system capability of the specified system. For traffic testing, the system under test may be loaded with C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate in order to stress test the system data transmission and receipt capabilities ("Busy hour scenario"). All data types (video, voice, cmd, tlm) supported by the system shall be tested. Tests should use the systems expected on orbit with simulated anticipated transmission latency and noise levels.

[CA6200V-PO] Concurrently monitoring and controlling in-space vehicles per the 8 test cases in CxP Lunar Sortie Concurrent Operations Table shall be verified by test. The testing shall consist of an end-to-end data flow that exercises command, health and status monitoring, file transfers, voice and video services of concurrent mission operations using flight equivalent units or emulators with Flight Software in simulated mission conditions. Scenarios that are described in the table shall be exercised for both nominal and off-nominal conditions. The verification shall be considered successful when test shows that the Mission Operations is ready to concurrently monitor and control in-space vehicles per the 8 test cases in CxP Lunar Sortie Concurrent Operations Table.

Rationale: Scenarios shall reasonably exercise the system capability of the specified system. For traffic testing, the system under test may be loaded with C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate in order to stress test the system data transmission and receipt capabilities ("Busy hour scenario"). All data types (video, voice, cmd, tlm) supported by the system shall be tested. Tests should use the systems expected on orbit with simulated anticipated transmission latency and noise levels.

[CA6201V-PO] Concurrently monitoring and controlling multiple in-space vehicles per the 12 test cases listed in the CxP Lunar Outpost Concurrent Operations Table shall be performed by test. The testing shall consist of an end-to-end data flow that exercises command, health and status monitoring, file transfers, voice and video services of concurrent mission operations using flight equivalent units or emulators with Flight Software in simulated mission conditions. Scenarios that are described in the table shall be exercised for both nominal and off-nominal conditions. The verification shall be considered successful when the test shows that the Mission Operations is ready to concurrently monitor and control in-space vehicles per the 12 test cases listed in the CxP Lunar Outpost Concurrent Operations Table.

Rationale: Scenarios shall reasonably exercise the system capability of the specified system. For traffic testing, the system under test may be loaded with C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate in order to stress test the system data transmission and receipt capabilities ("Busy hour scenario"). All data types (video, voice, cmd, tlm) supported by the system shall be tested. Tests should use the systems expected on orbit with simulated anticipated transmission latency and noise levels.

[CA6215V-PO] The processing by MS of received range safety telemetry within 350 msec (TBR-001-1147) during the launch/ascent phase shall be verified by test.

The test shall be performed using operational equivalent units or emulators with Operational Software in simulated mission conditions. The end-to-end tests shall time stamp the range safety telemetry upon receipt at the MS, and again after processing at the point of transmission (exiting MS). The test shall be performed on selected points during the flight timeline that cover the full range from launch through ascent. The time stamps shall be analyzed for compliance to the requirement within 95% confidence level. Recording of telemetry entrance and exit times with a packet analyzer or other measurement equipment can be used in place of time stamps.

The verification shall be considered successful when the analysis of the data collected by the test shows that the total time to process the telemetry is within the time specified for all points on the flight timeline.

Rationale: Testing system performance under mission-like conditions is a reasonable way to confirm that they are individually meeting their allocations. 95% confidence could be met with 20 points along the flight timeline where only 1 point does not meet the requirement. A packet analyzer may provide more time resolution and accuracy than time stamps, so is allowed as an option.

[CA6216V-PO] The MS processing of voice within 350 msec (TBR-001-1447) during the launch/ascent phase shall be verified by test.

The test shall be performed using operational equivalent units or emulators with Operational Software in simulated mission conditions. The external system and communication links may be simulated. The external system shall exchange voice data with MS for both nominal and dissimilar voice systems. Voice data shall be time stamped, measured, or recorded with a packet analyzer at the end points of the system. The end points for the test shall be defined as:

a. Voice entering or exiting MS

b. MS interface to voice creation or reproduction locations (e.g. microphones and speakers)

A representative of each type of path for voice shall be tested. The test shall be repeated for applicable modes and states where voice is exchanged, if applicable. The time measurements or time stamps shall be analyzed for compliance to the requirement.

The verification of MS processing voice for the launch/ascent phase shall be considered successful when the analysis of the data collected by the test shows that:

a. The total time to process voice is within the time specified

b. Both nominal and dissimilar voice is tested

c. Each voice path type is tested

Rationale: Testing system performance under mission-like conditions is a reasonable way to confirm that they are individually meeting their allocations. A packet analyzer may provide more time resolution and accuracy than time stamps, so is allowed as an option. The requirement does NOT stipulate voice direction or other limitations per the rationale, so the verification is written to cover ALL voice processing by MS.

4.7.6.2.9 MS Health and Status

[CA3127V-PO] The generation of Health and Status information by the MS shall be verified by Test. The Test shall use the operational MS hardware and software in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable Health and Status data defined in (TBD-001-714) document(s) shall be generated by the MS. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the Test shows that the health and status data identified in (TBD-001-714) document(s):

a. Health and Status data is generated by the MS in each applicable mission phase, state and mode.

b. Health and Status data agrees with the actual health and status of the MS.

Rationale: A Test of the generation of MS Health and Status data defined by (TBD-001-714) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-714) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the health and status parameters for the MS.

[CA5475V-PO] The provision of fault detection by the Mission Systems shall be verified by Test. The Test shall use the operational Mission Systems hardware and software in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-462) document(s) for applicable simulated mission phases, states, and modes for the Mission Systems at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-462) document(s) are detected by the Mission Systems in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the Mission Systems for the faults and fault scenarios identified by (TBD-001-462) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-462) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be detected.

[CA5476V-PO] The provision of fault isolation by the Mission Systems shall be verified by Test. The Test shall use the operational Mission Systems hardware and software in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-463) document(s) for applicable simulated mission phases, states, and modes for the Mission Systems at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-463) document(s) are isolated by the Mission Systems in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the Mission Systems for the faults and fault scenarios identified by (TBD-001-463) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-463) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be isolated.

[CA5477V-PO] The provision of fault recovery by the Mission Systems shall be verified by Test. The Test shall use the operational Mission Systems hardware and software in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-464) document(s) for applicable simulated mission phases, states, and modes for the Mission Systems at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-464) document(s) are recovered from by the Mission Systems in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the Mission Systems for the faults and fault scenarios identified by (TBD-001-464) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-464) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be recovered from.

4.7.6.2.10 MS Communications and Communications Security

[CA3128V-PO] The processing of telemetry by Mission Systems shall be verified by Test. The Test shall use the operational Mission Systems hardware and software in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable telemetry defined in (TBD-001-646) document(s) shall be processed by Mission Systems as specified in (TBD-001-646) document(s). (Exhaustive verification [tests] of each parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the Test shows that the telemetry identified in (TBD-001-646) document(s) is processed by Mission Systems in each applicable mission phase, state and mode as specified in (TBD-001-646) document(s).

Rationale: A Test of the processing of telemetry by Mission Systems defined by (TBD-001-646) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The(TBD-001-646) documents are the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the Health and Status parameters for the MS.

[CA4132V-PO] The provision of communication services to enable crew and system recovery by the Mission Systems shall be verified by analysis and test. An analysis shall be performed to show that the Mission Systems communicates with a landed Orion and an evacuated crew through all nominal and abort scenarios. This shall include simulated testing and/or modeling of environmental conditions. A non-environmental communication test shall be conducted between:

a. Orion and Mission Systems

b. Evacuated crew and Mission Systems, using communication test sets if required.

The verification shall be considered successful when the analysis and test shows Orionand crew can communicate with the Mission Systems.

Rationale: Since communication is critical to mission success and crew well being, analysis and testing using flight hardware and software components, ground control systems, and communication infrastructures are required. Modeling and simulation is used to assess performance in environmental conditions.

[CA5058V-PO] Mission Systems shall record System-generated digital data received from other Constellation Systems. The recording of System-generated digital data received from other Constellation Systems shall be verified by Demonstration

The demonstration shall be conducted in a SIL (or equivalent) using flight or similar assets. Test objectives shall be prepared using IRDs and SRDs to identify source systems for data recording and the data content to be recorded. The source system may be simulated but should be certified. The source data shall be transmitted for no less than 4 hours or for an entire mission phase, if shorter, at least twice.

The verification shall be considered successful when the Demonstration shows:

a. Source data is received for an entire mission phase or at least 4 hours

b. Demonstration is performed twice

c. All received data is recorded

d. An audit of the recorded data shows it to be correct

Rationale: Recording of System-generated digital is critical to support development, test, operation, and maintenance of systems. To confirm interoperability and functionality demonstrations are performed.

[CA5071V-PO] Connectivity between space originated voice connectivity and the public communications network by Mission Systems shall be verified by Demonstration.

The demonstration of the Mission Systems voice distribution system shall be conducted as a listening test using a recorded voice source transmitted over the ground segment of a space voice link. The voice data shall be routed to the public communications network and broadcast on a speaker or headphones. The recording shall be played for the listener using the same speaker or headphones for comparison purposes. The listening test source shall include at least four different voices, two male and two female. The listener shall evaluate absence of noise (20%), comprehension (60%), and voice identification (20%). Scoring for each criterion shall be recorded. Absence of noise, comprehension, and voice identification are positive attributes (full points). Noise masking voice, loss of comprehension, and lack of voice identification are negative attributes (no/lower points).

The verification shall be considered successful when the recorded voices are evaluated by an independent listener, who has listened to the original source recording for comparison. The average score for all voices shall be no less than 75%.

Rationale: Listening tests are typically used for voice quality evaluation. Specialized voice test equipment can be used if available.

[CA5903V-PO] Mission Systems capability to generate reconfigurable automated sequences shall be verified by demonstration. The demonstration shall use the operational Mission Systems hardware and software in simulated mission conditions. The command sequences identified in (TBD-001-995) documents shall be generated by Mission Systems. (Exhaustive verification of each automation sequence is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that:

a. The command sequences have been successfully generated.

b. The command sequences contain commands valid for execution on other Constellation Systems.

c. All command parameters are within expected ranges.

Rationale: A demonstration of Mission Systems capability to generate reconfigurable automation sequences is sufficient to verify this capability. The (TBD-001-995) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process, which specify the reconfigurable automated sequences for each Constellation System.

4.7.6.2.11 MS GN&C

[CA0158V-PO] Mission Systems navigation capability shall be verified by test and analysis. This shall be accomplished in a test facility that can accurately simulate the interfaces to the Constellation Architecture systems. The ground test facility shall verify the availability, integrity, and latency of the navigation products by taking simulated data, such as from tracking stations or onboard navigation sensor measurements, processing this data with actual algorithms to be used during flight, and providing output navigation products to simulated consumers of this data. The system will include actual flight hardware in the loop, where appropriate, and will have the fidelity to test the effects of Constellation Architecture system navigation component sensor errors on the navigation solution. The verification shall be considered successful when the ground test facility has shown that the performance criteria on navigation as defined in the MS Verification document (TBD-001-662) have been met.

Rationale: NR

Draft **[CA0160V-PO]** The ability of Mission Systems to determine stationary element location anywhere on the lunar surface to within (TBD-001-068) meters (TBD-001-068) feet) shall be verified by analysis. The Mission Systems determination of stationary element location accuracy on the lunar surface shall be verified by analysis. The simulation tools and analysis methodology, and the assumed non-ideal model behavior and design data which is used in the analysis shall be developed in accordance with the 6-step verification process defined in (TBD-001-1508). The dynamic simulation and analysis shall verify the accuracy of stationary element location on the lunar surface by taking error data from component level navigation sensor testing and processing this data with a dynamic model of the descent trajectory of either the LSAM or DDS landed elements. The verification shall be considered successful when the analysis and simulation show that there is at least a 95% probability with a "consumer's risk" of 10% that the accuracy criteria has been met.

Rationale: NR

[CA0270V-PO] Mission Systems target planning and maneuver targeting capability shall be verified by test and analysis. This shall be accomplished in a test facility that can accurately simulate the interfaces to the Constellation Architecture systems. The ground test facility shall verify the availability, integrity, and latency of the trajectory planning and maneuver targeting by taking simulated data, such as from tracking stations or onboard navigation sensor measurements, and processing this data with trajectory planning and maneuver targeting algorithms to be used during flight. The system will include actual flight hardware and MSE ground hardware in the loop, where appropriate, in terms of cost and availability. The verification shall be considered successful when the ground tests and analysis have shown that the performance criteria on trajectory planning and maneuver targeting as specified in CxP (TBD-001-1054), Mission Systems Verification Document have been met.

Rationale: NR

4.7.6.2.12 MS Reliability and Availability

[CA3065V-PO] The ability of Mission Systems to have a probability of launch of no less than 99.9 (TBR-001-1411)%, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt shall be verified by analysis. The verification analysis shall use only R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when analysis shows that the probability of launch per crew launch attempt is not less than 99.9 (TBR-001-1411)%, with an uncertainty of not greater than (TBD-001-363)% (TDS# SIG-01-004).

Rationale: Mission Systems will be responsible for verifying that all fixed and variable resources needed to support beginning at the start of cryogenic propellant loading and ending at close of day-of-launch window.

[CA5135V-PO] Operations for crewed missions no later than 90 minutes after the launch of the Ares V shall be verified by analysis. The analysis shall consist of a review that the reconfiguration of facility systems and Mission Control Center Systems satisfy the requirements to support operations of crewed missions no later than 90 minutes after the launch of the Ares V. The verification shall be considered successful when the analysis show that the reconfiguration of facilities and Mission Control Center Systems meet operations objectives for the crewed missions no later than 90 minutes after the launch of the Ares V for Lunar Sortie missions.

Rationale: NR

4.7.6.2.13 MS Maintainability, Supportability, and Logistics

[CA5130V-PO] Stowage management planning and analysis to allow delivery of pressurized cargo to the ISS shall be verified by analysis. The analysis shall consist of a formal review of Inventory Management System (IMS) and Cx Program Hardware Manifest databases and interfaces as described in the Cx Manifest Information ICD

(TBD-001-410). The verification shall be considered successful when an output file, with all necessary data generated from the Cx Program Hardware Manifest database, can be successfully imported into the IMS system database.

Rationale: NR

[CA5131V-PO] Stowage management planning and analysis to allow delivery of pressurized cargo to the Lunar surface shall be verified by analysis. The analysis shall consist of a formal review of Inventory Management System (IMS) and Cx Program Hardware Manifest databases and interfaces as described in the Cx Manifest Information ICD (TBD-001-410). The verification shall be considered successful when an output file, with all necessary data generated from the Cx Program Hardware Manifest database, can be successfully imported into the IMS system database.

Rationale: NR

[CA5132V-PO] Stowage management planning and analysis to allow return of pressurized cargo from the Lunar surface shall be verified by analysis. The analysis shall consist of a formal review of Inventory Management System (IMS) and Cx Program Hardware Manifest databases and interfaces as described in the Cx Manifest Information ICD (TBD-001-410). The verification shall be considered successful when an output file with all necessary data generated from the Cx Program Hardware Manifest database can be successfully imported into the IMS system database.

Rationale: NR

[CA5133V-PO] Stowage management planning and analysis, to allow return of pressurized cargo from the ISS, shall be verified by analysis. The analysis shall consist of a formal review of Inventory Management System (IMS) and Cx Program Hardware Manifest databases and interfaces as described in the Cx Manifest Information ICD (TBD-001-410). The verification shall be considered successful when an output file, with all necessary data generated from the Cx Program Hardware Manifest database, can be successfully imported into the IMS system database.

Rationale: NR

[CA5994V-PO] The ability of Mission Systems to generate Project Verified Engineering Builds after the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars) shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between *software deliveries, and/or more versions of the same software in parallel production, etc).*

[CA5995V-PO] The ability of the MS to generate Project Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5996V-PO] The ability of Mission Systems to generate day of launch updates shall be verified by demonstration. Demonstration shall be considered successful when day of launch updates have been successfully generated and applied during project verification and validation activities.

Rationale: The intent is to demonstrate that the day of launch update process can be successfully executed.

[CA5997V-PO] The ability of Mission Systems to provide fixes for selected non-conformances to the discovering organization shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when inspection determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: Timely correction of defects avoids operational workarounds. The Fast Track build process is used for rapid resolution of problems found in the production of Flight Builds and Engineering Builds. The time period starts after documentation of the non-conformance and ends when the resolution is submitted for re-integration into the test and verification process at the point where the non-conformance was found. A Program/Project disposition group reviews new problem reports and has the authority to allocate them to the fast track process. Project and Program resources will be allocated to support fast track activities. Criteria for the selection of fast track items may include the criticality of the problem, complexity of the fix, and availability of fast track resources. The process is not required for informal deliveries, but is strongly encouraged. Times are contiguous hours.

[CA6019V-PO] The ability of Missions Systems to produce mission integration products for a single mission within the threshold time limits identified in the Mission Integration Production Time Single Mission Constraints - ISS and Mission Integration Production Time Single Mission Constraints - Lunar Table shall be verified by analysis. The analysis shall consist of a review of allocated MS SRD requirements (flight design, flight-specific training, and flight operations products), as well as MS template and management process document (TBD-001-1084). The verification shall be considered successful when the allocated SRD requirements verifications are closed and when MS mission integration template plans and management processes meet the mission integration production for a single mission within the threshold time limits identified in Mission Integration Production Time Single Mission Constraints - ISS Table and Integration Production Time Single Mission Constraints - Lunar Table with a probability 85% (TBR-001-1094). The added Objective capability of requirement CA6019 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will be then updated.

Rationale: NR

[CA6036V-PO] The ability for the Mission Systems to operate each quiescent Orion vehicle at ISS with no more than 2 hours per week contiguous real-time command and control (consisting of 12 man-hours) under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated MS SRD and MS-CEV IRD requirements, as well as the MCCS Level IV requirements. Analysis shall consist of review of the Mission Systems Cx Baseline Operating Plan, MCCS personnel manning plans, as-built MCCS design. The inspection shall be considered successful when the allocated MCCS Level IV, MS SRD, and MS-CEV IRD verification requirements are closed and analysis shall be considered successful when the as-built MCCS design, and the MCCS personnel manning and operating plans confirm the ability to meet no more than 2 hours per week contiguous consisting of 12 man-hours of real-time command and control during quiescent ISS mission under nominal quiescent operations. The added Objective capability of requirement CA6036 will be addressed at design reviews. The Mission System’s capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

[CA6038V-PO] The ability for the Mission Systems to operate each quiescent vehicle with no more than 2 (TBR-001-1107) hours per week contiguous real-time command and control (consisting of (TBD-001-1086) man-hours) for Lunar missions under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated MS SRD, MS-LSAM IRD, and MS-CEV IRD requirements as well as the MCCS Level IV requirements. Analysis shall consist of review of the Mission Systems Cx Baseline Operating Plan, MCCS personnel manning plans, as-built MCCS design. The inspection shall be considered successful when the allocated MCCS Level IV, MS SRD, MS-LSAM IRD, and MS-CEV IRD verification requirements are closed and analysis shall be considered successful when the as-built MCCS design, and the MCCS personnel manning and operating plans, confirm the ability to meet no more than 2 (TBR-001-1107) hours per week contiguous real-time command and control (consisting of (TBD-001-1086) man-hours) for Lunar missions under nominal quiescent operations.

Rationale: NR

[CA6039V-PO] The ability for the Mission Systems to monitor a quiescent Orion vehicle without dedicated teams for ISS missions under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated MS SRD and MS-CEV IRD requirements, as well as the MCCS Level IV requirements. Analysis shall consist of review of the Mission Systems Cx Baseline Operating Plan, MCCS personnel manning plans, as-built MCCS design. The inspection shall be considered successful when the allocated MCCS Level IV, MS SRD, and MS-CEV IRD verification requirements are closed and analysis shall be considered successful when the as-built MCCS design, and the MCCS personnel manning and operating plans, confirm the ability to meet monitoring a quiescent Orion vehicle without dedicated teams for ISS missions under nominal quiescent operations.

Rationale: NR

[CA6040V-PO] The ability for the Mission Systems to monitor a quiescent vehicle without dedicated teams for Lunar missions under nominal quiescent operations shall be verified by inspection and analysis. The inspection shall consist of review of the allocated MS SRD, MS-LSAM IRD, and MS-CEV IRD requirements as well as the MCCS Level IV requirements. Analysis shall consist of review of the Mission Systems Cx Baseline Operating Plan, MCCS personnel manning plans, as-built MCCS design. The inspection shall be considered successful when the allocated MCCS Level IV, MS SRD, MS-LSAM IRD, and MS-CEV IRD verification requirements are closed and analysis shall be considered successful when the as-built MCCS design, and the MCCS personnel manning and operating plans confirm, the ability to meet monitoring a quiescent vehicle without dedicated teams for Lunar missions under nominal quiescent operations.

Rationale: NR

4.7.6.2.14 Reserved

4.7.6.2.15 Reserved

4.7.6.3 Reserved

4.7.6.4 MS External Interfaces

[CA0917V-PO] The MS interfaces with Orion shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the MS Project Office to demonstrate that the MS-to-Orion interface requirements defined within CxP 70029, Constellation Program Orion -to- Missions Systems (MS) Interface

Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion avionics and software and the Mission Systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site, for flight systems, shall also incorporate the Mission Systems to confirm interoperability and functionality between the Orion, GS, and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the MS interface verification requirements defined within CxP 70029, Constellation Program Orion -to- Missions Systems (MS) Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the MS Project Office to confirm that all of the MS-to-Orion interface requirements specified in the IRD have been satisfied. Integrated testing between the Orion avionics and software and the MS systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating MS systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0918V-PO] The MS interfaces with the Ares I shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the MS Project Office to demonstrate that the MS-to-Ares I interface requirements defined within CxP 70053, Constellation Program Ares I -to- Mission Systems Interface Requirements Document, have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares I avionics and software and the Mission Systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the Mission Systems to confirm interoperability and functionality between the Ares I, GS, and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the MS interface verification requirements defined within CxP 70053, Constellation Program Ares I -to- Mission Systems Interface Requirements Document , have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the MS Project Office to confirm that all of the MS-to-Ares I interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares I avionics and software and the Mission Systems via the SILs (or equivalents), will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating MS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0919V-PO] The MS interfaces with the LSAM shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the MS Project Office to demonstrate that the MS-to-LSAM interface requirements defined within CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -to-Mission Systems (MS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM avionics and software and Mission Systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the Mission Systems to confirm interoperability and functionality between the LSAM, GS, and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the MS interface verification requirements defined within CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) -to- Mission Systems (MS) Interface Requirements Document (IRD) , have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the MS Project Office to confirm that all of the MS-to-LSAM interface requirements specified in the IRD have been satisfied. Integrated testing between the LSAM avionics and software and the Mission Systems via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating Mission Systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational *mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.*

[CA0920V-PO] The MS interfaces with the Ares V shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the MS Project Office to demonstrate that the Ares V-to-MS interface requirements defined within CxP 70112, Constellation Program Ares V -to- Mission Systems (MS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Ares V avionics and software and the Mission Systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate Mission Systems to confirm interoperability and functionality between the Ares V, GS, and MS. Verification shall be considered successful when:

a. Analysis confirms that all of the MS interface verification requirements defined within CxP 70112, Constellation Program Ares V -to- Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the MS Project Office to confirm that all of the MS-to-Ares V interface requirements specified in the IRD have been satisfied. Integrated testing between the Ares V avionics and software, and Mission Systems via the SILs (or equivalents), will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating Mission Systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0921V-PO] The MS interfaces with GS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the MS Project Office to demonstrate that the MS-to-GS interface requirements defined within CxP 70054, Constellation Program Mission Systems (MS) -to- Ground Systems (GS) Interface Requirements Document (IRD). have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Multi-system testing performed at the launch site for flight systems shall also incorporate the GS and MS to confirm interoperability and functionality between MS and GS systems. Verification shall be considered successful when:

a. Analysis confirms that all of the MS interface verification requirements defined within CxP 70054, Constellation Program Mission Systems (MS) -to- Ground Systems (GS) Interface Requirements Document (IRD), have been satisfied

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the MS Project Office to confirm that all of the GS-to-MS interface requirements specified in the IRD have been satisfied. Integrating GS and MS into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes.

[CA0922V-PO] The MS interfaces with the Communications and Tracking Networks shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the MS Project Office to demonstrate that the MS interface requirements defined within CxP 70118-06, Constellation Program Systems -to- Communications and Tracking Network Interface Requirements Document,Volume 6: Mission Systems (MS) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Multi-system testing performed at the launch site, for flight systems, shall also incorporate the Communications and Tracking Network systems to confirm interoperability and functionality between MS and the Communications and Tracking Network. Verification shall be considered successful when:

a. Analysis confirms that all of the MS interface verification requirements defined within CxP 70118-06, Constellation Program Systems -to- Communications and Tracking Networks Interface Requirements Document, Volume 6: Mission Systems (MS) have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the MS Project Office to confirm that all of the MS-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrating the communication and network systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

4.7.6.5 Reserved

4.7.7 Mars Transfer Vehicle (MTV)

4.7.7.1 MTV Description

4.7.7.2 MTV Requirements

4.7.7.2.1 Reserved

4.7.7.2.2 Reserved

4.7.7.2.3 Reserved

4.7.7.2.4 Reserved

4.7.7.2.5 Reserved

4.7.7.2.6 MTV Architecture Definition

Draft **[CA0862V-PO]** (TBD-001-1044)

Rationale: (TBD-001-1044)

4.7.7.2.7 Reserved

4.7.7.2.8 Reserved

4.7.7.2.9 Reserved

4.7.7.2.10 Reserved

4.7.7.2.11 Reserved

4.7.7.2.12 Reserved

4.7.7.2.13 Reserved

4.7.7.2.14 Reserved

4.7.7.2.15 Reserved

4.7.7.3 Reserved

4.7.7.4 Reserved

4.7.7.5 Reserved

4.7.8 Descent/Ascent Vehicle (DAV)

4.7.8.1 DAV Description

4.7.8.2 DAV Requirements

4.7.8.2.1 Reserved

4.7.8.2.2 Reserved

4.7.8.2.3 Reserved

4.7.8.2.4 Reserved

4.7.8.2.5 Reserved

4.7.8.2.6 DAV Architecture Definition

Draft **[CA0863V-PO]** (TBD-001-1045)

Rationale: (TBD-001-1045)

4.7.8.2.7 Reserved

4.7.8.2.8 Reserved

4.7.8.2.9 Reserved

4.7.8.2.10 DAV Communications and Communications Security

Draft **[CA3282V-PO]** The use of a dissimilar voice communication system by DSS as specified in the requirement, shall be verified by Analysis and Demonstration. The analysis shall be performed on the DSS voice communication systems. The demonstration shall be performed on the DSS dissimilar voice system. The verification shall be considered successful when:

a. The demonstration verifies that the dissimilar voice system provides system-to-system communication using communication infrastructure paths.

b. The analysis shows the dissimilar system is independent when compared to the prime DSS voice communication system.

Rationale: Analysis shows the system as dissimilar compared to prime voice circuits. Demonstration is used to show functionality. Additional verifications are performed at a lower level. The communication methods and techniques are specified in the C3I compatibility specification.

Draft **[CA3290V-PO]** Simultaneous communication by DAV with MS and three (TBR-001-136) other systems, as specified in the requirement shall be verified by analysis and testing. Analysis of the specified data links shall be performed. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links using operational scenarios. The verification shall be considered a success when:

a. Testing shows the system can simultaneously exchange data with the specified systems without loss or apparent degradation.

b. Analysis shows that forward and received link margins are sufficient to support communication at the distances specified.

Rationale: Tests are needed that are specific to the system and its characteristic data are needed. Scenarios shall reasonably exercise the system capability of the as specified system. For load testing, the system under test may be loaded with C3I Interoperability compatible systems transferring information of appropriate types at their maximum expected rate to stress test the system data transmission and receipt capabilities. All data types supported by the system shall be tested. For systems with communications links, testing needs link testing according to the C3I interoperability specification and demonstration, where possible, with systems expected on-orbit using simulated transmission delays and noise levels.

4.7.8.2.11 Reserved

4.7.8.2.12 Reserved

4.7.8.2.13 Reserved

4.7.8.2.14 Reserved

4.7.8.2.15 Reserved

4.7.8.3 Reserved

4.7.8.4 Reserved

4.7.8.5 Reserved

4.7.9 Extravehicular Activities (EVA) System

4.7.9.1 EVA System Description

4.7.9.2 EVA System Requirements

[CA4127V-PO] The ability of the EVA System to perform at least two (TBR-001-163) microgravity EVA operations of at least 4 (TBR-001-223) hours duration each on Lunar missions shall be verified by analysis, demonstration, and test.

The analysis shall prove that the EVA System can provide the following function for 16 (TBR-001-497) hours (2 periods of 8 hours each):

a. Provisions for life sustaining nutrition and hydration

b. Provisions to collect human waste

c. Body thermal control

d. EVA System communication (voice, suit and biomed data) to the vehicle

e. CO2 washout and trace contaminant control

f. Certification for 8 hours pressurized operations with external space conditions (as defined in DSNE)

g. Decompression Sickness (DCS) compliance to appropriate risk level for EVA

h. Protection of the crew from the space environment

i. Infrastructure to receive and route vehicle life support to EVA suits (umbilicals, vehicle panel interfaces)

j. Suits to accommodate anthropometric ranges of crewmembers specified in HSIR

k. Pressurized suit mobility and stability to translate and perform vehicle tasks

l. Lighting for translation and worksites

m. Tools (safety tethers, hand tools, tool tethers) to perform the tasks

n. Camera equipment (if applicable to for the mission phase)

The demonstration shall consist of neutral buoyancy evaluations, with the Orion mockups outfitted with the proper internal volume, internal handrails, seats, volumetric mockups of all internal areas, umbilicals, operable hatch, all loose stowage items (which would normally not be stowed away for an EVA), translation path, worksite, simulated EVA tasks, and all external appendages as identified in the Orion drawings using flight-like EVA suits (pressurized). The demonstration will consist of crewmembers opening and closing the hatch, egressing and ingressing the mockup, evaluation of translation paths between hatch and worksites, worksite stabilization, worksite tasks, and reach and visibility to all vehicle controls necessary during an EVA (depress and repress controls, displays, etc.). The demonstration will be repeated by at least three different sets of crewmembers (for a total of six crewmembers to perform the demonstration). During egress and ingress phases of the demo, there will be at least four suited subjects (or two volumetric representations of suited subjects) located inside the Orion.

The test shall consist of Orion (LSAM) flight or flight equivalent hardware with a full complement of EVA System flight or flight equivalent hardware. The suits will be fully pressurized and receiving all functions from the Orion (LSAM) at ambient conditions for the following sequences. The test shall consist of Orion flight or flight equivalent hardware with a full complement of EVA System flight or flight equivalent hardware. The suits will be fully pressurized and receiving all functions from Orion at ambient conditions for the following sequences:

a. Four suits (and crewmembers) will be connected to all short umbilical positions with the suits performing simultaneously.

b. Four suits (and crewmembers) will be connected to the two long umbilical locations and two to short umbilical locations.

All suits will operate in the sequences for sufficient time to obtain steady state, with the sequence repeated until all suits have been swapped and operated simultaneously at all umbilical locations.

The verification shall be considered successful when the analysis confirms the functions listed can be performed for 16 (TBR-001-497) hours (2 periods of 8 hours), the demonstration reflects crew subjective acceptability for Orion ingress, egress, vehicle displays and controls, translations, worksite stability, and worksite tasks as documented in the Crew Consensus report, and the test data confirms all Orion (LSAM) and EVA System conform to CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document (CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD) specifications of all four suits simultaneously.

NOTE: Orion will be the first vehicle which this requirement is verified to, but LSAM is shown in parenthesis to indicate that the EVA System shall also need to prove verification to that vehicle also (at a later time).

Rationale: The analysis portion of this requirement will be satisfied once the flow-down requirements to the EVA System Project are satisfied. The analysis of functions will confirm that the EVA System has levied and closed out the next lower level requirements. The analysis documentation can be satisfied by the EVA System providing the requirements that address the functions (whether in CxP 72000, Constellation Program System Requirements for the Orion System, CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document, or CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to-Extravehicular Activity (EVA) Interface Requirements Document (IRD) to provide evidence as to how the EVA has accounted for providing those functions, and show that the verification for those requirements have been closed. The 16 (TBR-001-497) hour duration specified assumes 4 (TBR-001-223) hours of EVA, 4 (TBR-001-223) hours of in-suit prebreathe based on a 14.7 psia cabin per CxP 70024 (TBD-001-635) (HSIR) for two (TBR-001-163) EVAs, although the suits and ancillary gear only need to be certified to the external conditions for two 4-hour EVA periods (8 hrs total). The demonstration is needed to show that, subjectively all the operations required by the crew during suited operations for EVA (egress, ingress, translation, stability, reach and visibility to Orion control, etc.) with a full complement of crewmembers and in the Orion volume are viable. Six crewmembers historically represent the minimum number in order for the Astronaut Office to publish a Crew Consensus Report, which is the favored documentation source to this verification method. The test is necessary as it cannot be assumed at any other point in the Orion (LSAM) or EVA system certification that a full set of suits and Orion (LSAM) have been verified to operate together simultaneously. Four suits were chosen as this is the defined crew size for lunar missions (currently the contingency and unscheduled EVA is only applicable for lunar missions). Certification hardware can be used for the demonstration if flight hardware is not available. The swapping of suits to each umbilical outlet will provide a level of confidence that suits can operate in all vehicle locations.

[CA6078V-PO] The Control Mass requirement for the EVA System shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of these components is less than or equal to the required Control Mass.

Rationale: NR

[CA6080V-PO] The Control Mass requirement for the EVA System shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of these components is less than or equal to the required Control Mass.

Rationale: NR

4.7.9.2.1 EVA System Mission Success

[CA5946V-PO] Lunar Sortie LOM due to the EVA System shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows the calculated mean value of LOM for a Lunar Sortie mission due to EVA System is not greater than 1 in 600.

Rationale: NR

4.7.9.2.2 EVA System Crew Survival

[CA3003V-PO] The ability of the EVA System to sustain life of the suited crew without permanent disability in an unpressurized cabin for up to 144 hours shall be verified by analysis. The analysis shall consist of documentation that the EVA System can provide the following simultaneous functions while the habitable volume is depressurized:

a. EVA System provisions for life sustaining nutrition, hydration, and medicine for 144 hours

b. EVA System provisions to collect human waste for 144 hours

c. EVA System certified for 144 hours of pressurized life at vacuum

d. EVA System body thermal control for 144 hours

e. EVA System communication (voice, suit and biomed data) to the vehicle for 144 hours

f. Seat ingress/securing with Orion in a pressurized suit and ability to adjust the harness during cabin repress upon re-entry

g. EVA System pressurized mobility for vehicle operations to complete vehicle minimum performance needs to return to Earth

h. CO2 washout and trace contaminant control for 144 hours

i. Decompression Sickness (DCS) compliance to appropriate risk level for unpressurized survival contingency

The verification shall be considered successful when the analysis confirms the functions listed can be performed with the vehicle depressurized for 144 hours.

Rationale: This is an overarching EVA System parent requirement that is not reasonably verified by a full duration test, considering this is a contingency situation. As the next lower level requirements are Level III owned, it is not appropriate to list Level III requirements necessary to satisfy the functions necessary to satisfy this *parent. The analysis documentation can be satisfied by the EVA System providing the requirements that address the functions (whether in the EVA SRD, Orion-EVA IRD, etc.), provide evidence as to how the EVA System has accounted for providing those functions simultaneously with a depressurized cabin, and show that the verification for those requirements have been closed. Demonstration of a suit to support an individual for approximately 115 hours (in a 1-g environment) was performed in Apollo with minimal effects to the subjects. Although the future suit(s) will not be of identical design, similarity is expected to be close enough given that a long-duration 1-g test will have many test inaccuracies that are not relevant to a 144 hour space environment (e.g. suit variations would probably be in the noise). A demonstration to verify that the EVA System can provide nutrition/medical needs will likely be required in order to satisfy a lower level EVA System verification requirement.*

[CA5169V-PO] The suited crew capability for unassisted emergency egress to a safe haven during pre-launch activities shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using the EVA System, Orion, and launch support structure by performing a minimum of two runs with two different sets of suited crewmembers and collecting the task time for crew egress from Orion to a safe haven at ground level. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments. The analysis shall consist of the Ground System, EVA System, Ares I and Orion system documentation reviews that meet unassisted egress for the suited crew through the closure in CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document, Section (TBD-001-809), CxP 70052-02, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 2: Ares I -to- Ground Systems Interface Requirements Document (IRD), CxP 70052-03, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 3: First Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), and CxP 70052-04, Constellation Program Ares I -to- Ground Systems Interface Requirements Document, Volume 4: Upper Stage Elements -to- Ground Systems Elements Interface Requirements Document (IRD), Section (TBD-001-810), CxP 70028, Constellation Program Orion -to- Ground Systems (GS) Interface Requirements Document (IRD), Section (TBD-001-813), and CxP 72120, Ground Operations Project Plan, Section (TBD-001-812). The verification shall be considered successful when the analysis determines the demonstration meets unassisted emergency egress within 2 minutes (TBR-001-170).

Rationale: This is an overarching EVA Systems project verification requirement that can be satisfied once the flow-down requirements to the EVA Systems project are satisfied. The analysis can be satisfied by the EVA System providing the requirements that address the functions (whether in the SRR, ICD or IRD).

[CA5170V-PO] The suited crew capability for unassisted emergency egress out of Orion after landing (including both land and water) within 3 (TBR-001-1023) minutes starting from when the decision to egress Orion is made, shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using the EVA System and Orion by performing a minimum of two runs with two different sets of suited crewmembers egressing Orion. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments. The analysis shall consist of the EVA System and Orion system documentation reviews that meet unassisted egress for the suited crew through the closure in CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document Section (TBD-001-815). The verification shall be considered successful when the analysis determines the demonstration meets unassisted emergency egress out of Orion.

Rationale: For contingency or aborted landings, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons, or to assist in search and rescue operations. This should drive design of seat restraints, spacecraft aids, and space suit mobility components.

[CA5203V-PO] The suited crew capability for unassisted emergency egress out of Orion during pre-launch activities shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using EVA System and Orion by performing a minimum of two runs with two different sets of suited crewmembers and collecting the task time for crew egress from Orion to a safe haven at ground level. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments. The analysis shall consist of the EVA System and Orion system documentation reviews that meet unassisted egress for the suited crew through the closure in the CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document Section (TBD-001-814). The verification shall be considered successful when the analysis determines the demonstration meets unassisted emergency egress out of Orion within 2 minutes (TBR-001-173).

Rationale: This is an overarching EVA Systems project verification requirement that can be satisfied once the flow-down requirements to the EVA Systems project are satisfied. The analysis can be satisfied by the EVA System providing the requirements that address the functions (whether in the SRR, ICD or IRD).

[CA6076V-PO] The ability of EVA System to isolate any suited crewmember shall be verified by analysis. An analysis of the suit isolation design, procedures and timeline shall be performed to determine that an unrecoverable suit depressurization can be isolated from the remainder of the loop within the specified time. The verification shall be considered successful when the analysis shows the EVA System is capable of isolating any suited crewmember within the specified time.

Rationale: NR

4.7.9.2.2.1 EVA System Crew Survival Probabilities

[CA5945V-PO] Lunar Sortie LOC due to the EVA System shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program

Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows that the calculated mean value of LOC for a Lunar Sortie mission due to EVA System is not greater than 1 in 800.

Rationale: NR

4.7.9.2.3 Reserved

4.7.9.2.4 Reserved

4.7.9.2.5 EVA System Mission Rates and Duration

[CA6153V-PO] The ability of the EVA System to provide the capacity to perform four ISS and four Lunar flights in a year shall be verified by analysis. The analysis shall assess the time required to produce, transport, assemble, and test the EVA flight systems and integrate them into mission configuration. The verification shall be considered successful when analysis shows the EVA flight systems can be produced, transported, assembled, tested and integrated into mission configuration in time to meet mission objectives.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide fully functional EVA Systems in time to support the mission. An analysis of the timeline considering all aspects involved with processing the systems will determine the minimum amount of time to ready them for the mission. The analysis should also include any reprocessing or refurbishment activities planned.

