National Aeronautics and
Space Administration

CxP 70000

BASELINE

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CONSTELLATION ARCHITECTURE REQUIREMENTS DOCUMENT (CARD)

REVISION AND HISTORY PAGE

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	Baseline		Baseline (Reference CxCBD C000089/1-1 dated 12/14/06)	12/21/06

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 is comprised of a human-rated Crew Exploration Vehicle (CEV) and Lunar Surface Access Module (LSAM), the Mars Transfer Vehicle (MTV), the Descent Ascent Vehicle (DAV), a human-rated Crew Launch Vehicle (CLV), a Cargo Launch Vehicle (CaLV) which includes the Earth Departure Stage (EDS), Ground Systems, Missions Systems, and future Destination Surface systems, 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 Change Request (CR) to the appropriate Constellation Control Board 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 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".

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 is 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 systems with the allocations to the systems be captured in Appendix B. Section 3.3: Design and Construction Standards – This section contains the technical standard being invoked on the constellation program. Each technical standard was review 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 systems with the allocations to the systems be captured in Appendix B. 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 B. The requirements for each system in section 3.7 represent the suballocations 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 acronymsused 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 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 process and will be baselined through either a Program 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.

Document Number	Document Title	Rev
CxP 70023	Constellation Program Design Specification for Natural Environments (DSNE)	

Document Number	Document Title	Rev
CxP 70026	Constellation Program Crew Exploration Vehicle (CEV) to Crew Launch Vehicle (CLV) Interface Requirements Document (IRD)	
CxP 70022-01	"Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification"	CLV-GOE
CxP 70024	Constellation Program Human-Systems Integration Requirements (HSIR)	
CxP 70028	Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD)	
CxP 70029	Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD)	
CxP 70031	Constellation Program International Space Station (ISS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD)	
CxP 70033	Constellation Program Crew Exploration Vehicle (CEV) to Extravehicular Activity (EVA) Systems Interface Requirements Document (IRD)	
CxP 70034	Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD)	
CxP 70036	Constellation Environmental Qualification and Acceptance Testing Requirements (CEQATR) Document	

Document Number	**Document Title**	**Rev**
CxP 70050-01	Constellation Program Electrical Power System Specification, Volume 1: Electrical Power Quality Performance for 28 VDC	CLV-GOE
CxP 70052	Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD)	
CxP 70054	Constellation Program Mission Systems (MS) to Ground Systems (GS) Interface Requirements Document (IRD)	
CxP 70104	Constellation Program Extravehicular Activity (EVA) Systems to Ground Systems (GS) Interface Requirements Document (IRD)	
CxP 70105	Constellation Program Cargo Launch Vehicle (CaLV) to Ground Systems Interface Requirements Document (IRD)	
CxP 70106	Constellation Program Lunar Surface Access Module (LSAM) to Ground Systems Interface Requirements Document (IRD)	
CxP 70107	Constellation Program Lunar Surface Access Module (LSAM) to Extravehicular Activity (EVA) Interface Requirements Document (IRD)	
CxP 70109	Constellation Program Lunar Surface Access Module (LSAM) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD)	
CxP 70112	Constellation Program Cargo Launch Vehicle (CaLV) to Mission Systems (MS) Interface Requirements Document (IRD)	

Document Number	Document Title	Rev
CxP 70113	Constellation Program Lunar Surface Access Module (LSAM) to Mission Systems (MS) Interface Requirements Document (IRD)	
CxP 70080	Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document	
CxP 70050-02	Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28 VDC	
CxP 70118-01	Constellation Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD)	
CxP 70119	Crew Exploration Vehicle (CEV)-CALV Interface Requirements Document (IRD)	
CxP 70130	EVA Design and Construction Specification	
CxP 70135	Structural Design and Verification Requirements	
CxP 70070- ANX05	Constellation Prgraom Management Plan, Annex 05: Security Management Plan	
CxP 70142	Constellation Program Navigation Standards Specification Document	
CxP 72085	Crew Exploration Vehicle (CEV) Outer Mold Line	
CxP 70013	Systems Engineering Management Plan (SEMP)	
NASA-STD-5005	NASA Standard for Ground Support Equipment	B