[CA6262V-PO] The ability of the EVA Systems to launch on a 45 calendar day interval, measured from the launch of the first mission to the launch of the second mission shall be verified by analysis. The analysis shall assess the time required to test and integrate the EVA flight systems into mission configuration. Verification shall be considered successful when the analysis determines the EVA flight systems can be tested and integrated into mission configuration within 45 calendar days.

Rationale: The capacity to perform the required mission rates depends upon the ability to provide fully functional EVA Systems in time to support the mission. An analysis of the timeline considering all aspects involved with processing the systems will determine the minimum amount of time to ready them for the mission. The analysis should also include any reprocessing or refurbishment activities planned.

4.7.9.2.6 Reserved

4.7.9.2.7 EVA System Safety (System, Public, and Planetary)

[CA5400V-PO] The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the EVA System-level FMEA/CILs for compliance with JPR 8080.5, JSC Design and Procedural Standards, Section G-2. The verification shall be considered successful when the integrated analysis shows that redundant systems are separated or protected.

Rationale: Verification of this requirement will be performed in accordance with CxP 70043, Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology.

[CA5409V-PO] The control for critical hazard shall be verified by analysis. The analysis shall review the EVA System Hazard Analysis. The verification shall be considered successful when the analysis shows that critical hazards are controlled per CxP 70038, Constellation Program Hazard Analysis Methodology.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

[CA5410V-PO] Failure tolerance for catastrophic hazards shall be verified by analysis. An Integrated hazard analysis shall be performed, using system-level hazard analyses and FMEA to show compliance with the approved level of failure tolerance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled with the approved number of controls and all DFMR items are approved in the Hazard Reports.

Rationale: Verification requirement ensures that good systems engineering principles and practices are used to ensure an adequate level of safety.

4.7.9.2.8 Reserved

4.7.9.2.9 EVA System Health and Status

[CA3121V-PO] The generation of Health and Status information by the EVA System shall be verified by Test. The Test shall use the flight EVA System or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable Health and Status data defined in (TBD-001-591) document(s) shall be generated by the EVA System. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the Test shows that the Health and Status data identified in (TBD-001-591) document(s):

a. Health and Status data is generated by the EVA System in each applicable mission phase, state and mode.

b. Health and Status data agrees with the actual Health and Status of the EVA System.

Rationale: A Test of the generation of EVA System Health and Status data defined by (TBD-001-591) document(s) for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-591) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the Health and Status parameters for the EVA System.

[CA3122V-PO] The provision of Health and Status data by the EVA System to the crew shall be verified by Test. The Test shall use the flight EVA System or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable Health and Status data defined in (TBD-001-595) document(s) shall be observed by crew surrogates. (Exhaustive verification [tests] of each H&S parameter is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the Test shows that the Health and Status data identified in (TBD-001-595) document(s):

a. Health and Status Data is observed by crew surrogates in the EVA System in each applicable mission phase, state and mode.

b. Health and Status Data agrees with the actual health and status of the EVA System.

Rationale: A Test of the provision of EVA System Health and Status data defined by (TBD-001-595) document(s) to crew surrogates in the EVA System for each mission phase, state and mode for both nominal and off-nominal conditions is sufficient to verify this capability.

The (TBD-001-595) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the health and status parameters for the EVA System.

[CA4125V-PO] The provision of fault recovery by the EVA System shall be verified by Test. The Test shall use the flight EVA System or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-817) document(s) for the applicable simulated mission phases, states, and modes for the EVA System at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-817) document(s) are recovered from by the EVA System in every applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the EVA System for the faults and fault scenarios identified by (TBD-001-817) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-817) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be recovered from.

[CA5467V-PO] The provision of fault detection by the EVA System shall be verified by Test. The Test shall use the flight EVA System or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-456) document(s) for applicable simulated mission phases, states, and modes for the EVA System at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-456) document(s) are detected by the EVA System in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the EVA System for the faults and fault scenarios identified by (TBD-001-456) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-456) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be detected.

[CA5468V-PO] The provision of fault isolation by the EVA System shall be verified by Test. The Test shall use the flight EVA System or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-458) document(s) for applicable simulated mission phases, states, and modes for the EVA System at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-458) document(s) are isolated by the EVA System in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the EVA System for the faults and fault scenarios identified by (TBD-001-458) document(s) for each mission phase, state and mode is sufficient to verify this capability.

The (TBD-001-458) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify the faults to be isolated.

4.7.9.2.10 EVA System Communications and Communications Security

Draft **[CA5046V-PO]** The EVA System shall provide (TBD-001-221) bytes of digital storage for recording digital data received from other Constellation Systems. The provision of (TBD-001-221) bytes of digital storage for recording digital data shall be verified by Inspection and Demonstration.

An inspection shall be conducted on the systems digital storage system implementation. A demonstration shall be performed using flight or similar assets in a SIL (or equivalent) with data received from a simulated "other" system. The receiving system shall record until full.

The verification shall be considered successful when the inspection shows that (TBD-001-221) bytes are allocated for the storage of digital data received from other Constellation Systems, and the demonstration shows that the receiving system records at least (TBD-001-221) bytes of "other" system data and an audit of the data shows it to be correct.

Rationale: Inspection of implementation is adequate to ensure allocation. Demonstration of the capability is performed to ensure complete functionality.

Draft **[CA5047V-PO]** The EVA System shall record System-generated digital data received from other Constellation Systems. The recording of system-generated digital data received from other Constellation Systems shall be verified by Demonstration.

The demonstration shall be conducted in a SIL (or equivalent) using flight or similar assets. Test objectives shall be prepared using IRDs and SRDs to identify source systems for data recording and the data content to be recorded. The source system may be simulated but should be certified. The source data shall be transmitted for no less than 4 hours or for an entire mission phase, if shorter, at least twice.

The verification shall be considered successful when the Demonstration shows:

a. Source data is received for an entire mission phase or at least 4 hours.

b. Demonstration is performed twice.

c. All received data is recorded.

d. An audit of the recorded data shows it to be correct.

Rationale: Recording of System-generated digital is critical to support development, test, operation, and maintenance of systems. To confirm interoperability and functionality, demonstrations are performed.

[CA5909V-PO] Simultaneous communication by the EVA System with four (TBR-001-556) Constellation Systems during a Lunar Sortie Mission shall be verified by analysis and test.

Analysis of the specified data links shall be performed. The analysis shall include environmental factors for nominal and off-nominal Lunar Sortie Mission scenarios. The test shall consist of simulations of the communications for nominal and off-nominal Lunar Sortie Missions and shall be conducted at least twice each for nominal and maximum data rates for at least 1 hour. The test shall be conducted on flight or flight-like systems and simulated systems over simulated nominal space links.

The verification shall be considered successful when:

a. Testing shows the EVA System can simultaneously exchange data with four (TBR-001-556) Constellation Systems for Lunar Sortie Mission correctly, and without apparent degradation, for both nominal and maximum data rates for each scenario at least twice for at least 1 hour.

b. Analysis shows that hardline, networked, and RF data links, including forward and reverse margins, provide necessary bandwidth to support communication during nominal and off-nominal Lunar Sortie Missions.

Rationale: Analysis is used to verify that RF communication links will remain operational during the specified mission scenarios and environmental conditions. Testing is used to load the system to stress levels. Test results must be repeatable and consistent.

[CA5910V-PO] Simultaneous communication by the EVA System with six (TBR-001-557) Constellation Systems, during a Lunar Outpost Mission, shall be verified by analysis and test.

Analysis of the specified data links shall be performed. The analysis shall include environmental factors for nominal and off-nominal Lunar Outpost Mission scenarios. The test shall consist of simulations of the communications for nominal and off-nominal Lunar Outpost Mission and shall be conducted at least twice each for nominal and maximum data rates for at least 1 hour. The test shall be conducted on flight or flight-like systems and simulated systems over simulated nominal space links.

The verification shall be considered successful when:

a. Testing shows the EVA System can simultaneously exchange data with the six (TBR-001-557) Constellation Systems for Lunar Outpost Mission correctly and without apparent degradation for both nominal and maximum data rates for each scenario at least twice for at least 1 hour.

b. Analysis shows that hardline, networked, and RF data links, including forward and reverse margins, provide necessary bandwidth to support communication during nominal and off-nominal Lunar Outpost Mission.

Rationale: Analysis is used to verify that RF communication links will remain operational during the specified mission scenarios and environmental conditions. Testing is used to load the system to stress levels. Test results must be repeatable and consistent.

4.7.9.2.11 Reserved

4.7.9.2.12 EVA System Reliability and Availability

[CA3063V-PO] The ability of the EVA System to have a probability of launch of no less than 99.9 (TBR-001-562)%, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt shall be verified by analysis. The verification analysis shall use only R&M Panel approved data sources for MTBF and MTTR and shall be performed in accordance with the CxP 70087, Constellation Program Reliability, Availability, and Maintainability Plan. Verification shall be considered successful when analysis shows that the probability of launch per crew launch attempt is not less than 99.9% (TBR-001-562) with an uncertainty of not greater than (TBD-001-1014)% (TDS# SIG-01-004).

Rationale: It will be necessary for the EVA System to make certain that their system has the reliability to be available to support beginning at the start of cryogenic propellant loading and ending at close of day-of-launch window.

4.7.9.2.13 EVA System Maintainability, Supportability, and Logistics

[CA5182V-PO] The ability of the EVA System flight hardware to complete a single ISS mission, without preventive maintenance or repair, shall be verified by analysis. The analysis shall assess the EVA System Logistics Support Analysis, the EVA System

Maintenance Plan, the EVA System FMEA, identify limited-life items and scheduled maintenance procedures, and determine if they must be replaced or performed during a single ISS mission. Verification shall be considered successful when analysis determines that the EVA System flight hardware does not require preventive maintenance or repair to be performed during a single ISS mission.

Rationale: Any planned maintenance actions such as refurbishment and repairs will be identified in the EVA Maintenance Plan and planned for in the EVA System's Logistics Support Analysis (LSA). The EVA System's FMEA will identify the hardware items which are expected to fail during the timeframe of an ISS mission. Using this information, an analyst can determine if any refurbishments or repairs are planned to be performed during an ISS mission.

[CA5184V-PO] Verification that the EVA System flight hardware is designed for in-flight maintenance including replacement and repair of major end items shall be verified by analysis. The analysis shall include a maintainability analysis to identify potential corrective maintenance actions required to maintain the EVA System flight hardware and determine if the EVA System flight hardware is design for in-flight maintenance. Verification shall be considered successful when the analysis shows that identified preplanned corrective maintenance actions for EVA System flight hardware can be accomplished in flight including replacement and repair of major end items.

Rationale: It is important to implement EVA System designs that are reliable, easy to repair and require minimum maintenance in-flight.

[CA5998V-PO] The ability of the EVA System to generate Project Verified Engineering Builds after the first manned mission of a mission class (ISS, Lunar Transport, Lunar Outpost, Mars shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement are met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA5999V-PO] The ability of EVA System to generate Project Verified Flight Builds shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when analysis determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The

Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA6001V-PO] The ability of the EVA System to provide fixes for selected non-conformances to the discovering organization shall be verified by analysis. Analysis shall assess the time used to perform the process. Verification shall be considered successful when inspection determines that the durations specified in the requirement can be met 80% of the time. The added Objective capability of this requirement will be addressed at Program level design reviews. The Projects' capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: The intent is to collect metrics to see how well the process is adhering to required times. If the times are not being met, then either the process(es) need to be re-evaluated and adjusted to achieve those times, or the Program has to plan to accept the results (more procedure re-writes and/or longer intervals between software deliveries, and/or more versions of the same software in parallel production, etc.).

[CA6006V-PO] The ability of EVA System to conduct ground operations within the constraints levied in EVA Critical Path Allocations for Ares I/Orion Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6006 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

[CA6011V-PO] The ability of the EVA System to conduct ground operations within the constraints levied in EVA Critical Path Allocations for Ares V/LSAM Ground Operations Table shall be verified by analysis. The analysis shall consist of modeling the ground processing flow using an accredited discrete event simulation. The analysis shall incorporate an assessment of all ground operations requirements of the flight and ground systems and a corresponding assessment of the critical path impacts associated with conducting those operational requirements. The verification shall be considered successful when analysis shows, with a confidence level of 80% (TBR-001-1094), that the activities specified in the table can be accomplished within the critical path hours specified therein. The added Objective capability of requirement CA6011 will be addressed at design reviews. The Projects capability of meeting the high marks required by the Program will be identified and acknowledged. The verification will then be updated.

Rationale: NR

4.7.9.2.14 EVA System Habitability and Human Factors

[CA3058V-PO] The ability of the EVA System to provide for suit donning and connection to life support by the full crew within 1 (TBR-001-113) hour shall be verified by demonstration and analysis.

The demonstration shall consist of 1-g suit donning evaluations using flight or training quality suits in a representative Orion volume mockup, with the suits stowed in the designated Orion stowage location, performed by two different sets of crewmembers (six crewmembers per set) with two runs performed by each set, and collection of task time for suit retrieval per CA3108-PO, donning and umbilical connection per CA3058-PO, pressurization, leak recovery, and any other tasks required by the crew to complete the suit donning and pressurization process prior to total cabin depressurization.

The analysis shall consist of examination of task time collected during the 1-g demonstration, applying a program approved microgravity extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments.

The verification will be considered successful when the analysis shows that both sets of six crewmembers have not exceeded 1 (TBR-001-113) hour to don the suits and connect umbilicals.

Rationale: This demonstration is intended to satisfy several requirements associated with quick suit donning in case of a vehicle leak. Although a stand-alone donning demonstration might be extrapolated to verify that the full complement of subjects could don within the "feed the leak" time, it is recognized that the ability of crewmembers to simultaneously don suits is dictated by the volume available and stowage provisions of the suits within Orion. Since there are three primary factors (Orion free volume, suit stowage location, and suit design) essential in the ability for the crew to don their suits within the "feed the leak" time, the only seemingly valid approach to confirm is through an integrated demonstration. The analysis will pull together the donning times as collected during the 1-g evaluations, use the best factor available from ISS and SSP history with regards to additional time required for microgravity activities, and verify that those collective times (minus any test artificial time delays, etc.) will allow the crewmembers to retrieve, don, and connect their suits to life support within 1 (TBR-001-113) hour. Six crewmembers were chosen as *the maximum necessary to satisfy overarching Constellation requirements for ISS missions.*

[CA5168V-PO] The ability of the EVA System to provide for unassisted donning and doffing shall be verified by demonstration and analysis. The demonstration shall consist of 1-g and microgravity/partial gravity suit donning evaluations using flight or training quality suits.

The microgravity and partial gravity evaluations shall consist of crewmembers donning a representative Constellation EVA Configuration Suit while restricted to a confined volume on the microgravity aircraft. This volume shall be equivalent to the worst-case available volume for each DRM. The donning time will begin with crewmember(s) in undergarments, shall include all parts of the EVA System needed to sustain the crew for 120 hours in an unpressurized cabin, and shall end when the suit is configured for pressurization. Doffing will begin with the suits in a ready for pressurization state and shall end when crew is in undergarments. Assistance may be provided after a component is doffed to ensure proper equipment handling. Donning and doffing times will be collected throughout the evaluation and captured in a crew consensus report.

The 1-g evaluations shall be performed in a representative vehicle volume mockup, with the suits stowed in the designated stowage locations. Collection of task time for suit retrieval, donning, pressurization, and any other tasks required by a crew size, specified for the applicable DRM to complete the suit donning and pressurization process, shall be documented in a crew consensus report.

The analysis shall consist of examination of task time collected during the 1-g demonstration, applying a program approved microgravity extrapolation factor (based on suit donning/doffing times collected during the microgravity or partial gravity evaluations) as appropriate, and accounting for all practical anthropometric crew assignments.

The verification will be considered successful when:

a. The demonstrations show that the crewmembers can don and doff their suits without assistance, achieving a subjectively adequate fit, as documented in a crew consensus report.

b. The analysis shows the listed number of crewmembers do not exceed 1 (TBR-001-113) hour to retrieve, don, and configure the suits for pressurization, and do not require more than 30 minutes to doff the suits.

Rationale: There are three primary factors (free volume, suit stowage location, and suit design) essential in the ability for the crew to don their suits within the "feed the leak" time. The analysis will pull together the donning times (including free volume and stowage locations) as collected during the 1-g evaluations and verify that those collective times (minus any test artificial time delays, etc.) will allow the crewmembers to retrieve, don, and pressure their suits within 1 (TBR-001-113) hour. The use of the microgravity or partial gravity test results to produce a microgravity/partial gravity extrapolation factor, which can then be applied to the 1-g *evaluation times, acknowledges the differences between the Constellation EVA suits and those of past programs.*

[CA5659V-PO] The ability of EVA System to provide a suit operable to a minimum of 30 (TBR-001-191) kPa (4.3 psid) positive shall be verified by test and analysis. The test shall consist of runs performed from 0 to 101 kPa (0 to 14.7 psia) with EVA System pressure suit and all EVA System elements directly interfacing to the pressure suit (flight or certification classification). The analysis shall prove, through evaluation of test data and review of design, that the EVA System can provide a pressure suit certified to operate at vehicle cabin pressures 0 to 101 kPa (0 to 14.7 psia) to at least 30 (TBR-001-191) kPa (4.3 psid) positive. The verification shall be considered successful when the analysis confirms the functions listed can be performed.

Rationale: Testing and analysis is the standard process used as part of the EVA flight hardware certification process. Details of the test specifics will be worked as part of the EVA System Project certification activities, but listing the test requirement in the CARD ensures that the analysis used for certification is supported by a final integrated test of the EVA System (and not just the pressure suit as an individual element provided by the project).

4.7.9.2.15 EVA System Environmental Conditions

[CA5188V-PO] Compliance of EVA System with its requirements during and after exposure to CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) environments shall be verified by inspection and analysis. The analysis shall consist of an integrated analysis based on a systems engineering approach similar to that defined in Section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), and the allocation of the natural environments requirements to the lower tier elements and their verification methods and details. The analysis shall include the following integrated configurations: Orion/LSAM/EVA, Orion/EVA, and LSAM/EVA. The inspection will consist of a review of the lower tier verification closure data. The closure analysis shall utilize lower tier verification closure data and address interactions of each lower tier system on other systems to address integrated environment effects. The verification shall be considered successful when the inspection and integrated analyses show:

a. The analysis has been completed to address the scope of section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE).

b. The natural environment requirements and verification have been allocated to the lower tier systems in accordance with Section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE).

c. Lower tier verifications have been completed.

d. The EVA Systems meets its requirements during and after exposure to CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) environments in all integrated configurations.

Rationale: Verification of functional and performance requirements across the range of natural environments requires a systematic integrated approach to address dependencies on hardware configurations and operational mode. The DSNE Section 4 specifies a standard systems engineering technique for flowing down the natural environment from higher to lower levels using the Natural Environment Requirements Sensitivity and Applicability Matrix (NERSAM) for each mission phase. Lower tier verification close out data, analyses, and models are necessary to support the integrated analysis, but are not sufficient alone to close out the environment requirements from the integrated vehicle configuration.

[CA5559V-PO] The EVA System function and performance during and after exposure to induced environments shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the EVA/System IRD requirements.

b. Review of the induced environment verifications submitted against EVA/System SRD requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification. The verification shall be considered successful when the analysis shows that the EVA function and performance requirements are met during and after exposure to CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.

Rationale: Function and performance must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that:

a. The proper induced environments have been considered.

b. Sensitivities to these environments.

c. Synergistic effects have each been properly addressed for all mission phases.

[CA5564V-PO] EVA Systems induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

a. Review of the induced environmental verifications submitted against all of the EVA/System IRD requirements.

b. Review of the induced environment verifications submitted against EVA/System SRD requirements for DRM total induced environments.

The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification.

The verification shall be considered successful when the analysis shows that the EVA peak and cumulative induced environments will not exceed CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.

Rationale: Induced environment contributions must be verified for all mission phases and all induced environments. Only a comprehensive systems level analysis as described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that:

a. The proper induced environments have been met.

b. Sensitivities to these environments.

c. Synergistic effects have each been properly addressed for all mission phases.

4.7.9.3 Reserved

4.7.9.4 EVA System External Interfaces

[CA0923V-PO] The EVA System interfaces with Orion systems shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the EVA Project Office to demonstrate that the EVA System-to-Orion interface requirements defined within CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the Orion avionics, software, and fluid interfaces and the EVA System at a SIL (or equivalent). Multi-system testing performed at the launch site, for flight systems, shall also incorporate the EVA systems to confirm interoperability and functionality between the Orion, GS, and the EVA System. Verification shall be considered successful when:

a. Analysis confirms that all of the EVA System-to-Orion interface verification requirements defined within CxP 70033, Constellation Program Orion -to- EVA Systems Interface Requirements Document, have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the EVA Project Office to confirm that all of the EVA System-to-Orion interface requirements specified in the IRD have been satisfied. Integrated testing between the Orion avionics and software and the EVA System via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating EVA systems into the integrated flight system testing at the launch site will confirm *integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.*

[CA0924V-PO] The EVA System interface with the LSAM systems shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the EVA Project Office to demonstrate that the LSAM-to-EVA System interface requirements defined within CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM avionics, software, and fluid interfaces and the EVA System at a SIL (or equivalent). Multi-system testing performed at the launch site for flight systems shall also incorporate the EVA System to confirm interoperability and functionality between the LSAM, GS, and the EVA System. Verification shall be considered successful when:

a. Analysis confirms that all of the LSAM-to-EVA System interface verification requirements defined within CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) -to- Extravehicular Activity (EVA) Interface Requirements Document (IRD), have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the EVA Project Office to confirm that all of the EVA-System to-LSAM interface requirements specified in the IRD have been satisfied. Integrated testing between the LSAM avionics and software and the EVA System via the SILs (or equivalents) will provide verification of the adequacy of emulators and simulators used during the project-level verification activities. Integrating EVA Systems into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes, as well as provide assurance that the verification activities performed using various emulators and simulators were adequate.

[CA0925V-PO] The EVA System interfaces with the GS systems shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the EVA Project Office to demonstrate that the EVA System-to-GS interface requirements defined within CxP 70104, Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Multi-system testing performed at the launch site, for flight systems, shall also incorporate the EVA System to confirm interoperability and functionality between the GS and EVA System. Verification shall be considered successful when:

a. Analysis confirms that all of the EVA System interface verification requirements defined within CxP 70104, Constellation Program Extravehicular Activity Systems -to- Ground Systems Interface Requirements Document (IRD) , have been satisfied.

b. Integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.

Rationale: Since the Constellation Program Office (CxPO) has final closure authority/responsibility for the CARD requirements, the CxPO will evaluate the verification data provided by the EVA Project Office to confirm that all of the EVA System-to-GS interface requirements specified in the IRD have been satisfied. Integrating EVA System into the integrated flight system testing at the launch site will confirm integrated operability, functionality, and system stability during/after operational mode changes.

4.7.9.5 Reserved

4.7.10 Flight Crew Equipment

4.7.10.1 Reserved

4.7.10.2 Flight Crew Equipment Requirements

[CA6081V-PO] The Control Mass requirement for Flight Crew Equipment shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of these components is less than or equal to the required Control Mass.

Rationale: NR

[CA6082V-PO] The Control Mass requirement for Flight Crew Equipment shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of these components is less than or equal to the required Control Mass.

Rationale: NR

APPENDIX A
ACRONYMS AND ABBREVIATIONS
AND GLOSSARY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

All Acronyms and Glossary terms shown in this appendix are linked directly from CxP 70072-ANX01, Constellation Program Management Systems Plan, Annex 01: Common Glossary and Acronyms.

TABLE A-1 - ACRONYMS

Acronym	Acronym Description
6-DOF	Six Degrees of Freedom
ADL	Applicable Document List
ADS	Altitude Determination System
AFSCN	Air Force Satellite Control Network
APO	Advanced Projects Office
ASAP	Aerospace Safety Advisory Panel
C&T	Communications and Tracking
C&TN	Communications and Tracking Network
C3I	Command, Control, Communications, and Information
CA	Constellation Architecture
CaLV	Cargo Launch Vehicle
CARD	Constellation Architecture Requirements Document
CCBD	Configuration Control Board Directive
CEQATR	Constellation Environment Qualification and Acceptance Testing
CEV	Crew Exploration Vehicle
CIL	Critical Items List
CLV	Crew Launch Vehicle
cm	centimeter
CM	Command Module Configuration Management Crew Module
cmd	command
CMG	Control Moment Gyroscope
CO2	Carbon Dioxide
CoFR	Certification of Flight Readiness

Acronym	Acronym Description
CONOP	(TBD A-1)
CONUS	Continental United States
CR	Change Request
CSCI	Computer Software Configuration Item
Cx	Constellation
CxCB	Constellation Program Control Board
CxP	Constellation Program
CxPMD	Constellation Program Management Directive
CxPO	Constellation Program Office
D&C	Displays and Controls
DAC	Design Analysis Cycle
DAEZ	Down-range Abort Exclusion Zone
DAV	Descent Ascent Vehicle
DC	Direct Current
DCS	Decompression Sickness
DDMS	Data Distribution Management System
DDT&E	Design, Development, Test and Evaluation
deg	degree
delta-V	delta-Velocity
DFI	Development Flight Instrumentation
DFMR	Design for Minimum Risk
DoD	Department of Defense
DOI	(TBD A-1)
DOLILU	Day of Launch I-Load Update
DRM	Design Reference Mission
DSIL	Distributed System Integration Laboratory
DSNE	Design Specification for Natural Environments
DSS	Destination Surface Systems
DTO	Development Test Objective
DV	(TBD A-1)
E3	Electromagnetic Environmental Effects
EARD	Exploration Architecture Requirements Document
Ec	Expectation of Casualty
ECANS	Exploration Communication and Navigation System
ECLS	Environment Control and Life Support

Acronym	Acronym Description
ECLSS	Environmental Control and Life Support System
EDS	Earth Departure Stage
EEE	Electrical, Electronic, and Electromechanical
EELV	Evolved Expendable Launch Vehicle
ELV	Expendable Launch Vehicle
EMC	Electromagnetic Compatibility
EMU	Extravehicular Mobility Unit
EOR	Earth Orbit Rendezvous
ERO	Earth Rendezvous Orbit
ERTT	ESAS Requirements Transition Team
ESAS	Exploration Systems Architecture Study
ESM	(TBD A-1)
ESMD	Exploration Systems Mission Directorate
EVA	Extravehicular Activity
f/s	feet per second
FC	(TBD A-1)
FCE	Flight Crew Equipment
FCO	Flight Control Officer
FDIR	Fault Detection, Isolation, and Recovery/Reconfiguration
FEIT	Flight Element Integration Testing
FFBD	Functional Flow Block Diagram
FIPS PUB	Federal Information Processing Standard Publication
FMEA	Failure Modes and Effects Analysis
FOD	Foreign Object Debris
FQT	Formal Qualification Testing
FRAM	Flight Releasable Attachment Mechanism
FSE	Flight Support Equipment
ft	feet
ft/s	feet per second
ft3	cubic feet
FTS	Flight Termination System
GFE	Government Furnished Equipment
GMO	Ground and Mission Operations
GN&C	Guidance, Navigation, and Control
GO	Ground Operations

Acronym	**Acronym Description**
GPS	Global Positioning System
GS	Ground Systems
GSE	Ground Support Equipment
GS-SRD	Ground Systems-System Requirements Document
GS-SSRD	Ground Systems-Subsystem Requirements Document
H&S	Health and Status
HQ	NASA Headquarters
hr	hour
HRR	Human Rating Requirements
HSIR	Human-Systems Integration Requirements
HST	Hubble Space Telescope
HW	Hardware
ICD	Interface Control Document
ICE	Integrated Collaboration Environment
IDAC	Integrated Design Analysis Cycle
IEDS	Induced Environment Design Specifications
ILS	Integrated Logistics Support
IMS	Inventory Management System
in	inch
IOC	Initial Operational Capability
IP	Internet Protocol
IRD	Interface Requirements Document
ISDS	(TBD A-1)
Isp	Specific Gravity
ISS	International Space Station
IT	Information Technology
IT&V	Integrated Test and Verification
IVA	Intravehicular Activity
JPR	JSC Procedural Requirement
kbps	kilobytes per second
kg	kilogram
km	kilometer
kPa	kilo-Pascal
KSC	Kennedy Space Center

Acronym	**Acronym Description**
kW	kilowatt
LAS	Launch Abort System
lb	pounds
lbm	pounds-mass
LCC	Launch Control Center
LDO	Lunar Destination Orbit
LEO	Low Earth Orbit
LH2	Liquid Hydrogen
LLO	Low Lunar Orbit
LLV	(TBD A-1)
LM	Lunar Module
LOC	Loss of Crew
LOI	Lunar Orbit Insertion
LOM	Loss of Mission
LOR	Lunar Orbit Rendezvous
LOV	Loss of Vehicle
LOX	Liquid Oxygen
LPRP	Lunar Precursor and Robotic Program
LRO	Lunar Rendezvous Orbit
LRU	Line-Replaceable Unit
LSA	Logistics Support Analysis
LSAM	Lunar Surface Access Module
LSAR	Logistics Support Analysis Records
LSP	Logistics Support Plan
m	meter
M&P	Materials and Processes
m/s	meters per second
m3	cubic meter
Mbps	Megabits per second
MCC	Mission Control Center
MCC-H	Mission Control Center-Houston
MCCS	Mission Control Center System
MEIT	Multi-Element Integration Test
MEL	Mission Engineering Link
min	minute

Acronym	Acronym Description
ML	Mobile Launcher
mm	millimeter
MOU	Memorandum of Understanding
MRD	Mission Requirements Definition
MS	Mission Systems
MS-CEV	Mission Systems-Crew Exploration Vehicle
MSE	Mission Systems Element
msec	millisecond
MSP	Management Systems Plan
MSVP	Mechanical Systems Verification Plan
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
MTV	Mars Transfer Vehicle
NAVSTAR	Navigation Signal Timing and Ranging
NERSAM	Natural Environment Requirement Sensitivity and Applicability Matrix
NGO	Need, Goals, and Objectives
NISN	NASA Integrated Services Network
nmi	nautical mile
nnnn	unique 4-digit number
NOAA	National Oceanic and Atmospheric Administration
NR	Not Required
NSS	NASA Safety Standard
OMRSD	Operations and Maintenance Requirements and Specifications Document
OPR	Office of Primary Responsibility
ORU	Orbital Replacement Unit
OSE	Orbital Support Equipment
OVEIWG	(TBD A-1)
PAO	Public Affairs Office
Pc	Probability of Casualty
PHS&T	Packaging, Handling, Storage, and Transportation
Pi	Probability of Impact
PLR	Packet Loss Rate
PO	Program Office

Acronym	Acronym Description
POD	Point of Departure
ppO2	Partial Pressure Oxygen
PRA	Probabilistic Risk Assessment
PSE	(TBD A-1)
psia	pounds per square inch absolute
psid	pounds per square inch differential
PSRD	Program Support Requirements Document
PTT	Part Task Trainer
R&M	Reliability and Maintainability
RAD	Reference Architecture Document
RCS	Reaction Control System
RF	Radio Frequency
RFCV	Radio Frequency Contingency Voice
RFHRP2P	Radio Frequency High Rate Point-to-Point
RFOP2P	Radio Frequency Operational Point-to-Point
RFPMP	Radio Frequency Point-to-Multipoint
RLEP	Robotic Lunar Exploration Program
ROCC	Range Operations Control Center
ROD	Review of Design
RPOD	Rendezvous-Proximity Operation-Docking
RPODU	Rendezvous-Proximity Operation-Docking-Undocking
RTM	Requirements Traceability Matrix
S	Second
s	seconds
SA	Single Access Spacecraft Adapter
SAPA	(TBD A-1)
SAR	Search and Rescue
SCaN	Space Communication and Navigation
SDR	System Design Review
SE	Systems Engineering
SE&I	Systems Engineering and Integration
SEMP	Systems Engineering Management Plan
SI	International System of Units
SIL	Systems Integration Laboratory

Acronym	Acronym Description
SIM	Scientific Instrument Module
SM	Service Module
SOMD	Space Operations Mission Directorate
SPDM OTCM	(TBD A-1)
SPE	Solar Particle Events
SRB	Solid Rocket Booster
SRD	System Requirements Document
SRM	Solid Rocket Motor
SRR	System Requirements Review
SSP	Space Shuttle Program
SSRB	Shuttle Solid Rocket Booster
SSRD	Subsystem Requirements Document
STS	Space Transportation System
SVP	Structural Verification Plan
SW	Software
T-0	Time minus Zero
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Supplied
TCM	Trajectory Correction Maneuver
TD	(TBD A-1)
TDRSS	Tracking and Data Relay Satellite System
TDS	Task Description Sheet
TEI	Trans-Earth Injection
TIG	(TBD A-1)
TLC	Trans-Lunar Coast
TLI	Trans-Lunar Injection
tlm	Telemetry
TPI	(TBD A-1)
TVC	Thrust Vector Control
Umbi	Umbilical
USAF	United States Air Force
UTC	Universal Time Code
V	Volt

Acronym	**Acronym Description**
V&V	Verification and Validation
VAB	Vehicle Assembly Building
VCRM	Verification Cross Reference Matrix
Vdc	Volt Direct Current
VR	Verification Requirement
VSE	Vision for Space Exploration

A2.0 GLOSSARY OF TERMS

Glossary Term	Description
Abort	Early termination of the mission or mission phase prior to reaching the mission destination due to a failure or other condition that endangers the crew. At the moment an Abort is declared, the focus of the operation switches from flying the planned mission to saving the crew. A successful Abort ultimately places the crew in the portion of the space flight system normally used for reentry, and places them in a safe situation suitable for successful return and rescue. Aborts include scenarios where the vehicle is damaged or not recovered.
Architecture	The system of systems that comprise the Constellation Program to achieve the Need, Goals and Objectives of ESMD.
Automated	Control or execution of a system or process without human intervention or commanding. Function performed via ground and/or onboard software interaction. This does not exclude the possibility of operator input, but such input is explicitly not required for an automated function.
Automatic	Control or execution of a system or process without human intervention or commanding. Function performed via ground and/or onboard software interaction. This does not exclude the possibility of operator input, but such input is explicitly not required for an automatic function. Automatic may also imply that the function begins without human intervention.
Availability	A measure of the degree to which an item is in an operable state and can be committed for immediate use.
Cargo	For Lunar and Mars missions, a piece of the Destination Surface System, including associated consumables, and payloads (see definition). For ISS missions, payloads and any ISS vehicle or crew systems equipment, samples, or consumables that must be delivered to the ISS to accomplish ISS objectives including any specific carrier equipment required to transport this equipment. Cargo being transported away from ISS includes payloads as well as waste, trash, and other unwanted ISS components. Cargo does not include Spacecraft Elements or their consumables.

Glossary Term	Description
Catastrophic Hazard	A condition that may cause loss of life or permanently disabling injury. Also includes a condition that may cause loss of vehicle prior to completing its primary mission. For example, a hazard that could cause loss of Orion prior to rendezvous with the LSAM would be considered catastrophic. A hazard that may cause loss of Orion after the crew has evacuated during a water landing would not be considered catastrophic.
Command	Directive to a processor or system to perform a particular action or function. Parameters can be specified at the time of command initiation.
Conjunction-Class Mission	Typified by stay times on Mars on the order of 500 Earth days, a phase angle between Earth and Mars of 180 degrees midway during the mission, and optimum phasing for outbound and return transfers.
Consumable	Resource that is consumed in the course of conducting a given mission. Examples include propellant, power, habitability items (e.g., gaseous oxygen), and crew supplies.
Contingency EVA	An EVA performed to deal with critical failures or circumstances, which are not adequately protected by redundancy or other means. An EVA not scheduled in the pre-mission timeline required to affect the safety of the crew, outpost, and/or safe return of the vehicle.
Control Mass	The design upper limit to the mass of an element or module (e.g., "Orion mass shall be no greater than X lb."). The same Control Mass may be the lower limit to the amount of mass another propulsive element or module can carry (e.g. "The Ares I shall deliver no less than X lb to a 28.5-degree Low Earth Orbit.")
Crew	Human onboard the spacecraft or space system during a mission.
Crew Survival	Ability to keep the crew alive using capabilities such as abort, escape, safe haven, emergency egress, and rescue in response to an imminent catastrophic condition.
Communication and Tracking Network	Ground and space-based infrastructure assets used to communicate between Constellation Systems and to track Constellation flight Systems. Includes NASA managed components such as the Deep Space Network, Space Network, Ground Network, possible Lunar Relay Satellite System, and NISN. May include external governmental or commercial communication and tracking assets contracted by NASA.

Glossary Term	Description
Control of Automation	The commanded ability to select, initiate, inhibit, override, and terminate automation.
Design for Minimum Risk (DFMR)	A process in which risks are reduced/controlled (in lieu of compliance with specific failure tolerance requirements) through specified factors of safety, material properties, or other properties inherent to the design of the part, component, subassembly, or assembly. The process includes design and certification in accordance with approved consensus standards, with design implementation and verification provisions to enhance the reliability of safety critical space systems to the maximum extent practical. Examples include structures, pressure vessels, pressurized lines and fittings, material compatibility, and flammability.
Design Reference Mission (DRM)	Typical mission scenario encompassing tasks that are most likely to drive the architecture system design requirements. The DRMs are analyzed for all mission aspects from failure tolerance to hardware layout, software functionality and design suitability.
Docking	Mating of two independently operating spacecraft or other systems in space using independent control of the two vehicles' flight paths and attitudes during contact and capture. Docking begins at the time of initial contact of the vehicles' docking mechanisms and concludes when full rigidization of the interface is achieved. Final mating is generally accomplished by the docking mechanism.
Earth Rendezvous Orbit (ERO)	The orbit in which Constellation systems rendezvous and dock prior to departure for exploration destinations.
Environment Constraint	Any operational limitation that reduces the magnitude or severity of environment design specifications to allow designing to a less severe case.
Earth Weather Services	The generation, acquisition, and distribution of terrestrial weather data necessary to support ground processing, launch, ascent, entry, recovery, and rescue operations. This includes acquisition (via NASA assets) of weather data, the acquisition of weather data from non-NASA external sources, and the processing of that data for use by the Constellation Architecture.
Fault	An anomalous condition of a system, which includes hardware and software.
Fault Detection	Determine and notify that a fault has occurred.

Glossary Term	Description
Fault Isolation	Determine the cause of a fault/failure to a specific component and failure mode, or to a limited group of potential components.
Fault Tolerance	Built-in capability of a system to perform as intended in the presence of specified hardware or software faults. EVA, emergency systems, or emergency operations may not be used as a leg of fault tolerance.
Flight Termination	An emergency action taken by range safety when a vehicle violates established safety criteria for the protection of life and property. This action circumvents the vehicles' normal control modes and ends its powered and/or controlled flight.
Ground Support Equipment (GSE)	Non-flight systems, equipment, or devices necessary to support such operations as transporting, receiving, handling, assembly, inspection, test, checkout, servicing, launch, and recovery of space systems.
Geometric Visibility	Geometric visibility exists from one system to another system when the field of regard of the 1st system includes the 2nd system. Geometric visibility exists between a space communications and tracking network resource and a user spacecraft when the field of regard of the network asset contains the user spacecraft. Geometric visibility for one side of the link does not imply the ability to communicate. Geometric visibility is required by both ends of a link, establishing line of sight communication.
Habitable Environment	The environment that is necessary to sustain the life of the crew and to allow the crew to perform their functions in an efficient manner. These environments are described in CxP-70024, Human Systems Integration Requirements.
Hazard	A state or a set of conditions, internal or external to a system that has the potential to cause harm.
Health and Status	Information on subsystem performance and flight performance, including configuration data, vehicle state data, subsystem status, failures, hazards and measured parameters outside of normal limits.
Human-Rated	The certification that a system has been developed and is capable of being operated in a manner appropriate for use by human crews at minimal risk. Human-rated certification includes: (1) human safety; (2) human performance (both nominal and degraded states of operation); and (3) human health management and care as applicable.
Inhibit	To prevent initiation of a function, process, or operation

Glossary Term	Description
Integrated Logistics Support	The logistics activities that range from flight (includes in-space) and ground systems design support and maintenance planning to logistics resource acquisition (spare parts, supplies, consumables tools, and protective clothing), Packaging, Handling, Storage, and Transportation (PHS&T), and on-site/off-site depot operations (repair, manufacturing, calibration, cleaning). These logistics support elements enable safe and efficient ground processing and in-flight activities. Logistics support includes development of support requirements that are related to readiness objectives, to design, and to each other. Requirements in turn drive acquisition of required support; logistics support is then employed during the operational phase. Logistics support does not include maintenance, documentation, or control of operational flight or ground software.
ISS Orbit	An orbit around the Earth with an inclination of 51.3 - 51.9 degrees, an altitude of 150 - 248 nmi (342.6 - 459.3 km) and eccentricity less than or equal to 0.0081. The solar beta angle in the ISS orbit varies between plus and minus 75 degrees.
IVA Maintenance	Corrective or preventive maintenance performed by the crew within the pressurized spacecraft during a mission.
Information Assurance	Ensuring the availability, integrity, and confidentiality of information assets.
Information Assurance Functions	The functions performed on information (or on the invocation of information system functions) in order to assure availability, integrity, and confidentiality. These functions are: authentication, authorization, encryption, decryption, integrity validation, and logging.
Launch Opportunity	The period of time during which the alignment of the launch site and planned orbital plane permits the launch vehicle to reach its ascent target.
Line-Replaceable Unit (LRU)	A piece of equipment which, if it fails, can be removed and replaced with a working spare by a user or operator.
Loss of Crew	Death of or permanently debilitating injury to one or more crew members.
Loss of Mission	Loss of or inability to complete significant/primary mission objectives.
Low Earth Orbit (LEO)	A geocentric orbit with an altitude much less than the Earth's radius. Constellation missions are envisioned to use low Earth orbits with inclinations between 28.5 and 51.9 degrees, and altitudes less than 500 nmi (926 km).

Glossary Term	Description
Low Lunar Orbit (LLO)	A selenocentric orbit with an altitude much less than the Moon's radius. Constellation missions are envisioned to use Low Lunar Orbits with altitudes of 54 nmi (100 km) +/- (TBD-003-001) and inclinations of any value, optimized for each mission.
Mission	A flight to a destination in space, intended to accomplish specific scientific and technical objectives. Mission phases include TBS.
Mission Critical	An event, system, subsystem or process that must function properly in order to prevent loss of mission, launch scrub, or major facility damage.
Mission Planning	The development of operations scenarios and timelines needed to prepare for a mission.
Mission Class	A specified set of missions imposing a unified set of requirements on the operations system. If a new set of missions will likely require a significant delta to the existing operations design, then it is convenient to group the set of missions as a new Mission Class. For operations definition, the set of Constellation Mission Classes are the Orion mission to ISS (including unmanned test flights, cargo missions, and human missions), robotic precursor and support missions (potentially partitioned into multiple mission classes, e.g., for orbiters and surface missions), and lunar sorties. Potential later Mission Classes are lunar outpost missions and human Mars missions.
Multi-Hop Communication	The ability of a System to communicate with other Systems with which it does not have direct data-link level connectivity by using intermediate Systems as relays.
Navigation	The process of determining the translational state (time tagged position and velocity). Navigation may entail estimation of an updated state by incorporation of sensor data or simply a state propagation/prediction with environment models. Navigation is a shared function across the architecture.
Net Habitable Volume	The total remaining volume available to on-orbit crew after accounting for the loss of volume due deployed equipment, stowage, and any other structural inefficiencies (nooks and crannies) which decrease functional volume.
Override	To halt, manually or automatically, operation of a function in progress.

Glossary Term	Description
Preventive Maintenance	Maintenance actions performed to retain system hardware in a specified condition. Preventive maintenance includes activities such as inspection, sampling, calibration, adjustment, and lubrication.
Payload	Research and technology demonstration equipment required to meet defined mission objectives as well as equipment and samples that must be returned to Earth for analysis.
Quiescent Mode	Low power, keep-alive state which maintains the health of the System required for the next phase of operation; for ISS missions this mode maintains Orion health while docked to ISS; for Lunar missions this mode ensures functionality to accomplish redocking between Orion and LSAM.
Quiescent Vehicle	Any crewed or uncrewed vehicle in loiter mode, docked but not supporting active operations, or pre-deployed but in a standby mode, which requires only periodic health and status checks by flight crew or ground. Some minimal, nominal commanding may be required.
Rationale	A record of the justification for any decisions.
Recover	To perform post-landing or splashdown activities that include vehicle safing, inspection of the flight element for safety, configuring the Orion CM for crew egress, egress of the flight crew, providing access to stowed items, flight element retrieval (Ares I first stage, Ares V SRBs, Orion CM), transportation to the launch site and/or refurbishment site, and turnover of time-critical cargo to the provider.
Relative Navigation	The specific mode of navigation between two vehicles in which the navigational state vector of one vehicle is estimated with respect to the other, which may or may not include relative sensor measurements between the two vehicles.
Rendezvous	Mission phase during which the maneuvering vehicle approaches the target vehicle using a series of coarse maneuvers targeted to move the maneuvering vehicle into the proximity of the target vehicle.
Requirement	A necessary, quantifiable, and verifiable capability, function, property, characteristic, or behavior that a product must exhibit to solve a real world problem, or a constraint that it must satisfy or be satisfied.
Rescue	The process of locating the crew, proceeding to their position, providing assistance and transporting them to a location free from danger. (NPR 8705.2A, Human-Rating Requirements For Space Systems)

Glossary Term	Description
Safe Haven	A specifically designated area, location or facility that protects crew or ground team from unplanned hazardous or dangerous events. A safe haven provides essential life support functions to keep personnel alive and healthy until the dangerous condition has been mitigated or rescue is performed. Also a protected location into which a space vehicle, such as the Ares I/Orion, can be moved for protection from hazardous conditions until the hazard no longer exists.
Safety Critical	An event, system, subsystem or process, which if lost or degraded, would result in a critical or catastrophic hazard.
Skip Entry	An atmospheric entry from a hyperbolic or elliptical approach orbit to the ground by utilizing an altitude increase during some portion of entry flight that reduces aerodynamic accelerations below 0.2 G (local). Skip entry may or may not utilize a small propulsive correction maneuver to facilitate the "second" entry (i.e., before accelerations increase above 0.2 G (local) upon second entry), but this maneuver will not insert the vehicle into an exo-atmospheric orbit.
Stowage	Physical accommodation of items in a safe and secure manner in a System. This does not include provisions for thermal control or power supply. Does not include installed items.
Unimpeded Access	Immediately visible and accessible without being blocked or constrained by other equipment. Unimpeded Access is important for Emergency Systems and other critical items.

APPENDIX B
OPEN WORK

B1.0 TO BE DETERMINED

The table below specified items To Be Determined (TBD). As resolutions are developed, they will be added to the text of the CARD by CR. If new TBDs are added they will be added to this list, numbered, and tracked. Original TBDs will not be renumbered. Draft requirements in this document and their associated TBDs may not have resolution plans at this time, but will be incorporated as they are developed. Section 4 resolution plans.

TABLE B1 – TO BE DETERMINED ITEMS

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-012	Analyze Lunar surface landing accuracies, and lunar surface positioning accuracies, assess landing accuracies acheivable using earth based tracking only.	IDAC-5	CA0406-PO CA0862-PO CA0863-PO	CARD_3.7.1.2.6.2 CARD_3.7.7.2.6 CARD_3.7.8.2.6
TBD-001-013	Define launch probability w.r.t. weather via assessment of DSNE specs and CaLV requirements.	SDR Initiation	CA0407-PO	CARD_3.2.6
TBD-001-031	Analysis of the further developed Ops Concept for the Mars mission class and further developed vehicle systems will be used to determine the optimal transfer location.	MARS SRR	CA0347-PO	CARD_3.7.1.2.3
TBD-001-034	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA0099-HQ CA0099V-PO	CARD_3.2.1
TBD-001-036	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA0474-HQ CA0474V-PO	CARD_3.2.2.1
TBD-001-041	The specific amount of cargo that must be transferred to the Martian surface will be validated by analysis of the NASA NGOs and compared against the capabilities of the CA.	MARS SRR	CA0212-HQ	CARD_3.2.4
TBD-001-050	Future IDAC supporting Mars DRM	CxP Mars SRR	CA3039-HQ CA3039V-HQ	CARD_3.2.1
TBD-001-054	Future IDAC supporting Mars DRM	CxP Mars SRR	CA3037-HQ CA3037V-HQ	CARD_3.2.2.1

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-058	Future IDAC supporting Lunar Outpost DRM	CxP Lunar Outpost SRR	CA3038-HQ CA3038V-HQ	CARD_3.2.1
TBD-001-064	IDAC-3 SOA-00-1000 Launch Availability is in work	IDAC-3	CA0123-PO CA5605-PO CA5605V-PO	CARD_3.2.12 CARD_3.7.3.2.12
TBD-001-068	Work with HQ to specify value. Conduct analysis of Earth based or in-situ navigation techniques to achieve required accuracy if necessary. This requirement is driven in part by HQ studies regarding lunar surface mission objectives and plans for executing outpost missions, so will require coordination with ESMD to resolve.	LC SRR	CA0160-PO CA3141-PO CA0160V-PO CA3141V-PO	CARD_3.7.6.2.11 CARD_3.2.11
TBD-001-072	Continue to monitor this requirement to determine whether it becomes a driving requirement for the CaLV. In the distant future, perform TDS analysis to determine actual capability of CaLV and update value as appropriate.	Mars SRR	CA0282-PO CA3214-HQ CA3216-PO	CARD_3.7.4.2.4 CARD_3.2.6 CARD_3.7.4.2.11
TBD-001-076	TDS for analysis by Flight Dynamics group	LC SRR	CA5234-PO	CARD_3.7.1.2.2.2
TBD-001-090	Continuation of analyses by APO/ARDIG, LSAM, and CaLV to further refine the ability to close the lunar architectures.	LSAM SRR	CA0836-PO	CARD_3.7.3.2.6.1
TBD-001-091	Analysis of the martian surface science and engineering objectives from the program/headquarters will be translated into the needed volume. Assessments of the current volume return capability in the Martian systems vehicles and the sensitivity of return volume to vehicle performance will be made. Perform trades with vehicle subsystems/architecture if more payload volume is required.	MARS SRR	CA0823-HQ	CARD_3.2.4

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-096	The TBD will be resolved whenever the status of it is changed from Commentable to Riddable. LSAM may decide to delete this requirement or modify it to use similar words/rationale as the CEV Flight Data Recorder CA0511	CxP PDR	CA0517-PO	CARD_3.7.3.2.10
TBD-001-097	Lunar surface landing accuracies, and lunar surface positioning accuracies are targetted for analysis during IDAC#5.	LC SRR	CA0826-PO CA0826V-PO	CARD_3.2.11
TBD-001-1004	Continuation of analysis to further define CaLV capability.	CaLV SRR	CA4139-PO	CARD_3.7.1.2.6.1
TBD-001-1005	Review results of analysis performed by CxAT Lunar Team to determine Delta-Vs based on current DRMs. The proper amount of additional Delta-V to be added to the study results to cover Management Reserve will be decided before a final number is determined. CR in work to remove TBR-001-571	LSAM SRR	CA4145-PO	CARD_3.7.3.2.6.2
TBD-001-1008	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5816V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1009	The OCE action to determine how uncertainty/confidence levels need to be defined for analysis results was reported out in May 2007. Resolution of probability numbers such as this are being worked by T&V and are anticipated to be available in September 2007.	9/30/07	CA5605V-PO	
TBD-001-1010	Historical data research to determine acceptable performance value.	LC SRR	CA0397V-HQ	
TBD-001-1011	Placeholder for future document.	LC SRR	CA0397V-HQ	
TBD-001-1014	Resolution per TDS# SIG-01-004	IDAC-3	CA3063V-PO	
TBD-001-1016	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5470V-PO	
TBD-001-1018	Define launch probability w.r.t. weather via assessment of DSNE specs and CaLV requirements.	Ares V SDR	CA0414V-PO	
TBD-001-1026	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	Orion PDR	CA5940-PO	CARD_3.4
TBD-001-1031	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0404V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1032	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0074V-PO	
TBD-001-1033	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0212V-HQ	
TBD-001-1034	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0823V-PO	
TBD-001-1035	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0073V-HQ	
TBD-001-1036	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0047V-PO	
TBD-001-1037	The ARDIG is currently beginning a process to work the results of the LAT and will submit TBD/TBR closure and draft requirement changes at the end of the process.	Lunar Outpost SRR	CA5247V-PO	
TBD-001-1038	The ARDIG is currently beginning a process to work the results of the LAT and will submit TBD/TBR closure and draft requirement changes at the end of the process.	Lunar Outpost SRR	CA0353V-PO	
TBD-001-1039	The ARDIG is currently beginning a process to work the results of the LAT and will submit TBD/TBR closure and draft requirement changes at the end of the process.	Lunar Outpost SRR	CA0407V-PO	
TBD-001-1040	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0347V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1041	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0373V-PO	
TBD-001-1042	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0406V-PO	
TBD-001-1044	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0862V-PO	
TBD-001-1045	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0863V-PO	
TBD-001-1051	Update the reference to the section in EVA Design and Construction Specification.	IDAC-3	CA3166V-PO	
TBD-001-1052	Update the reference to the HSIR requirement.	IDAC-3	CA3166V-PO	
TBD-001-1053	This TBD is for a pointer to a specific section within an IRD to be developed between LSAM/EDS and CEV. The IRD is not scheduled to be baselined until the timeframe following each of the Project SRRs. Closure of this will be accomplished by or as part of the CxP SDR.	CxP SDR	CA0183V-PO	
TBD-001-1054	MS Verification Document to be given an official document number by the MS SRR	CxP SDR	CA0270V-PO	
TBD-001-1059	VR will be provided by Orion PDR.	Orion PDR	CA5940V-PO	
TBD-001-1065	Following the current activity to close the lunar, the ARDIG will begin a process to coordinate, review and close the MARS items.	MARS SRR	CA0465V-HQ	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1070	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0134V-PO	
TBD-001-1072	Determine times.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBD-001-1073	Determine times.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBD-001-1074	Determine times.	Cx SDR	CA6012-PO CA6015-PO CA6017-PO CA6015V-PO CA6015V-PO-Objective CA6017V-PO CA6017V-PO-Objective	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.3.2.13
TBD-001-1075	Determine times.	Cx SDR	CA6012-PO CA6015-PO-Objective CA6017-PO-Objective	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.3.2.13
TBD-001-1076	Determine times	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBD-001-1077	Determine time.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBD-001-1078	Determine times.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBD-001-1079	Determine time.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1080	Determine time.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBD-001-1081	Determine time.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBD-001-1083	Determine time.	Cx SDR	CA6012-PO	CARD_3.2.13
TBD-001-1084	Develop document.	Cx SDR	CA6012V-PO CA6013V-PO CA6013V-PO-Objective CA6015V-PO CA6015V-PO-Objective CA6017V-PO CA6017V-PO-Objective CA6019V-PO	
TBD-001-1085	TDS scheduled for IDAC-4; technical analysis for refining TBR period of time for Lunar cases and TBD manpower estimates for ISS & Lunar cases.	IDAC-4	CA6027-PO CA6027V-PO	CARD_3.2.13
TBD-001-1086	TDS scheduled for IDAC-4; technical analysis for refining TBR period of time for Lunar cases and TBD manpower estimates for ISS & Lunar cases.	IDAC-4	CA6035-PO CA6038-PO CA6035V-PO CA6038V-PO	CARD_3.7.3.2.13 CARD_3.7.6.2.13
TBD-001-1120	TDS scheduled for IDAC-4; technical analysis for refining TBR period of time for Lunar cases and TBD manpower estimates for ISS & Lunar cases.	IDAC-4	CA6028-PO CA6028V-PO	CARD_3.2.13
TBD-001-1123			CA5935V-PO	
TBD-001-1300	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6009-PO CA6010-PO	CARD_3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13
TBD-001-1301	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6009-PO CA6010-PO	CARD_3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13
TBD-001-1302	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6008-PO CA6009-PO CA6010-PO CA6011-PO	CARD_3.2.13 CARD_3.7.3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1303	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6008-PO CA6009-PO CA6010-PO CA6011-PO	CARD_3.2.13 CARD_3.7.3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBD-001-1304	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6008-PO CA6009-PO CA6010-PO CA6011-PO	CARD_3.2.13 CARD_3.7.3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBD-001-1305	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6008-PO CA6009-PO CA6010-PO CA6011-PO	CARD_3.2.13 CARD_3.7.3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBD-001-1306	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6008-PO CA6009-PO CA6010-PO	CARD_3.2.13 CARD_3.7.3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13
TBD-001-1307	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6008-PO CA6009-PO CA6010-PO	CARD_3.2.13 CARD_3.7.3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13
TBD-001-1308	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6008-PO CA6009-PO CA6010-PO CA6011-PO	CARD_3.2.13 CARD_3.7.3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBD-001-1309	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6008-PO CA6009-PO CA6010-PO CA6011-PO	CARD_3.2.13 CARD_3.7.3.2.13 CARD_3.7.4.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBD-001-1310	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6010-PO	CARD_3.2.13 CARD_3.7.5.2.13
TBD-001-1311	Complete IDAC4 TDS SIG-09-xxx to define TBD critical path hour values in Table.	IDAC-4	CA6007-PO CA6010-PO	CARD_3.2.13 CARD_3.7.5.2.13
TBD-001-1312	Determine applicability to FCE.	Orion PDR	CA0296-HQ	CARD_3.2.10

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1313	The number of simultaneous systems will be obtained from the driving scenarios developed in lunar-phase CONOPs work based on the results of a study planned for Integrated Design Analysis Cycle IDAC-4.	IDAC-4	CA6065-PO CA6065V-PO	CARD_3.2.10
TBD-001-1314	During LEO operations of lunar phase missions the driving scenario for simultaneous communications will be identified by further study in IDAC-4.	IDAC-4	CA6066-PO CA6066V-PO	CARD_3.7.1.2.10
TBD-001-1315	During LLO operations of lunar phase missions the driving scenario for simultaneous communications will be identified by further study in IDAC-4.	IDAC-4	CA6067-PO CA6067V-PO	CARD_3.7.1.2.10
TBD-001-1316	During lunar phase missions the driving scenario for simultaneous communications will be determined as a product of an IDAC-4 study focused on lunar CONOPs and lunar simultaneous communications needs.	IDAC-4	CA6068-PO CA6068V-PO	CARD_3.7.1.2.6
TBD-001-1400	ODAC-2 TDS will trade between use of onboard consumables vs. ground ops resources for launch attempt crew support.		CA6100-PO CA6100V-PO	CARD_3.7.1.2.12
TBD-001-1401		IDAC-4	CA5913-PO CA5914-PO	CARD_3.7.1.2.2.1 CARD_3.7.2.2.2.1
TBD-001-1402	ODAC-2 TDS will trade between use of onboard consumables vs. ground ops resources for launch attempt crew support.		CA6101-PO	CARD_3.7.5.2.12
TBD-001-1403			CA6106-PO	CARD_3.2.7
TBD-001-1404	TBD		CA5065-PO	CARD_3.2.10
TBD-001-1500			CA6203-PO CA6203V-PO	CARD_3.7.2.2.12
TBD-001-1501			CA6204-PO CA6204V-PO	CARD_3.7.5.2.12

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1502			CA6205-PO CA6205V-PO	CARD_3.7.1.2.12
TBD-001-1503			CA6206-PO CA6206V-PO	CARD_3.7.4.2.12
TBD-001-1504			CA6207-PO CA6207V-PO	CARD_3.7.3.2.12
TBD-001-1505			CA6208-PO CA6208V-PO	CARD_3.7.5.2.12
TBD-001-1506			CA6209-PO CA6209V-PO	CARD_3.7.5.2.12
TBD-001-1507		IDAC-4	CA6210-PO	CARD_3.2.10
TBD-001-1508			CA0002V-HQ CA0062V-PO CA0081V-PO CA0090V-PO CA0129V-PO CA0137V-PO CA0160V-PO CA0274V-PO CA0284V-PO CA0325V-PO CA0329V-PO CA0333V-PO CA0397V-HQ CA0416V-PO CA0418V-PO CA0461V-PO CA0462V-PO CA0579V-PO CA0848V-PO CA0837V-PO CA0839V-PO CA0847V-PO CA0864V-PO CA0865V-PO CA0866V-PO CA0868V-PO CA0529V-PO CA3182V-PO CA0049V-PO CA0072V-PO CA3202V-PO CA3203V-PO CA3204V-PO CA3205V-PO CA3206V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
			CA3207V-PO CA3208V-PO CA3209V-PO CA3212V-PO CA3213V-PO CA3215V-PO CA3216-PO CA3217V-PO CA5233V-PO CA1023V-PO CA0850V-PO CA0051V-PO CA1000V-PO CA1005V-PO CA0059V-PO CA0131V-PO CA0133V-PO CA0369V-PO CA0135V-PO CA5275V-PO CA5284V-PO CA5292V-PO CA5303V-PO CA5312V-PO CA5316V-PO CA5234V-PO CA5236V-PO CA5237V-PO CA5238V-PO CA5240V-PO CA0324V-PO CA0211V-HQ CA0829V-PO CA0209V-HQ CA0282V-PO CA0191V-PO CA0281V-HQ CA5265-PO CA5323V-PO CA5259-PO CA4135V-PO CA4138V-PO CA4140V-PO CA4141V-PO CA4143V-PO CA4145V-PO CA5319V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
			CA0187V-PO CA4128V-PO CA5286V-PO CA5290V-PO CA0128V-PO CA0183V-PO CA4165V-PO CA5819V-PO CA5285V-PO CA5921V-PO CA5948V-PO CA0056V-PO	
TBD-001-1509			CA6110V-PO	
TBD-001-187	Lunar surface landing accuracies, and lunar surface positioning accuracies are targetted for analysis during IDAC#5.	LC SRR	CA0826-PO CA0826V-PO	CARD_3.2.11
TBD-001-221	New study for IDAC3 (System Data Queuing) that will leverage the results of SIG-13-109 (Data Flow Modeling Tool) and SIG-13-111 (Communication Services)	IDAC-3	CA5046-PO CA5046V-PO	CARD_3.7.9.2.10
TBD-001-252	New study for IDAC-3 extending the results of GOP-00-001 to include unassisted emergency egress for ground crew scenario for pre-launch activities	IDAC-3	CA0311-PO CA0337V-PO CA0311V-PO	CARD_3.2.2.2
TBD-001-263	Two tailored documents are being produced; one for Ares I integrated launch vehicle and the second for Ares V integrated launch vehicle. These documents are being targeted for 2011 and 2015 respectively. A common CxP document number with a dash (-) I and a -V are being requested.	01-01-2011	CA0100-HQ	CARD_3.2.7

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TBD-001-268	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0216V-PO	
TBD-001-277	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0170V-PO	

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TBD-001-287	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0427V-PO	
TBD-001-322		Lunar Outpost SRR	CA0005V-HQ	
TBD-001-323	Outside of the scope of the 1'st SRR	Mars Outpost SRR	CA0011V-HQ	
TBD-001-330	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0428V-PO	

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TBD-001-331	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0431V-PO	
TBD-001-336	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0517V-PO	

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TBD-001-343	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA1054V-PO	
TBD-001-344		Ares I CDR	CA1055V-PO	
TBD-001-345	IDAC-4 analysis	IDAC-4	CA1066V-PO CA1068V-PO	
TBD-001-346	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA1084V-PO	

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TBD-001-347	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA1086V-PO	
TBD-001-364	Future analysis once mission is better identified.	LCCR	CA3200V-PO	
TBD-001-365	This TBD is a place-holder pointer for a particular book that has not been identified/developed yet. This book will need to be drafted/identified prior to the LSAM SRR. Therefore, this TBD would be updated following the LSAM SRR.	LSAM SRR	CA3200V-PO	
TBD-001-368			CA3214V-PO	
TBD-001-371	Define acceptable clearance	Ares V SRR	CA3217V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-372	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0217V-PO	
TBD-001-382	MOU (TBD-001-382) between Cx and search organization(s) to confirm coordination for SAR support to be determined during IDAC-4	IDAC-4	CA0146V-PO CA5146V-PO CA0172V-PO	
TBD-001-382	MOU (TBD-001-382) between Cx and search organization(s) to confirm coordination for SAR support to be determined during IDAC-4	IDAC-4	CA4123V-PO	
TBD-001-407	The OCE action to determine how uncertainty/confidence levels need to be defined for analysis results was reported out in May 2007. Resolution of probability numbers such as this are being worked by T&V and are anticipated to be available in September 2007.	9/30/07	CA0413V-PO	
TBD-001-409	Update TBD once MOU between MS (or Haedquarters/CxP) and NOAA is baselined for space weather services provision to MS.	3/30/2008	CA5125V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-410	Once the Cx Manifest Information ICD is baselined showing interfaces between CxP database (with manifest and stowage information) and the MS invemntory management system, update TBD with document number.	6/30/08	CA5130V-PO CA5131V-PO CA5132V-PO CA5133V-PO	
TBD-001-414	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3302V-PO	
TBD-001-423	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5433V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-424	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA1085V-PO	
TBD-001-426	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3257V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-432	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5472V-PO	
TBD-001-435	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5473V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-438	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5474V-PO	
TBD-001-452	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5465V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-454	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5466V-PO	
TBD-001-456	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5467V-PO	

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TBD-001-458	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5468V-PO	
TBD-001-459	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5469V-PO	
TBD-001-460	TDS to evaluate lighting conditions based on preliminary LSAM design, including crew visibility/cameras and landing sensors. Will be worked in conjunction with Human Factors and SR&QA.	LSAM SRR	CA5303-PO CA5303V-PO	CARD_3.7.3.2.6

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-461	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5471V-PO	
TBD-001-462	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5475V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-463	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5476V-PO	
TBD-001-464	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5477V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-465	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5478V-PO	
TBD-001-466	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5479V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-467	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5480V-PO	
TBD-001-468	Update the reference to the section in EVA Design and Construction Specification.	IDAC-3	CA3168V-PO	
TBD-001-501	Review results of analysis performed by CxAT Lunar Team to determine Delta-Vs based on current DRMs. The proper amount of additional Delta-V to be added to the study results to cover Management Reserve will be decided before a final number is determined.	CaLV SRR	CA0051-PO	CARD_3.7.4.2.6.2
TBD-001-515	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA3023-PO CA3023V-PO	CARD_3.7.1.2.1
TBD-001-517	IDAC3 SOA-00-1000 Launch Availability is in work.	IDAC-3	CA0123-PO CA5600-PO CA5600V-PO	CARD_3.2.12 CARD_3.2.12
TBD-001-527	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA3027-PO CA3027V-PO	CARD_3.7.6.2.1
TBD-001-536	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA3030-PO CA3030V-PO	CARD_3.7.6.2.1
TBD-001-552	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA3035-PO CA3035V-PO	CARD_3.7.6.2.2

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-557	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA3036-PO CA3036V-PO	CARD_3.7.3.2.1
TBD-001-559	Future IDAC supporting Lunar Outpost DRM	CxP Lunar Outpost SRR	CA3040-PO CA3040V-PO	CARD_3.7.1.2.2.1
TBD-001-560	Future IDAC supporting Lunar Outpost DRM	CxP Lunar Outpost SRR	CA3041-PO CA3041V-PO	CARD_3.7.3.2.2.1
TBD-001-561	Future IDAC supporting Lunar Outpost DRM	CxP Lunar Outpost SRR	CA3042-PO CA3042V-PO	CARD_3.7.3.2.1
TBD-001-565	TDS for analysis to determine optimum orbit for Mar missions. This will have to take into account the number of launches required to assemble the cargo mission before insertion into the Mars trajectory, orbit degradation, and cargo mass.	Mars SRR	CA3215-PO	CARD_3.7.4.2
TBD-001-565			CA3215V-PO	
TBD-001-566	TDS to address allowable deviations based on CaLV Delta-V capability. This may vary for the different missions.	IDAC-4	CA3216-PO	CARD_3.7.4.2.11
TBD-001-566			CA3216-PO	
TBD-001-572	TDS to evaluate the proper window which will trade performance with launch probabilities, taking into account future determination of lunar outpost site.	CaLV SRR	CA5259-PO CA5259-PO	CARD_3.7.4.2.12
TBD-001-573	TDS to perform trade between operational aspects of length of launch window, mission planning requirements, and vehicle system constraints.	CaLV SRR	CA5265-PO CA5265-PO	CARD_3.7.4.2.12

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-591	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3121V-PO	
TBD-001-595	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3122V-PO	
TBD-001-600	The ARDIG is currently beginning a process to work the results of the LAT and will submit TBD/TBR closure and draft requirement changes at the end of the process.	Lunar Outpost SRR	CA0022V-HQ	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-603	Conduct net habit archetecture studies.	Lander SRR	CA0426-PO CA5385-PO CA0375V-PO CA0426V-PO CA5385V-PO	CARD_3.7.1.2.14 CARD_3.7.3.2.14
TBD-001-625	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3115V-PO	
TBD-001-631	The OCE action to determine how uncertainty/confidence levels need to be defined for analysis results was reported out in May 2007. Resolution of probability numbers such as this are being worked by T&V and are anticipated to be available in September 2007.	9/30/07	CA5600V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-634	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5432V-PO	
TBD-001-635	Update the reference to the HSIR.	IDAC-3	CA4127V-PO	
TBD-001-637	Flight performance/upmass, center of gravity, ECLSS resources, thermal, HSIR verification for anthropometry, cockpit design, the capability to accommodate (physically in terms of space) min and max crews, plus, reconfiguration capability to cover in-between configurations and TBD-001-637.		CA0010V-PO	
TBD-001-637	Upon completion of the CEV preliminary design, identify the bounding crew/cargo/system configurations to be analyzed to verify the capability to support crew complements of 0, 1, 2, 3, 4, 5, and 6, and revise the verification statement to clearly identify the configurations to be analyzed. Estimated completion date: ~8 weeks following CEV PDR.	Orion PDR	CA0447V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-640	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3272V-PO	
TBD-001-641	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3274V-PO	
TBD-001-645	New study for IDAC3 (System Data Queuing) that will leverage the results of SIG-13-109 (Data Flow Modeling Tool) and SIG-13-111 (Communication Services)	IDAC-3	CA5047-PO	CARD_3.7.9.2.10

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-646	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3128V-PO	
TBD-001-649	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA1028V-PO	
TBD-001-651	The ARDIG is currently beginning a process to work the results of the LAT and will submit TBD/TBR closure and draft requirement changes at the end of the process.	Lunar Outpost SRR	CA0287V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-662	MS Verification Document to be given an official document number by the MS SRR	CxP SDR	CA0158V-PO	
TBD-001-701	Need to do modeling with assumptions about system design to get expected demand: mass/volume/crew time. Mars will not be addressed.	IDAC-4	CA0550-PO	CARD_3.2.13
TBD-001-703	Update the TBD with the appropriate section in the EVA Design and Construction Specification.	IDAC-4	CA0202V-PO	
TBD-001-708	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3118V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-711	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3124V-PO	
TBD-001-714	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3127V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-718	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3130V-PO	
TBD-001-727	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3111V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-729	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3112V-PO	
TBD-001-732	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3113V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-734	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3256V-PO	
TBD-001-738	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3258V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-742	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3254V-PO CA3250V-PO	
TBD-001-746	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3273V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-750	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3249V-PO	
TBD-001-755	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5431V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-759	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3255V-PO	
TBD-001-763	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3275V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-768	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3276V-PO	
TBD-001-772	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3277V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-780	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5434V-PO	
TBD-001-783	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5435V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-786	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5436V-PO	
TBD-001-789	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5437V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-792	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5438V-PO	
TBD-001-795	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5439V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-799	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5440V-PO	
TBD-001-803	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0522V-PO	
TBD-001-809	Update TBDs based on IRD requirement sections.	IDAC-3	CA5169V-PO	
TBD-001-810	Update TBDs based on IRD requirement sections.	IDAC-3	CA5169V-PO	
TBD-001-811	Update TBDs based on IRD requirement sections.	IDAC-3	CA5169V-PO	
TBD-001-812	Update TBDs based on IRD requirement sections.	IDAC-3	CA5169V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-813	Update TBDs based on IRD requirement sections.	IDAC-3	CA5169V-PO	
TBD-001-814	Update TBDs based on IRD requirement sections.	IDAC-3	CA5203V-PO	
TBD-001-815	Update TBDs based on IRD requirement sections.	IDAC-3	CA5170V-PO	
TBD-001-817	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA4125V-PO	
TBD-001-851	TDS to CEV flight dynamics team to determine center-of-gravity envelope for stable entry. CR in work to remove TBR-001-851	11/05/07	CA5233-PO	CARD_3.7.1.2.4

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-852	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA1053V-PO	
TBD-001-906	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA0438V-PO	
TBD-001-907	Reference correct section when Cx70080 is baselined.	8/1/07	CA0555V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-914	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA3110V-PO	
TBD-001-927	The OCE action to determine how uncertainty/confidence levels need to be defined for analysis results was reported out in May 2007. Resolution of probability numbers such as this are being worked by T&V and are anticipated to be available in September 2007.	9/30/07	CA6203V-PO CA6204V-PO CA6206V-PO CA6207V-PO CA6208V-PO CA6209V-PO CA0123V-PO CA0178V-PO CA3064V-PO	
TBD-001-943	CaLV verification document number will be assigned by the CaLV project	CaLV SRR	CA3146V-PO	
TBD-001-945	Update reference to documentation as LSAM design matures.	IDAC-3	CA5193V-PO	
TBD-001-946	LSAM SRD document number to be assigned by LSAM project	LSAM SRR	CA3144V-PO CA3145V-PO CA5818V-HQ	
TBD-001-947	Update IDAC-3 Analysis	CxP SDR	CA5913-PO CA5913V-PO	CARD_3.7.1.2.2.1
TBD-001-948	Update IDAC-3 Analysis	CxP SDR	CA5914-PO CA5914V-PO	CARD_3.7.2.2.2.1
TBD-001-967	IDAC3 SOA-00-1000 Launch Availability is in work	IDAC-3	CA0123-PO	CARD_3.2.12
TBD-001-968	IDAC3 SOA-00-1000 Launch Availability is in work	IDAC-3	CA0123-PO	CARD_3.2.12

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-969	IDAC3 SOA-00-1000 Launch Availability is in work	IDAC-3	CA0123-PO	CARD_3.2.12
TBD-001-970	IDAC3 SOA-00-1000 Launch Availability is in work	IDAC-3	CA0123-PO	CARD_3.2.12
TBD-001-971	IDAC-4 Analysis	IDAC-4	CA0123-PO CA0413-PO CA0413V-PO	CARD_3.2.12 CARD_3.7.4.2.12
TBD-001-972	Define launch probability w.r.t. weather via assessment of DSNE specs and CaLV requirements.	IDAC-4	CA0123-PO CA0414-PO CA0414V-PO	CARD_3.2.12 CARD_3.7.4.2.12
TBD-001-973	IDAC3 SOA-00-1000 Launch Availability is in work	IDAC-3	CA0123-PO	CARD_3.2.12
TBD-001-975	Analysis continues to determine compatibility of this requirement with the CaLV EDS Delta-V capability and the LSAM control mass. Study being performed by ARDIG.	LC SRR	CA0839-PO CA0850-PO CA0839V-PO CA0850V-PO	CARD_3.7.3.2.5 CARD_3.7.4.2.5
TBD-001-977	Need to do modeling with assumptions about system design to get expected demand: mass/volume/crew time. Mars will not be addressed.	IDAC-4	CA0550-PO	CARD_3.2.13
TBD-001-978	Need to do modeling with assumptions about system design to get expected demand: mass/volume/crew time. Mars will not be addressed.	IDAC-4	CA0550-PO	CARD_3.2.13
TBD-001-981	Need to do modeling with assumptions about system design to get expected demand: mass/volume/crew time. Mars will not be addressed.	IDAC-4	CA0550-PO	CARD_3.2.13
TBD-001-982	Need to do modeling with assumptions about system design to get expected demand: mass/volume/crew time. Mars will not be addressed.	IDAC-4	CA0550-PO	CARD_3.2.13
TBD-001-983	Continuation of analyses to further define the CaLV capability	CaLV SRR	CA0847-PO	CARD_3.7.4.2.6.1

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-984	Analysis of all Delta-V necessary for Trajectory Correction Maneuvers (TCMs) during the Trans-Lunar Coast (TLC), and the Lunar Orbit Injection (LOI) into the Lunar Destination Orbit (LDO) for the LSAM-A/CEV mated configuration.	LSAM SRR	CA0837-PO	CARD_3.7.3.2.6.2
TBD-001-985	Need to do modeling with assumptions about system design to get expected demand: mass/volume/crew time. Mars will not be addressed.	IDAC-4	CA0550-PO	CARD_3.2.13
TBD-001-993	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5901V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-994	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5902V-PO	
TBD-001-995	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5903V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-996	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5904V-PO	
TBD-001-997	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5905V-PO	

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-998	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5906V-PO	
TBD-001-999	The TBD serves as a placeholder for the location(s) in the Level III project documentation where the pertinent information will be located - it is not the intent of the Level II program to define this information for the projects or to proscribe that a certain document must contain this information. After the Level III SRR(s), Level II will obtain the appropriate document numbers and titles from the Level III document tree(s) and use them to fill in the TBD. If it is not necessary to refer to specific documents, the TBD will be replaced with a generic description of the documentation where this information will be located.	Orion PDR	CA5907V-PO	
TBR-001-1439	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO CA6214-PO CA6214V-PO	CARD_3.2.10 CARD_3.7.2.2.10
TBD-ADL-0001	CxP 70034 has not been baselined.			
TBD-ADL-0002	CxP 70054 has not been baselined.			

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-ADL-0003	CxP 70084 has not been baselined.			
TBD-ADL-0004	CxP 70104 has not been baselined.			
TBD-ADL-0005	CxP 70105 has not been baselined.			
TBD-ADL-0006	CxP 70106 has not been baselined.			
TBD-ADL-0007	CxP 70107 has not been baselined.			
TBD-ADL-0008	CxP 70109 has not been baselined.			
TBD-ADL-0009	CxP 70112 has not been baselined.			
TBD-ADL-0010	CxP 70113 has not been baselined.			
TBD-ADL-0011	CxP 70118-03 has not been baselined.			
TBD-ADL-0012	CxP 70118-04 has not been baselined.			
TBD-ADL-0013	CxP 70118-05 has not been baselined.			
TBD-ADL-0014	CxP 70118-06 has not been baselined.			
TBD-ADL-0015	CxP 70119 has not been baselined.			
TBD-ADL-0016	CxP 70142 has not been baselined.			
TBD-ADL-0017	CxP 70143 has not been baselined.			
TBD-ADL-0018	CxP 70155-02 has not been baselined.			
TBD-ADL-0019	CxP 70155-03 has not been baselined.			
TBD-ADL-0020	CxP 70159 has not been baselined.			
TBD-ADL-0021	CxP 70169 has not been baselined.			
TBD-ADL-0022	CxP 72001 has not been baselined.			
TBD-ADL-0023	CxP 72002 has not been baselined.			
TBD-ADL-0024	CxP 72004 has not been baselined.			
TBD-ADL-0025	CxP 72006 has not been baselined.			

TBD #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-ADL-0026	CxP 72034 has not been baselined.			
TBD-ADL-0027	CxP 72085 has not been baselined.			
TBD-ADL-0028	CxP 72136 has not been baselined.			
TBD-ADL-0029	CxP 70136 has not been baselined.			
TBD-ADL-0030	CxP 70136-ANX01 has not been baselined.			

B2.0 TBR MATRIX

The table below specified items To Be Resolved (TBR). As resolutions are developed, they will be added to the text of the CARD by CR. If new TBRs are added they will be added to this list, numbered, and tracked. Original TBRs will not be renumbered. Draft requirements in this document and their associated TBRs may not have resolution plans at this time, but will be incorporated as they are developed.