Document Number	Document Title	Rev
NASA-STD-4003	Electrical Bonding for NASA Launch Vehicles, Spacecraft, and Flight Equipment	9/8/03
JPR 8080.5	JSC Design and Procedural Standards	
NASA-STD-(I)-6016	Standard Manned Spacecraft Requirements for Materials and Processes	Bsl
NASA-STD-5017	Design and Development Requirements for Mechanisms	B/L
NPR 8715.5	Range Safety Program	
NSS-1740.14	Guidelines and Assessment Procedures for Limiting Orbital Debris	
JSC 62550	Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications	Draft
NASA-STD-5019	Fracture Control Requirements for Spaceflight Hardware	
JSC 62809	Constellation Spacecraft Pyrotechnic Specification	

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.

Document Number	Document Title	Rev
CxP 70044	Constellation Program Natural Environment Definition for Design (NEDD)	
CxP 70007	Constellation Design Reference Missions and Operational Concepts Document	

Document Number	Document Title	Rev
CxP 70017	Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document	
CxP 70003-ANX01	Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO)	
CxP 70087	Constellation Program Reliability and Maintainability (R&M) Plan	
CxP 70053	Constellation Program Crew Launch Vehicle (CLV) to Mission Systems (MS) Interface Requirements Document (IRD)	
AFSPCMAN-91-710	Eastern and Western Range Safety User Requirements, Volumes 2, 3 and 4	
NPR 2810.1	Security of Information Technology	A
NPR 8705.2	Human Rating Requirements for Space Systems	
NASA-TM-2005-214062	Exploration Systems Architecture Study Report	B/L
NIST SP 811	Guide for the Use of the International System of Units (SI)	

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 Figure 1 Constellation Architecture System 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 the Crew Exploration Vehicle (CEV), and the Lunar Surface Access Module (LSAM). The CEV consists of a Crew Module (CM), a Service Module (SM), Spacecraft Adapter (SA) and a Launch Abort System (LAS). Several configurations of the CEV are envisioned to meet the needs of the Constellation Architecture DRMs. The Lunar Surface Access Module (LSAM), or lunar lander, 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 un-crewed 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. The CEV is launched atop a human-rated Crew Launch Vehicle (CLV), which provides safe, reliable transportation of the CEV to Low Earth Orbit (LEO). The Cargo Launch Vehicle (CaLV) is the heavy-lift companion to the CLV, and will provide over 250,000 lb cargo to LEO. Integral to the CaLV 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, communication, tracking, 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 document (TBD-001-990).