TABLE B2-1 TO BE RESOLVED ISSUES

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1007	Review results of analysis performed by APO/ARDIG to determine control mass based on current DRMs. The proper amount of margin to be added to the study results to cover Management Reserve will be decided before a final number is determined.	LSAM SRR	CA5231-PO	CARD_3.7.3.2.6.1
TBD-001-1071	Determine time.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBR-001-002	Recommend removal of TBR based on discussion with A. Tabakman. Agreement is to determine at later date what capability of Orion is (how many hours support) and possibly update requirement then. TBR ready to close during next CARD update.	9/30/07	CA0493-PO	CARD_3.7.1.2.2
TBR-001-004	TDS will be written to investigate ability to safely separate the vehicle without complete knowledge of state data or possibly full attitude control functions. Will also require coordination with Human Factors SIG and ILS&M SIG.	IDAC-4	CA0463-PO	CARD_3.7.1.2.11
TBR-001-008	TDS to determine trade between LSAM descent stage weight and propellant requirements and lunar outpost cargo traffic model requirements.	LCCR	CA0137-PO	CARD_3.7.3.2.4

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-010	Obtain lunar surface science and engineering objectives from the program/headquarters Translate these objectives into crew workload; assess if any crews less than four are feasible given objectives. Assess the capability of the lunar lander and CEV to support more than a crew of four at the outpost per rotation. Assess cost of adding additional transportation capability Assess handover periods in terms of consumable usage, transportation available, and outpost volume.	Lunar Outpost SRR	CA0020-HQ	CARD_3.2.3
TBR-001-012	CxAT Lunar Team to determine mission needs for Lunar landing to accomplish Exploration objectives.	IDAC-5	CA0356-PO CA0418-PO	CARD_3.2.11 CARD_3.7.3.2.11
TBR-001-018	New study for IDAC-3 extending the results of GOP-00-001 to include unassisted emergency egress for suited crew scenario for pre-launch activities. Expecting the GO/MO SIG will be leading this integrated TBR resolution with help from the EVA SIG, EVA Project, CEV Project, and GO Project.	IDAC-3	CA0310-PO	CARD_3.2.2.2
TBR-001-020	Extended through to IDAC-3 Issue being addressed by SOA-00-1000 TDS.	IDAC-3	CA0038-HQ CA4121-PO CA5135-PO	CARD_3.2.12 CARD_3.7.5.2.5 CARD_3.7.6.2.12
TBR-001-021	TDS for IDAC-4	IDAC-4	CA0123-PO	CARD_3.2.12
TBR-001-033	Need to resolve uncertainties associated with lunar mission timeline relative to LSAM crewed ops, including navigation, "anywhere access on lunar surface", and contingencies.	Lunar Requirement Phase III	CA0813-PO	CARD_3.7.3.2.14
TBR-001-035	Further analysis of ISS mission and CEV capability to accommodate cargo	IDAC-3	CA0565-HQ	CARD_3.7.1.2.4

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-035	TDS to be submitted by PTI to the AWG. This TDS will require inputs from FP, SAIR, E&C, & ILS&M SIG's. Results from TDS will be used to identify the correct duration required for vehicle to remain in stacked configuration. This volume requirement should be an additional item to be considered by crew cabin utilization group.		CA0410V-PO	
TBR-001-038	6 tasks are planned to address pressure and oxygen concentration TBR's: commonality study, materials certification study, lunar operations timeline assessment, prebreathe assessment, vehicle pressure control assessment, and gas consumables assessment.	Lunar Requirement Phase III	CA3062-PO	CARD_3.7.3.2.14
TBR-001-039	ARDIG owns the parent 210 day Lunar Outpost mission requirement from which this number is merely reflected. ARDIG owns this TBR plan. Obtain lunar surface science and engineering objectives from the program/headquarters Translate these objectives into duration reqts. Understand what contingency duration is needed in addition to the nominal mission. Assess the capability of the lunar lander and CEV to support the 210 days at the outpost or in lunar orbit per rotation Assess cost of adding additional duration/benefit of reducing duration.	LC SRR	CA0082-PO CA0842-PO CA5289-PO	CARD_3.7.1.2.5 CARD_3.7.3.2.5 CARD_3.2.5
TBR-001-044	CxAT Lunar Team to determine mission needs for Lunar landing to accomplish Exploration objectives.	IDAC-5	CA0284-PO CA0529-PO	CARD_3.7.3.2.11 CARD_3.2.11
TBR-001-047	New study of SAR capabilities to validate this requirement. Must be coordinated with CEV study of 36 hours crew survival. The 95% probability of recovering the crew within 24 hours at an undesignated landing site will be determined by trade study.	IDAC-4	CA5146-PO	CARD_3.7.5.2.2
TBR-001-052	Update IDAC-3 Analysis	CxP SDR	CA0485-PO	CARD_3.7.4.2.2.1
TBR-001-053	Update IDAC-3 Analysis	CxP SDR	CA0486-PO	CARD_3.7.4.2.1
TBR-001-054	Update IDAC-3 Analysis	CxP SDR	CA0487-PO	CARD_3.7.4.2.1

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-059	Update IDAC-3 Analysis	CxP SDR	CA0503-PO	CARD_3.7.3.2.2.1
TBR-001-060	Update IDAC-3 Analysis	CxP SDR	CA0504-PO	CARD_3.7.3.2.1
TBR-001-075	Continuation of analyses by APO/ARDIG, LSAM, and CaLV to further refine the ability to close the lunar architectures	LSAM SRR	CA0836-PO	CARD_3.7.3.2.6.1
TBR-001-076	Continuation of analyses to further define the CaLV capability	CaLV SRR	CA0847-PO	CARD_3.7.4.2.6.1
TBR-001-077	Continuation of analyses to further define the CaLV capability	CaLV SRR	CA0848-PO	CARD_3.7.4.2.6.1
TBR-001-082	Obtain Mars surface science and engineering objectives from the program/headquarters. Translate these objectives into crew workload and assess if any crews less than six are feasible given objectives. Assess the capability of the Mars vehicles to support more than a crew of six. Assess cost of adding additional transportation capability.	MARS SRR	CA0010-HQ CA0347-PO	CARD_3.2.3 CARD_3.7.1.2.3
TBR-001-1000	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-1001	Will be resolved as part of Lunar SRR	CxP Lunar SRR	CA0296-HQ	CARD_3.2.10
TBR-001-1002	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-1004	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-1005	Will be resolved as part of Lunar SRR	CxP Lunar SRR	CA0296-HQ	CARD_3.2.10
TBR-001-1007	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-1008	Will be resolved as part of Lunar SRR	CxP Lunar SRR	CA0296-HQ	CARD_3.2.10
TBR-001-1009	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-1010	Will be resolved as part of Lunar SRR	CxP Lunar SRR	CA0296-HQ	CARD_3.2.10
TBR-001-1011	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-1021	ARES analysis currently determining value	IDAC-4	CA4135-PO	CARD_3.7.1.2.6.1
TBR-001-1022	New study for IDAC-4 extending the results of SIG-09-001 to include unassisted emergency egress for ground crew scenario for ARES V pre-launch activities.	IDAC-4	CA5160-PO	CARD_3.7.4.2.2

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-1023	G/MO SIG owns the parent requirement and the sister Orion Project requirement. This TBR is the same as the one in the Orion requirement. The G/MO SIG owns this TBR. G/MO SIG will have results of this TDS and TBR burn down.	IDAC-4	CA0466-PO CA5170-PO	CARD_3.7.1.2.2.2 CARD_3.7.9.2.2
TBR-001-1024	New study for IDAC-4 extending the results of SIG-09-001 to include unassisted emergency egress for ground crew scenario for ARES V pre-launch activities.	IDAC-4	CA5160-PO	CARD_3.7.4.2.2
TBR-001-1025	G/MO to provide closure plan.		CA5947-PO	CARD_3.7.1.2.2.2
TBR-001-1026			CA5950-PO	CARD_3.7.1.2.4
TBR-001-1027			CA5960-PO	CARD_3.7.1.2.4
TBR-001-1028			CA5961-PO	CARD_3.7.1.2.4
TBR-001-1029	Define times.	Cx SDR	CA5964-PO	CARD_3.2.13
TBR-001-1037	Determine times	Cx SDR	CA5974-PO	CARD_3.7.1.2.13
TBR-001-1045	Determine time.	Cx SDR	CA5978-PO	CARD_3.7.2.2.13
TBR-001-105	Will need new IDAC-4 study	IDAC-4	CA3043-PO	CARD_3.2.10
TBR-001-1054	Determine time.	Cx SDR	CA5982-PO	CARD_3.7.3.2.13
TBR-001-1062	Determine time.	Cx SDR	CA5986-PO	CARD_3.7.4.2.13
TBR-001-1070	Determine time.	Cx SDR	CA5990-PO	CARD_3.7.5.2.13
TBR-001-1078	Determine time.	Cx SDR	CA5994-PO	CARD_3.7.6.2.13
TBR-001-1086	Determine time.	Cx SDR	CA5998-PO	CARD_3.7.9.2.13
TBR-001-109	IDAC-3 TDS SIG-06-1001 validated 30% value for Orion max O2 concentration. Recommend TBR be closed.	IDAC-3	CA3061-PO	CARD_3.7.1.2.14
TBR-001-1094	The OCE action to determine how uncertainty/confidence levels need to be defined for analysis results was reported out in May 2007. Resolution of probability numbers such as this are being worked by T&V and are anticipated to be available in September 2007.	9/30/07	CA6013V-PO-Objective CA6015V-PO-Objective CA6017V-PO-Objective	
TBR-001-1095	Determine time.	Cx SDR	CA6012-PO CA6013-PO CA6013V-PO-Objective	CARD_3.2.13 CARD_3.7.1.2.13
TBR-001-1096	Determine times.	Cx SDR	CA6012-PO CA6013-PO-Objective	CARD_3.2.13 CARD_3.7.1.2.13

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-1097	Determine time.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBR-001-1098	Determine times.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBR-001-1099	Determine times.	Cx SDR	CA6012-PO CA6019-PO	CARD_3.2.13 CARD_3.7.6.2.13
TBR-001-1101	Determine times.	Cx SDR	CA6012-PO	CARD_3.2.13
TBR-001-1102	Determine times.	Cx SDR	CA6012-PO	CARD_3.2.13
TBR-001-1105	TDS scheduled for IDAC-4; technical analysis for refining TBR period of time for Lunar cases and TBD manpower estimates for ISS & Lunar cases.	IDAC-4	CA6024-PO CA6026-PO CA6024V-PO-Objective	CARD_3.2.13 CARD_3.2.13
TBR-001-1106	TDS scheduled for IDAC-4; technical analysis for refining TBR period of time for Lunar cases and TBD manpower estimates for ISS & Lunar cases.	IDAC-4	CA6027-PO CA6028-PO CA6031-PO CA6033-PO CA6034-PO	CARD_3.2.13 CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.1.2.13 CARD_3.7.3.2.13
TBR-001-1107	TDS scheduled for IDAC-4; technical analysis for refining TBR period of time for Lunar cases and TBD manpower estimates for ISS & Lunar cases.	IDAC-4	CA6035-PO CA6038-PO	CARD_3.7.3.2.13 CARD_3.7.6.2.13
TBR-001-1108	TBR resolution through IDAC-3 analysis by 31 July – TBR is also closely associated with loiter time resolution from the Mission Success TDS resolution.	IDAC-4	CA5963-PO	CARD_3.2.13
TBR-001-1110	TDS scheduled for IDAC-4; technical analysis for refining TBR period of time for Lunar cases and TBD manpower estimates for ISS & Lunar cases.	IDAC-4	CA6032-PO	CARD_3.7.1.2.13
TBR-001-1111	TDS scheduled for IDAC-4; technical analysis for refining TBR period of time for Lunar cases and TBD manpower estimates for ISS & Lunar cases.	IDAC-4	CA6033-PO	CARD_3.7.1.2.13
TBR-001-113	IDAC-3 TDS final status is scheduled for the 10/24 AWG. This TBR will probably not be closed in IDAC3. Further analysis and work is needed based on ESR2 and Orion's suit leak check capabilities.	IDAC-3	CA3058-PO	CARD_3.7.9.2.14
TBR-001-1200	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6004-PO CA6005-PO	CARD_3.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-1201	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6004-PO CA6005-PO	CARD_3.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13
TBR-001-1202	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6003-PO CA6004-PO CA6005-PO CA6006-PO	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBR-001-1203	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6003-PO CA6004-PO CA6005-PO CA6006-PO	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBR-001-1204	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6003-PO CA6004-PO CA6005-PO CA6006-PO	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBR-001-1205	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6003-PO CA6004-PO CA6005-PO CA6006-PO	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBR-001-1206	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6003-PO CA6004-PO CA6005-PO	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13
TBR-001-1207	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6003-PO CA6004-PO CA6005-PO	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13
TBR-001-1208	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6003-PO CA6004-PO CA6005-PO CA6006-PO	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBR-001-1209	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6003-PO CA6004-PO CA6005-PO CA6006-PO	CARD_3.2.13 CARD_3.7.1.2.13 CARD_3.7.2.2.13 CARD_3.7.5.2.13 CARD_3.7.9.2.13
TBR-001-1210	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6005-PO	CARD_3.2.13 CARD_3.7.5.2.13

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-1211	Complete IDAC3 TDS SIG-09-1016 to refine TBR critical path hour values in Table.	IDAC-4	CA6002-PO CA6005-PO	CARD_3.2.13 CARD_3.7.5.2.13
TBR-001-1216	Communications range requirements will be based on additional navigation inputs (future study) that currently indicate 100 km for ranging during Orion-LLV RPOD is desirable.		CA6066-PO	CARD_3.7.1.2.10
TBR-001-122	New study for IDAC-3 extending the results of GOP-00-001 to include unassisted emergency egress for suited crew scenario for pre-launch activities	IDAC-3	CA0334-PO	CARD_3.7.1.2.2.2
TBR-001-129	Will be resolved as part of Lunar SRR	CxP Lunar SRR	CA3289-PO	CARD_3.7.3.2.10
TBR-001-130	6 tasks are planned to address pressure and oxygen concentration TBR's: commonality study, materials certification study, lunar operations timeline assessment, prebreathe assessment, vehicle pressure control assessment, and gas consumables assessment.	Lunar Requirement Phase III	CA3135-PO	CARD_3.7.3.2.14
TBR-001-1300	Analysis of prelaunch timeline by ground and mission ops to determine crew support time following hatch closure through hatch opening following launch scrub.	IDAC 4	CA6100-PO	CARD_3.7.1.2.12
TBR-001-1301	ECLSS SIG to work with Orion System and EVA System to arrive at detailed leak check protocol and overall operational timeline with contributing requirements to prepare for crew survival after a total cabin depressurization.		CA3105-PO	CARD_3.7.1.2.14
TBR-001-1302	Analysis of prelaunch timeline by ground and mission ops to determine crew support time following hatch closure through hatch opening following launch scrub.		CA6101-PO	CARD_3.7.5.2.12
TBR-001-1303			CA3022-PO	CARD_3.7.1.2.1
TBR-001-131	Need to resolve uncertainties associated with lunar mission ascent timeline relative to contingency scenarios and post-dock crew support time in LSAM.	Lunar Requirement Phase III	CA3165-PO	CARD_3.7.3.2.14

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-134	New study for IDAC-3 extending the results of GOP-00-001 to include unassisted emergency egress for suited crew scenario for pre-launch activities. Expecting the GO/MO SIG will be leading this integrated TBR resolution with help from the EVA SIG, EVA Project, CEV Project, and GO Project.	IDAC-3	CA0336-PO	CARD_3.7.5.2.2
TBR-001-136	Will need new IDAC-4 study	IDAC-4	CA3290-PO	CARD_3.7.8.2.10
TBR-001-1400		Lunar Outpost SRR	CA3285-PO	CARD_3.7.6.2.8
TBR-001-1401		Lunar Outpost SRR	CA3285-PO	CARD_3.7.6.2.8
TBR-001-1402		Lunar Outpost SRR	CA3285-PO	CARD_3.7.6.2.8
TBR-001-1403		Lunar Sortie SRR	CA6200-PO	CARD_3.7.6.2.8
TBR-001-1404		Lunar Sortie SRR	CA6200-PO	CARD_3.7.6.2.8
TBR-001-1405		Lunar Sortie SRR	CA6200-PO	CARD_3.7.6.2.8
TBR-001-1406		Lunar Sortie SRR	CA6200-PO	CARD_3.7.6.2.8
TBR-001-1407		Lunar Outpost SRR	CA6201-PO	CARD_3.7.6.2.8
TBR-001-1408		Lunar Outpost SRR	CA6201-PO	CARD_3.7.6.2.8
TBR-001-1409		Lunar Outpost SRR	CA6201-PO	CARD_3.7.6.2.8
TBR-001-1410		Lunar Outpost SRR	CA6201-PO	CARD_3.7.6.2.8
TBR-001-1411		IDAC-4	CA0123-PO CA3065-PO	CARD_3.2.12 CARD_3.7.6.2.12
TBR-001-1412		IDAC-4	CA0123-PO CA3064-PO	CARD_3.2.12 CARD_3.7.5.2.12
TBR-001-1413			CA6203-PO	CARD_3.7.2.2.12
TBR-001-1414			CA6203-PO	CARD_3.7.2.2.12
TBR-001-1415			CA6203-PO	CARD_3.7.2.2.12

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-1416			CA6204-PO	CARD_3.7.5.2.12
TBR-001-1417			CA6204-PO	CARD_3.7.5.2.12
TBR-001-1418			CA6204-PO	CARD_3.7.5.2.12
TBR-001-1419			CA6205-PO	CARD_3.7.1.2.12
TBR-001-1420			CA6205-PO	CARD_3.7.1.2.12
TBR-001-1421			CA6205-PO	CARD_3.7.1.2.12
TBR-001-1422			CA6206-PO	CARD_3.7.4.2.12
TBR-001-1423			CA6206-PO	CARD_3.7.4.2.12
TBR-001-1424			CA6206-PO	CARD_3.7.4.2.12
TBR-001-1425			CA6207-PO	CARD_3.7.3.2.12
TBR-001-1426			CA6207-PO	CARD_3.7.3.2.12
TBR-001-1427			CA6207-PO	CARD_3.7.3.2.12
TBR-001-1428			CA6209-PO	CARD_3.7.5.2.12
TBR-001-1429			CA6209-PO	CARD_3.7.5.2.12
TBR-001-1430			CA6209-PO	CARD_3.7.5.2.12
TBR-001-1431			CA6072-PO CA6075-PO CA6076-PO	CARD_3.2.2 CARD_3.7.1.2.2 CARD_3.7.9.2.2
TBR-001-1432			CA6072-PO CA6073-PO CA6075-PO CA6076-PO	CARD_3.2.2 CARD_3.2.2 CARD_3.7.1.2.2 CARD_3.7.9.2.2
TBR-001-1433			CA6072-PO CA6075-PO	CARD_3.2.2 CARD_3.7.1.2.2
TBR-001-1434	Parties to be involved: 1. ATA (Traffic Model Study); 2. Operations Integration (Conversation and e-mail are they doing anything related to this issue and if not do they want to participate); Find out capability of ground processing infrastructure, and what is impact if they can't; Work with CEV and CLV on production rate and refurbishment, their plan and impacts. Work with Mission Systems to determine if there is an issue with their support of these flight rates (MCC, Crew Training).	IDAC-3	CA0036-HQ	CARD_3.2.5

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-1435	Parties to be involved: 1. ATA (Traffic Model Study); 2. Operations Integration (Conversation and e-mail are they doing anything related to this issue and if not do they want to participate); Find out capability of ground processing infrastructure, and what is impact if they can't; Work with CEV and CLV on production rate and refurbishment, their plan and impacts. Work with Mission Systems to determine if there is an issue with their support of these flight rates (MCC, Crew Training).	IDAC-3	CA0036-HQ	CARD_3.2.5
TBR-001-1436	IDAC-4 Analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10
TBR-001-1437	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10
TBR-001-1438	IDAC-4 Analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10
TBR-001-144	Determine time for 8 ground crew to egress the pad structure to a safe haven from egress initiation to last person in the safe haven.	IDAC-3	CA0337-PO	CARD_3.7.5.2.2
TBR-001-1440	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO CA6212-PO	CARD_3.2.10 CARD_3.7.1.2.10
TBR-001-1441	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO CA6213-PO	CARD_3.2.10 CARD_3.7.1.2.10
TBR-001-1442	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10
TBR-001-1443	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10
TBR-001-1444	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10
TBR-001-1445	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10
TBR-001-1446	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO CA6215-PO	CARD_3.2.10 CARD_3.7.6.2.8
TBR-001-1447	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO CA6216-PO	CARD_3.2.10 CARD_3.7.6.2.8
TBR-001-1448	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10
TBR-001-1449	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6210-PO	CARD_3.2.10

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-1450	IDAC-4 analysis to determine acceptable latencies.	1/22/08	CA6211-PO	CARD_3.7.5.2.10
TBR-001-147	6 tasks are planned to address pressure and oxygen concentration TBR's: commonality study, materials certification study, lunar operations timeline assessment, prebreathe assessment, vehicle pressure control assessment, and gas consumables assessment.	Lunar Requirement Phase III	CA0814-PO	CARD_3.7.3.2.14
TBR-001-149	Analysis of all Delta-V necessary for Trajectory Correction Maneuvers (TCMs) during the Trans-Lunar Coast (TLC), and the Lunar Orbit Injection (LOI) into the Lunar Destination Orbit (LDO) for the LSAM-A/CEV mated configuration.	LSAM SRR	CA0837-PO	CARD_3.7.3.2.6.2
TBR-001-154	TDS to study blast effects and determine actual time required for the CEV to escape. This analysis will be done when the CEV LAS design is further matured. TDS CLV-34-1001.	Ares I CDR	CA1055-PO	CARD_3.7.2.2.7
TBR-001-157	EVA SIG to perform feasability assessment of the entire unpressurized survival scenario, which includes time to don suits with CEV volume, prebreathe protocols, suit pressures, etc. This TBR is associated with TDS SIG-07-1001	IDAC-3	CA3108-PO	CARD_3.7.1.2.2
TBR-001-159	Continuation of analysis to further define CaLV capability.	CaLV SRR	CA4139-PO	CARD_3.7.1.2.6.1
TBR-001-161	Determine time for GS to recover crew for landings in designated landing sites.	IDAC-3	CA4122-PO	CARD_3.7.5.2
TBR-001-163	10/11 - AWG agreed to retire this TBR	IDAC-3	CA4127-PO	CARD_3.7.9.2
TBR-001-166	This TBR is planned to be updated based on Orion analysis. The volume is the space required to transport 100Kg of lunar materials. Though the mass is a FP issue, the volume would only matter to Human Systems, ECLSS, and Loads due to packaging/storage/enviromental factors. Reference Requirement CA0547-PO.	IDAC-4	CA5155-PO	CARD_3.7.1.2.4

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-167	Obtain science and technology development objectives and requirements from the Constellation Program and Headquarters stakeholders; understand what return volume may fall out of these objectives. Assess current volume return capability in the LSAM ascent stage and CEV and assess sensitivity of return volume to vehicle performance. Perform trades with vehicle subsystems/architecture if more payload volume is required.	Lunar Sortie SRR	CA5156-PO	CARD_3.7.3.2.4
TBR-001-168	Determine emergency egress time for six ground crew to safe haven starting from initiation of event at launch pad to last person in safe haven.	IDAC-3	CA5159-PO	CARD_3.7.2.2.2.2
TBR-001-170	New G/MO study for IDAC-3 extending the results of GOP-00-001 to include unassisted emergency egress for suited crew scenario for pre-launch activities.	IDAC-3	CA5169-PO	CARD_3.7.9.2.2
TBR-001-171	Review of analysis already performed will continue to determine reasonable nominal LSAM-CEV rendezvous timeline.	LSAM SRR	CA5193-PO	CARD_3.7.3.2.2
TBR-001-172	EVA scenarios/operations and EVA timeline will be assessed as the LSAM design matures. Identified EVA scenarios will be brought to the Constellation SECB/CxCB for approval	LSAM SRR	CA5194-PO	CARD_3.7.3.2.2
TBR-001-173	New G/MO study for IDAC-3 extending the results of GOP-00-001 to include unassisted emergency egress for suited crew scenario for pre-launch activities.	IDAC-3	CA5203-PO	CARD_3.7.9.2.2
TBR-001-176	Review results of analysis performed by APO/ARDIG to determine control mass based on current DRMs. The proper amount of margin to be added to the study results to cover Management Reserve will be decided before a final number is determined.	LSAM SRR	CA5231-PO	CARD_3.7.3.2.6.1
TBR-001-183	New TDS	LSAM SRR	CA5532-PO	CARD_3.7.3.2.12
TBR-001-191	TBR ready to close during next CARD update.	IDAC-3	CA5659-PO	CARD_3.7.9.2.14

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-202	Define egress time for ground and suited flight crew form CEV from initiation of egress to last person out of CEV hatch.	IDAC-3	CA0335-PO	CARD_3.7.1.2.2.2
TBR-001-206	10/11 - AWG agreed to retire this TBR	IDAC-3	CA3166-PO	CARD_3.7.1.2.6
TBR-001-207	10/11 - AWG agreed to retire this TBR	IDAC-3	CA3166-PO	CARD_3.7.1.2.6
TBR-001-211	Determine maximum number of ground crew that would be conducting pad operations that require emergency egress from pad to a safe haven.	IDAC-3	CA5159-PO	CARD_3.7.2.2.2.2
TBR-001-214	EVA scenarios/operations and EVA timeline will be assessed as the LSAM design matures. Identified EVA scenarios will be brought to the Constellation SECB/CxCB for approval	LSAM SRR	CA5191-PO	CARD_3.7.3.2.2
TBR-001-217	EVA scenarios/operations and EVA timeline will be assessed as the LSAM design matures. Identified EVA scenarios will be brought to the Constellation SECB/CxCB for approval.	LSAM SRR	CA5195-PO	CARD_3.7.3.2.6
TBR-001-218	Determine maximum number of LSAMs to be operated in-space concurrently with overlapping missions, rates and intervals assumed in CA0036 and CA5604 requirements.	IDAC-4	CA5149-PO	CARD_3.7.3.2.6
TBR-001-220	TDS for architecture closure on the Mars exploration missions.	Post IDAC-5	CA0282-PO	CARD_3.7.4.2.4
TBR-001-223	10/11 - AWG agreed to retire this TBR	IDAC-3	CA4127-PO	CARD_3.7.9.2
TBR-001-240	Parties to be involved: 1. ATA (Traffic Model Study); 2. Operations Integration (Conversation and e-mail are they doing anything related to this issue and if not do they want to participate); Find out capability of ground processing infrastructure, and what is impact if they can't; Work with CEV and CLV on production rate and refurbishment, their plan and impacts. Work with Mission Systems to determine if there is an issue with their support of these flight rates (MCC, Crew Training).	IDAC-3	CA0036-HQ	CARD_3.2.5

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-241	Parties to be involved: 1. ATA (Traffic Model Study); 2. Operations Integration (Conversation and e-mail are they doing anything related to this issue and if not do they want to participate); Find out capability of ground processing infrastructure, and what is impact if they can't; Work with CEV and CLV on production rate and refurbishment, their plan and impacts. Work with Mission Systems to determine if there is an issue with their support of these flight rates (MCC, Crew Training).	IDAC-3	CA0036-HQ	CARD_3.2.5
TBR-001-242	Parties to be involved: 1. ATA (Traffic Model Study); 2. Operations Integration (Conversation and e-mail are they doing anything related to this issue and if not do they want to participate); Find out capability of ground processing infrastructure, and what is impact if they can't; Work with CEV and CLV on production rate and refurbishment, their plan and impacts. Work with Mission Systems to determine if there is an issue with their support of these flight rates (MCC, Crew Training).	IDAC-3	CA0036-HQ	CARD_3.2.5
TBR-001-244	EVA scenarios/operations and EVA timeline will be assessed as the LSAM design matures. Identified EVA scenarios will be brought to the Constellation SECB/CxCB for approval.	LSAM SRR	CA5191-PO CA5195-PO	CARD_3.7.3.2.2 CARD_3.7.3.2.6
TBR-001-2500	Project Buy-in to the referenced verification method will be obtained.	Lander SRR		
TBR-001-2501	Work with Lander project on feed a leak requirements during Lunar requirement development	Lunar Requirement Phase III	CA3107-PO CA3181-PO	CARD_3.7.3.2.14 CARD_3.7.3.2.14

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-258	Review results of analysis performed by CxAT Lunar Team to determine Delta-Vs based on current DRMs. The proper amount of additional Delta-V to be added to the study results to cover Management Reserve will be decided before a final number is determined.	LSAM SRR	CA0051-PO	CARD_3.7.4.2.6.2
TBR-001-304	The OCE action to determine how uncertainty/confidence levels need to be defined for analysis results was reported out in May 2007. Resolution of probability numbers such as this are being worked by T&V and are anticipated to be available in September 2007.	9/30/07		
TBR-001-409	Perform feasability assessment of the entire unpressurized survival scenario, which includes time to don suits with CEV volume, prebreathe protocols, suit pressures, etc. which will drive the required umbilical lengths. EVA SIG to perform feasability assessment of the entire unpressurized survival scenario, which requires analysis input fro other SIGs and Project. This TBR is associated with TDS SIG-07-1001.	IDAC-3		
TBR-001-410	Perform feasability assessment of the entire unpressurized survival scenario, which includes time to don suits with CEV volume, prebreathe protocols, suit pressures, etc. which will drive the required umbilical lengths. EVA SIG to perform feasability assessment of the entire unpressurized survival scenario, which requires analysis input fro other SIGs and Project. This TBR is associated with TDS SIG-07-1001.	IDAC-3		
TBR-001-493	ATA-00-001 Extended through to IDAC-3	IDAC-3		

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-497	Multiplication of TBR-001-223 and will be resolved based on that TBR. . EVA scenarios/operations and EVA timeline will be assessed as the CEV design matures. Identified EVA scenarios will be brought to the Constellation SECB/CxCB for approval	IDAC-3		
TBR-001-503	Analysis to be performed: Obtain lunar surface science and engineering objectives from the program/headquarters Translate these objectives into duration reqts. Understand what contingency duration is needed in addition to the nominal mission. Assess the capability of the lunar lander and CEV to support the 210 days at the outpost or in lunar orbit per rotation. Assess cost of adding additional duration/benefit of reducing duration.	IDAC-4	CA0822-HQ	CARD_3.2.4
TBR-001-512	This requirement will include the total mass of the CEV at the time of CaLV EDS rendezvous and the Program Mass Reserve.	LSAM SRR	CA4140-PO	CARD_3.7.3.2.4
TBR-001-513	Review results of analysis performed by APO/ARDIG to determine Delta-Vs based on current DRMs. The proper amount of additional Delta-V to be added to the study results to cover Management Reserve will be decided before a final number is determined.	LSAM SRR	CA4141-PO	CARD_3.7.3.2.6.2
TBR-001-514	Review results of analysis performed by APO/ARDIG to determine Delta-Vs based on current DRMs. The proper amount of additional Delta-V to be added to the study results to cover Management Reserve will be decided before a final number is determined.	LSAM SRR	CA4143-PO	CARD_3.7.3.2.6.2
TBR-001-528	EVA scenarios operations and EVA timeline will assessed as the LSAM design matures.	LSAM SRR		

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-529	EVA scenarios operations and EVA timeline will assess as the LSAM design matures. Identified EVA scenarios will be brought to the Constellation SECB/CxCB for approval.	LSAM SRR		
TBR-001-530	EVA scenarios operations and EVA timeline will assess as the LSAM design matures. Identified EVA scenarios will be brought to the Constellation SECB/CxCB for approval.	LSAM SRR		
TBR-001-538	Combination of the amount of TBR-001-207 hrs for EVA and prebreathe which is based on the cabin pressure defined in the HSIR. Resolution will include the following: (1) EVA scenarios/operations and EVA timeline will be assessed as the CEV design matures. Identified EVA scenarios will be brought to the Constellation SECB/CxCB for approval. (2) Update reference to the HSIR requirement. On-hold pending completion of the CEV SDR and evolution of EVA operational scenarios. This TBR is associated with TDS SIG-07-1000. The new burn down plan was discussed at the IDAC3 mid-term outbrief and the recommendation of the ATA.	IDAC-3		
TBR-001-545	Define maximum number of ground crew that would be assisting flight crew ingressing and being strapped into seats prior to CEV hatch closure for launch.	IDAC-3	CA0335-PO CA5947-PO	CARD_3.7.1.2.2.2 CARD_3.7.1.2.2.2
TBR-001-556	Will need new IDAC-4 study and LAT 2 Study results	IDAC-4	CA5909-PO	CARD_3.7.9.2.10
TBR-001-557	Will need new IDAC-4 study and LAT 2 Study results	IDAC-4	CA5910-PO	CARD_3.7.9.2.10
TBR-001-562	IDAC-4 Analysis	IDAC-4	CA0123-PO CA3063-PO	CARD_3.2.12 CARD_3.7.9.2.12

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-571	Review results of analysis performed by CxAT Lunar Team to determine Delta-Vs based on current DRMs. The proper amount of additional Delta-V to be added to the study results to cover Management Reserve will be decided before a final number is determined.	LSAM SRR	CA4145-PO	CARD_3.7.3.2.6.2
TBR-001-750	CEV ODAC-1 analysis did look at this volume, but a new volume analysis will be performed at a new location related to the sim bay assessment (currently planned for ODAC-2). TBR must remain until Orion location volume analysis complete, possibly longer.	IDAC-4	CA0547-PO	CARD_3.7.1.2.4
TBR-001-752	Analysis of possible tasks and EVA crew capabilities on the lunar surface to confirm the safe travel distance during sortie missions.	IDAC-4	CA0287-PO	CARD_3.2.6
TBR-001-753	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-755	Will be resolved as part of Lunar SRR	CxP Lunar SRR	CA0887-PO	CARD_3.7.3.2.10
TBR-001-907	6 tasks are planned to address pressure and oxygen concentration TBR's: commonality study, materials certification study, lunar operations timeline assessment, prebreathe assessment, vehicle pressure control assessment, and gas consumables assessment.	Lunar Requirement Phase III	CA0814-PO	CARD_3.7.3.2.14
TBR-001-908	6 tasks are planned to address pressure and oxygen concentration TBR's: commonality study, materials certification study, lunar operations timeline assessment, prebreathe assessment, vehicle pressure control assessment, and gas consumables assessment.	Lunar Requirement Phase III	CA0814-PO	CARD_3.7.3.2.14
TBR-001-910	Continuation of analyses to further define the CaLV capability	CaLV SRR	CA0848-PO	CARD_3.7.4.2.6.1

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-913	6 tasks are planned to address pressure and oxygen concentration TBR's: commonality study, materials certification study, lunar operations timeline assessment, prebreathe assessment, vehicle pressure control assessment, and gas consumables assessment.	Lunar Requirement Phase III	CA3135-PO	CARD_3.7.3.2.14
TBR-001-914	6 tasks are planned to address pressure and oxygen concentration TBR's: commonality study, materials certification study, lunar operations timeline assessment, prebreathe assessment, vehicle pressure control assessment, and gas consumables assessment.	Lunar Requirement Phase III	CA3135-PO	CARD_3.7.3.2.14
TBR-001-919	ATA-00-001 Extended through to IDAC-3	IDAC-3	CA5532-PO CA5533-PO	CARD_3.7.3.2.12 CARD_3.7.4.2.12
TBR-001-936	Review results of IDAC-2 analysis to determine whether additional trades are necessary to define ascent target inclination and attitude for the lunar missions	IDAC-3	CA3202-PO	CARD_3.7.2.2.6
TBR-001-937	IDAC-4 Analysis	IDAC-4	CA0123-PO CA0178-PO CA3031V-PO	CARD_3.2.12 CARD_3.7.1.2.12
TBR-001-939	IDAC-4 Analysis	IDAC-4	CA0123-PO CA1066-PO	CARD_3.2.12 CARD_3.7.2.2.12
TBR-001-940	IDAC-4 Analysis	IDAC-4	CA0123-PO CA1068-PO	CARD_3.2.12 CARD_3.7.2.2.12
TBR-001-960	Project Buy-in has been obtained for use of JSC 63557. However the TBR is tied to TDS CEV-07-1002 , which includes NHV Calculation and assessment using B 9 mockups.	Orion SDR		
TBR-001-962	Determine max number of ground personnel on the launch pad prior to launch that would need to evacuate to a safe haven in an emergency.	IDAC-3	CA0311-PO CA0337-PO	CARD_3.2.2.2 CARD_3.7.5.2.2
TBR-001-964	Deferred SIG-09-1006 from the IDAC-3 cycle study to IDAC-4 cycle on late access for time critical cargo (no later than time on pad).	IDAC-4	CA5815-PO	CARD_3.2.13
TBR-001-979	New study for IDAC-5 on launch readiness duration for CaLV lunar cargo missions	IDAC-5	CA0071-PO	CARD_3.2.12

TBR #	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-990	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-991	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-992	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-993	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-994	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-995	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-996	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-997	Will be resolved as part of Lunar SRR	CxP Lunar SRR	CA0296-HQ	CARD_3.2.10
TBR-001-998	Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-999	Will be resolved as part of Lunar SRR	CxP Lunar SRR	CA0296-HQ	CARD_3.2.10

B3.0 OPEN CARD ACTIONS

CARD Open Work to be updated Revision C

- GMO to develop a new CARD requirement to be the parent for the MS requirement (R.MS1003) to support 210 day ISS missions.
- JPR 8080.5 Review for Complete Allocation – Ensure all requirements from JPR 8080.5 are included in Program Documentation.
- Workmanship Standards Review for complete allocation
- Sync with EARD
- Traceability Review – Top-down/Bottom up review to identify mission
- requirements/allocations.
- Document Title Consistency between ADL and all CARD text.
- Addition of the Window Optics Standard. JSC 63307 (Optical Performance Requirements for Windows in Human Space Flight Applications), is not called out by the Glass structural standard.
- Probabilities Updates – Update final set of probabilistic VRs to reflect correct usage and wording as proposed by the OCE.

APPENDIX C
VERIFICATION CROSS REFERENCE MATRIX (VCRM)

The VCRM contains requirements that are baselined (i.e. Draft requirements and their associated verifications do not appear in the VCRM). In addition, if a Verification Requirement is (TBD), the method will not appear in this matrix.

Verification Method Legend is as follows I = Inspection; A = Analysis; D = Demonstration; T = Test.

TABLE C-1 - VERIFICATION CROSS REFERENCE MATRIX

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
CARD_3.2	CA0001-HQ	X				CA0001V-HQ
	CA0003-HQ		X			CA0003V-HQ
	CA0004-HQ		X			CA0004V-HQ
	CA0005-HQ		X			CA0005V-HQ
	CA0006-HQ		X			CA0006V-HQ
	CA0013-HQ	X				CA0013V-HQ
	CA0202-HQ	X	X	X	X	CA0202V-PO
	CA0892-HQ	X				CA0892V-PO
	CA6077-PO		X		X	CA6077V-PO
	CA6079-PO		X		X	CA6079V-PO
CARD_3.2.1	CA0033-HQ		X			CA0033V-HQ
	CA0095-HQ		X			CA0095V-PO
	CA0097-HQ		X			CA0097V-PO
	CA0099-HQ		X			CA0099V-PO
CARD_3.2.2	CA0028-PO	X				CA0028V-PO
	CA0107-HQ		X			CA0107V-HQ
	CA0172-PO		X	X	X	CA0172V-PO
	CA0312-PO	X				CA0312V-PO
	CA6072-PO		X			CA6072V-PO
	CA6073-PO	X				CA6073V-PO
CARD_3.2.2.1	CA0032-HQ		X			CA0032V-HQ
	CA0096-HQ		X			CA0096V-PO
	CA0474-HQ		X			CA0474V-PO
	CA5818-HQ		X			CA5818V-HQ
CARD_3.2.2.2	CA0027-PO	X	X			CA0027V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA0310-PO		X	X		CA0310V-PO
	CA0311-PO		X	X		CA0311V-PO
	CA0352-HQ	X	X			CA0352V-HQ
	CA0530-PO	X				CA0530V-PO
	CA3226-PO	X				CA3226V-PO
CARD_3.2.3	CA0020-HQ		X			CA0020V-HQ
	CA0203-HQ	X				CA0203V-HQ
	CA0388-HQ	X				CA0388V-HQ
CARD_3.2.4	CA0209-HQ		X			CA0209V-HQ
	CA0211-HQ		X			CA0211V-HQ
	CA0822-HQ		X			CA0822V-HQ
CARD_3.2.5	CA0036-HQ	X	X			CA0036V-PO
	CA0207-HQ		X			CA0207V-HQ
	CA6102-PO		X			CA6102V-PO
CARD_3.2.6	CA0021-PO		X		X	CA0021V-PO
	CA0029-HQ	X				CA0029V-HQ
	CA0039-HQ	X				CA0039V-HQ
	CA0044-PO	X				CA0044V-PO
	CA0046-PO		X			CA0046V-PO
	CA0121-HQ	X				CA0121V-HQ
	CA0181-HQ	X				CA0181V-HQ
	CA0281-HQ	X				CA0281V-HQ
	CA0316-PO	X				CA0316V-PO
	CA3175-PO	X				CA3175V-PO
	CA3184-PO	X				CA3184V-PO
CARD_3.2.7	CA0100-HQ	X	X			CA0100V-HQ
	CA0213-PO		X			CA0213V-PO
	CA0214-PO		X			CA0214V-PO
	CA0215-PO		X			CA0215V-PO
	CA0569-PO		X			CA0569V-PO
	CA5812-HQ		X		X	CA5812V-HQ
	CA6041-PO		X		X	CA6041V-PO
	CA6106-PO			X		CA6106V-PO
CARD_3.2.8	CA0449-PO		X	X		CA0449V-PO
	CA5604-PO		X	X		CA5604V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
CARD_3.2.9	CA0216-PO			X		CA0216V-PO
	CA0217-PO			X		CA0217V-PO
	CA6050-PO		X		X	CA6050V-PO
CARD_3.2.9.1	CA6051-PO		X			CA6051V-PO
CARD_3.2.10	CA0296-HQ		X		X	CA0296V-HQ
	CA0476-PO		X		X	CA0476V-PO
	CA0993-PO		X			CA0993V-PO
	CA3007-PO		X	X		CA3007V-PO
	CA3021-PO			X		CA3021V-PO
	CA3043-PO		X			CA3043V-PO
	CA3051-PO			X		CA3051V-PO
	CA5065-PO		X	X		CA5065V-PO
	CA5817-PO		X		X	CA5817V-PO
	CA5820-PO		X	X		CA5820V-PO
	CA5821-PO		X	X		CA5821V-PO
	CA6065-PO		X		X	CA6065V-PO
	CA6105-PO		X			CA6105V-PO
	CA6210-PO		X		X	CA6210V-PO
CARD_3.2.11	CA0314-PO	X				CA0314V-PO
	CA5601-PO	X				CA5601V-PO
	CA5602-PO	X				CA5602V-PO
CARD_3.2.12	CA0037-PO		X			CA0037V-PO
	CA0038-HQ		X			CA0038V-PO
	CA0040-PO		X			CA0040V-PO
	CA0071-PO	X	X			CA0071V-PO
	CA0123-PO	X	X			CA0123V-PO
	CA0125-PO		X			CA0125V-PO
	CA5600-PO		X			CA5600V-PO
CARD_3.2.13	CA3293-PO			X		CA3293V-PO
	CA5814-PO		X	X		CA5814V-PO
	CA5815-PO		X	X		CA5815V-PO
	CA5935-PO	X	X			CA5935V-PO
	CA5962-PO	X	X			CA5962V-PO
	CA5963-PO	X	X			CA5963V-PO
	CA5964-PO		X			CA5964V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA5965-PO		X			CA5965V-PO
	CA5966-PO		X			CA5966V-PO
	CA5967-PO		X			CA5967V-PO
	CA5968-PO			X		CA5968V-PO
	CA5969-PO			X		CA5969V-PO
	CA5970-PO		X			CA5970V-PO
	CA5971-PO		X			CA5971V-PO
	CA5972-PO			X	X	CA5972V-PO
	CA5973-PO	X	X			CA5973V-PO
	CA6002-PO		X			CA6002V-PO
	CA6007-PO		X			CA6007V-PO
	CA6012-PO		X			CA6012V-PO
	CA6020-PO	X	X	X		CA6020V-PO
	CA6020-PO-Objective					
	CA6022-PO	X	X		X	CA6022V-PO
	CA6022-PO-Objective					
	CA6024-PO	X				CA6024V-PO
	CA6024-PO-Objective					
	CA6026-PO	X				CA6026V-PO
	CA6027-PO	X				CA6027V-PO
	CA6028-PO	X				CA6028V-PO
CARD_3.2.14						
CARD_3.2.15	CA0048-PO	X	X			CA0048V-PO
	CA0991-PO		X		X	CA0991V-PO
	CA5552-PO	X	X			CA5552V-PO
CARD_3.3						
CARD_3.3.1	CA0817-PO	X	X			CA0817V-PO
	CA0990-PO	X				CA0990V-PO
CARD_3.3.1.1	CA0554-PO	X			X	CA0554V-PO
	CA0555-PO	X	X		X	CA0555V-PO
	CA5811-PO	X			X	CA5811V-PO
CARD_3.3.2	CA3004-PO	X				CA3004V-PO
	CA3005-PO	X				CA3005V-PO
	CA3187-PO	X	X		X	CA3187V-PO
	CA3193-PO	X				CA3193V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA3222-PO	X				CA3222V-PO
	CA3237-PO	X				CA3237V-PO
CARD_3.3.3						
CARD_3.3.4	CA0042-PO	X				CA0042V-PO
CARD_3.3.5	CA0383-PO	X				CA0383V-PO
	CA5800-PO	X				CA5800-PO
CARD_3.3.6	CA3167-PO	X				CA3167V-PO
CARD_3.3.7	CA3252-PO		X			CA3252V-PO
	CA5618-PO	X		X		CA5618V-PO
CARD_3.3.8	CA5680-PO	X				CA5680V-PO
CARD_3.3.9	CA4111-PO		X			CA4111V-PO
CARD_3.4	CA0069-HQ		X		X	CA0069V-HQ
	CA0077-HQ		X		X	CA0077V-HQ
	CA5750-PO	X	X		X	CA5750V-PO
	CA5941-PO	X	X		X	CA5941V-PO
	CA5942-PO	X				CA5942V-PO
	CA6069-PO	X	X		X	CA6069V-PO
CARD_3.5	CA0023-PO	X				CA0023V-PO
CARD_3.6						
CARD_3.7						
CARD_3.7.1						
CARD_3.7.1.1						
CARD_3.7.1.2	CA0056-PO		X			CA0056V-PO
	CA0091-PO		X			CA0091V-PO
	CA3203-PO		X			CA3203V-PO
	CA5312-PO	X				CA5312V-PO
	CA5748-PO	X				CA5748V-PO
	CA5749-PO				X	CA5749V-PO
CARD_3.7.1.2.1	CA0088-PO		X			CA0088V-PO
	CA0399-PO		X			CA0399V-PO
	CA3022-PO		X			CA3022V-PO
	CA3023-PO		X			CA3023V-PO
CARD_3.7.1.2.2	CA0194-PO		X			CA0194V-PO
	CA0274-PO		X			CA0274V-PO
	CA0325-PO		X			CA0325V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA0493-PO		X			CA0493V-PO
	CA0532-PO		X			CA0532V-PO
	CA0983-PO		X			CA0983V-PO
	CA0984-PO		X		X	CA0984V-PO
	CA3108-PO		X	X		CA3108V-PO
	CA3138-PO	X	X		X	CA3138V-PO
	CA3259-PO	X				CA3259V-PO
	CA4154-PO		X			CA4154V-PO
	CA6074-PO	X				CA6074V-PO
	CA6075-PO		X		X	CA6075V-PO
CARD_3.7.1.2.2.1	CA0398-PO		X			CA0398V-PO
	CA0501-PO		X			CA0501V-PO
	CA3040-PO		X			CA3040V-PO
	CA5913-PO		X			CA5913V-PO
CARD_3.7.1.2.2.2	CA0170-PO		X		X	CA0170V-PO
	CA0333-PO		X		X	CA0333V-PO
	CA0334-PO		X	X		CA0334V-PO
	CA0335-PO		X	X		CA0335V-PO
	CA0416-PO		X			CA0416V-PO
	CA0466-PO		X	X		CA0466V-PO
	CA0498-PO		X			CA0498V-PO
	CA0522-PO				X	CA0522V-PO
	CA0579-PO		X			CA0579V-PO
	CA5234-PO		X			CA5234V-PO
	CA5237-PO		X		X	CA5237V-PO
	CA5439-PO				X	CA5439V-PO
	CA5947-PO		X	X		CA5947V-PO
CARD_3.7.1.2.3	CA0447-PO		X			CA0447V-PO
CARD_3.7.1.2.4	CA0547-PO	X				CA0547V-PO
	CA0565-HQ		X			CA0565V-PO
	CA0864-PO		X			CA0864V-PO
	CA0865-PO		X			CA0865V-PO
	CA0866-PO		X			CA0866V-PO
	CA0868-PO		X			CA0868V-PO
	CA3182-PO		X			CA3182V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA5155-PO		X			CA5155V-PO
	CA5233-PO		X			CA5233V-PO
	CA5950-PO	X				CA5950V-PO
	CA5960-PO	X				CA5960V-PO
	CA5961-PO	X				CA5961V-PO
CARD_3.7.1.2.5	CA0060-HQ	X	X			CA0060V-HQ
	CA0082-PO		X			CA0082V-PO
	CA3164-PO		X			CA3164V-PO
	CA6084-PO		X			CA6084V-PO
	CA6084-PO-Objective					
	CA6103-PO		X			CA6103V-PO
	CA6258-PO		X			CA6258V-PO
	CA6258-PO-Objective					
	CA6260-PO		X			CA6260V-PO
	CA6260-PO-Objective					
CARD_3.7.1.2.6	CA0191-PO		X			CA0191V-PO
	CA0324-PO		X			CA0324V-PO
	CA0351-PO		X			CA0351V-PO
	CA0494-PO				X	CA0494V-PO
	CA3166-PO		X	X	X	CA3166V-PO
	CA3168-PO		X	X		CA3168V-PO
	CA3204-PO		X			CA3204V-PO
	CA3207-PO		X			CA3207V-PO
	CA3209-PO		X			CA3209V-PO
	CA4152-PO		X	X		CA4152V-PO
	CA5148-PO		X		X	CA5148V-PO
	CA5240-PO		X			CA5240DV-PO
			X			CA5240V-PO
	CA5319-PO		X			CA5319V-PO
	CA6068-PO		X		X	CA6068V-PO
CARD_3.7.1.2.6.1	CA0827-PO		X		X	CA0827V-PO
	CA4134-PO		X		X	CA4134V-PO
	CA4135-PO		X	X		CA4135V-PO
	CA4139-PO		X		X	CA4139V-PO
	CA4163-PO		X		X	CA4163V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA4164-PO		X		X	CA4164V-PO
CARD_3.7.1.2.6.2	CA0829-PO		X			CA0829V-PO
	CA5948-PO					CA5948V-PO
CARD_3.7.1.2.7	CA0435-PO		X			CA0435V-PO
	CA0436-PO		X			CA0436V-PO
	CA0437-PO		X			CA0437V-PO
CARD_3.7.1.2.8	CA0134-PO				X	CA0134V-PO
	CA0448-PO		X	X		CA0448V-PO
	CA3110-PO				X	CA3110V-PO
	CA3249-PO				X	CA3249V-PO
	CA3254-PO				X	CA3254V-PO
	CA3255-PO		X		X	CA3255V-PO
	CA5039-PO	X		X		CA5039V-PO
	CA5040-PO			X		CA5040V-PO
CARD_3.7.1.2.9	CA0427-PO				X	CA0427V-PO
	CA0428-PO				X	CA0428V-PO
	CA0438-PO				X	CA0438V-PO
	CA5465-PO				X	CA5465V-PO
	CA5466-PO				X	CA5466V-PO
CARD_3.7.1.2.10	CA0344-PO		X		X	CA0344V-PO
	CA0470-PO		X		X	CA0470V-PO
	CA0511-PO				X	CA0511V-PO
	CA3280-PO		X	X		CA3280V-PO
	CA3287-PO		X		X	CA3287V-PO
	CA3288-PO		X		X	CA3288V-PO
	CA5901-PO			X		CA5901V-PO
	CA5904-PO			X		CA5904V-PO
	CA6066-PO		X		X	CA6066V-PO
	CA6067-PO		X		X	CA6067V-PO
	CA6070-PO		X		X	CA6070V-PO
	CA6108-PO		X			CA6108V-PO
	CA6110-PO					CA6110V-PO
	CA6212-PO				X	CA6212V-PO
	CA6213-PO				X	CA6213V-PO
CARD_3.7.1.2.11	CA0059-PO		X	X	X	CA0059V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA0081-PO		X	X	X	CA0081V-PO
	CA0131-PO	X	X		X	CA0131V-PO
	CA0133-PO		X	X	X	CA0133V-PO
	CA0187-PO		X			CA0187V-PO
	CA0329-PO		X			CA0329V-PO
	CA0369-PO		X	X	X	CA0369V-PO
	CA0462-PO		X		X	CA0462V-PO
	CA0463-PO		X	X		CA0463V-PO
	CA0497-PO		X		X	CA0497V-PO
	CA3142-PO		X		X	CA3142V-PO
	CA3248-PO		X			CA3248V-PO
	CA4128-PO		X			CA4128V-PO
	CA5286-PO		X			CA5286V-PO
	CA5819-PO		X			CA5819V-PO
	CA5921-PO		X			CA5921V-PO
CARD_3.7.1.2.12	CA0178-PO		X			CA0178V-PO
	CA6100-PO	X	X			CA6100V-PO
	CA6205-PO		X			CA6205V-PO
CARD_3.7.1.2.13	CA5495-PO		X		X	CA5495V-PO
	CA5974-PO		X			CA5974V-PO
	CA5975-PO		X			CA5975V-PO
	CA5976-PO			X		CA5976V-PO
	CA5977-PO		X			CA5977V-PO
	CA6003-PO		X			CA6003V-PO
	CA6013-PO		X			CA6013V-PO
	CA6013-PO-Objective					
	CA6015-PO		X			CA6015V-PO
	CA6015-PO-Objective					
	CA6029-PO	X	X			CA6029V-PO
	CA6029-PO-Objective					
	CA6031-PO	X	X			CA6031V-PO
	CA6032-PO	X	X			CA6032V-PO
	CA6033-PO	X	X			CA6033V-PO
CARD_3.7.1.2.14	CA0288-PO				X	CA0288V-PO
	CA0426-PO		X			CA0426V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA0886-PO		X		X	CA0886V-PO
	CA3061-PO		X		X	CA3061V-PO
	CA3105-PO		X		X	CA3105V-PO
	CA3106-PO		X		X	CA3106V-PO
	CA3133-PO				X	CA3133V-PO
	CA3140-PO		X			CA3140V-PO
	CA5711-PO		X			CA5711V-PO
CARD_3.7.1.2.15	CA0374-PO	X	X			CA0374V-PO
	CA5555-PO	X	X			CA5555V-PO
	CA5560-PO	X	X			CA5560V-PO
CARD_3.7.1.3						
CARD_3.7.1.4	CA0361-PO		X		X	CA0361V-PO
	CA0429-PO		X		X	CA0429V-PO
	CA0800-PO		X		X	CA0800V-PO
	CA0893-PO		X		X	CA0893V-PO
	CA0894-PO		X		X	CA0894V-PO
	CA0895-PO		X		X	CA0895V-PO
	CA0896-PO		X		X	CA0896V-PO
CARD_3.7.1.5	CA0386-HQ	X				CA0386V-HQ
	CA5933-PO		X			CA5933V-PO
CARD_3.7.2						
CARD_3.7.2.1						
CARD_3.7.2.2						
CARD_3.7.2.2.1	CA1065-PO		X			CA1065V-PO
	CA5805-PO		X			CA5805V-PO
	CA5916-PO		X			CA5916V-PO
CARD_3.7.2.2.2	CA0258-PO		X			CA0258V-PO
	CA5435-PO		X		X	CA5435V-PO
CARD_3.7.2.2.2.1	CA5914-PO		X			CA5914V-PO
CARD_3.7.2.2.2.2	CA5159-PO		X	X		CA5159V-PO
CARD_3.7.2.2.3						
CARD_3.7.2.2.4						
CARD_3.7.2.2.5	CA6087-PO		X			CA6087V-PO
	CA6087-PO-Objective					
	CA6089-PO		X			CA6089V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA6089-PO-Objective					
CARD_3.7.2.2.6	CA0389-HQ	X				CA0389V-HQ
	CA1023-PO		X			CA1023V-PO
	CA3202-PO		X			CA3202V-PO
	CA3221-PO				X	CA3221V-PO
	CA3223-PO				X	CA3223V-PO
	CA5677-PO		X			CA5677V-PO
CARD_3.7.2.2.6.1	CA1000-PO		X			CA1000V-PO
	CA1005-PO		X			CA1005V-PO
	CA4138-PO		X			CA4138V-PO
	CA4165-PO		X			CA4165V-PO
CARD_3.7.2.2.6.2						
CARD_3.7.2.2.7	CA0566-PO	X				CA0566V-PO
	CA1053-PO				X	CA1053V-PO
	CA1054-PO				X	CA1054V-PO
	CA1055-PO				X	CA1055V-PO
	CA1056-PO			X		CA1056V-PO
	CA5825-PO		X			CA5825V-PO
	CA5917-PO			X		CA5917V-PO
	CA5919-PO	X		X		CA5919V-PO
CARD_3.7.2.2.8	CA1028-PO				X	CA1028V-PO
	CA1029-PO			X		CA1029V-PO
	CA3112-PO				X	CA3112V-PO
	CA3256-PO				X	CA3256V-PO
	CA3275-PO				X	CA3275V-PO
CARD_3.7.2.2.9	CA1084-PO				X	CA1084V-PO
	CA1085-PO				X	CA1085V-PO
	CA1086-PO				X	CA1086V-PO
	CA3118-PO				X	CA3118V-PO
	CA5816-PO				X	CA5816V-PO
	CA6107-PO	X	X			CA6107V-PO
CARD_3.7.2.2.10	CA5906-PO			X		CA5906V-PO
	CA5912-PO		X		X	CA5912V-PO
	CA6214-PO				X	CA6214V-PO
CARD_3.7.2.2.11	CA3143-PO		X		X	CA3143V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
CARD_3.7.2.2.12	CA0072-PO		X			CA0072V-PO
	CA1008-PO		X			CA1008V-PO
	CA1066-PO		X			CA1066V-PO
	CA1068-PO		X			CA1068V-PO
	CA5323-PO		X			CA5323V-PO
	CA6203-PO		X			CA6203V-PO
CARD_3.7.2.2.13	CA5713-PO		X			CA5713V-PO
	CA5978-PO		X			CA5978V-PO
	CA5979-PO		X			CA5979V-PO
	CA5980-PO			X		CA5980V-PO
	CA5981-PO		X			CA5981V-PO
	CA6004-PO		X			CA6004V-PO
CARD_3.7.2.2.14						
CARD_3.7.2.2.15	CA1069-PO	X	X			CA1069V-PO
	CA5557-PO	X	X			CA5557V-PO
	CA5562-PO	X	X			CA5562V-PO
CARD_3.7.2.3						
CARD_3.7.2.4	CA0430-PO		X		X	CA0430V-PO
	CA0897-PO		X		X	CA0897V-PO
	CA0898-PO		X		X	CA0898V-PO
	CA0899-PO		X		X	CA0899V-PO
CARD_3.7.2.5						
CARD_3.7.3						
CARD_3.7.3.1						
CARD_3.7.3.2	CA3213-PO		X			CA3213V-PO
CARD_3.7.3.2.1						
CARD_3.7.3.2.2						
CARD_3.7.3.2.2.1						
CARD_3.7.3.2.2.2	CA5236-PO		X		X	CA5236V-PO
	CA5316-PO		X			CA5316V-PO
CARD_3.7.3.2.3						
CARD_3.7.3.2.4	CA4140-PO		X			CA4140V-PO
CARD_3.7.3.2.5	CA6091-PO		X			CA6091V-PO
	CA6091-PO-Objective					
	CA6093-PO		X			CA6093V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA6093-PO-Objective					
	CA6202-PO		X			CA6202V-PO
CARD_3.7.3.2.6	CA0394-HQ	X				CA0394V-PO
	CA0397-HQ		X		X	CA0397V-HQ
	CA3200-PO		X		X	CA3200V-PO
	CA3206-PO		X			CA3206V-PO
	CA3208-PO		X			CA3208V-PO
	CA5149-PO		X		X	CA5149V-PO
	CA5195-PO		X	X	X	CA5195V-PO
	CA5303-PO		X		X	CA5303V-PO
CARD_3.7.3.2.6.1						
CARD_3.7.3.2.6.2	CA0837-PO		X			CA0837V-PO
	CA4141-PO		X			CA4141V-PO
	CA4143-PO		X			CA4143V-PO
	CA4145-PO		X			CA4145V-PO
CARD_3.7.3.2.7						
CARD_3.7.3.2.8	CA5434-PO		X		X	CA5434V-PO
	CA5801-PO		X	X		CA5801V-PO
CARD_3.7.3.2.9						
CARD_3.7.3.2.10	CA0887-PO		X		X	CA0887V-PO
	CA3289-PO		X		X	CA3289V-PO
	CA5902-PO			X		CA5902V-PO
	CA5905-PO			X		CA5905V-PO
	CA6109-PO				X	CA6109V-PO
CARD_3.7.3.2.11	CA0135-PO		X	X	X	CA0135V-PO
	CA0461-PO		X			CA0461V-PO
	CA3205-PO		X			CA3205V-PO
	CA5275-PO		X		X	CA5275V-PO
	CA5278-PO		X		X	CA5278V-PO
	CA5284-PO	X	X		X	CA5284V-PO
	CA5285-PO		X	X	X	CA5285V-PO
	CA5290-PO		X			CA5290V-PO
	CA5293-PO	X			X	CA5293V-PO
CARD_3.7.3.2.12	CA6207-PO		X			CA6207V-PO
CARD_3.7.3.2.13	CA5505-PO		X			CA5505V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA5982-PO		X			CA5982V-PO
	CA5983-PO		X			CA5983V-PO
	CA5985-PO		X			CA5985V-PO
	CA6008-PO		X			CA6008V-PO
	CA6017-PO		X			CA6017V-PO
	CA6017-PO-Objective					
	CA6034-PO	X	X			CA6034V-PO
	CA6035-PO	X	X			CA6035V-PO
CARD_3.7.3.2.14						
CARD_3.7.3.2.15						
CARD_3.7.3.3						
CARD_3.7.3.4	CA0432-PO		X		X	CA0432V-PO
CARD_3.7.3.5						
CARD_3.7.4						
CARD_3.7.4.1						
CARD_3.7.4.2						
CARD_3.7.4.2.1						
CARD_3.7.4.2.2						
CARD_3.7.4.2.2.1						
CARD_3.7.4.2.3						
CARD_3.7.4.2.4						
CARD_3.7.4.2.5	CA6095-PO		X			CA6095V-PO
	CA6095-PO-Objective					
	CA6097-PO		X			CA6097V-PO
	CA6097-PO-Objective					
	CA6104-PO		X			CA6104V-PO
CARD_3.7.4.2.6	CA0391-HQ	X				CA0391V-HQ
CARD_3.7.4.2.6.1						
CARD_3.7.4.2.6.2						
CARD_3.7.4.2.7	CA5918-PO			X		CA5918V-PO
	CA5920-PO	X		X		CA5920V-PO
CARD_3.7.4.2.8	CA3113-PO				X	CA3113V-PO
	CA3276-PO				X	CA3276V-PO
	CA3302-PO				X	CA3302V-PO
CARD_3.7.4.2.9						

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
CARD_3.7.4.2.10						
CARD_3.7.4.2.11	CA0129-PO	X	X			CA0129V-PO
	CA0183-PO		X			CA0183V-PO
	CA5292-PO		X		X	CA5292V-PO
CARD_3.7.4.2.12	CA5533-PO		X			CA5533V-PO
	CA6206-PO		X			CA6206V-PO
CARD_3.7.4.2.13	CA5986-PO		X			CA5986V-PO
	CA5987-PO		X			CA5987V-PO
	CA5988-PO			X		CA5988V-PO
	CA5989-PO		X			CA5989V-PO
	CA6009-PO		X			CA6009V-PO
CARD_3.7.4.2.14						
CARD_3.7.4.2.15						
CARD_3.7.4.3						
CARD_3.7.4.4						
CARD_3.7.4.5						
CARD_3.7.5						
CARD_3.7.5.1						
CARD_3.7.5.2	CA0140-PO	X	X			CA0140V-PO
	CA0142-PO		X		X	CA0142V-PO
	CA0145-PO		X			CA0145V-PO
	CA0858-PO		X			CA0858V-PO
	CA4122-PO		X		X	CA4122V-PO
	CA4123-PO		X	X	X	CA4123V-PO
	CA5701-PO		X	X	X	CA5701V-PO
CARD_3.7.5.2.1						
CARD_3.7.5.2.2	CA0146-PO		X	X	X	CA0146V-PO
	CA0151-PO		X			CA0151V-PO
	CA0306-PO		X		X	CA0306V-PO
	CA0336-PO		X	X		CA0336V-PO
	CA0337-PO		X	X		CA0337V-PO
	CA5146-PO		X	X	X	CA5146V-PO
	CA5408-PO		X			CA5408V-PO
	CA5438-PO		X		X	CA5438V-PO
CARD_3.7.5.2.3						

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
CARD_3.7.5.2.4						
CARD_3.7.5.2.5	CA4121-PO		X			CA4121V-PO
	CA5690-PO	X				CA5690V-PO
	CA5702-PO		X			CA5702V-PO
	CA6099-PO		X			CA6099V-PO
	CA6099-PO-Objective					
	CA6253-PO		X			CA6253V-PO
	CA6253-PO-Objective					
	CA6255-PO		X			CA6255V-PO
	CA6255-PO-Objective					
CARD_3.7.5.2.6	CA0148-PO	X	X			CA0148V-PO
	CA0444-PO		X			CA0444V-PO
	CA0853-PO		X	X		CA0853V-PO
	CA0856-PO		X			CA0856V-PO
CARD_3.7.5.2.7	CA5406-PO		X			CA5406V-PO
CARD_3.7.5.2.8	CA3274-PO				X	CA3274V-PO
CARD_3.7.5.2.9	CA3130-PO				X	CA3130V-PO
	CA5478-PO				X	CA5478V-PO
	CA5479-PO				X	CA5479V-PO
	CA5480-PO				X	CA5480V-PO
CARD_3.7.5.2.10	CA5051-PO			X		CA5051V-PO
	CA5907-PO			X		CA5907V-PO
	CA5908-PO		X		X	CA5908V-PO
	CA6064-PO		X		X	CA6064V-PO
	CA6211-PO				X	CA6211V-PO
CARD_3.7.5.2.11						
CARD_3.7.5.2.12	CA3064-PO		X			CA3064V-PO
	CA6101-PO	X	X			CA6101V-PO
	CA6204-PO		X			CA6204V-PO
	CA6208-PO		X			CA6208V-PO
	CA6209-PO		X			CA6209V-PO
CARD_3.7.5.2.13	CA5712-PO		X			CA5712V-PO
	CA5803-PO		X			CA5803V-PO
	CA5934-PO	X	X			CA5934V-PO
	CA5990-PO		X			CA5990V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA5991-PO		X			CA5991V-PO
	CA5992-PO			X		CA5992V-PO
	CA5993-PO		X			CA5993V-PO
	CA6005-PO		X			CA6005V-PO
	CA6010-PO		X			CA6010V-PO
CARD_3.7.5.2.14						
CARD_3.7.5.2.15	CA3018-PO		X		X	CA3018V-PO
	CA5112-PO		X	X		CA5112V-PO
	CA5360-PO	X	X			CA5360V-PO
	CA5931-PO	X	X			CA5931V-PO
	CA5932-PO	X	X			CA5932V-PO
	CA6071-PO				X	CA6071V-PO
CARD_3.7.5.3						
CARD_3.7.5.4	CA0910-PO		X		X	CA0910V-PO
	CA0911-PO		X		X	CA0911V-PO
	CA0912-PO		X		X	CA0912V-PO
	CA0914-PO		X		X	CA0914V-PO
	CA0915-PO		X		X	CA0915V-PO
	CA0916-PO		X		X	CA0916V-PO
CARD_3.7.5.5						
CARD_3.7.6						
CARD_3.7.6.1						
CARD_3.7.6.2	CA0139-PO		X		X	CA0139V-PO
	CA0152-PO		X		X	CA0152V-PO
	CA0293-PO		X		X	CA0293V-PO
	CA5669-PO		X			CA5669V-PO
CARD_3.7.6.2.1						
CARD_3.7.6.2.2	CA0163-PO		X		X	CA0163V-PO
	CA5437-PO		X		X	CA5437V-PO
CARD_3.7.6.2.3	CA5128-PO		X			CA5128V-PO
	CA5129-PO		X			CA5129V-PO
CARD_3.7.6.2.4						
CARD_3.7.6.2.5	CA6157-PO		X			CA6157V-PO
	CA6157-PO-Objective					
	CA6160-PO		X			CA6160V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
CARD_3.7.6.2.6	CA0883-PO		X			CA0883V-PO
	CA5125-PO	X				CA5125V-PO
CARD_3.7.6.2.7	CA5405-PO		X			CA5405V-PO
	CA5407-PO		X			CA5407V-PO
CARD_3.7.6.2.8	CA3273-PO				X	CA3273V-PO
	CA3285-PO				X	CA3285V-PO
	CA6200-PO				X	CA6200V-PO
	CA6215-PO				X	CA6215V-PO
	CA6216-PO				X	CA6216V-PO
CARD_3.7.6.2.9	CA3127-PO				X	CA3127V-PO
	CA5475-PO				X	CA5475V-PO
	CA5476-PO				X	CA5476V-PO
	CA5477-PO				X	CA5477V-PO
CARD_3.7.6.2.10	CA3128-PO				X	CA3128V-PO
	CA4132-PO		X		X	CA4132V-PO
	CA5058-PO			X		CA5058V-PO
	CA5071-PO			X		CA5071V-PO
	CA5903-PO			X		CA5903V-PO
CARD_3.7.6.2.11	CA0158-PO		X		X	CA0158V-PO
	CA0270-PO		X		X	CA0270V-PO
CARD_3.7.6.2.12	CA3065-PO		X			CA3065V-PO
	CA5135-PO		X			CA5135V-PO
CARD_3.7.6.2.13	CA5130-PO		X			CA5130V-PO
	CA5131-PO		X			CA5131V-PO
	CA5132-PO		X			CA5132V-PO
	CA5133-PO		X			CA5133V-PO
	CA5994-PO		X			CA5994V-PO
	CA5995-PO		X			CA5995V-PO
	CA5996-PO			X		CA5996V-PO
	CA5997-PO		X			CA5997V-PO
	CA6019-PO		X			CA6019V-PO
	CA6036-PO	X	X			CA6036V-PO
	CA6036-PO-Objective					
	CA6038-PO	X	X			CA6038V-PO
	CA6039-PO	X	X			CA6039V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA6040-PO	X	X			CA6040V-PO
CARD_3.7.6.2.14						
CARD_3.7.6.2.15						
CARD_3.7.6.3						
CARD_3.7.6.4	CA0917-PO		X		X	CA0917V-PO
	CA0918-PO		X		X	CA0918V-PO
	CA0919-PO		X		X	CA0919V-PO
	CA0920-PO		X		X	CA0920V-PO
	CA0921-PO		X		X	CA0921V-PO
	CA0922-PO		X		X	CA0922V-PO
CARD_3.7.6.5						
CARD_3.7.7						
CARD_3.7.7.1						
CARD_3.7.7.2						
CARD_3.7.7.2.1						
CARD_3.7.7.2.2						
CARD_3.7.7.2.3						
CARD_3.7.7.2.4						
CARD_3.7.7.2.5						
CARD_3.7.7.2.6						
CARD_3.7.7.2.7						
CARD_3.7.7.2.8						
CARD_3.7.7.2.9						
CARD_3.7.7.2.10						
CARD_3.7.7.2.11						
CARD_3.7.7.2.12						
CARD_3.7.7.2.13						
CARD_3.7.7.2.14						
CARD_3.7.7.2.15						
CARD_3.7.7.3						
CARD_3.7.7.4						
CARD_3.7.7.5						
CARD_3.7.8						
CARD_3.7.8.1						
CARD_3.7.8.2						

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
CARD_3.7.8.2.1						
CARD_3.7.8.2.2						
CARD_3.7.8.2.3						
CARD_3.7.8.2.4						
CARD_3.7.8.2.5						
CARD_3.7.8.2.6						
CARD_3.7.8.2.7						
CARD_3.7.8.2.8						
CARD_3.7.8.2.9						
CARD_3.7.8.2.10						
CARD_3.7.8.2.11						
CARD_3.7.8.2.12						
CARD_3.7.8.2.13						
CARD_3.7.8.2.14						
CARD_3.7.8.2.15						
CARD_3.7.8.3						
CARD_3.7.8.4						
CARD_3.7.8.5						
CARD_3.7.9						
CARD_3.7.9.1						
CARD_3.7.9.2	CA4127-PO		X	X	X	CA4127V-PO
	CA6078-PO		X		X	CA6078V-PO
	CA6080-PO		X		X	CA6080V-PO
CARD_3.7.9.2.1	CA5946-PO		X			CA5946V-PO
CARD_3.7.9.2.2	CA3003-PO		X			CA3003V-PO
	CA5169-PO		X	X		CA5169V-PO
	CA5170-PO		X	X		CA5170V-PO
	CA5203-PO		X	X		CA5203V-PO
	CA6076-PO		X			CA6076-PO
CARD_3.7.9.2.2.1	CA5945-PO		X			CA5945V-PO
CARD_3.7.9.2.3						
CARD_3.7.9.2.4						
CARD_3.7.9.2.5	CA6153-PO		X			CA6153V-PO
	CA6153-PO-Objective					
	CA6262-PO		X			CA6262V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA6262-PO-Objective					
CARD_3.7.9.2.6						
CARD_3.7.9.2.7	CA5400-PO		X			CA5400V-PO
	CA5409-PO		X			CA5409V-PO
	CA5410-PO		X			CA5410V-PO
CARD_3.7.9.2.8						
CARD_3.7.9.2.9	CA3121-PO				X	CA3121V-PO
	CA3122-PO				X	CA3122V-PO
	CA4125-PO				X	CA4125V-PO
	CA5467-PO				X	CA5467V-PO
	CA5468-PO				X	CA5468V-PO
CARD_3.7.9.2.10	CA5909-PO		X		X	CA5909V-PO
	CA5910-PO		X		X	CA5910V-PO
CARD_3.7.9.2.11						
CARD_3.7.9.2.12	CA3063-PO		X			CA3063V-PO
CARD_3.7.9.2.13	CA5182-PO		X			CA5182V-PO
	CA5184-PO		X			CA5184V-PO
	CA5998-PO		X			CA5998V-PO
	CA5999-PO		X			CA5999V-PO
	CA6001-PO		X			CA6001V-PO
	CA6006-PO		X			CA6006V-PO
	CA6011-PO		X			CA6011V-PO
CARD_3.7.9.2.14	CA3058-PO		X	X		CA3058V-PO
	CA5168-PO			X		CA5168V-PO
	CA5659-PO		X		X	CA5659V-PO
CARD_3.7.9.2.15	CA5188-PO	X	X			CA5188V-PO
	CA5559-PO	X	X			CA5559V-PO
	CA5564-PO	X	X			CA5564V-PO
CARD_3.7.9.3						
CARD_3.7.9.4	CA0923-PO		X		X	CA0923V-PO
	CA0924-PO		X		X	CA0924V-PO
	CA0925-PO		X		X	CA0925V-PO
CARD_3.7.9.5						
CARD_3.7.10						
CARD_3.7.10.1						

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
CARD_3.7.10.2	CA6081-PO		X		X	CA6081V-PO
	CA6082-PO		X		X	CA6082V-PO

APPENDIX D
REQUIREMENTS ALLOCATION MATRIX

This Allocation Matrix shows how requirements will be allocated from the Architecture level to the Projects. The functionality may be allocated directly to the Project via the Project SRD.

Allocations of Draft requirements are shown with a darker background. The allocations to these requirements are not fully matured because the requirements are not matured. Trade studies and analyses are in work to properly decompose and allocate requirements associated with Lunar Surface and Mars missions.