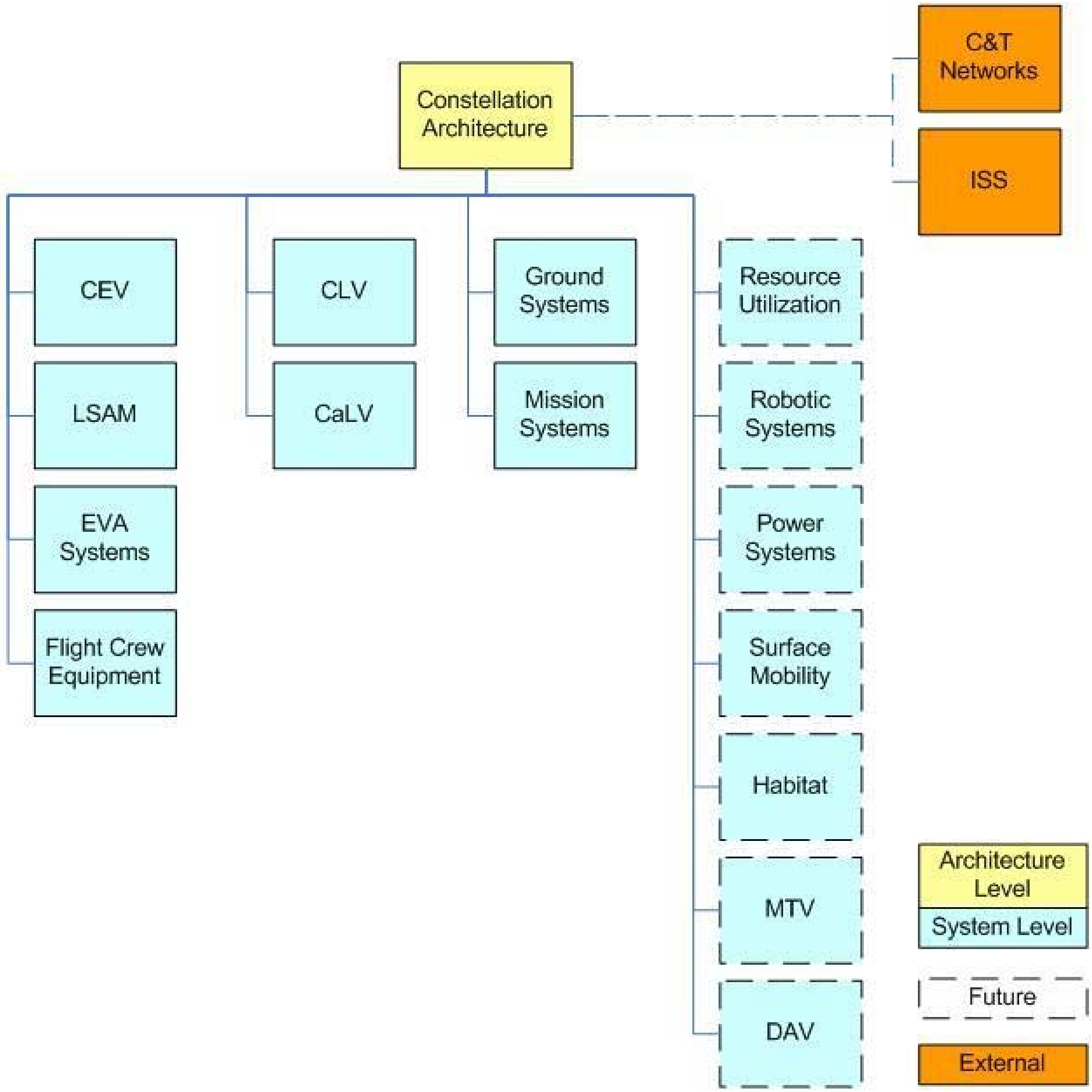

Figure 1 - CONSTELLATION ARCHITECTURE HIERARCHY

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 1- CONSTELLATION ARCHITECTURE INTERFACE CHART

Functional Interfaces between Constellation Systems

System in top row has an interface (in first column) with the System(s) identified in the intersecting cell	**CEV**	**CLV**	**CaLV**	**LSAM**	**EVA**	**GS**	**MS**
Loads, Structures, and Mechanisms							
Loads	CLV, CaLV, LSAM, EVA, GS	CEV, GS	CEV, LSAM, GS	CEV, CaLV, EVA, GS	CEV, LSAM	CEV, CLV, CaLV, LSAM	None
Structures	CLV, LSAM, EVA, GS	CEV, GS	GS	CEV, EVA, GS	CEV, LSAM, GS	CEV, CLV, CaLV, LSAM, EVA	None
Mechanisms	CLV, LSAM	CEV, GS	GS	CEV, EVA, GS	LSAM	CLV, CaLV, LSAM	None
Umbilicals	EVA, GS	GS	GS	None	CEV, LSAM, GS	CEV, CLV, CaLV, EVA	None
Power							
Power Characteristics	LSAM, EVA, GS	GS	GS	CEV, EVA, GS	CEV, LSAM, GS	CEV, CLV, CaLV, LSAM, EVA	None
Isolation	LSAM, EVA, GS	GS	GS	CEV	CEV, LSAM	CEV, CLV, CaLV	None
Circuit Protection	EVA	None	GS	None	None	CaLV	None
Electromagnetic Environmental Effects	CLV LSAM, EVA, GS	CEV, GS	LSAM, GS	CEV, CaLV, EVA, GS	CEV, LSAM	CEV, CLV, CaLV, LSAM	None
Bonding and Grounding	CLV, LSAM, EVA, GS	CEV, GS	LSAM, GS	CEV, CaLV	CEV, LSAM	CEV, CLV, CaLV	None
Environmental Control and Life Support							
Atmosphere	LSAM, EVA	None	None	CEV, EVA, GS	CEV, LSAM, GS	LSAM, EVA	None
Thermal	LSAM	None	None	CEV	None	None	None
Potable Water	EVA	None	None	None	CEV	None	None