TABLE D-1 - REQUIREMENTS ALLOCATION MATRIX

Section No	CARD REQ No.	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA	FCE
3.2	CA0001-HQ	X	X	X	X	X	X			X	
	CA0003-HQ	X		X		X	X				
	CA0004-HQ	X		X		X	X				
	CA0005-HQ	X	X	X	X	X	X			X	
	CA0006-HQ										
	CA0011-HQ										
	CA0013-HQ	X	X	X	X	X	X			X	
	CA0074-PO										
	CA0202-HQ			X			X			X	
	CA0404-HQ										
	CA0889-HQ	X	X		X	X	X	X	X		
	CA0892-HQ	X	X		X	X	X			X	
	CA6077-PO	X								X	X
	CA6079-PO	X								X	
3.2.1	CA0033-HQ	X	X	X	X	X	X			X	
	CA0095-HQ	X	X			X	X			X	
	CA0097-HQ	X	X			X	X				
	CA0099-HQ	X	X	X	X	X	X			X	
	CA3038-HQ			X	X	X	X				
	CA3039-HQ									X	
3.2.2	CA0028-PO	X		X							
	CA0107-HQ	X		X		X	X		X	X	
	CA0172-PO	X				X	X			X	
	CA0312-PO	X									
	CA6072-PO	X		X							
	CA6073-PO	X		X						X	
3.2.2.1	CA0032-HQ	X	X	X	X	X	X			X	
	CA0096-HQ	X	X			X	X			X	
	CA0474-HQ	X	X	X	X	X	X			X	
	CA3037-HQ									X	
	CA5818-HQ	X	X							X	
3.2.2.2	CA0027-PO	X	X	X	X	X	X				
	CA0310-PO	X				X				X	
	CA0311-PO	X	X		X	X					
	CA0352-HQ	X		X						X	

Section No	CARD REQ No.	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA	FCE
	CA0530-PO	X		X						X	
	CA3226-PO	X				X	X				
3.2.3	CA0010-HQ	X								X	
	CA0020-HQ	X	X	X			X			X	
	CA0203-HQ	X		X			X			X	
	CA0388-HQ	X	X			X	X			X	
3.2.4	CA0002-HQ			X							
	CA0209-HQ			X		X	X				
	CA0211-HQ	X		X		X	X				
	CA0212-HQ										
	CA0822-HQ	X		X							
	CA0823-HQ										
3.2.5	CA0036-HQ	X	X	X	X	X	X			X	
	CA0047-HQ										
	CA0073-HQ										
	CA0207-HQ	X		X			X			X	
	CA5289-PO	X		X						X	
	CA6102-PO			X	X	X					
3.2.6	CA0021-PO			X						X	
	CA0022-HQ			X						X	
	CA0029-HQ	X	X	X	X	X	X				
	CA0039-HQ	X	X	X	X	X	X			X	
	CA0044-PO	X				X					
	CA0046-PO	X	X	X	X		X				
	CA0121-HQ	X	X	X	X		X				
	CA0181-HQ	X		X		X	X			X	
	CA0281-HQ	X	X	X	X	X					
	CA0287-PO			X						X	
	CA0316-PO	X		X	X						
	CA0353-PO										
	CA0405-HQ			X	X						
	CA0407-PO			X						X	
	CA0465-HQ									X	
	CA3175-PO	X		X		X	X			X	
	CA3184-PO	X	X			X	X				
	CA3211-PO			X	X						
	CA3214-HQ				X						
	CA5247-PO			X							

Section No	CARD REQ No.	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA	FCE
3.2.7	CA0100-HQ		X		X	X					
	CA0213-PO	X	X	X	X	X	X			X	
	CA0214-PO	X	X	X	X	X	X			X	
	CA0215-PO	X	X	X	X					X	
	CA0569-PO	X	X	X	X						
	CA5812-HQ		X		X						
	CA6041-PO	X		X	X						
	CA6106-PO	X	X		X	X	X				
3.2.8	CA0449-PO	X	X	X	X	X	X			X	
	CA5604-PO	X		X			X			X	
3.2.9	CA0216-PO	X	X	X	X	X	X			X	
	CA0217-PO	X	X	X	X	X	X			X	
	CA6050-PO	X	X	X	X					X	
3.2.9.1	CA6051-PO	X	X	X	X					X	
3.2.10	CA0296-HQ	X	X	X	X	X	X		X	X	
	CA0476-PO	X	X	X	X	X	X		X	X	
	CA0993-PO	X		X	X	X	X			X	
	CA3007-PO	X	X	X		X	X			X	
	CA3021-PO	X	X	X	X	X	X			X	
	CA3043-PO	X	X	X	X	X	X			X	
	CA3051-PO	X		X	X	X	X			X	
	CA5065-PO	X	X	X	X	X	X			X	
	CA5817-PO	X		X		X	X				
	CA5820-PO	X	X	X	X						
	CA5821-PO					X	X				
	CA6065-PO	X		X	X					X	
	CA6105-PO	X	X		X	X	X				
	CA6210-PO	X	X		X	X	X				
3.2.11	CA0314-PO	X		X							
	CA0356-PO			X			X				
	CA0529-PO			X			X				
	CA0826-PO			X			X			X	
	CA3141-PO			X			X				
	CA5601-PO	X		X							
	CA5602-PO	X		X							
3.2.12	CA0037-PO	X	X	X	X	X	X			X	
	CA0038-HQ					X	X				
	CA0040-PO	X	X		X	X					

Section No	CARD REQ No.	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA	FCE
	CA0071-PO	X	X	X	X	X	X			X	
	CA0123-PO	X	X	X		X	X			X	
	CA0125-PO	X	X			X	X			X	
	CA5600-PO		X	X	X	X					
3.2.13	CA0550-PO	X		X			X	X	X	X	
	CA3293-PO	X		X		X				X	
	CA5814-PO	X	X	X	X	X					
	CA5815-PO	X	X	X	X	X					
	CA5935-PO	X		X							
	CA5962-PO	X	X	X	X	X					
	CA5963-PO	X	X	X	X	X					
	CA5964-PO	X	X	X		X	X			X	
	CA5965-PO	X	X	X		X	X			X	
	CA5966-PO	X	X	X	X	X	X			X	
	CA5967-PO	X	X	X	X	X	X			X	
	CA5968-PO	X	X	X	X	X	X			X	
	CA5969-PO	X	X	X	X	X	X			X	
	CA5970-PO	X	X	X	X	X	X			X	
	CA5971-PO	X	X	X	X	X	X			X	
	CA5972-PO	X	X	X	X	X	X			X	
	CA5973-PO	X	X	X	X	X	X			X	
	CA6002-PO	X	X			X				X	
	CA6007-PO			X	X	X				X	
	CA6012-PO	X	X	X	X		X			X	
	CA6020-PO	X		X			X				
	CA6020-PO-Objective	X		X			X				
	CA6022-PO	X		X			X				
	CA6022-PO-Objective	X		X			X				
	CA6024-PO	X					X				
	CA6024-PO-Objective	X					X				
	CA6026-PO	X					X				
	CA6027-PO	X		X			X				
	CA6028-PO	X		X			X				
3.2.14											
3.2.15	CA0048-PO	X	X	X	X	X				X	
	CA0991-PO	X	X		X	X		X			
	CA5552-PO	X	X	X	X	X				X	
3.3											

Section No	CARD REQ No.	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA	FCE
3.3.1	CA0817-PO	X	X	X	X					X	
	CA0990-PO	X	X	X	X					X	
3.3.1.1	CA0554-PO	X	X	X	X	X				X	
	CA0555-PO	X	X	X	X	X				X	
	CA5811-PO	X	X	X	X	X				X	
3.3.2	CA3004-PO	X	X	X	X	X					
	CA3005-PO	X	X	X	X					X	
	CA3187-PO	X	X	X	X					X	
	CA3193-PO	X	X	X	X					X	
	CA3222-PO	X	X	X	X					X	
	CA3237-PO	X	X	X	X					X	
3.3.3											
3.3.4	CA0042-PO	X	X	X	X	X	X			X	
3.3.5	CA0383-PO	X	X	X	X	X	X			X	
	CA5800-PO	X	X	X	X	X	X	X	X	X	
3.3.6	CA3167-PO	X		X						X	
3.3.7	CA3252-PO	X	X	X	X		X			X	
	CA5618-PO		X			X	X			X	
3.3.8	CA5680-PO	X	X	X	X	X	X	X	X	X	
3.3.9	CA4111-PO	X	X	X	X		X	X	X	X	
3.4	CA0069-HQ	X	X	X	X	X	X			X	
	CA0077-HQ	X									
	CA5750-PO	X	X	X	X	X	X				
	CA5940-PO						X				
	CA5941-PO	X	X	X	X	X	X				
	CA5942-PO	X	X		X	X	X				
	CA6069-PO	X		X		X	X			X	
3.5	CA0023-PO	X	X	X	X						

APPENDIX E
REQUIREMENTS TRACEABILITY MATRIX (RTM)

The first table in this appendix, shown below, outlines the traceability from each of the parent requirements (shown in the left-hand column) down to their respective child requirements (shown in the right-hand column).

TABLE E-1 - REQUIREMENTS TRACEABILITY MATRIX - PARENT CHILD

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0001-HQ	CARD_3.2	CA0005-HQ	CARD_3.2
		CA0006-HQ	CARD_3.2
		CA0013-HQ	CARD_3.2
		CA0021-PO	CARD_3.2.6
		CA0023-PO	CARD_3.5
		CA0029-HQ	CARD_3.2.6
		CA0036-HQ	CARD_3.2.5
		CA0038-HQ	CARD_3.2.12
		CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
		CA0042-PO	CARD_3.3.4
		CA0044-PO	CARD_3.2.6
		CA0048-PO	CARD_3.2.15
		CA0071-PO	CARD_3.2.12
		CA0100-HQ	CARD_3.2.7
		CA0107-HQ	CARD_3.2.2
		CA0121-HQ	CARD_3.2.6
		CA0123-PO	CARD_3.2.12
		CA0125-PO	CARD_3.2.12
		CA0145-PO	CARD_3.7.5.2
		CA0152-PO	CARD_3.7.6.2

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0203-HQ	CARD_3.2.3
		CA0207-HQ	CARD_3.2.5
		CA0209-HQ	CARD_3.2.4
		CA0361-PO	CARD_3.7.1.4
		CA0386-HQ	CARD_3.7.1.5
		CA0389-HQ	CARD_3.7.2.2.6
		CA0391-HQ	CARD_3.7.4.2.6
		CA0397-HQ	CARD_3.7.3.2.6
		CA0429-PO	CARD_3.7.1.4
		CA0432-PO	CARD_3.7.3.4
		CA0800-PO	CARD_3.7.1.4
		CA0822-HQ	CARD_3.2.4
		CA3200-PO	CARD_3.7.3.2.6
		CA3226-PO	CARD_3.2.2.2
		CA3252-PO	CARD_3.3.7
		CA5552-PO	CARD_3.2.15
		CA5618-PO	CARD_3.3.7
		CA5713-PO	CARD_3.7.2.2.13
		CA5803-PO	CARD_3.7.5.2.13

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5817-PO	CARD_3.2.10
		CA5818-HQ	CARD_3.2.2.1
		CA5942-PO	CARD_3.4
		CA5962-PO	CARD_3.2.13
		CA5964-PO	CARD_3.2.13
		CA5966-PO	CARD_3.2.13
		CA5968-PO	CARD_3.2.13
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
		CA5973-PO	CARD_3.2.13
		CA6027-PO	CARD_3.2.13
		CA6028-PO	CARD_3.2.13
CA0003-HQ	CARD_3.2	CA0139-PO	CARD_3.7.6.2
		CA0152-PO	CARD_3.7.6.2
		CA0211-HQ	CARD_3.2.4
		CA0293-PO	CARD_3.7.6.2
		CA0547-PO	CARD_3.7.1.2.4
		CA0822-HQ	CARD_3.2.4
		CA5821-PO	CARD_3.2.10
		CA6027-PO	CARD_3.2.13
		CA6028-PO	CARD_3.2.13
CA0004-HQ	CARD_3.2	CA0139-PO	CARD_3.7.6.2
		CA0152-PO	CARD_3.7.6.2
		CA0293-PO	CARD_3.7.6.2
		CA6027-PO	CARD_3.2.13
		CA6028-PO	CARD_3.2.13

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0005-HQ	CARD_3.2	CA0020-HQ	CARD_3.2.3
		CA0099-HQ	CARD_3.2.1
		CA0474-HQ	CARD_3.2.2.1
		CA3213-PO	CARD_3.7.3.2
		CA5821-PO	CARD_3.2.10
CA0006-HQ	CARD_3.2	CA5821-PO	CARD_3.2.10
CA0013-HQ	CARD_3.2	CA0032-HQ	CARD_3.2.2.1
		CA0033-HQ	CARD_3.2.1
		CA0046-PO	CARD_3.2.6
		CA0207-HQ	CARD_3.2.5
		CA5303-PO	CARD_3.7.3.2.6
CA0020-HQ	CARD_3.2.3		
CA0021-PO	CARD_3.2.6		
CA0023-PO	CARD_3.5	CA0827-PO	CARD_3.7.1.2.6.1
		CA4134-PO	CARD_3.7.1.2.6.1
		CA4135-PO	CARD_3.7.1.2.6.1
		CA4138-PO	CARD_3.7.2.2.6.1
		CA4139-PO	CARD_3.7.1.2.6.1
		CA4140-PO	CARD_3.7.3.2.4
		CA4163-PO	CARD_3.7.1.2.6.1
		CA4164-PO	CARD_3.7.1.2.6.1
		CA4165-PO	CARD_3.7.2.2.6.1
CA0027-PO	CARD_3.2.2.2	CA0170-PO	CARD_3.7.1.2.2.2

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0333-PO	CARD_3.7.1.2.2.2
		CA0498-PO	CARD_3.7.1.2.2.2
		CA0522-PO	CARD_3.7.1.2.2.2
		CA0579-PO	CARD_3.7.1.2.2.2
		CA1055-PO	CARD_3.7.2.2.7
		CA5234-PO	CARD_3.7.1.2.2.2
		CA5236-PO	CARD_3.7.3.2.2.2
		CA5434-PO	CARD_3.7.3.2.8
		CA5435-PO	CARD_3.7.2.2.2
		CA5437-PO	CARD_3.7.6.2.2
		CA5438-PO	CARD_3.7.5.2.2
		CA5439-PO	CARD_3.7.1.2.2.2
CA0028-PO	CARD_3.2.2	CA0416-PO	CARD_3.7.1.2.2.2
		CA5316-PO	CARD_3.7.3.2.2.2
		CA5319-PO	CARD_3.7.1.2.6
CA0029-HQ	CARD_3.2.6	CA0148-PO	CARD_3.7.5.2.6
		CA0569-PO	CARD_3.2.7

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0032-HQ	CARD_3.2.2.1	CA0501-PO	CARD_3.7.1.2.2.1
		CA5825-PO	CARD_3.7.2.2.7
		CA5945-PO	CARD_3.7.9.2.2.1
CA0033-HQ	CARD_3.2.1	CA0088-PO	CARD_3.7.1.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA5946-PO	CARD_3.7.9.2.1
CA0036-HQ	CARD_3.2.5	CA5964-PO	CARD_3.2.13
		CA5966-PO	CARD_3.2.13
		CA5968-PO	CARD_3.2.13
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
		CA5973-PO	CARD_3.2.13
		CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
		CA6084-PO	CARD_3.7.1.2.5
		CA6084-PO-Objective	CARD_3.7.1.2.5
		CA6087-PO	CARD_3.7.2.2.5
		CA6087-PO-Objective	CARD_3.7.2.2.5
		CA6089-PO	CARD_3.7.2.2.5
		CA6089-PO-Objective	CARD_3.7.2.2.5
		CA6091-PO	CARD_3.7.3.2.5
		CA6091-PO-Objective	CARD_3.7.3.2.5

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA6093-PO	CARD_3.7.3.2.5
		CA6093-PO-Objective	CARD_3.7.3.2.5
		CA6095-PO	CARD_3.7.4.2.5
		CA6095-PO-Objective	CARD_3.7.4.2.5
		CA6097-PO	CARD_3.7.4.2.5
		CA6097-PO-Objective	CARD_3.7.4.2.5
		CA6099-PO	CARD_3.7.5.2.5
		CA6153-PO	CARD_3.7.9.2.5
		CA6153-PO-Objective	CARD_3.7.9.2.5
		CA6157-PO	CARD_3.7.6.2.5
		CA6157-PO-Objective	CARD_3.7.6.2.5
		CA6160-PO	CARD_3.7.6.2.5
		CA6099-PO-Objective	CARD_3.7.5.2.5
		CA6253-PO	CARD_3.7.5.2.5
		CA6253-PO-Objective	CARD_3.7.5.2.5
		CA6255-PO	CARD_3.7.5.2.5
		CA6255-PO-Objective	CARD_3.7.5.2.5
		CA6258-PO	CARD_3.7.1.2.5
		CA6258-PO-Objective	CARD_3.7.1.2.5
		CA6260-PO	CARD_3.7.1.2.5
		CA6260-PO-Objective	CARD_3.7.1.2.5
		CA6262-PO	CARD_3.7.9.2.5
		CA6262-PO-Objective	CARD_3.7.9.2.5

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0036-HQ	CARD_3.2.5	CA5964-PO	CARD_3.2.13
		CA5966-PO	CARD_3.2.13
		CA5968-PO	CARD_3.2.13
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
		CA5973-PO	CARD_3.2.13
		CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
		CA6084-PO	CARD_3.7.1.2.5
		CA6084-PO-Objective	CARD_3.7.1.2.5
		CA6087-PO	CARD_3.7.2.2.5
		CA6087-PO-Objective	CARD_3.7.2.2.5
		CA6089-PO	CARD_3.7.2.2.5
		CA6089-PO-Objective	CARD_3.7.2.2.5
		CA6091-PO	CARD_3.7.3.2.5
		CA6091-PO-Objective	CARD_3.7.3.2.5
		CA6093-PO	CARD_3.7.3.2.5
		CA6093-PO-Objective	CARD_3.7.3.2.5
		CA6095-PO	CARD_3.7.4.2.5
		CA6095-PO-Objective	CARD_3.7.4.2.5
		CA6097-PO	CARD_3.7.4.2.5
		CA6097-PO-Objective	CARD_3.7.4.2.5
		CA6099-PO	CARD_3.7.5.2.5
		CA6153-PO	CARD_3.7.9.2.5
		CA6153-PO-Objective	CARD_3.7.9.2.5
		CA6157-PO	CARD_3.7.6.2.5

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA6157-PO-Objective	CARD_3.7.6.2.5
		CA6160-PO	CARD_3.7.6.2.5
		CA6099-PO-Objective	CARD_3.7.5.2.5
		CA6253-PO	CARD_3.7.5.2.5
		CA6253-PO-Objective	CARD_3.7.5.2.5
		CA6255-PO	CARD_3.7.5.2.5
		CA6255-PO-Objective	CARD_3.7.5.2.5
		CA6258-PO	CARD_3.7.1.2.5
		CA6258-PO-Objective	CARD_3.7.1.2.5
		CA6260-PO	CARD_3.7.1.2.5
		CA6260-PO-Objective	CARD_3.7.1.2.5
		CA6262-PO	CARD_3.7.9.2.5
		CA6262-PO-Objective	CARD_3.7.9.2.5
CA0037-PO	CARD_3.2.12	CA5533-PO	CARD_3.7.4.2.12
		CA6202-PO	CARD_3.7.3.2.5
CA0038-HQ	CARD_3.2.12	CA4121-PO	CARD_3.7.5.2.5
		CA5135-PO	CARD_3.7.6.2.12
CA0039-HQ	CARD_3.2.6	CA0444-PO	CARD_3.7.5.2.6
		CA5750-PO	CARD_3.4
CA0040-PO	CARD_3.2.12	CA0351-PO	CARD_3.7.1.2.6
		CA5112-PO	CARD_3.7.5.2.15

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5677-PO	CARD_3.7.2.2.6
CA0042-PO	CARD_3.3.4	CA3133-PO	CARD_3.7.1.2.14
CA0044-PO	CARD_3.2.6	CA0324-PO	CARD_3.7.1.2.6
		CA0329-PO	CARD_3.7.1.2.11
		CA0494-PO	CARD_3.7.1.2.6
		CA4122-PO	CARD_3.7.5.2
		CA5941-PO	CARD_3.4
CA0046-PO	CARD_3.2.6		
CA0048-PO	CARD_3.2.15	CA0374-PO	CARD_3.7.1.2.15
		CA0983-PO	CARD_3.7.1.2.2
		CA0984-PO	CARD_3.7.1.2.2
		CA1069-PO	CARD_3.7.2.2.15
		CA3018-PO	CARD_3.7.5.2.15
		CA5188-PO	CARD_3.7.9.2.15
		CA5360-PO	CARD_3.7.5.2.15
		CA5963-PO	CARD_3.2.13
CA0069-HQ	CARD_3.4	CA0922-PO	CARD_3.7.6.4
CA0069-HQ	CARD_3.4	CA0922-PO	CARD_3.7.6.4

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0071-PO	CARD_3.2.12	CA3065-PO	CARD_3.7.6.2.12
CA0077-HQ	CARD_3.4		
CA0095-HQ	CARD_3.2.1	CA0399-PO	CARD_3.7.1.2.1
		CA1065-PO	CARD_3.7.2.2.1
CA0096-HQ	CARD_3.2.2.1	CA0398-PO	CARD_3.7.1.2.2.1
CA0097-HQ	CARD_3.2.1	CA1065-PO	CARD_3.7.2.2.1
		CA3022-PO	CARD_3.7.1.2.1
CA0099-HQ	CARD_3.2.1	CA1065-PO	CARD_3.7.2.2.1
		CA3023-PO	CARD_3.7.1.2.1
CA0100-HQ	CARD_3.2.7	CA0566-PO	CARD_3.7.2.2.7
		CA1053-PO	CARD_3.7.2.2.7
		CA1054-PO	CARD_3.7.2.2.7
		CA1056-PO	CARD_3.7.2.2.7
		CA5812-HQ	CARD_3.2.7
		CA5917-PO	CARD_3.7.2.2.7
		CA5919-PO	CARD_3.7.2.2.7
CA0107-HQ	CARD_3.2.2	CA0027-PO	CARD_3.2.2.2
		CA0028-PO	CARD_3.2.2
		CA0274-PO	CARD_3.7.1.2.2

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0306-PO	CARD_3.7.5.2.2
		CA0310-PO	CARD_3.2.2.2
		CA0311-PO	CARD_3.2.2.2
		CA0312-PO	CARD_3.2.2
		CA0334-PO	CARD_3.7.1.2.2.2
		CA0335-PO	CARD_3.7.1.2.2.2
		CA0336-PO	CARD_3.7.5.2.2
		CA0337-PO	CARD_3.7.5.2.2
		CA0352-HQ	CARD_3.2.2.2
		CA0444-PO	CARD_3.7.5.2.6
		CA0466-PO	CARD_3.7.1.2.2.2
		CA0493-PO	CARD_3.7.1.2.2
		CA0530-PO	CARD_3.2.2.2
		CA0883-PO	CARD_3.7.6.2.6
		CA3061-PO	CARD_3.7.1.2.14
		CA3138-PO	CARD_3.7.1.2.2
		CA3226-PO	CARD_3.2.2.2
		CA3259-PO	CARD_3.7.1.2.2
		CA3280-PO	CARD_3.7.1.2.10

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA4123-PO	CARD_3.7.5.2
		CA4132-PO	CARD_3.7.6.2.10
		CA5125-PO	CARD_3.7.6.2.6
		CA5146-PO	CARD_3.7.5.2.2
		CA5168-PO	CARD_3.7.9.2.14
		CA5170-PO	CARD_3.7.9.2.2
		CA5236-PO	CARD_3.7.3.2.2.2
		CA5711-PO	CARD_3.7.1.2.14
		CA5801-PO	CARD_3.7.3.2.8
		CA6041-PO	CARD_3.2.7
CA0121-HQ	CARD_3.2.6	CA0028-PO	CARD_3.2.2
		CA0056-PO	CARD_3.7.1.2
		CA0059-PO	CARD_3.7.1.2.11
		CA0082-PO	CARD_3.7.1.2.5
		CA0091-PO	CARD_3.7.1.2
		CA0129-PO	CARD_3.7.4.2.11
		CA0131-PO	CARD_3.7.1.2.11
		CA0133-PO	CARD_3.7.1.2.11
		CA0135-PO	CARD_3.7.3.2.11

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0183-PO	CARD_3.7.4.2.11
		CA0187-PO	CARD_3.7.1.2.11
		CA0281-HQ	CARD_3.2.6
		CA0314-PO	CARD_3.2.11
		CA0316-PO	CARD_3.2.6
		CA0369-PO	CARD_3.7.1.2.11
		CA0461-PO	CARD_3.7.3.2.11
		CA0462-PO	CARD_3.7.1.2.11
		CA0463-PO	CARD_3.7.1.2.11
		CA0829-PO	CARD_3.7.1.2.6.2
		CA0837-PO	CARD_3.7.3.2.6.2
		CA0886-PO	CARD_3.7.1.2.14
		CA3164-PO	CARD_3.7.1.2.5
		CA3204-PO	CARD_3.7.1.2.6
		CA3205-PO	CARD_3.7.3.2.11
		CA3206-PO	CARD_3.7.3.2.6
		CA3207-PO	CARD_3.7.1.2.6
		CA3208-PO	CARD_3.7.3.2.6
		CA3209-PO	CARD_3.7.1.2.6

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA3221-PO	CARD_3.7.2.2.6
		CA3223-PO	CARD_3.7.2.2.6
		CA4128-PO	CARD_3.7.1.2.11
		CA4135-PO	CARD_3.7.1.2.6.1
		CA4138-PO	CARD_3.7.2.2.6.1
		CA4139-PO	CARD_3.7.1.2.6.1
		CA4140-PO	CARD_3.7.3.2.4
		CA4143-PO	CARD_3.7.3.2.6.2
		CA5275-PO	CARD_3.7.3.2.11
		CA5284-PO	CARD_3.7.3.2.11
		CA5285-PO	CARD_3.7.3.2.11
		CA5286-PO	CARD_3.7.1.2.11
		CA5290-PO	CARD_3.7.3.2.11
		CA5292-PO	CARD_3.7.4.2.11
		CA5293-PO	CARD_3.7.3.2.11
		CA5602-PO	CARD_3.2.11
		CA5819-PO	CARD_3.7.1.2.11
		CA5921-PO	CARD_3.7.1.2.11

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0123-PO	CARD_3.2.12	CA0072-PO	CARD_3.7.2.2.12
		CA0178-PO	CARD_3.7.1.2.12
		CA0444-PO	CARD_3.7.5.2.6
		CA1066-PO	CARD_3.7.2.2.12
		CA3063-PO	CARD_3.7.9.2.12
		CA3065-PO	CARD_3.7.6.2.12
		CA5323-PO	CARD_3.7.2.2.12
		CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
CA0125-PO	CARD_3.2.12	CA1008-PO	CARD_3.7.2.2.12
		CA5690-PO	CARD_3.7.5.2.5
		CA5702-PO	CARD_3.7.5.2.5
		CA6100-PO	CARD_3.7.1.2.12
		CA6101-PO	CARD_3.7.5.2.12
CA0172-PO	CARD_3.2.2	CA0146-PO	CARD_3.7.5.2.2
		CA0163-PO	CARD_3.7.6.2.2
		CA0306-PO	CARD_3.7.5.2.2
		CA0344-PO	CARD_3.7.1.2.10
		CA3259-PO	CARD_3.7.1.2.2

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA4123-PO	CARD_3.7.5.2
		CA5146-PO	CARD_3.7.5.2.2
CA0181-HQ	CARD_3.2.6	CA0895-PO	CARD_3.7.1.4
		CA0915-PO	CARD_3.7.5.4
		CA0923-PO	CARD_3.7.9.4
		CA0924-PO	CARD_3.7.9.4
		CA0925-PO	CARD_3.7.9.4
		CA3140-PO	CARD_3.7.1.2.14
		CA3167-PO	CARD_3.3.6
		CA3168-PO	CARD_3.7.1.2.6
		CA4127-PO	CARD_3.7.9.2
		CA4152-PO	CARD_3.7.1.2.6
		CA5195-PO	CARD_3.7.3.2.6
CA0202-HQ	CARD_3.2		
CA0203-HQ	CARD_3.2.3	CA0202-HQ	CARD_3.2
		CA0288-PO	CARD_3.7.1.2.14
		CA0426-PO	CARD_3.7.1.2.14

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3164-PO	CARD_3.7.1.2.5
		CA5128-PO	CARD_3.7.6.2.3
CA0207-HQ	CARD_3.2.5	CA3164-PO	CARD_3.7.1.2.5
CA0209-HQ	CARD_3.2.4	CA5131-PO	CARD_3.7.6.2.13
		CA5701-PO	CARD_3.7.5.2
CA0211-HQ	CARD_3.2.4	CA0868-PO	CARD_3.7.1.2.4
		CA5132-PO	CARD_3.7.6.2.13
CA0213-PO	CARD_3.2.7	CA0435-PO	CARD_3.7.1.2.7
		CA5405-PO	CARD_3.7.6.2.7
		CA5406-PO	CARD_3.7.5.2.7
		CA5409-PO	CARD_3.7.9.2.7
		CA5805-PO	CARD_3.7.2.2.1
		CA5916-PO	CARD_3.7.2.2.1
CA0214-PO	CARD_3.2.7	CA0436-PO	CARD_3.7.1.2.7
		CA5407-PO	CARD_3.7.6.2.7
		CA5408-PO	CARD_3.7.5.2.2
		CA5410-PO	CARD_3.7.9.2.7

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5805-PO	CARD_3.7.2.2.1
CA0215-PO	CARD_3.2.7	CA0258-PO	CARD_3.7.2.2.2
		CA0437-PO	CARD_3.7.1.2.7
		CA5400-PO	CARD_3.7.9.2.7
CA0216-PO	CARD_3.2.9	CA0438-PO	CARD_3.7.1.2.9
		CA1084-PO	CARD_3.7.2.2.9
		CA1085-PO	CARD_3.7.2.2.9
		CA1086-PO	CARD_3.7.2.2.9
		CA4125-PO	CARD_3.7.9.2.9
		CA5465-PO	CARD_3.7.1.2.9
		CA5466-PO	CARD_3.7.1.2.9
		CA5467-PO	CARD_3.7.9.2.9
		CA5468-PO	CARD_3.7.9.2.9
		CA5475-PO	CARD_3.7.6.2.9
		CA5476-PO	CARD_3.7.6.2.9
		CA5477-PO	CARD_3.7.6.2.9
		CA5478-PO	CARD_3.7.5.2.9

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5479-PO	CARD_3.7.5.2.9
		CA5480-PO	CARD_3.7.5.2.9
		CA5816-PO	CARD_3.7.2.2.9
CA0217-PO	CARD_3.2.9	CA0427-PO	CARD_3.7.1.2.9
		CA0428-PO	CARD_3.7.1.2.9
		CA3118-PO	CARD_3.7.2.2.9
		CA3121-PO	CARD_3.7.9.2.9
		CA3122-PO	CARD_3.7.9.2.9
		CA3127-PO	CARD_3.7.6.2.9
		CA3128-PO	CARD_3.7.6.2.10
		CA3130-PO	CARD_3.7.5.2.9
CA0281-HQ	CARD_3.2.6	CA0091-PO	CARD_3.7.1.2
		CA0827-PO	CARD_3.7.1.2.6.1
		CA1005-PO	CARD_3.7.2.2.6.1
		CA1023-PO	CARD_3.7.2.2.6
		CA1028-PO	CARD_3.7.2.2.8
		CA1029-PO	CARD_3.7.2.2.8

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3202-PO	CARD_3.7.2.2.6
		CA4121-PO	CARD_3.7.5.2.5
		CA4134-PO	CARD_3.7.1.2.6.1
CA0296-HQ	CARD_3.2.10	CA0069-HQ	CARD_3.4
		CA0470-PO	CARD_3.7.1.2.10
		CA0476-PO	CARD_3.2.10
		CA0887-PO	CARD_3.7.3.2.10
		CA0894-PO	CARD_3.7.1.4
		CA0896-PO	CARD_3.7.1.4
		CA0898-PO	CARD_3.7.2.4
		CA0899-PO	CARD_3.7.2.4
		CA0914-PO	CARD_3.7.5.4
		CA0916-PO	CARD_3.7.5.4
		CA0917-PO	CARD_3.7.6.4
		CA0918-PO	CARD_3.7.6.4
		CA0919-PO	CARD_3.7.6.4
		CA0920-PO	CARD_3.7.6.4
		CA0921-PO	CARD_3.7.6.4

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0922-PO	CARD_3.7.6.4
		CA3043-PO	CARD_3.2.10
		CA3051-PO	CARD_3.2.10
		CA3280-PO	CARD_3.7.1.2.10
		CA5071-PO	CARD_3.7.6.2.10
		CA5908-PO	CARD_3.7.5.2.10
		CA6070-PO	CARD_3.7.1.2.10
		CA6210-PO	CARD_3.2.10
CA0296-HQ	CARD_3.2.10	CA0069-HQ	CARD_3.4
		CA0470-PO	CARD_3.7.1.2.10
		CA0476-PO	CARD_3.2.10
		CA0887-PO	CARD_3.7.3.2.10
		CA0894-PO	CARD_3.7.1.4
		CA0896-PO	CARD_3.7.1.4
		CA0898-PO	CARD_3.7.2.4
		CA0899-PO	CARD_3.7.2.4
		CA0914-PO	CARD_3.7.5.4
		CA0916-PO	CARD_3.7.5.4
		CA0917-PO	CARD_3.7.6.4

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0918-PO	CARD_3.7.6.4
		CA0919-PO	CARD_3.7.6.4
		CA0920-PO	CARD_3.7.6.4
		CA0921-PO	CARD_3.7.6.4
		CA0922-PO	CARD_3.7.6.4
		CA3043-PO	CARD_3.2.10
		CA3051-PO	CARD_3.2.10
		CA3280-PO	CARD_3.7.1.2.10
		CA5071-PO	CARD_3.7.6.2.10
		CA5908-PO	CARD_3.7.5.2.10
		CA6070-PO	CARD_3.7.1.2.10
		CA6210-PO	CARD_3.2.10
CA0310-PO	CARD_3.2.2.2	CA0151-PO	CARD_3.7.5.2.2
		CA0334-PO	CARD_3.7.1.2.2.2
		CA0336-PO	CARD_3.7.5.2.2
		CA5169-PO	CARD_3.7.9.2.2
		CA5203-PO	CARD_3.7.9.2.2
CA0311-PO	CARD_3.2.2.2	CA0151-PO	CARD_3.7.5.2.2

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0335-PO	CARD_3.7.1.2.2.2
		CA0337-PO	CARD_3.7.5.2.2
		CA5159-PO	CARD_3.7.2.2.2.2
		CA5947-PO	CARD_3.7.1.2.2.2
CA0312-PO	CARD_3.2.2	CA0194-PO	CARD_3.7.1.2.2
		CA0344-PO	CARD_3.7.1.2.10
		CA0983-PO	CARD_3.7.1.2.2
		CA0984-PO	CARD_3.7.1.2.2
CA0314-PO	CARD_3.2.11		
CA0316-PO	CARD_3.2.6	CA0432-PO	CARD_3.7.3.4
		CA0800-PO	CARD_3.7.1.4
CA0352-HQ	CARD_3.2.2.2	CA0532-PO	CARD_3.7.1.2.2
		CA3003-PO	CARD_3.7.9.2.2
		CA4154-PO	CARD_3.7.1.2.2
		CA5237-PO	CARD_3.7.1.2.2.2
		CA5240-PO	CARD_3.7.1.2.6
		CA5948-PO	CARD_3.7.1.2.6.2
CA0383-PO	CARD_3.3.5		

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0383-PO	CARD_3.3.5		
CA0388-HQ	CARD_3.2.3	CA0081-PO	CARD_3.7.1.2.11
		CA0288-PO	CARD_3.7.1.2.14
		CA0426-PO	CARD_3.7.1.2.14
		CA0447-PO	CARD_3.7.1.2.3
		CA1000-PO	CARD_3.7.2.2.6.1
		CA5129-PO	CARD_3.7.6.2.3
CA0449-PO	CARD_3.2.8	CA0069-HQ	CARD_3.4
		CA0134-PO	CARD_3.7.1.2.8
		CA0430-PO	CARD_3.7.2.4
		CA0448-PO	CARD_3.7.1.2.8
		CA3110-PO	CARD_3.7.1.2.8
		CA3112-PO	CARD_3.7.2.2.8
		CA3113-PO	CARD_3.7.4.2.8
		CA3249-PO	CARD_3.7.1.2.8
		CA3254-PO	CARD_3.7.1.2.8
		CA3255-PO	CARD_3.7.1.2.8
		CA3256-PO	CARD_3.7.2.2.8

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3273-PO	CARD_3.7.6.2.8
		CA3274-PO	CARD_3.7.5.2.8
		CA3275-PO	CARD_3.7.2.2.8
		CA3276-PO	CARD_3.7.4.2.8
CA0449-PO	CARD_3.2.8	CA0069-HQ	CARD_3.4
		CA0134-PO	CARD_3.7.1.2.8
		CA0430-PO	CARD_3.7.2.4
		CA0448-PO	CARD_3.7.1.2.8
		CA3110-PO	CARD_3.7.1.2.8
		CA3112-PO	CARD_3.7.2.2.8
		CA3113-PO	CARD_3.7.4.2.8
		CA3249-PO	CARD_3.7.1.2.8
		CA3254-PO	CARD_3.7.1.2.8
		CA3255-PO	CARD_3.7.1.2.8
		CA3256-PO	CARD_3.7.2.2.8
		CA3273-PO	CARD_3.7.6.2.8
		CA3274-PO	CARD_3.7.5.2.8
		CA3275-PO	CARD_3.7.2.2.8

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA3276-PO	CARD_3.7.4.2.8
CA0474-HQ	CARD_3.2.2.1	CA3040-PO	CARD_3.7.1.2.2.1
CA0476-PO	CARD_3.2.10	CA3285-PO	CARD_3.7.6.2.8
		CA3287-PO	CARD_3.7.1.2.10
		CA3288-PO	CARD_3.7.1.2.10
		CA3289-PO	CARD_3.7.3.2.10
		CA5908-PO	CARD_3.7.5.2.10
		CA5909-PO	CARD_3.7.9.2.10
		CA5910-PO	CARD_3.7.9.2.10
		CA5912-PO	CARD_3.7.2.2.10
CA0530-PO	CARD_3.2.2.2	CA0532-PO	CARD_3.7.1.2.2
		CA3003-PO	CARD_3.7.9.2.2
		CA3058-PO	CARD_3.7.9.2.14
		CA3105-PO	CARD_3.7.1.2.14
		CA3106-PO	CARD_3.7.1.2.14
		CA3108-PO	CARD_3.7.1.2.2
		CA3140-PO	CARD_3.7.1.2.14
		CA4154-PO	CARD_3.7.1.2.2

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5168-PO	CARD_3.7.9.2.14
		CA5659-PO	CARD_3.7.9.2.14
CA0554-PO	CARD_3.3.1.1		
CA0555-PO	CARD_3.3.1.1	CA3018-PO	CARD_3.7.5.2.15
CA0569-PO	CARD_3.2.7		
CA0817-PO	CARD_3.3.1		
CA0822-HQ	CARD_3.2.4	CA5155-PO	CARD_3.7.1.2.4
CA0892-HQ	CARD_3.2	CA0023-PO	CARD_3.5
		CA0029-HQ	CARD_3.2.6
		CA0036-HQ	CARD_3.2.5
		CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
		CA0042-PO	CARD_3.3.4
		CA0044-PO	CARD_3.2.6
		CA0048-PO	CARD_3.2.15
		CA0060-HQ	CARD_3.7.1.2.5
		CA0071-PO	CARD_3.2.12
		CA0077-HQ	CARD_3.4
		CA0081-PO	CARD_3.7.1.2.11
		CA0095-HQ	CARD_3.2.1
		CA0096-HQ	CARD_3.2.2.1
		CA0097-HQ	CARD_3.2.1
		CA0100-HQ	CARD_3.2.7
		CA0107-HQ	CARD_3.2.2

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0123-PO	CARD_3.2.12
		CA0145-PO	CARD_3.7.5.2
		CA0152-PO	CARD_3.7.6.2
		CA0386-HQ	CARD_3.7.1.5
		CA0388-HQ	CARD_3.2.3
		CA0389-HQ	CARD_3.7.2.2.6
		CA0429-PO	CARD_3.7.1.4
		CA0565-HQ	CARD_3.7.1.2.4
		CA0864-PO	CARD_3.7.1.2.4
		CA0865-PO	CARD_3.7.1.2.4
		CA0866-PO	CARD_3.7.1.2.4
		CA3182-PO	CARD_3.7.1.2.4
		CA3184-PO	CARD_3.2.6
		CA3203-PO	CARD_3.7.1.2
		CA3226-PO	CARD_3.2.2.2
		CA3248-PO	CARD_3.7.1.2.11
		CA3252-PO	CARD_3.3.7
		CA4163-PO	CARD_3.7.1.2.6.1
		CA4164-PO	CARD_3.7.1.2.6.1

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA4165-PO	CARD_3.7.2.2.6.1
		CA5233-PO	CARD_3.7.1.2.4
		CA5312-PO	CARD_3.7.1.2
		CA5552-PO	CARD_3.2.15
		CA5618-PO	CARD_3.3.7
		CA5713-PO	CARD_3.7.2.2.13
		CA5803-PO	CARD_3.7.5.2.13
		CA5817-PO	CARD_3.2.10
		CA5818-HQ	CARD_3.2.2.1
		CA5942-PO	CARD_3.4
		CA5962-PO	CARD_3.2.13
		CA5964-PO	CARD_3.2.13
		CA5966-PO	CARD_3.2.13
		CA5968-PO	CARD_3.2.13
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
		CA5973-PO	CARD_3.2.13
		CA6024-PO	CARD_3.2.13
		CA6024-PO-Objective	CARD_3.2.13
		CA6026-PO	CARD_3.2.13
CA0990-PO	CARD_3.3.1		
CA0990-PO	CARD_3.3.1		
CA0991-PO	CARD_3.2.15	CA3018-PO	CARD_3.7.5.2.15
		CA6071-PO	CARD_3.7.5.2.15
CA0993-PO	CARD_3.2.10	CA0511-PO	CARD_3.7.1.2.10
		CA5039-PO	CARD_3.7.1.2.8

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5040-PO	CARD_3.7.1.2.8
		CA5051-PO	CARD_3.7.5.2.10
		CA5058-PO	CARD_3.7.6.2.10
CA3004-PO	CARD_3.3.2		
CA3005-PO	CARD_3.3.2		
CA3007-PO	CARD_3.2.10	CA3221-PO	CARD_3.7.2.2.6
		CA3223-PO	CARD_3.7.2.2.6
		CA5901-PO	CARD_3.7.1.2.10
		CA5902-PO	CARD_3.7.3.2.10
		CA5903-PO	CARD_3.7.6.2.10
		CA5904-PO	CARD_3.7.1.2.10
		CA5905-PO	CARD_3.7.3.2.10
		CA5906-PO	CARD_3.7.2.2.10
		CA5907-PO	CARD_3.7.5.2.10
CA3021-PO	CARD_3.2.10	CA0993-PO	CARD_3.2.10
CA3043-PO	CARD_3.2.10		
CA3043-PO	CARD_3.2.10		
CA3051-PO	CARD_3.2.10		
CA3167-PO	CARD_3.3.6	CA4152-PO	CARD_3.7.1.2.6
CA3167-PO	CARD_3.3.6	CA4152-PO	CARD_3.7.1.2.6