System in top row has an interface (in first column) with the System(s) identified in the intersecting cell	**CEV**	**CLV**	**CaLV**	**LSAM**	**EVA**	**GS**	**MS**
Gasses and Fluids							
Propellant Fluids	GS	GS	GS	GS	None	CEV, CLV CaLV, LSAM	None
Thermal Gasses and Fluids	CLV, EVA, GS	CEV	LSAM	CaLV	CEV, LSAM, GS	CEV, EVA	None

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 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 crew members 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, pre-launch 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 ever more 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 SYSTEM INTERNATIONALE (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 1, 2 and 3 requirements documents SI will be shown as primary with the English unit equivalent in parenthesis. All Level 1, 2, and 3 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 4 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 SI units 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 SP811 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 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 insure 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 on-board 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 un-crewed 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 S 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), and 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 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.

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 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 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 pre-launch 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 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.

[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 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).

[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."

[CA0014-HQ] **Draft** The Constellation Architecture shall establish a Lunar Outpost located within 5 degrees latitude of the lunar South Pole (TBR-001-009).

Rationale: Polar Regions of the moon present unique opportunities for lunar resource utilization, scientific investigations, advantages for transportation system flexibility, efficiency. Specific outpost site selection criteria will be developed and documented in a separate (TBD-001-009) HQ controlled document as was done during Apollo.

[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 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.

[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.

[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.

[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.

[CA0889-HQ] **Draft** 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.

[CA0011-HQ] **Draft** 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.

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

Rationale: Establishes the 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.

[CA0074-PO] **Draft** 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 CEV Earth entry. Three days independent crew flight time in the CEV represents a trade between CEV lifetime and MTV propulsive diversion requirements.

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 (TBR-001-007).

Rationale: The 1 in 20 (TBR-001-007) means a .05 (or 5%) probability of LOM 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.

[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.

[CA3038-HQ] **Draft** 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.

[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 (TBR-001-017).

Rationale: The 1 in 200 (TBR-001-017) 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 (TBR-001-967).

Rationale: The 1 in 200 (TBR-001-967) 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.

[CA3039-HQ] **Draft** 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

[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.

[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 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 CEV using internal equipment along with communications with the CEV. The CEV can complete the orbit transfer to the LRO, participate in RPODU activities, perform the TEI and complete Earth entry. For ISS missions, the CEV can perform undocking, proximity operations and entry activities using only internal equipment.

[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 CEV 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 the CEV need to be addressed. The 36 hours comes from CA0194-PO which requires CEV to provide safe haven post touchdown for 36 hours.

[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.

3.2.2.1 CREW SURVIVAL PROBABILITIES

[CA5818-HQ] The Constellation Architecture shall limit the risk of loss of crew (LOC) during a pad or ascent abort to no greater than 1 in 10 (TBR-001-959).

Rationale: The 1 in 10 (TBR-001-959) means a .1 (or 10%) probability of LOC during any ascent abort. 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): 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.

[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 (TBR-001-014).

Rationale: The 1 in 100 (TBR-001-014) 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.

[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.

[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 (TBR-001-015).

Rationale: The 1 in 1000 (TBR-001-015) 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 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.

[CA3037-HQ] **Draft** 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.

3.2.2.2 EMERGENCY EGRESS, ABORTS, AND EARLY RETURN FOR SURVIVABILITY

[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 the ground crew with the capability for unassisted emergency egress from the launch pad within (TBD-001-252) 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.

[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' is meant to open up landing to anywhere on the Earth, being water or land (not necessarily CONUS) as 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 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.

[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.

[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 Cx glossary.

[CA0352-HQ] The Constellation Architecture shall return the crew from the surface of the moon to the surface of the Earth within 130 (TBR-001-005) hours after the decision to return has been made.

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 Earth at any time from anywhere on the lunar surface. The number of hours, determined by analysis, is based on the total time required for the following activities: (1) crew to prepare the LSAM for ascent and retask the CEV into the LSAM ascent plane, (2) the LSAM to perform ascent and RPODU with the CEV, (3) crew to transfer to the CEV from the LSAM and jettison the LSAM, (4) the crew and CEV to prepare and execute the TEI, (5) the trans-Earth coast, and (6) the crew and CEV to prepare and perform the atmospheric entry.

3.2.3 CREW SIZE

[CA0203-HQ] The Constellation Architecture shall deliver crew sizes ranging from 2 to 4 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.

[CA0020-HQ] The Constellation Architecture shall provide for at least 4 (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 4 crewmembers.

[CA0388-HQ] The Constellation Architecture shall deliver/return 0, 1, 2, 3, 4, 5, and 6 crewmembers to/from the ISS.

Rationale: 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 Document, 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.

[CA0010-HQ] **Draft** The Constellation Architecture shall transport 6 (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.

3.2.4 CARGO DELIVERY AND RETURN

[CA0209-HQ] The Constellation Architecture shall deliver at least 500 kg (1100 lb) 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.

[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.

[CA0002-HQ] **Draft** 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.

[CA0212-HQ] **Draft** 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.

[CA0823-HQ] **Draft** 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

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

Rationale: The Cx architecture must manage it's systems in a manner consistent with established flight rates, intervals, durations, and per approved manifests, which may drive overlapping mission classes (i.e. ISS and Lunar). This includes the ability to manage multiple missions and flight systems concurrently and uniquely identify and control the individual vehicles. CA0036-PO dictates mission rates, intervals and overlapping mission classes from which concurrent operations of multiple in-space vehicles are derived. This requirement establishes a capability that each system will need to refine considering their assessment of concurrent operations requirements. Performing concurrent operations of multiple in-space (i.e., Earth orbit, Lunar orbit, Lunar surface) vehicles (e.g. CEV and LSAM for lunar missions or multiple CEVs during ISS missions) drives facility, staffing and infrastructure resources. This requirement does not address parallel ground processing of vehicles.

[CA0036-HQ] The Constellation Architecture shall provide the capacity to perform missions according to the mission rates and opportunities specified in the System Flight 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 Flight Rate 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 nominal flight 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 flight rate surges. The nominal rate is intended to be applied to variable resources; however, in order to preserve the ability to add a flight when budgets permit, long lead or fixed resources should apply the maximum rate. The following assumptions are incorporated into the flight rate plan:

1) Intervals are measured from launch to launch of each system.

2) Concurrent ops scenarios are limited to the ISS Crew rotation/Lunar Sortie missions and Lunar Sortie/Lunar Outpost missions

3) During lunar sortie mission, planned CEV operations for ISS will be limited to docked (quiescent) operations.

4) Lunar Sortie and Lunar Outpost missions may be conducted concurrently.

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

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

Table 2 - SYSTEM FLIGHT RATES

System	Mission	Nominal Annual Rate	Maximum Annual Rate	Minimum Interval
CLV	ISS	5	6	45 days (TBR-001-239)
	Lunar Sortie	2	3	180 days (TBR-001-239)
	Lunar Outpost	2	3	180 days (TBR-001-239)
	Mars	(TBD-001-319)	(TBD-001-319)	(TBD-001-319)
CEV	ISS	2 crew	3 crew	4 months (TBR-001-240)
		3 cargo	3 cargo	4 months (TBR-001-240)
	Lunar Sortie	2	3	180 days (TBR-001-240)
	Lunar Outpost	2	3	180 days (TBR-001-240)
	Mars	(TBD-001-320)	(TBD-001-320)	(TBD-001-320)
CaLV/EDS	Lunar Sortie	2	3	180 days (TBR-001-241)
	Lunar Outpost	4	5	90 days (TBR-001-241)
	Mars	(TBD-001-321)	(TBD-001-321)	(TBD-001-321)
LSAM	LSAM Crew	2	3	180 days (TBR-001-242)
	LSAM Cargo	2	2	180 days (TBR-001-242)
Cx All		6 (TBR-001-1016)	8 (TBR-001-1017)	45 days (TBR-001-1018)