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA3175-PO	CARD_3.2.6	CA0895-PO	CARD_3.7.1.4
		CA0915-PO	CARD_3.7.5.4
		CA0923-PO	CARD_3.7.9.4
		CA0924-PO	CARD_3.7.9.4
		CA0925-PO	CARD_3.7.9.4
		CA3140-PO	CARD_3.7.1.2.14
		CA3167-PO	CARD_3.3.6
		CA4127-PO	CARD_3.7.9.2
		CA4152-PO	CARD_3.7.1.2.6
		CA5195-PO	CARD_3.7.3.2.6
CA3184-PO	CARD_3.2.6	CA0191-PO	CARD_3.7.1.2.6
		CA1023-PO	CARD_3.7.2.2.6
		CA1028-PO	CARD_3.7.2.2.8
		CA1029-PO	CARD_3.7.2.2.8
		CA3202-PO	CARD_3.7.2.2.6
		CA4135-PO	CARD_3.7.1.2.6.1
		CA5748-PO	CARD_3.7.1.2

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5749-PO	CARD_3.7.1.2
CA3187-PO	CARD_3.3.2		
CA3193-PO	CARD_3.3.2		
CA3222-PO	CARD_3.3.2		
CA3226-PO	CARD_3.2.2.2	CA0145-PO	CARD_3.7.5.2
		CA0146-PO	CARD_3.7.5.2.2
		CA0163-PO	CARD_3.7.6.2.2
		CA0172-PO	CARD_3.2.2
		CA0293-PO	CARD_3.7.6.2
		CA0306-PO	CARD_3.7.5.2.2
		CA0325-PO	CARD_3.7.1.2.2
		CA0494-PO	CARD_3.7.1.2.6
		CA3259-PO	CARD_3.7.1.2.2
		CA4123-PO	CARD_3.7.5.2
CA3237-PO	CARD_3.3.2		
CA3252-PO	CARD_3.3.7	CA0158-PO	CARD_3.7.6.2.11
		CA0163-PO	CARD_3.7.6.2.2
		CA0270-PO	CARD_3.7.6.2.11
		CA3142-PO	CARD_3.7.1.2.11
		CA3143-PO	CARD_3.7.2.2.11

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3248-PO	CARD_3.7.1.2.11
CA3252-PO	CARD_3.3.7	CA0158-PO	CARD_3.7.6.2.11
		CA0163-PO	CARD_3.7.6.2.2
		CA0270-PO	CARD_3.7.6.2.11
		CA3142-PO	CARD_3.7.1.2.11
		CA3143-PO	CARD_3.7.2.2.11
		CA3248-PO	CARD_3.7.1.2.11
CA3293-PO	CARD_3.2.13		
CA4111-PO	CARD_3.3.9		
CA5065-PO	CARD_3.2.10	CA5071-PO	CARD_3.7.6.2.10
		CA5820-PO	CARD_3.2.10
CA5065-PO	CARD_3.2.10	CA5071-PO	CARD_3.7.6.2.10
		CA5820-PO	CARD_3.2.10
CA5552-PO	CARD_3.2.15	CA5555-PO	CARD_3.7.1.2.15
		CA5557-PO	CARD_3.7.2.2.15
		CA5559-PO	CARD_3.7.9.2.15
		CA5560-PO	CARD_3.7.1.2.15
		CA5562-PO	CARD_3.7.2.2.15
		CA5564-PO	CARD_3.7.9.2.15

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5931-PO	CARD_3.7.5.2.15
		CA5932-PO	CARD_3.7.5.2.15
		CA5962-PO	CARD_3.2.13
CA5600-PO	CARD_3.2.12	CA1068-PO	CARD_3.7.2.2.12
		CA3064-PO	CARD_3.7.5.2.12
		CA6203-PO	CARD_3.7.2.2.12
		CA6204-PO	CARD_3.7.5.2.12
		CA6205-PO	CARD_3.7.1.2.12
		CA6206-PO	CARD_3.7.4.2.12
		CA6207-PO	CARD_3.7.3.2.12
		CA6208-PO	CARD_3.7.5.2.12
		CA6209-PO	CARD_3.7.5.2.12
CA5601-PO	CARD_3.2.11	CA0497-PO	CARD_3.7.1.2.11
		CA5278-PO	CARD_3.7.3.2.11
CA5602-PO	CARD_3.2.11	CA3248-PO	CARD_3.7.1.2.11
CA5604-PO	CARD_3.2.8	CA3285-PO	CARD_3.7.6.2.8
		CA5148-PO	CARD_3.7.1.2.6
		CA5149-PO	CARD_3.7.3.2.6
		CA6200-PO	CARD_3.7.6.2.8
CA5618-PO	CARD_3.3.7		

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5618-PO	CARD_3.3.7		
CA5680-PO	CARD_3.3.8		
CA5680-PO	CARD_3.3.8		
CA5750-PO	CARD_3.4		
CA5750-PO	CARD_3.4		
CA5800-PO	CARD_3.3.5		
CA5811-PO	CARD_3.3.1.1		
CA5812-HQ	CARD_3.2.7		
CA5812-HQ	CARD_3.2.7		
CA5814-PO	CARD_3.2.13	CA0893-PO	CARD_3.7.1.4
		CA0897-PO	CARD_3.7.2.4
		CA0910-PO	CARD_3.7.5.4
		CA0911-PO	CARD_3.7.5.4
		CA0912-PO	CARD_3.7.5.4
		CA0915-PO	CARD_3.7.5.4
CA5815-PO	CARD_3.2.13		
CA5817-PO	CARD_3.2.10		
CA5818-HQ	CARD_3.2.2.1	CA5913-PO	CARD_3.7.1.2.2.1
		CA5914-PO	CARD_3.7.2.2.2.1
CA5820-PO	CARD_3.2.10	CA0858-PO	CARD_3.7.5.2
CA5821-PO	CARD_3.2.10		
CA5935-PO	CARD_3.2.13		
CA5941-PO	CARD_3.4		
CA5941-PO	CARD_3.4		
CA5942-PO	CARD_3.4		

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5962-PO	CARD_3.2.13	CA5963-PO	CARD_3.2.13
CA5962-PO	CARD_3.2.13	CA5963-PO	CARD_3.2.13
CA5963-PO	CARD_3.2.13		
CA5964-PO	CARD_3.2.13	CA5965-PO	CARD_3.2.13
		CA5974-PO	CARD_3.7.1.2.13
		CA5978-PO	CARD_3.7.2.2.13
		CA5982-PO	CARD_3.7.3.2.13
		CA5986-PO	CARD_3.7.4.2.13
		CA5990-PO	CARD_3.7.5.2.13
		CA5994-PO	CARD_3.7.6.2.13
		CA5998-PO	CARD_3.7.9.2.13
CA5964-PO	CARD_3.2.13	CA5965-PO	CARD_3.2.13
		CA5974-PO	CARD_3.7.1.2.13
		CA5978-PO	CARD_3.7.2.2.13
		CA5982-PO	CARD_3.7.3.2.13
		CA5986-PO	CARD_3.7.4.2.13
		CA5990-PO	CARD_3.7.5.2.13
		CA5994-PO	CARD_3.7.6.2.13
		CA5998-PO	CARD_3.7.9.2.13
CA5965-PO	CARD_3.2.13		
CA5966-PO	CARD_3.2.13	CA5967-PO	CARD_3.2.13
		CA5975-PO	CARD_3.7.1.2.13

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5979-PO	CARD_3.7.2.2.13
		CA5983-PO	CARD_3.7.3.2.13
		CA5987-PO	CARD_3.7.4.2.13
		CA5991-PO	CARD_3.7.5.2.13
		CA5995-PO	CARD_3.7.6.2.13
		CA5999-PO	CARD_3.7.9.2.13
CA5967-PO	CARD_3.2.13		
CA5968-PO	CARD_3.2.13	CA5969-PO	CARD_3.2.13
		CA5976-PO	CARD_3.7.1.2.13
		CA5980-PO	CARD_3.7.2.2.13
		CA5988-PO	CARD_3.7.4.2.13
		CA5992-PO	CARD_3.7.5.2.13
		CA5996-PO	CARD_3.7.6.2.13
CA5968-PO	CARD_3.2.13	CA5969-PO	CARD_3.2.13
		CA5976-PO	CARD_3.7.1.2.13
		CA5980-PO	CARD_3.7.2.2.13
		CA5988-PO	CARD_3.7.4.2.13
		CA5992-PO	CARD_3.7.5.2.13
		CA5996-PO	CARD_3.7.6.2.13
CA5969-PO	CARD_3.2.13		

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5970-PO	CARD_3.2.13	CA5971-PO	CARD_3.2.13
		CA5977-PO	CARD_3.7.1.2.13
		CA5981-PO	CARD_3.7.2.2.13
		CA5985-PO	CARD_3.7.3.2.13
		CA5989-PO	CARD_3.7.4.2.13
		CA5993-PO	CARD_3.7.5.2.13
		CA5997-PO	CARD_3.7.6.2.13
		CA6001-PO	CARD_3.7.9.2.13
CA5971-PO	CARD_3.2.13		
CA5972-PO	CARD_3.2.13	CA5974-PO	CARD_3.7.1.2.13
		CA5975-PO	CARD_3.7.1.2.13
		CA5976-PO	CARD_3.7.1.2.13
		CA5977-PO	CARD_3.7.1.2.13
		CA5978-PO	CARD_3.7.2.2.13
		CA5979-PO	CARD_3.7.2.2.13
		CA5980-PO	CARD_3.7.2.2.13
		CA5981-PO	CARD_3.7.2.2.13
		CA5982-PO	CARD_3.7.3.2.13
		CA5983-PO	CARD_3.7.3.2.13

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5985-PO	CARD_3.7.3.2.13
		CA5986-PO	CARD_3.7.4.2.13
		CA5987-PO	CARD_3.7.4.2.13
		CA5988-PO	CARD_3.7.4.2.13
		CA5989-PO	CARD_3.7.4.2.13
		CA5990-PO	CARD_3.7.5.2.13
		CA5991-PO	CARD_3.7.5.2.13
		CA5992-PO	CARD_3.7.5.2.13
		CA5993-PO	CARD_3.7.5.2.13
		CA5994-PO	CARD_3.7.6.2.13
		CA5995-PO	CARD_3.7.6.2.13
		CA5996-PO	CARD_3.7.6.2.13
		CA5997-PO	CARD_3.7.6.2.13
		CA5998-PO	CARD_3.7.9.2.13
		CA5999-PO	CARD_3.7.9.2.13
		CA6001-PO	CARD_3.7.9.2.13
CA5973-PO	CARD_3.2.13	CA5182-PO	CARD_3.7.9.2.13
		CA5184-PO	CARD_3.7.9.2.13
		CA5495-PO	CARD_3.7.1.2.13

	PARENT		CHILDREN
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5505-PO	CARD_3.7.3.2.13
		CA5934-PO	CARD_3.7.5.2.13
		CA5935-PO	CARD_3.2.13
CA6002-PO	CARD_3.2.13	CA0140-PO	CARD_3.7.5.2
		CA0142-PO	CARD_3.7.5.2
		CA0853-PO	CARD_3.7.5.2.6
		CA0856-PO	CARD_3.7.5.2.6
		CA5701-PO	CARD_3.7.5.2
		CA5814-PO	CARD_3.2.13
		CA5815-PO	CARD_3.2.13
		CA6003-PO	CARD_3.7.1.2.13
		CA6004-PO	CARD_3.7.2.2.13
		CA6005-PO	CARD_3.7.5.2.13
		CA6006-PO	CARD_3.7.9.2.13
CA6002-PO	CARD_3.2.13	CA0140-PO	CARD_3.7.5.2
		CA0142-PO	CARD_3.7.5.2
		CA0853-PO	CARD_3.7.5.2.6
		CA0856-PO	CARD_3.7.5.2.6

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5701-PO	CARD_3.7.5.2
		CA5814-PO	CARD_3.2.13
		CA5815-PO	CARD_3.2.13
		CA6003-PO	CARD_3.7.1.2.13
		CA6004-PO	CARD_3.7.2.2.13
		CA6005-PO	CARD_3.7.5.2.13
		CA6006-PO	CARD_3.7.9.2.13
CA6007-PO	CARD_3.2.13	CA0140-PO	CARD_3.7.5.2
		CA0142-PO	CARD_3.7.5.2
		CA0853-PO	CARD_3.7.5.2.6
		CA0856-PO	CARD_3.7.5.2.6
		CA5701-PO	CARD_3.7.5.2
		CA5712-PO	CARD_3.7.5.2.13
		CA5814-PO	CARD_3.2.13
		CA5815-PO	CARD_3.2.13
		CA6008-PO	CARD_3.7.3.2.13
		CA6009-PO	CARD_3.7.4.2.13
		CA6010-PO	CARD_3.7.5.2.13
		CA6011-PO	CARD_3.7.9.2.13
CA6012-PO	CARD_3.2.13	CA0139-PO	CARD_3.7.6.2

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0293-PO	CARD_3.7.6.2
		CA6013-PO	CARD_3.7.1.2.13
		CA6013-PO-Objective	CARD_3.7.1.2.13
		CA6015-PO	CARD_3.7.1.2.13
		CA6015-PO-Objective	CARD_3.7.1.2.13
		CA6017-PO	CARD_3.7.3.2.13
		CA6017-PO-Objective	CARD_3.7.3.2.13
CA6012-PO	CARD_3.2.13	CA0139-PO	CARD_3.7.6.2
		CA0293-PO	CARD_3.7.6.2
		CA6013-PO	CARD_3.7.1.2.13
		CA6013-PO-Objective	CARD_3.7.1.2.13
		CA6015-PO	CARD_3.7.1.2.13
		CA6015-PO-Objective	CARD_3.7.1.2.13
		CA6017-PO	CARD_3.7.3.2.13
		CA6017-PO-Objective	CARD_3.7.3.2.13
CA6020-PO	CARD_3.2.13		
CA6020-PO	CARD_3.2.13		
CA6020-PO-Objective	CARD_3.2.13	CA0416-PO	CARD_3.7.1.2.2.2

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA6020-PO-Objective	CARD_3.2.13	CA0416-PO	CARD_3.7.1.2.2.2
CA6022-PO	CARD_3.2.13	CA0416-PO	CARD_3.7.1.2.2.2
CA6022-PO-Objective	CARD_3.2.13	CA0416-PO	CARD_3.7.1.2.2.2
CA6024-PO	CARD_3.2.13	CA6029-PO	CARD_3.7.1.2.13
		CA6036-PO	CARD_3.7.6.2.13
CA6024-PO-Objective	CARD_3.2.13	CA6029-PO-Objective	CARD_3.7.1.2.13
		CA6036-PO-Objective	CARD_3.7.6.2.13
CA6026-PO	CARD_3.2.13	CA6032-PO	CARD_3.7.1.2.13
		CA6039-PO	CARD_3.7.6.2.13
CA6027-PO	CARD_3.2.13	CA6031-PO	CARD_3.7.1.2.13
		CA6034-PO	CARD_3.7.3.2.13
		CA6038-PO	CARD_3.7.6.2.13
CA6028-PO	CARD_3.2.13	CA6032-PO	CARD_3.7.1.2.13
		CA6033-PO	CARD_3.7.1.2.13
		CA6035-PO	CARD_3.7.3.2.13
		CA6039-PO	CARD_3.7.6.2.13
		CA6040-PO	CARD_3.7.6.2.13
CA6041-PO	CARD_3.2.7		
CA6050-PO	CARD_3.2.9		
CA6051-PO	CARD_3.2.9.1		
CA6065-PO	CARD_3.2.10	CA6064-PO	CARD_3.7.5.2.10
		CA6066-PO	CARD_3.7.1.2.10

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA6067-PO	CARD_3.7.1.2.10
		CA6068-PO	CARD_3.7.1.2.6
CA6069-PO	CARD_3.4		
CA6069-PO	CARD_3.4		
CA6072-PO	CARD_3.2.2	CA0107-HQ	CARD_3.2.2
		CA6075-PO	CARD_3.7.1.2.2
CA6073-PO	CARD_3.2.2	CA0107-HQ	CARD_3.2.2
		CA6074-PO	CARD_3.7.1.2.2
		CA6076-PO	CARD_3.7.9.2.2
CA6077-PO	CARD_3.2	CA0892-HQ	CARD_3.2
		CA6080-PO	CARD_3.7.9.2
		CA6081-PO	CARD_3.7.10.2
CA6079-PO	CARD_3.2	CA6078-PO	CARD_3.7.9.2
		CA6082-PO	CARD_3.7.10.2
CA6102-PO	CARD_3.2.5	CA6103-PO	CARD_3.7.1.2.5
		CA6104-PO	CARD_3.7.4.2.5
CA6105-PO	CARD_3.2.10		
CA6106-PO	CARD_3.2.7	CA6107-PO	CARD_3.7.2.2.9
		CA6108-PO	CARD_3.7.1.2.10
		CA6109-PO	CARD_3.7.3.2.10
		CA6110-PO	CARD_3.7.1.2.10

	PARENT		CHILDREN
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA6106-PO	CARD_3.2.7	CA6107-PO	CARD_3.7.2.2.9
		CA6108-PO	CARD_3.7.1.2.10
		CA6109-PO	CARD_3.7.3.2.10
		CA6110-PO	CARD_3.7.1.2.10
CA6210-PO	CARD_3.2.10	CA6211-PO	CARD_3.7.5.2.10
		CA6212-PO	CARD_3.7.1.2.10
		CA6213-PO	CARD_3.7.1.2.10
		CA6214-PO	CARD_3.7.2.2.10
		CA6215-PO	CARD_3.7.6.2.8
		CA6216-PO	CARD_3.7.6.2.8

The second table in this Appendix, shown below, outlines the traceability from each of the child requirements (shown in the left-hand column) up to their respective parent requirements (shown in the right-hand column).

TABLE E-2 - REQUIREMENTS TRACEABILITY MATRIX - CHILD PARENT

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0005-HQ	CARD_3.2	CA0001-HQ	CARD_3.2
CA0006-HQ	CARD_3.2	CA0001-HQ	CARD_3.2
CA0013-HQ	CARD_3.2		
		CA0001-HQ	CARD_3.2
CA0020-HQ	CARD_3.2.3	CA0005-HQ	CARD_3.2
CA0021-PO	CARD_3.2.6	CA0001-HQ	CARD_3.2
CA0023-PO	CARD_3.5		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0027-PO	CARD_3.2.2.2	CA0107-HQ	CARD_3.2.2
CA0028-PO	CARD_3.2.2	CA0107-HQ	CARD_3.2.2
		CA0121-HQ	CARD_3.2.6
CA0029-HQ	CARD_3.2.6	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0032-HQ	CARD_3.2.2.1	CA0013-HQ	CARD_3.2
CA0033-HQ	CARD_3.2.1	CA0013-HQ	CARD_3.2
CA0036-HQ	CARD_3.2.5	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0036-HQ	CARD_3.2.5	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0038-HQ	CARD_3.2.12		

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
CA0039-HQ	CARD_3.2.6	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0040-PO	CARD_3.2.12	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0042-PO	CARD_3.3.4		
		HS10048	
		HS6104	
		CA0001-HQ	CARD_3.2
		8	
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0044-PO	CARD_3.2.6	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0892-HQ	CARD_3.2
CA0046-PO	CARD_3.2.6	CA0013-HQ	CARD_3.2
CA0048-PO	CARD_3.2.15	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0056-PO	CARD_3.7.1.2		
		CA0121-HQ	CARD_3.2.6
CA0059-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA0060-HQ	CARD_3.7.1.2.5		
		CA0892-HQ	CARD_3.2
CA0069-HQ	CARD_3.4		
		CA0296-HQ	CARD_3.2.10
		CA0449-PO	CARD_3.2.8
CA0069-HQ	CARD_3.4		
		CA0296-HQ	CARD_3.2.10
		CA0449-PO	CARD_3.2.8
CA0071-PO	CARD_3.2.12	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0072-PO	CARD_3.7.2.2.12		
		CA0123-PO	CARD_3.2.12
CA0077-HQ	CARD_3.4	CA0892-HQ	CARD_3.2
CA0081-PO	CARD_3.7.1.2.11		
		CA0388-HQ	CARD_3.2.3
		CA0892-HQ	CARD_3.2
CA0082-PO	CARD_3.7.1.2.5		
		CA0121-HQ	CARD_3.2.6
		CA5289-PO	CARD_3.2.5
CA0088-PO	CARD_3.7.1.2.1		
		CA0033-HQ	CARD_3.2.1
CA0091-PO	CARD_3.7.1.2		
		CA0121-HQ	CARD_3.2.6

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0281-HQ	CARD_3.2.6
CA0095-HQ	CARD_3.2.1	CA0892-HQ	CARD_3.2
CA0096-HQ	CARD_3.2.2.1	CA0892-HQ	CARD_3.2
CA0097-HQ	CARD_3.2.1	CA0892-HQ	CARD_3.2
CA0099-HQ	CARD_3.2.1	CA0005-HQ	CARD_3.2
CA0100-HQ	CARD_3.2.7	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0107-HQ	CARD_3.2.2		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
		CA6072-PO	CARD_3.2.2
		CA6073-PO	CARD_3.2.2
CA0121-HQ	CARD_3.2.6	CA0001-HQ	CARD_3.2
CA0123-PO	CARD_3.2.12	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0125-PO	CARD_3.2.12	CA0001-HQ	CARD_3.2
CA0129-PO	CARD_3.7.4.2.11	CA0121-HQ	CARD_3.2.6
CA0131-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA0133-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA0134-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA0135-PO	CARD_3.7.3.2.11		
		CA0121-HQ	CARD_3.2.6
CA0139-PO	CARD_3.7.6.2		
		CA0003-HQ	CARD_3.2
		CA0004-HQ	CARD_3.2
		CA6012-PO	CARD_3.2.13
CA0140-PO	CARD_3.7.5.2		

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
CA0142-PO	CARD_3.7.5.2		
		CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
CA0145-PO	CARD_3.7.5.2		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
		CA3226-PO	CARD_3.2.2.2
CA0146-PO	CARD_3.7.5.2.2		
		CA0172-PO	CARD_3.2.2
		CA3226-PO	CARD_3.2.2.2
CA0148-PO	CARD_3.7.5.2.6		
		CA0029-HQ	CARD_3.2.6
CA0151-PO	CARD_3.7.5.2.2		
		CA0310-PO	CARD_3.2.2.2
		CA0311-PO	CARD_3.2.2.2
CA0152-PO	CARD_3.7.6.2		
		CA0001-HQ	CARD_3.2
		CA0003-HQ	CARD_3.2
		CA0004-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0158-PO	CARD_3.7.6.2.11		
		CA0152-PO	CARD_3.7.6.2
		CA0356-PO	CARD_3.2.11
		CA0529-PO	CARD_3.2.11
		CA0826-PO	CARD_3.2.11
		CA3252-PO	CARD_3.3.7
CA0163-PO	CARD_3.7.6.2.2		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0152-PO	CARD_3.7.6.2
		CA0172-PO	CARD_3.2.2
		CA3226-PO	CARD_3.2.2.2
		CA3252-PO	CARD_3.3.7
CA0170-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA0172-PO	CARD_3.2.2	CA3226-PO	CARD_3.2.2.2
CA0178-PO	CARD_3.7.1.2.12		
		CA0123-PO	CARD_3.2.12
CA0183-PO	CARD_3.7.4.2.11	CA0121-HQ	CARD_3.2.6
CA0187-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA0191-PO	CARD_3.7.1.2.6	CA3184-PO	CARD_3.2.6
CA0194-PO	CARD_3.7.1.2.2		
		CA0312-PO	CARD_3.2.2
CA0202-HQ	CARD_3.2		
		CA0203-HQ	CARD_3.2.3
CA0203-HQ	CARD_3.2.3	CA0001-HQ	CARD_3.2
CA0207-HQ	CARD_3.2.5	CA0001-HQ	CARD_3.2
		CA0013-HQ	CARD_3.2
CA0209-HQ	CARD_3.2.4		
		CA0001-HQ	CARD_3.2
CA0211-HQ	CARD_3.2.4		
		CA0003-HQ	CARD_3.2
CA0258-PO	CARD_3.7.2.2.2		
		CA0215-PO	CARD_3.2.7
CA0270-PO	CARD_3.7.6.2.11		
		CA0152-PO	CARD_3.7.6.2
		CA0293-PO	CARD_3.7.6.2

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA3252-PO	CARD_3.3.7
		CA5669-PO	CARD_3.7.6.2
CA0274-PO	CARD_3.7.1.2.2		
		CA0107-HQ	CARD_3.2.2
CA0281-HQ	CARD_3.2.6	CA0121-HQ	CARD_3.2.6
CA0288-PO	CARD_3.7.1.2.14		
		CA0203-HQ	CARD_3.2.3
		CA0388-HQ	CARD_3.2.3
CA0293-PO	CARD_3.7.6.2		
		CA0003-HQ	CARD_3.2
		CA0004-HQ	CARD_3.2
		CA3226-PO	CARD_3.2.2.2
		CA6012-PO	CARD_3.2.13
CA0306-PO	CARD_3.7.5.2.2		
		CA0107-HQ	CARD_3.2.2
		CA0145-PO	CARD_3.7.5.2
		CA0172-PO	CARD_3.2.2
		CA3226-PO	CARD_3.2.2.2
CA0310-PO	CARD_3.2.2.2	CA0107-HQ	CARD_3.2.2
CA0311-PO	CARD_3.2.2.2	CA0107-HQ	CARD_3.2.2
CA0312-PO	CARD_3.2.2	CA0107-HQ	CARD_3.2.2
CA0314-PO	CARD_3.2.11	CA0121-HQ	CARD_3.2.6
CA0316-PO	CARD_3.2.6	CA0121-HQ	CARD_3.2.6
CA0324-PO	CARD_3.7.1.2.6		
		CA0044-PO	CARD_3.2.6

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA0325-PO	CARD_3.7.1.2.2		
		CA3226-PO	CARD_3.2.2.2
CA0329-PO	CARD_3.7.1.2.11		
		CA0044-PO	CARD_3.2.6
CA0333-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA0334-PO	CARD_3.7.1.2.2.2		
		CA0107-HQ	CARD_3.2.2
		CA0310-PO	CARD_3.2.2.2
CA0335-PO	CARD_3.7.1.2.2.2		
		CA0107-HQ	CARD_3.2.2
		CA0311-PO	CARD_3.2.2.2
CA0336-PO	CARD_3.7.5.2.2		
		CA0107-HQ	CARD_3.2.2
		CA0310-PO	CARD_3.2.2.2
CA0337-PO	CARD_3.7.5.2.2		
		CA0107-HQ	CARD_3.2.2
		CA0311-PO	CARD_3.2.2.2
CA0344-PO	CARD_3.7.1.2.10		
		CA0172-PO	CARD_3.2.2
		CA0312-PO	CARD_3.2.2
CA0351-PO	CARD_3.7.1.2.6		
		CA0040-PO	CARD_3.2.12
CA0352-HQ	CARD_3.2.2.2		
		CA0107-HQ	CARD_3.2.2
CA0361-PO	CARD_3.7.1.4		
		CA0001-HQ	CARD_3.2
CA0369-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA0374-PO	CARD_3.7.1.2.15		
		CA0048-PO	CARD_3.2.15
CA0384-PO		CA0383-PO	CARD_3.3.5
CA0386-HQ	CARD_3.7.1.5		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0388-HQ	CARD_3.2.3	CA0892-HQ	CARD_3.2
CA0389-HQ	CARD_3.7.2.2.6		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0391-HQ	CARD_3.7.4.2.6		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
CA0391-HQ	CARD_3.7.4.2.6		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
CA0394-HQ	CARD_3.7.3.2.6		
		CA0022-HQ	CARD_3.2.6
CA0394-HQ	CARD_3.7.3.2.6		
		CA0022-HQ	CARD_3.2.6
CA0397-HQ	CARD_3.7.3.2.6		
		CA0001-HQ	CARD_3.2
CA0398-PO	CARD_3.7.1.2.2.1		
		CA0096-HQ	CARD_3.2.2.1
CA0399-PO	CARD_3.7.1.2.1		
		CA0095-HQ	CARD_3.2.1
CA0416-PO	CARD_3.7.1.2.2.2		
		CA0028-PO	CARD_3.2.2
		CA6020-PO-Objective	CARD_3.2.13
		CA6022-PO	CARD_3.2.13
		CA6022-PO-Objective	CARD_3.2.13

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0426-PO	CARD_3.7.1.2.14		
		CA0010-HQ	CARD_3.2.3
		CA0203-HQ	CARD_3.2.3
		CA0388-HQ	CARD_3.2.3
CA0427-PO	CARD_3.7.1.2.9		
		CA0217-PO	CARD_3.2.9
CA0427-PO	CARD_3.7.1.2.9		
		CA0217-PO	CARD_3.2.9
CA0428-PO	CARD_3.7.1.2.9		
		CA0217-PO	CARD_3.2.9
CA0429-PO	CARD_3.7.1.4		
		CA0001-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA0430-PO	CARD_3.7.2.4		
		CA0449-PO	CARD_3.2.8
CA0432-PO	CARD_3.7.3.4		
		CA0001-HQ	CARD_3.2
		CA0316-PO	CARD_3.2.6
CA0432-PO	CARD_3.7.3.4		
		CA0001-HQ	CARD_3.2
		CA0316-PO	CARD_3.2.6
CA0435-PO	CARD_3.7.1.2.7		
		CA0213-PO	CARD_3.2.7
CA0436-PO	CARD_3.7.1.2.7		
		CA0214-PO	CARD_3.2.7
CA0437-PO	CARD_3.7.1.2.7		
		CA0215-PO	CARD_3.2.7
CA0438-PO	CARD_3.7.1.2.9		
		CA0216-PO	CARD_3.2.9
CA0438-PO	CARD_3.7.1.2.9		
		CA0216-PO	CARD_3.2.9
CA0444-PO	CARD_3.7.5.2.6		
		CA0039-HQ	CARD_3.2.6
		CA0107-HQ	CARD_3.2.2

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0123-PO	CARD_3.2.12
CA0447-PO	CARD_3.7.1.2.3		
		CA0388-HQ	CARD_3.2.3
CA0448-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA0461-PO	CARD_3.7.3.2.11		
		CA0121-HQ	CARD_3.2.6
CA0462-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA0463-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA0466-PO	CARD_3.7.1.2.2.2		
		CA0107-HQ	CARD_3.2.2
CA0470-PO	CARD_3.7.1.2.10		
		CA0296-HQ	CARD_3.2.10
CA0470-PO	CARD_3.7.1.2.10		
		CA0296-HQ	CARD_3.2.10
CA0474-HQ	CARD_3.2.2.1	CA0005-HQ	CARD_3.2
CA0476-PO	CARD_3.2.10	CA0296-HQ	CARD_3.2.10
CA0493-PO	CARD_3.7.1.2.2		
		CA0107-HQ	CARD_3.2.2
CA0494-PO	CARD_3.7.1.2.6		
		CA0044-PO	CARD_3.2.6
		CA3226-PO	CARD_3.2.2.2
CA0497-PO	CARD_3.7.1.2.11		
		CA5601-PO	CARD_3.2.11
CA0498-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA0501-PO	CARD_3.7.1.2.2.1		
		CA0032-HQ	CARD_3.2.2.1
CA0511-PO	CARD_3.7.1.2.10		

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0993-PO	CARD_3.2.10
CA0522-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA0530-PO	CARD_3.2.2.2	CA0107-HQ	CARD_3.2.2
CA0532-PO	CARD_3.7.1.2.2		
		CA0352-HQ	CARD_3.2.2.2
		CA0530-PO	CARD_3.2.2.2
CA0547-PO	CARD_3.7.1.2.4		
		CA0003-HQ	CARD_3.2
CA0565-HQ	CARD_3.7.1.2.4		
		CA0892-HQ	CARD_3.2
CA0566-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA0569-PO	CARD_3.2.7	CA0029-HQ	CARD_3.2.6
CA0579-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA0800-PO	CARD_3.7.1.4		
		CA0001-HQ	CARD_3.2
		CA0316-PO	CARD_3.2.6
CA0800-PO	CARD_3.7.1.4		
		CA0001-HQ	CARD_3.2
		CA0316-PO	CARD_3.2.6
CA0822-HQ	CARD_3.2.4	CA0001-HQ	CARD_3.2
		CA0003-HQ	CARD_3.2
CA0827-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0281-HQ	CARD_3.2.6
CA0829-PO	CARD_3.7.1.2.6.2		
		CA0121-HQ	CARD_3.2.6
CA0837-PO	CARD_3.7.3.2.6.2		
		CA0121-HQ	CARD_3.2.6

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0853-PO	CARD_3.7.5.2.6		
		CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
CA0856-PO	CARD_3.7.5.2.6		
		CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
CA0858-PO	CARD_3.7.5.2		
		CA5820-PO	CARD_3.2.10
CA0864-PO	CARD_3.7.1.2.4		
		CA0892-HQ	CARD_3.2
CA0865-PO	CARD_3.7.1.2.4		
		CA0892-HQ	CARD_3.2
CA0866-PO	CARD_3.7.1.2.4		
		CA0892-HQ	CARD_3.2
CA0868-PO	CARD_3.7.1.2.4		
		CA0211-HQ	CARD_3.2.4
CA0883-PO	CARD_3.7.6.2.6		
		CA0107-HQ	CARD_3.2.2
		CA0152-PO	CARD_3.7.6.2
CA0886-PO	CARD_3.7.1.2.14		
		CA0121-HQ	CARD_3.2.6
CA0887-PO	CARD_3.7.3.2.10		
		CA0296-HQ	CARD_3.2.10
CA0887-PO	CARD_3.7.3.2.10		
		CA0296-HQ	CARD_3.2.10
CA0892-HQ	CARD_3.2	CA6077-PO	CARD_3.2
CA0893-PO	CARD_3.7.1.4		
		CA5814-PO	CARD_3.2.13
CA0894-PO	CARD_3.7.1.4		
		CA0296-HQ	CARD_3.2.10
CA0895-PO	CARD_3.7.1.4		

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA0895-PO	CARD_3.7.1.4		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA0896-PO	CARD_3.7.1.4		
		CA0296-HQ	CARD_3.2.10
CA0896-PO	CARD_3.7.1.4		
		CA0296-HQ	CARD_3.2.10
CA0897-PO	CARD_3.7.2.4		
		CA5814-PO	CARD_3.2.13
CA0897-PO	CARD_3.7.2.4		
		CA5814-PO	CARD_3.2.13
CA0898-PO	CARD_3.7.2.4		
		CA0296-HQ	CARD_3.2.10
CA0898-PO	CARD_3.7.2.4		
		CA0296-HQ	CARD_3.2.10
CA0899-PO	CARD_3.7.2.4		
		CA0296-HQ	CARD_3.2.10
CA0899-PO	CARD_3.7.2.4		
		CA0296-HQ	CARD_3.2.10
CA0910-PO	CARD_3.7.5.4		
		CA5814-PO	CARD_3.2.13
CA0911-PO	CARD_3.7.5.4		
		CA5814-PO	CARD_3.2.13
CA0911-PO	CARD_3.7.5.4		
		CA5814-PO	CARD_3.2.13
CA0912-PO	CARD_3.7.5.4		
		CA5814-PO	CARD_3.2.13
CA0914-PO	CARD_3.7.5.4		
		CA0296-HQ	CARD_3.2.10
CA0915-PO	CARD_3.7.5.4		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
		CA5814-PO	CARD_3.2.13
CA0915-PO	CARD_3.7.5.4		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
		CA5814-PO	CARD_3.2.13
CA0916-PO	CARD_3.7.5.4		
		CA0296-HQ	CARD_3.2.10
CA0916-PO	CARD_3.7.5.4		
		CA0296-HQ	CARD_3.2.10
CA0917-PO	CARD_3.7.6.4		
		CA0296-HQ	CARD_3.2.10
CA0918-PO	CARD_3.7.6.4		
		CA0296-HQ	CARD_3.2.10
CA0918-PO	CARD_3.7.6.4		
		CA0296-HQ	CARD_3.2.10
CA0919-PO	CARD_3.7.6.4		
		CA0296-HQ	CARD_3.2.10
CA0920-PO	CARD_3.7.6.4		
		CA0296-HQ	CARD_3.2.10
CA0921-PO	CARD_3.7.6.4		
		CA0296-HQ	CARD_3.2.10
CA0922-PO	CARD_3.7.6.4		
		CA0069-HQ	CARD_3.4
		CA0296-HQ	CARD_3.2.10
CA0922-PO	CARD_3.7.6.4		
		CA0069-HQ	CARD_3.4
		CA0296-HQ	CARD_3.2.10
CA0923-PO	CARD_3.7.9.4		

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA0923-PO	CARD_3.7.9.4		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA0924-PO	CARD_3.7.9.4		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA0924-PO	CARD_3.7.9.4		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA0925-PO	CARD_3.7.9.4		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA0925-PO	CARD_3.7.9.4		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA0983-PO	CARD_3.7.1.2.2		
		CA0048-PO	CARD_3.2.15
		CA0312-PO	CARD_3.2.2
CA0984-PO	CARD_3.7.1.2.2		
		CA0048-PO	CARD_3.2.15
		CA0312-PO	CARD_3.2.2
CA0993-PO	CARD_3.2.10	CA3021-PO	CARD_3.2.10
CA1000-PO	CARD_3.7.2.2.6.1		
		CA0388-HQ	CARD_3.2.3
CA1000-PO	CARD_3.7.2.2.6.1		
		CA0388-HQ	CARD_3.2.3

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA1005-PO	CARD_3.7.2.2.6.1		
		CA0281-HQ	CARD_3.2.6
CA1005-PO	CARD_3.7.2.2.6.1		
		CA0281-HQ	CARD_3.2.6
CA1008-PO	CARD_3.7.2.2.12		
		CA0125-PO	CARD_3.2.12
CA1023-PO	CARD_3.7.2.2.6		
		CA0281-HQ	CARD_3.2.6
		CA3184-PO	CARD_3.2.6
CA1023-PO	CARD_3.7.2.2.6		
		CA0281-HQ	CARD_3.2.6
		CA3184-PO	CARD_3.2.6
CA1028-PO	CARD_3.7.2.2.8		
		CA0281-HQ	CARD_3.2.6
		CA3184-PO	CARD_3.2.6
CA1029-PO	CARD_3.7.2.2.8		
		CA0281-HQ	CARD_3.2.6
		CA3184-PO	CARD_3.2.6
CA1053-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA1053-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA1054-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA1055-PO	CARD_3.7.2.2.7		
		CA0027-PO	CARD_3.2.2.2
CA1056-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA1065-PO	CARD_3.7.2.2.1		
		CA0033-HQ	CARD_3.2.1
		CA0095-HQ	CARD_3.2.1
		CA0097-HQ	CARD_3.2.1
		CA0099-HQ	CARD_3.2.1
CA1066-PO	CARD_3.7.2.2.12		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0123-PO	CARD_3.2.12
CA1068-PO	CARD_3.7.2.2.12		
		CA5600-PO	CARD_3.2.12
CA1068-PO	CARD_3.7.2.2.12		
		CA5600-PO	CARD_3.2.12
CA1069-PO	CARD_3.7.2.2.15		
		CA0048-PO	CARD_3.2.15
CA1084-PO	CARD_3.7.2.2.9		
		CA0216-PO	CARD_3.2.9
CA1085-PO	CARD_3.7.2.2.9		
		CA0216-PO	CARD_3.2.9
CA1086-PO	CARD_3.7.2.2.9		
		CA0216-PO	CARD_3.2.9
CA3003-PO	CARD_3.7.9.2.2		
		CA0352-HQ	CARD_3.2.2.2
		CA0530-PO	CARD_3.2.2.2
CA3003-PO	CARD_3.7.9.2.2		
		CA0352-HQ	CARD_3.2.2.2
		CA0530-PO	CARD_3.2.2.2
CA3018-PO	CARD_3.7.5.2.15		
		CA0048-PO	CARD_3.2.15
		CA0555-PO	CARD_3.3.1.1
		CA0991-PO	CARD_3.2.15
CA3022-PO	CARD_3.7.1.2.1		
		CA0097-HQ	CARD_3.2.1
CA3022-PO	CARD_3.7.1.2.1		
		CA0097-HQ	CARD_3.2.1
CA3023-PO	CARD_3.7.1.2.1		
		CA0099-HQ	CARD_3.2.1
CA3024-PO		CA0097-HQ	CARD_3.2.1
CA3025-PO		CA0095-HQ	CARD_3.2.1
CA3026-PO		CA0033-HQ	CARD_3.2.1