NOTE: The flight rates in the table reflect the expected nominal flight rate plus a surge capacity accounted for by the maximum flight rate in conjunction with the minimum interval. Budgets will determine opportunities for flight rate surges. The nominal rate is intended to be applied to variable resources; however, in order to preserve the ability to add a flight when budgets permit, long lead for fixed resources should apply the maximum flight rate. The following assumptions are incorporated into the flight rate plan:
1. Intervals are measured from launch to launch of each system.
2. ISS crew rotations and lunar missions may be conducted concurrently.
3. Lunar Sortie and Lunar Outpost missions may be conducted concurrently.
4. There will not be more than one vehicle launching or landing per day.

[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.

[CA5289-PO] **Draft** 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 Document, 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.

[CA0073-HQ] **Draft** 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 insures 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.

[CA0047-HQ] **Draft** 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.

3.2.6 ARCHITECTURE DEFINITION

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

Rationale: Establishes LSAM as the cargo-delivery method for Lunar Outpost and CaLV as the launch vehicle for the Lunar Cargo Mission. NASA-TM-2005-214062, Exploration Systems Architecture Study Report, showed that an alternate, cargo-only configuration of LSAM on a single CaLV 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.

[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 GFE to the systems.

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

Rationale: The KSC/Eastern Range is NASA's primary launch site for human space missions and is the lowest latitude contiguous 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 (CLV, CEV, CaLV, LSAM). It is not intended to prohibit launch of small cargo or payloads (such as ORU's) on other available launch systems when time, cost or other circumstances are appropriate.

[CA0044-PO] The Constellation Architecture shall return to Earth at designated CONUS landing sites.

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

[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 Document, indicates that the crew will launch in the CEV using the CLV and the LSAM using the CaLV 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 CaLV/LSAM includes the propulsion system needed for trans-lunar injection, this launch strategy necessitates that the CEV, with the crew, and CaLV/LSAM rendezvous in Earth orbit. The docked CEV/LSAM configuration transfers to LLO. The LSAM accesses the lunar surface while the CEV remains in LLO. Thus, the LSAM and CEV require a lunar orbit rendezvous when the LSAM returns from the lunar surface to transfer the crew from the LSAM to the CEV. The CEV 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.

[CA3211-PO] **Draft** 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.

[CA0281-HQ] The Constellation Architecture shall deliver the crew for lunar surface missions with two launches consisting of one CaLV+LSAM launch and a separate CLV+CEV 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 CaLV launches to deliver uncrewed cargo to the lunar surface. This mission approach was the result of numerous trade studies and performance analyses. ESAS determined that a single CaLV launch represents the best balance of performance, cost and risk trades, documented in NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study.

[CA0353-PO] **Draft** 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. Pre-deployed mission assets could include surface infrastructure such as habitats, power systems, in-situ resource utilization equipment, exploration elements, and landing navigation beacons.

[CA0405-HQ] **Draft** 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.

[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 CEV 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 CEV.

[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 CEV 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 CEV and LSAM/EDS in LEO to allow a lunar mission to continue.

[CA0022-HQ] **Draft** 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.

[CA0287-PO] **Draft** The Constellation Architecture shall provide assets for the crew members 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 crew members traveled further from the lunar excursion module. These explorations are constrained by the present proven maximum safe walk back distance for a suited crew member of 10 (TBR-001-752) km (5.4 nmi).

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

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

Rationale: Based on experience during the Apollo Program, the 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 CEV, CEV 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.

[CA0465-HQ] **Draft** 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.

[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.

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

Rationale: Establishes CaLV 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 CaLV design solutions.

[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.).

3.2.7 SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA5812-HQ] The Constellation Architecture shall implement GPS metric tracking for ascent flight operations.

Rationale: NASA plans to include GPS metric tracking capability as part of the launch vehicle acquisition process for vehicles that will launch after 2010, with the understanding that the Air Force 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). CA0100V-PO requires that a NASA tailored version AFSPCMAN 91-710, Range Safety User Requirements Manual be developed, and specific GPS requirements on NASA launch systems will be documented or referenced in this document.

[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.

[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 process the Cx Program will use to determine the probabilities flight to flight and to review each risk number for acceptance is provided in the CxP 70070-ANX01, Constellation Program Management Plan, Annex 1: Boards and Panels Structure (TBR-001-262). 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, and (TBD-001-263).

[CA0569-PO] The Constellation Architecture shall dispose of expendable modules and other orbital debris in accordance with NPD 8710.3B, NASA Policy for Limiting Orbital Debris Generation.

Rationale: The Constellation Architecture will jettison several objects during nominal missions and contingency scenarios (e.g. SRB's, upper stages, LAS, farings, 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 NPD 8710.3, NASA Policy for Limiting Orbital Debris Generation process. These options represent an effective method for controlling growth of the environment while limiting the cost impact on future programs.

[CA0214-PO] The Constellation Architecture shall be two fault tolerant to catastrophic hazards, except for areas approved to use Design for Minimum Risk criteria. The fault tolerance must be achieved without the use of EVA, emergency operations or emergency systems.

Rationale: Two Fault Tolerance protects against catastrophic failures and is dictated by programmatic decision to ensure mission safety. 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. Protection from a single fault that takes out several means of fault tolerance or redundancy is part of this requirement.

[CA0213-PO] The Constellation Architecture shall be single fault tolerant for critical hazards 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 EVA, 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. Protection from a single fault that takes out several means of fault tolerance or redundancy is part of this requirement.

3.2.8 COMMAND AND CONTROL

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

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.

3.2.9 HEALTH AND STATUS

[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.

[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.

3.2.10 COMMUNICATIONS AND COMMUNICATIONS SECURITY

[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 crew members, 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 70025 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.

[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 IRDs. Link classes are defined in the CxP 70022, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, and include the RF Operational Point to Point, RF High Rate Point to Point, RF Contingency Voice, RF Recovery and Hardline classes.

Table 3 - CONSTELLATION ARCHITECTURE COMMUNICATION INTERACTIONS

	CEV	LSAM	EVA	DSS	CLV	CALV	ISS	GS	MS	C&T
CEV	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
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)	N/A	Hardline (Direct)	N/A	Hardline (Direct)	N/A (via C&T)	RFOP2P RFHRP2P RFCV

	CEV	LSAM	EVA	DSS	CLV	CALV	ISS	GS	MS	C&T
				km)						
EVA			Hardline (Umbi) RFPMP (10 (TBR-001-1005) km) RFCV (10 (TBR-001-1007) km)	Hardline (Umbi) RFPMP (10 (TBR-001-1008) km) RFCV (10 (TBR-001-1009) km)	N/A	N/A	N/A	Hardline (Direct)	N/A (via C&T)	N/A
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
CLV					N/A	N/A	N/A	Hardline (Direct)	N/A (via C&T)	RFOP2P
CALV						N/A	N/A	Hardline (Direct)	N/A (via C&T)	RFOP2P
ISS							N/A	N/A	N/A (via C&T)	N/A - Outside Cx Program
GS								N/A	N/A (via C&T)	Hardline (Direct) (NISN)

	CEV	LSAM	EVA	DSS	CLV	CALV	ISS	GS	MS	C&T
MS									N/A (via C&T)	Hardline (Direct) (NISN)
C&T										N/A

[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, per 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 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 per CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO) [CxP-O40].

[CA0476-PO] The Constellation Architecture shall simultaneously communicate between at least 9 (TBR-001-119) systems.

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 FFBD analysis. The number of 9 (TBR-001-119) simultaneous systems is obtained from the driving case lunar outpost crew exchange, consisting of two CEV's, two LSAM's, the outpost, MS and GS in addition to two paths provisioned for test. The number of simultaneous systems will be based on the results of a study planned for IDAC3.

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

Rationale: Data recording is required through all stages of the lifecycle 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 on-board 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, on-board 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 lifecycle 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 lifecycle.

[CA3043-PO] The Constellation Architecture shall have a bit error rate of not greater than 1E-8 (TBR-001-105) for end-to-end communications.

Rationale: 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 bit error rate 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 lunar landing, CEV/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 and audio will be the norm in most US homes by first flight.