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA3032-PO		CA0096-HQ	CARD_3.2.2.1
CA3034-PO		CA0032-HQ	CARD_3.2.2.1
CA3040-PO	CARD_3.7.1.2.2.1		
		CA0474-HQ	CARD_3.2.2.1
CA3043-PO	CARD_3.2.10	CA0296-HQ	CARD_3.2.10
		CEV-LSAM	
CA3043-PO	CARD_3.2.10	CA0296-HQ	CARD_3.2.10
		CEV-LSAM	
CA3051-PO	CARD_3.2.10	CA0296-HQ	CARD_3.2.10
CA3058-PO	CARD_3.7.9.2.14		
		CA0530-PO	CARD_3.2.2.2
CA3061-PO	CARD_3.7.1.2.14		
		CA0107-HQ	CARD_3.2.2
CA3063-PO	CARD_3.7.9.2.12		
		CA0123-PO	CARD_3.2.12
CA3064-PO	CARD_3.7.5.2.12		
		CA5600-PO	CARD_3.2.12
CA3065-PO	CARD_3.7.6.2.12		
		CA0071-PO	CARD_3.2.12
		CA0123-PO	CARD_3.2.12
		CA0152-PO	CARD_3.7.6.2
		CA0293-PO	CARD_3.7.6.2
CA3105-PO	CARD_3.7.1.2.14		
		CA0530-PO	CARD_3.2.2.2
CA3106-PO	CARD_3.7.1.2.14		
		CA0530-PO	CARD_3.2.2.2
CA3108-PO	CARD_3.7.1.2.2		
		CA0530-PO	CARD_3.2.2.2
CA3110-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA3112-PO	CARD_3.7.2.2.8		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0449-PO	CARD_3.2.8
CA3113-PO	CARD_3.7.4.2.8	CA0449-PO	CARD_3.2.8
CA3118-PO	CARD_3.7.2.2.9		
		CA0217-PO	CARD_3.2.9
CA3121-PO	CARD_3.7.9.2.9		
		CA0217-PO	CARD_3.2.9
CA3122-PO	CARD_3.7.9.2.9		
		CA0217-PO	CARD_3.2.9
CA3127-PO	CARD_3.7.6.2.9		
		CA0217-PO	CARD_3.2.9
CA3128-PO	CARD_3.7.6.2.10		
		CA0152-PO	CARD_3.7.6.2
		CA0217-PO	CARD_3.2.9
CA3130-PO	CARD_3.7.5.2.9		
		CA0217-PO	CARD_3.2.9
CA3133-PO	CARD_3.7.1.2.14		
		CA0042-PO	CARD_3.3.4
CA3138-PO	CARD_3.7.1.2.2		
		CA0107-HQ	CARD_3.2.2
CA3140-PO	CARD_3.7.1.2.14		
		CA0181-HQ	CARD_3.2.6
		CA0530-PO	CARD_3.2.2.2
		CA3175-PO	CARD_3.2.6
CA3142-PO	CARD_3.7.1.2.11		
		CA3252-PO	CARD_3.3.7
CA3143-PO	CARD_3.7.2.2.11		
		CA3252-PO	CARD_3.3.7
CA3164-PO	CARD_3.7.1.2.5		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0121-HQ	CARD_3.2.6
		CA0203-HQ	CARD_3.2.3
		CA0207-HQ	CARD_3.2.5
CA3166-PO	CARD_3.7.1.2.6		
		CA0022-HQ	CARD_3.2.6
CA3166-PO	CARD_3.7.1.2.6		
		CA0022-HQ	CARD_3.2.6
CA3167-PO	CARD_3.3.6		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA3167-PO	CARD_3.3.6		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA3168-PO	CARD_3.7.1.2.6		
		CA0181-HQ	CARD_3.2.6
CA3182-PO	CARD_3.7.1.2.4		
		CA0892-HQ	CARD_3.2
CA3184-PO	CARD_3.2.6	CA0892-HQ	CARD_3.2
CA3200-PO	CARD_3.7.3.2.6		
		CA0001-HQ	CARD_3.2
CA3202-PO	CARD_3.7.2.2.6		
		CA0281-HQ	CARD_3.2.6
		CA3184-PO	CARD_3.2.6
CA3203-PO	CARD_3.7.1.2		
		CA0892-HQ	CARD_3.2
CA3204-PO	CARD_3.7.1.2.6	CA0121-HQ	CARD_3.2.6
CA3205-PO	CARD_3.7.3.2.11		
		CA0121-HQ	CARD_3.2.6
CA3206-PO	CARD_3.7.3.2.6		
		CA0121-HQ	CARD_3.2.6
CA3207-PO	CARD_3.7.1.2.6		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0121-HQ	CARD_3.2.6
CA3208-PO	CARD_3.7.3.2.6		
		CA0121-HQ	CARD_3.2.6
CA3209-PO	CARD_3.7.1.2.6		
		CA0121-HQ	CARD_3.2.6
CA3213-PO	CARD_3.7.3.2		
		CA0005-HQ	CARD_3.2
CA3221-PO	CARD_3.7.2.2.6		
		CA0121-HQ	CARD_3.2.6
		CA3007-PO	CARD_3.2.10
CA3223-PO	CARD_3.7.2.2.6		
		CA0121-HQ	CARD_3.2.6
		CA3007-PO	CARD_3.2.10
CA3226-PO	CARD_3.2.2.2	CA0001-HQ	CARD_3.2
		CA0107-HQ	CARD_3.2.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA3248-PO	CARD_3.7.1.2.11		
		CA0892-HQ	CARD_3.2
		CA3252-PO	CARD_3.3.7
		CA5602-PO	CARD_3.2.11
CA3249-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA3252-PO	CARD_3.3.7		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA3252-PO	CARD_3.3.7		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA3254-PO	CARD_3.7.1.2.8		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0449-PO	CARD_3.2.8
CA3255-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA3256-PO	CARD_3.7.2.2.8		
		CA0449-PO	CARD_3.2.8
CA3259-PO	CARD_3.7.1.2.2		
		CA0107-HQ	CARD_3.2.2
		CA0172-PO	CARD_3.2.2
		CA3226-PO	CARD_3.2.2.2
CA3273-PO	CARD_3.7.6.2.8		
		CA0152-PO	CARD_3.7.6.2
		CA0449-PO	CARD_3.2.8
CA3274-PO	CARD_3.7.5.2.8		
		CA0449-PO	CARD_3.2.8
CA3275-PO	CARD_3.7.2.2.8		
		CA0449-PO	CARD_3.2.8
CA3276-PO	CARD_3.7.4.2.8	CA0449-PO	CARD_3.2.8
CA3280-PO	CARD_3.7.1.2.10		
		CA0107-HQ	CARD_3.2.2
		CA0296-HQ	CARD_3.2.10
CA3285-PO	CARD_3.7.6.2.8		
		CA0152-PO	CARD_3.7.6.2
		CA0476-PO	CARD_3.2.10
		CA5604-PO	CARD_3.2.8
CA3285-PO	CARD_3.7.6.2.8		
		CA0152-PO	CARD_3.7.6.2
		CA0476-PO	CARD_3.2.10
		CA5604-PO	CARD_3.2.8
CA3287-PO	CARD_3.7.1.2.10		

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0476-PO	CARD_3.2.10
CA3288-PO	CARD_3.7.1.2.10		
		CA0476-PO	CARD_3.2.10
CA3289-PO	CARD_3.7.3.2.10		
		CA0476-PO	CARD_3.2.10
CA3289-PO	CARD_3.7.3.2.10		
		CA0476-PO	CARD_3.2.10
CA3302-PO	CARD_3.7.4.2.8	CA3212-PO	CARD_3.7.4.2
		CA3215-PO	CARD_3.7.4.2
CA4121-PO	CARD_3.7.5.2.5		
		CA0038-HQ	CARD_3.2.12
		CA0281-HQ	CARD_3.2.6
CA4122-PO	CARD_3.7.5.2		
		CA0044-PO	CARD_3.2.6
		CA0145-PO	CARD_3.7.5.2
CA4123-PO	CARD_3.7.5.2		
		CA0107-HQ	CARD_3.2.2
		CA0172-PO	CARD_3.2.2
		CA3226-PO	CARD_3.2.2.2
CA4125-PO	CARD_3.7.9.2.9		
		CA0216-PO	CARD_3.2.9
CA4127-PO	CARD_3.7.9.2		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA4128-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA4132-PO	CARD_3.7.6.2.10		
		CA0107-HQ	CARD_3.2.2
		CA0152-PO	CARD_3.7.6.2

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA4134-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0281-HQ	CARD_3.2.6
CA4135-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0121-HQ	CARD_3.2.6
		CA3184-PO	CARD_3.2.6
CA4138-PO	CARD_3.7.2.2.6.1		
		CA0023-PO	CARD_3.5
		CA0121-HQ	CARD_3.2.6
CA4139-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0121-HQ	CARD_3.2.6
CA4140-PO	CARD_3.7.3.2.4		
		CA0023-PO	CARD_3.5
		CA0121-HQ	CARD_3.2.6
CA4141-PO	CARD_3.7.3.2.6.2		
		CA3206-PO	CARD_3.7.3.2.6
CA4143-PO	CARD_3.7.3.2.6.2		
		CA0121-HQ	CARD_3.2.6
CA4145-PO	CARD_3.7.3.2.6.2		
		CA3213-PO	CARD_3.7.3.2
CA4152-PO	CARD_3.7.1.2.6		
		CA0181-HQ	CARD_3.2.6
		CA3167-PO	CARD_3.3.6

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3175-PO	CARD_3.2.6
CA4154-PO	CARD_3.7.1.2.2		
		CA0352-HQ	CARD_3.2.2.2
		CA0530-PO	CARD_3.2.2.2
CA4154-PO	CARD_3.7.1.2.2		
		CA0352-HQ	CARD_3.2.2.2
		CA0530-PO	CARD_3.2.2.2
CA4163-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0892-HQ	CARD_3.2
CA4163-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0892-HQ	CARD_3.2
CA4164-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0892-HQ	CARD_3.2
CA4165-PO	CARD_3.7.2.2.6.1		
		CA0023-PO	CARD_3.5
		CA0892-HQ	CARD_3.2
CA5039-PO	CARD_3.7.1.2.8		
		CA0993-PO	CARD_3.2.10
CA5039-PO	CARD_3.7.1.2.8		
		CA0993-PO	CARD_3.2.10
CA5040-PO	CARD_3.7.1.2.8		
		CA0993-PO	CARD_3.2.10
CA5051-PO	CARD_3.7.5.2.10		
		CA0993-PO	CARD_3.2.10

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5058-PO	CARD_3.7.6.2.10		
		CA0152-PO	CARD_3.7.6.2
		CA0993-PO	CARD_3.2.10
CA5071-PO	CARD_3.7.6.2.10		
		CA0296-HQ	CARD_3.2.10
		CA5065-PO	CARD_3.2.10
CA5112-PO	CARD_3.7.5.2.15		
		CA0040-PO	CARD_3.2.12
CA5125-PO	CARD_3.7.6.2.6		
		CA0107-HQ	CARD_3.2.2
		CA0152-PO	CARD_3.7.6.2
CA5128-PO	CARD_3.7.6.2.3		
		CA0139-PO	CARD_3.7.6.2
		CA0203-HQ	CARD_3.2.3
CA5129-PO	CARD_3.7.6.2.3		
		CA0139-PO	CARD_3.7.6.2
		CA0388-HQ	CARD_3.2.3
CA5130-PO	CARD_3.7.6.2.13		
		CA0293-PO	CARD_3.7.6.2
CA5131-PO	CARD_3.7.6.2.13		
		CA0209-HQ	CARD_3.2.4
		CA0293-PO	CARD_3.7.6.2
CA5132-PO	CARD_3.7.6.2.13		
		CA0211-HQ	CARD_3.2.4
		CA0293-PO	CARD_3.7.6.2

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5133-PO	CARD_3.7.6.2.13		
		CA0293-PO	CARD_3.7.6.2
CA5135-PO	CARD_3.7.6.2.12		
		CA0038-HQ	CARD_3.2.12
		CA0152-PO	CARD_3.7.6.2
CA5146-PO	CARD_3.7.5.2.2		
		CA0107-HQ	CARD_3.2.2
		CA0172-PO	CARD_3.2.2
CA5148-PO	CARD_3.7.1.2.6		
		CA5604-PO	CARD_3.2.8
CA5149-PO	CARD_3.7.3.2.6		
		CA5604-PO	CARD_3.2.8
CA5155-PO	CARD_3.7.1.2.4		
		CA0822-HQ	CARD_3.2.4
CA5159-PO	CARD_3.7.2.2.2.2		
		CA0311-PO	CARD_3.2.2.2
CA5168-PO	CARD_3.7.9.2.14		
		CA0107-HQ	CARD_3.2.2
		CA0530-PO	CARD_3.2.2.2
CA5168-PO	CARD_3.7.9.2.14		
		CA0107-HQ	CARD_3.2.2
		CA0530-PO	CARD_3.2.2.2
CA5169-PO	CARD_3.7.9.2.2		
		CA0310-PO	CARD_3.2.2.2
CA5170-PO	CARD_3.7.9.2.2		
		CA0107-HQ	CARD_3.2.2

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5182-PO	CARD_3.7.9.2.13		
		CA5973-PO	CARD_3.2.13
CA5184-PO	CARD_3.7.9.2.13		
		CA5973-PO	CARD_3.2.13
CA5188-PO	CARD_3.7.9.2.15		
		CA0048-PO	CARD_3.2.15
CA5195-PO	CARD_3.7.3.2.6		
		CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
CA5203-PO	CARD_3.7.9.2.2		
		CA0310-PO	CARD_3.2.2.2
CA5233-PO	CARD_3.7.1.2.4		
		CA0892-HQ	CARD_3.2
CA5234-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA5236-PO	CARD_3.7.3.2.2.2		
		CA0027-PO	CARD_3.2.2.2
		CA0107-HQ	CARD_3.2.2
CA5237-PO	CARD_3.7.1.2.2.2		
		CA0352-HQ	CARD_3.2.2.2
CA5240-PO	CARD_3.7.1.2.6		
		CA0352-HQ	CARD_3.2.2.2
CA5275-PO	CARD_3.7.3.2.11		
		CA0121-HQ	CARD_3.2.6
CA5278-PO	CARD_3.7.3.2.11		
		CA5601-PO	CARD_3.2.11
CA5284-PO	CARD_3.7.3.2.11		
		CA0121-HQ	CARD_3.2.6
CA5285-PO	CARD_3.7.3.2.11		
		CA0121-HQ	CARD_3.2.6

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5286-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA5290-PO	CARD_3.7.3.2.11		
		CA0121-HQ	CARD_3.2.6
CA5292-PO	CARD_3.7.4.2.11	CA0121-HQ	CARD_3.2.6
CA5293-PO	CARD_3.7.3.2.11		
		CA0121-HQ	CARD_3.2.6
CA5303-PO	CARD_3.7.3.2.6		
		CA0013-HQ	CARD_3.2
CA5312-PO	CARD_3.7.1.2		
		CA0892-HQ	CARD_3.2
CA5316-PO	CARD_3.7.3.2.2.2		
		CA0028-PO	CARD_3.2.2
CA5319-PO	CARD_3.7.1.2.6		
		CA0028-PO	CARD_3.2.2
CA5323-PO	CARD_3.7.2.2.12		
		CA0123-PO	CARD_3.2.12
CA5360-PO	CARD_3.7.5.2.15		
		CA0048-PO	CARD_3.2.15
CA5400-PO	CARD_3.7.9.2.7		
		CA0215-PO	CARD_3.2.7
CA5405-PO	CARD_3.7.6.2.7		
		CA0213-PO	CARD_3.2.7
CA5406-PO	CARD_3.7.5.2.7		
		CA0213-PO	CARD_3.2.7
CA5407-PO	CARD_3.7.6.2.7		
		CA0214-PO	CARD_3.2.7
CA5408-PO	CARD_3.7.5.2.2		
		CA0214-PO	CARD_3.2.7
CA5409-PO	CARD_3.7.9.2.7		
		CA0213-PO	CARD_3.2.7
CA5410-PO	CARD_3.7.9.2.7		
		CA0214-PO	CARD_3.2.7

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5434-PO	CARD_3.7.3.2.8		
		CA0027-PO	CARD_3.2.2.2
CA5435-PO	CARD_3.7.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA5437-PO	CARD_3.7.6.2.2		
		CA0027-PO	CARD_3.2.2.2
		CA0152-PO	CARD_3.7.6.2
CA5438-PO	CARD_3.7.5.2.2		
		CA0027-PO	CARD_3.2.2.2
CA5439-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA5465-PO	CARD_3.7.1.2.9		
		CA0216-PO	CARD_3.2.9
CA5466-PO	CARD_3.7.1.2.9		
		CA0216-PO	CARD_3.2.9
CA5467-PO	CARD_3.7.9.2.9		
		CA0216-PO	CARD_3.2.9
CA5467-PO	CARD_3.7.9.2.9		
		CA0216-PO	CARD_3.2.9
CA5468-PO	CARD_3.7.9.2.9		
		CA0216-PO	CARD_3.2.9
CA5468-PO	CARD_3.7.9.2.9		
		CA0216-PO	CARD_3.2.9
CA5475-PO	CARD_3.7.6.2.9		
		CA0216-PO	CARD_3.2.9
CA5476-PO	CARD_3.7.6.2.9		
		CA0216-PO	CARD_3.2.9
CA5477-PO	CARD_3.7.6.2.9		
		CA0216-PO	CARD_3.2.9
CA5478-PO	CARD_3.7.5.2.9		
		CA0216-PO	CARD_3.2.9
CA5479-PO	CARD_3.7.5.2.9		
		CA0216-PO	CARD_3.2.9

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5480-PO	CARD_3.7.5.2.9		
		CA0216-PO	CARD_3.2.9
CA5495-PO	CARD_3.7.1.2.13		
		CA5973-PO	CARD_3.2.13
CA5505-PO	CARD_3.7.3.2.13		
		CA5973-PO	CARD_3.2.13
CA5533-PO	CARD_3.7.4.2.12	CA0037-PO	CARD_3.2.12
CA5552-PO	CARD_3.2.15	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5555-PO	CARD_3.7.1.2.15		
		CA5552-PO	CARD_3.2.15
CA5557-PO	CARD_3.7.2.2.15		
		CA5552-PO	CARD_3.2.15
CA5559-PO	CARD_3.7.9.2.15		
		CA5552-PO	CARD_3.2.15
CA5560-PO	CARD_3.7.1.2.15		
		CA5552-PO	CARD_3.2.15
CA5562-PO	CARD_3.7.2.2.15		
		CA5552-PO	CARD_3.2.15
CA5564-PO	CARD_3.7.9.2.15		
		CA5552-PO	CARD_3.2.15
CA5602-PO	CARD_3.2.11	CA0121-HQ	CARD_3.2.6
CA5618-PO	CARD_3.3.7		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5618-PO	CARD_3.3.7		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5659-PO	CARD_3.7.9.2.14		
		CA0530-PO	CARD_3.2.2.2
CA5669-PO	CARD_3.7.6.2		

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0293-PO	CARD_3.7.6.2
CA5677-PO	CARD_3.7.2.2.6		
		CA0040-PO	CARD_3.2.12
CA5690-PO	CARD_3.7.5.2.5		
		CA0125-PO	CARD_3.2.12
CA5701-PO	CARD_3.7.5.2		
		CA0209-HQ	CARD_3.2.4
		CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
CA5702-PO	CARD_3.7.5.2.5		
		CA0125-PO	CARD_3.2.12
CA5711-PO	CARD_3.7.1.2.14		
		CA0107-HQ	CARD_3.2.2
CA5712-PO	CARD_3.7.5.2.13		
		CA6007-PO	CARD_3.2.13
CA5713-PO	CARD_3.7.2.2.13		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5748-PO	CARD_3.7.1.2		
		CA3184-PO	CARD_3.2.6
CA5749-PO	CARD_3.7.1.2		
		CA3184-PO	CARD_3.2.6
CA5750-PO	CARD_3.4	CA0039-HQ	CARD_3.2.6
CA5750-PO	CARD_3.4	CA0039-HQ	CARD_3.2.6
CA5801-PO	CARD_3.7.3.2.8		
		CA0107-HQ	CARD_3.2.2
CA5803-PO	CARD_3.7.5.2.13		
		CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0892-HQ	CARD_3.2
CA5805-PO	CARD_3.7.2.2.1		
		CA0213-PO	CARD_3.2.7
		CA0214-PO	CARD_3.2.7
CA5812-HQ	CARD_3.2.7		
		CA0100-HQ	CARD_3.2.7
CA5812-HQ	CARD_3.2.7		
		CA0100-HQ	CARD_3.2.7
CA5814-PO	CARD_3.2.13	CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
CA5815-PO	CARD_3.2.13	CA6002-PO	CARD_3.2.13
		CA6007-PO	CARD_3.2.13
CA5816-PO	CARD_3.7.2.2.9		
		CA0216-PO	CARD_3.2.9
CA5817-PO	CARD_3.2.10	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5818-HQ	CARD_3.2.2.1	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5819-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA5820-PO	CARD_3.2.10	CA5065-PO	CARD_3.2.10
CA5821-PO	CARD_3.2.10	CA0003-HQ	CARD_3.2
		CA0005-HQ	CARD_3.2
		CA0006-HQ	CARD_3.2
CA5825-PO	CARD_3.7.2.2.7		
		CA0032-HQ	CARD_3.2.2.1
CA5901-PO	CARD_3.7.1.2.10		
		CA3007-PO	CARD_3.2.10
CA5902-PO	CARD_3.7.3.2.10		
		CA3007-PO	CARD_3.2.10
CA5903-PO	CARD_3.7.6.2.10		
		CA3007-PO	CARD_3.2.10

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5904-PO	CARD_3.7.1.2.10		
		CA3007-PO	CARD_3.2.10
CA5905-PO	CARD_3.7.3.2.10		
		CA3007-PO	CARD_3.2.10
CA5906-PO	CARD_3.7.2.2.10		
		CA3007-PO	CARD_3.2.10
CA5907-PO	CARD_3.7.5.2.10		
		CA3007-PO	CARD_3.2.10
CA5908-PO	CARD_3.7.5.2.10		
		CA0296-HQ	CARD_3.2.10
		CA0476-PO	CARD_3.2.10
CA5909-PO	CARD_3.7.9.2.10		
		CA0476-PO	CARD_3.2.10
CA5910-PO	CARD_3.7.9.2.10		
		CA0476-PO	CARD_3.2.10
CA5912-PO	CARD_3.7.2.2.10		
		CA0476-PO	CARD_3.2.10
CA5913-PO	CARD_3.7.1.2.2.1		
		CA5818-HQ	CARD_3.2.2.1
CA5914-PO	CARD_3.7.2.2.2.1		
		CA5818-HQ	CARD_3.2.2.1
CA5916-PO	CARD_3.7.2.2.1		
		CA0213-PO	CARD_3.2.7
CA5917-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA5918-PO	CARD_3.7.4.2.7	CA0874-PO	CARD_3.7.4.2.7
CA5919-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA5920-PO	CARD_3.7.4.2.7	CA0874-PO	CARD_3.7.4.2.7
CA5921-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA5931-PO	CARD_3.7.5.2.15		
		CA5552-PO	CARD_3.2.15
CA5932-PO	CARD_3.7.5.2.15		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5552-PO	CARD_3.2.15
CA5933-PO	CARD_3.7.1.5		
		CA0550-PO	CARD_3.2.13
CA5934-PO	CARD_3.7.5.2.13		
		CA5973-PO	CARD_3.2.13
CA5935-PO	CARD_3.2.13	CA5973-PO	CARD_3.2.13
CA5941-PO	CARD_3.4	CA0044-PO	CARD_3.2.6
		R.MS0045	
CA5941-PO	CARD_3.4	CA0044-PO	CARD_3.2.6
		R.MS0045	
CA5942-PO	CARD_3.4	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5945-PO	CARD_3.7.9.2.2.1		
		CA0032-HQ	CARD_3.2.2.1
CA5946-PO	CARD_3.7.9.2.1		
		CA0033-HQ	CARD_3.2.1
CA5947-PO	CARD_3.7.1.2.2.2		
		CA0311-PO	CARD_3.2.2.2
CA5948-PO	CARD_3.7.1.2.6.2		
		CA0352-HQ	CARD_3.2.2.2
CA5962-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
		CA5552-PO	CARD_3.2.15
CA5962-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
		CA5552-PO	CARD_3.2.15
CA5963-PO	CARD_3.2.13	CA0048-PO	CARD_3.2.15
		CA5962-PO	CARD_3.2.13
CA5964-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0036-HQ	CARD_3.2.5

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5964-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0036-HQ	CARD_3.2.5
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5965-PO	CARD_3.2.13	CA5964-PO	CARD_3.2.13
CA5966-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0036-HQ	CARD_3.2.5
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5967-PO	CARD_3.2.13	CA5966-PO	CARD_3.2.13
CA5968-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0036-HQ	CARD_3.2.5
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5968-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0036-HQ	CARD_3.2.5
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5969-PO	CARD_3.2.13	CA5968-PO	CARD_3.2.13
CA5970-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0036-HQ	CARD_3.2.5
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5971-PO	CARD_3.2.13	CA5970-PO	CARD_3.2.13
CA5972-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0036-HQ	CARD_3.2.5
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2
CA5973-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0036-HQ	CARD_3.2.5
		CA0889-HQ	CARD_3.2
		CA0892-HQ	CARD_3.2

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5974-PO	CARD_3.7.1.2.13		
		CA5964-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5975-PO	CARD_3.7.1.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5976-PO	CARD_3.7.1.2.13		
		CA5968-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5977-PO	CARD_3.7.1.2.13		
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5978-PO	CARD_3.7.2.2.13		
		CA5964-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5979-PO	CARD_3.7.2.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5979-PO	CARD_3.7.2.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5980-PO	CARD_3.7.2.2.13		
		CA5968-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5981-PO	CARD_3.7.2.2.13		
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5982-PO	CARD_3.7.3.2.13		
		CA5964-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5982-PO	CARD_3.7.3.2.13		
		CA5964-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5983-PO	CARD_3.7.3.2.13		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5983-PO	CARD_3.7.3.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5984-PO		CA5968-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5985-PO	CARD_3.7.3.2.13		
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5986-PO	CARD_3.7.4.2.13	CA5964-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5987-PO	CARD_3.7.4.2.13	CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5987-PO	CARD_3.7.4.2.13	CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5988-PO	CARD_3.7.4.2.13	CA5968-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5989-PO	CARD_3.7.4.2.13	CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5990-PO	CARD_3.7.5.2.13		
		CA5964-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5991-PO	CARD_3.7.5.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5991-PO	CARD_3.7.5.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5992-PO	CARD_3.7.5.2.13		
		CA5968-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5993-PO	CARD_3.7.5.2.13		
		CA5970-PO	CARD_3.2.13

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5972-PO	CARD_3.2.13
CA5994-PO	CARD_3.7.6.2.13		
		CA5964-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5995-PO	CARD_3.7.6.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5995-PO	CARD_3.7.6.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5996-PO	CARD_3.7.6.2.13		
		CA5968-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5997-PO	CARD_3.7.6.2.13		
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5998-PO	CARD_3.7.9.2.13		
		CA5964-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA5999-PO	CARD_3.7.9.2.13		
		CA5966-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA6001-PO	CARD_3.7.9.2.13		
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA6001-PO	CARD_3.7.9.2.13		
		CA5970-PO	CARD_3.2.13
		CA5972-PO	CARD_3.2.13
CA6002-PO	CARD_3.2.13	CA0036-HQ	CARD_3.2.5
		CA0123-PO	CARD_3.2.12
CA6002-PO	CARD_3.2.13	CA0036-HQ	CARD_3.2.5
		CA0123-PO	CARD_3.2.12
CA6003-PO	CARD_3.7.1.2.13		
		CA6002-PO	CARD_3.2.13

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA6004-PO	CARD_3.7.2.2.13		
		CA6002-PO	CARD_3.2.13
CA6005-PO	CARD_3.7.5.2.13		
		CA6002-PO	CARD_3.2.13
CA6006-PO	CARD_3.7.9.2.13		
		CA6002-PO	CARD_3.2.13
CA6007-PO	CARD_3.2.13	CA0036-HQ	CARD_3.2.5
		CA0123-PO	CARD_3.2.12
CA6008-PO	CARD_3.7.3.2.13		
		CA6007-PO	CARD_3.2.13
CA6009-PO	CARD_3.7.4.2.13	CA6007-PO	CARD_3.2.13
CA6010-PO	CARD_3.7.5.2.13		
		CA6007-PO	CARD_3.2.13
CA6011-PO	CARD_3.7.9.2.13		
		CA6007-PO	CARD_3.2.13
CA6012-PO	CARD_3.2.13		
CA6012-PO	CARD_3.2.13		
CA6013-PO	CARD_3.7.1.2.13		
		CA6012-PO	CARD_3.2.13
CA6013-PO-Objective	CARD_3.7.1.2.13		
		CA6012-PO	CARD_3.2.13
CA6015-PO	CARD_3.7.1.2.13		
		CA6012-PO	CARD_3.2.13
CA6015-PO-Objective	CARD_3.7.1.2.13		
		CA6012-PO	CARD_3.2.13
CA6017-PO	CARD_3.7.3.2.13		
		CA6012-PO	CARD_3.2.13
CA6017-PO-Objective	CARD_3.7.3.2.13		
		CA6012-PO	CARD_3.2.13
CA6019-PO	CARD_3.7.6.2.13		
CA6020-PO	CARD_3.2.13		
CA6020-PO	CARD_3.2.13		
CA6020-PO-Objective	CARD_3.2.13		

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA6020-PO-Objective	CARD_3.2.13		
CA6022-PO	CARD_3.2.13		
CA6022-PO-Objective	CARD_3.2.13		
CA6024-PO	CARD_3.2.13	CA0892-HQ	CARD_3.2
CA6024-PO-Objective	CARD_3.2.13	CA0892-HQ	CARD_3.2
CA6026-PO	CARD_3.2.13	CA0892-HQ	CARD_3.2
CA6027-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0003-HQ	CARD_3.2
		CA0004-HQ	CARD_3.2
CA6028-PO	CARD_3.2.13	CA0001-HQ	CARD_3.2
		CA0003-HQ	CARD_3.2
		CA0004-HQ	CARD_3.2
CA6029-PO	CARD_3.7.1.2.13		
		CA6024-PO	CARD_3.2.13
CA6029-PO-Objective	CARD_3.7.1.2.13		
		CA6024-PO-Objective	CARD_3.2.13
CA6031-PO	CARD_3.7.1.2.13		
		CA6027-PO	CARD_3.2.13
CA6032-PO	CARD_3.7.1.2.13		
		CA6026-PO	CARD_3.2.13
		CA6028-PO	CARD_3.2.13
CA6033-PO	CARD_3.7.1.2.13		
		CA6028-PO	CARD_3.2.13
CA6034-PO	CARD_3.7.3.2.13		
		CA6027-PO	CARD_3.2.13
CA6035-PO	CARD_3.7.3.2.13		
		CA6028-PO	CARD_3.2.13
CA6036-PO	CARD_3.7.6.2.13	CA6024-PO	CARD_3.2.13
CA6036-PO-Objective	CARD_3.7.6.2.13	CA6024-PO-Objective	CARD_3.2.13
CA6038-PO	CARD_3.7.6.2.13	CA6027-PO	CARD_3.2.13
CA6039-PO	CARD_3.7.6.2.13	CA6026-PO	CARD_3.2.13
		CA6028-PO	CARD_3.2.13

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA6040-PO	CARD_3.7.6.2.13	CA6028-PO	CARD_3.2.13
CA6041-PO	CARD_3.2.7	CA0107-HQ	CARD_3.2.2
CA6064-PO	CARD_3.7.5.2.10	CA6065-PO	CARD_3.2.10
CA6066-PO	CARD_3.7.1.2.10		
		CA6065-PO	CARD_3.2.10
CA6067-PO	CARD_3.7.1.2.10		
		CA6065-PO	CARD_3.2.10
CA6068-PO	CARD_3.7.1.2.6		
		CA6065-PO	CARD_3.2.10
CA6070-PO	CARD_3.7.1.2.10		
		CA0296-HQ	CARD_3.2.10
CA6071-PO	CARD_3.7.5.2.15	CA0991-PO	CARD_3.2.15
CA6071-PO	CARD_3.7.5.2.15	CA0991-PO	CARD_3.2.15
CA6074-PO	CARD_3.7.1.2.2		
		CA6073-PO	CARD_3.2.2
CA6075-PO	CARD_3.7.1.2.2		
		CA6072-PO	CARD_3.2.2
CA6076-PO	CARD_3.7.9.2.2		
		CA6073-PO	CARD_3.2.2
CA6078-PO	CARD_3.7.9.2		
		CA6079-PO	CARD_3.2
CA6080-PO	CARD_3.7.9.2		
		CA6077-PO	CARD_3.2
CA6081-PO	CARD_3.7.10.2	CA6077-PO	CARD_3.2
CA6082-PO	CARD_3.7.10.2	CA6079-PO	CARD_3.2
CA6084-PO	CARD_3.7.1.2.5		
		CA0036-HQ	CARD_3.2.5
CA6084-PO-Objective	CARD_3.7.1.2.5		
		CA0036-HQ	CARD_3.2.5
CA6087-PO	CARD_3.7.2.2.5		
		CA0036-HQ	CARD_3.2.5
CA6087-PO-Objective	CARD_3.7.2.2.5		
		CA0036-HQ	CARD_3.2.5

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA6089-PO	CARD_3.7.2.2.5		
		CA0036-HQ	CARD_3.2.5
CA6089-PO-Objective	CARD_3.7.2.2.5		
		CA0036-HQ	CARD_3.2.5
CA6091-PO	CARD_3.7.3.2.5	CA0036-HQ	CARD_3.2.5
CA6091-PO-Objective	CARD_3.7.3.2.5	CA0036-HQ	CARD_3.2.5
CA6093-PO	CARD_3.7.3.2.5	CA0036-HQ	CARD_3.2.5
CA6093-PO-Objective	CARD_3.7.3.2.5	CA0036-HQ	CARD_3.2.5
CA6095-PO	CARD_3.7.4.2.5	CA0036-HQ	CARD_3.2.5
CA6095-PO-Objective	CARD_3.7.4.2.5	CA0036-HQ	CARD_3.2.5
CA6097-PO	CARD_3.7.4.2.5	CA0036-HQ	CARD_3.2.5
CA6097-PO-Objective	CARD_3.7.4.2.5	CA0036-HQ	CARD_3.2.5
CA6099-PO	CARD_3.7.5.2.5	CA0036-HQ	CARD_3.2.5
CA6099-PO-Objective	CARD_3.7.5.2.5	CA0036-HQ	CARD_3.2.5
CA6100-PO	CARD_3.7.1.2.12		
		CA0125-PO	CARD_3.2.12
CA6101-PO	CARD_3.7.5.2.12	CA0125-PO	CARD_3.2.12
CA6103-PO	CARD_3.7.1.2.5		
		CA6102-PO	CARD_3.2.5
CA6104-PO	CARD_3.7.4.2.5	CA6102-PO	CARD_3.2.5
CA6104-PO	CARD_3.7.4.2.5	CA6102-PO	CARD_3.2.5
CA6105-PO	CARD_3.2.10	CA6107-PO	CARD_3.7.2.2.9
CA6107-PO	CARD_3.7.2.2.9		
		CA6106-PO	CARD_3.2.7
CA6107-PO	CARD_3.7.2.2.9		
		CA6106-PO	CARD_3.2.7
CA6108-PO	CARD_3.7.1.2.10		
		CA6106-PO	CARD_3.2.7
CA6109-PO	CARD_3.7.3.2.10	CA6106-PO	CARD_3.2.7
CA6110-PO	CARD_3.7.1.2.10		
		CA6106-PO	CARD_3.2.7
CA6153-PO	CARD_3.7.9.2.5		
		CA0036-HQ	CARD_3.2.5

	CHILD		PARENT(s)
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA6153-PO-Objective	CARD_3.7.9.2.5		
		CA0036-HQ	CARD_3.2.5
CA6157-PO	CARD_3.7.6.2.5		
		CA0036-HQ	CARD_3.2.5
CA6157-PO	CARD_3.7.6.2.5		
		CA0036-HQ	CARD_3.2.5
CA6157-PO-Objective	CARD_3.7.6.2.5		
		CA0036-HQ	CARD_3.2.5
CA6160-PO	CARD_3.7.6.2.5		
		CA0036-HQ	CARD_3.2.5
CA6200-PO	CARD_3.7.6.2.8		
		CA5604-PO	CARD_3.2.8
CA6201-PO	CARD_3.7.6.2.8	CA5604-PO	CARD_3.2.8
CA6202-PO	CARD_3.7.3.2.5	CA0037-PO	CARD_3.2.12
CA6203-PO	CARD_3.7.2.2.12		
		CA5600-PO	CARD_3.2.12
CA6204-PO	CARD_3.7.5.2.12	CA5600-PO	CARD_3.2.12
CA6205-PO	CARD_3.7.1.2.12		
		CA5600-PO	CARD_3.2.12
CA6206-PO	CARD_3.7.4.2.12	CA5600-PO	CARD_3.2.12
CA6207-PO	CARD_3.7.3.2.12	CA5600-PO	CARD_3.2.12
CA6208-PO	CARD_3.7.5.2.12	CA5600-PO	CARD_3.2.12
CA6209-PO	CARD_3.7.5.2.12	CA5600-PO	CARD_3.2.12
CA6210-PO	CARD_3.2.10	CA0296-HQ	CARD_3.2.10
CA6211-PO	CARD_3.7.5.2.10	CA6210-PO	CARD_3.2.10
CA6212-PO	CARD_3.7.1.2.10		
		CA6210-PO	CARD_3.2.10
CA6213-PO	CARD_3.7.1.2.10		
		CA6210-PO	CARD_3.2.10
CA6214-PO	CARD_3.7.2.2.10		
		CA6210-PO	CARD_3.2.10
CA6215-PO	CARD_3.7.6.2.8	CA6210-PO	CARD_3.2.10
CA6216-PO	CARD_3.7.6.2.8	CA6210-PO	CARD_3.2.10
CA6253-PO	CARD_3.7.5.2.5	CA0036-HQ	CARD_3.2.5

	CHILD		PARENT(s)
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA6253-PO-Objective	CARD_3.7.5.2.5	CA0036-HQ	CARD_3.2.5
CA6255-PO	CARD_3.7.5.2.5	CA0036-HQ	CARD_3.2.5
CA6255-PO-Objective	CARD_3.7.5.2.5	CA0036-HQ	CARD_3.2.5
CA6258-PO	CARD_3.7.1.2.5		
		CA0036-HQ	CARD_3.2.5
CA6258-PO-Objective	CARD_3.7.1.2.5		
		CA0036-HQ	CARD_3.2.5
CA6260-PO	CARD_3.7.1.2.5		
		CA0036-HQ	CARD_3.2.5
CA6260-PO-Objective	CARD_3.7.1.2.5		
		CA0036-HQ	CARD_3.2.5
CA6262-PO	CARD_3.7.9.2.5		
		CA0036-HQ	CARD_3.2.5
CA6262-PO-Objective	CARD_3.7.9.2.5		
		CA0036-HQ	CARD_3.2.5