3.2.11 GUIDANCE, NAVIGATION, AND CONTROL

[CA5601-PO] The Constellation Architecture shall provide on-board 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 Rendezvous Proximity Operations, Dock and Undock (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.

[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.

[CA0529-PO] **Draft** 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.

[CA0356-PO] **Draft** 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.

[CA3141-PO] **Draft** 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).

[CA0826-PO] **Draft** 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 crew members 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.

3.2.12 RELIABILITY AND AVAILABILITY

[CA0123-PO] The Constellation Architecture system shall have an 88% (TBR-001-021) probability of launch per crew launch attempt, starting at "LCC Call to Station" and ending at close of day-of-launch window.

Rationale: A high probability of launch is required for all missions, but CEV lunar missions are assumed to be the driver, to enable rendezvous with the EDS and maintenance of mission schedule and lunar phase constraints. This requirement decomposes into other "probability of go" requirements that need to be placed on the separate elements: CEV hardware ready; CEV abort landing site requirements met; CLV hardware ready; CLV weather related launch constraints, and the ground systems readiness are met. The decomposition of this requirement is shown in the Launch Probability and Contributing Conditional Probabilities table. This requirement is inclusive of both the probability of delay and the probable duration of such delay to perform review, repair or replacements.

Table 4 - LAUNCH PROBABILITY AND CONTRIBUTING CONDITIONAL PROBABILITIES

	Crewed Launch	Cargo Launch
Net Probability of Launch:* *Range Safety Probability excluded	0.88 (TBR-001-021)	(TBD-001-064)
Contributing Conditional Probabilities:		
CEV hardware availability	0.98 (TBR-001-937)	(TBD-001-967)
CEV probability of meeting abort zone weather constraints	0.98 (TBR-001-938)	(TBD-001-968)
CLV hardware availability	0.98 (TBR-001-939)	(TBD-001-969)
CLV probability of meeting launch site weather constraints	0.95 (TBR-001-940)	N/A
MS hardware / system availability	(TBD-001-973)	(TBD-001-970)
GS hardware / system availability	(TBD-001-974)	(TBD-001-064)
CaLV hardware availability	N/A	(TBD-001-971)

CaLV probability of meeting launch site weather constraints	N/A	(TBD-001-972)
EVA hardware / system availability	(TBR-001-021)	N/A
LSAM hardware availability	N/A	(TBD-001-064)
Probability of meeting Range Safety Constraints	No Spec	No Spec

[CA5600-PO] The Constellation Architecture shall have an (TBD-001-517)% probability of launch per uncrewed launch attempt, starting at "LCC Call to Station" and ending at close of day of launch window.

Rationale: The Lunar missions' success hinge on meeting very small Trans-Lunar Injection Windows of approximately 1 Low Earth Orbital pass per month. In order to be prepared to meet this tight window, both the uncrewed stack and the crewed stack must launch on time. This requirement decomposes into other launch availability requirements that need to be placed on the separate elements: CaLV hardware ready and LSAM hardware ready. Additionally, launch site weather and the launch range as well as the mission systems and ground systems readiness are contributing factors to the uncrewed stack launch probability. However, these are more constrained by the crewed launch probability requirement (CA0123-PO) than by this requirement. Therefore, these areas are not allocated for the uncrewed stack as they are considered less constraining.

[CA0038-HQ] The Constellation Architecture shall provide an initial launch opportunity of the CLV no later than 1 (TBR-001-020) day after launch of the CaLV.

Rationale: This requirement allows a high confidence one-day out from CLV launch of system go/no-go on both vehicles and good weather prior to cargo launch. It also provides for minimizing EDS/LSAM wait times. Launch of CaLV will always occur prior to CLV.

[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 on-board 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 5 - SYSTEM LAUNCH READINESS

Mission	Applicable Systems	Launch Ready State (Duration – Not Less Than)
ISS	CEV, CLV, EVA, GS, MS	2 Hours
Lunar Sortie	CEV, CaLV, CLV, EVA, GS, LSAM, MS	2 Hours
Lunar Outpost	CEV, CaLV, CLV, EVA, LSAM, GS, MS	2 Hours
Lunar Cargo	CaLV, GS, LSAM, MS	4 (TBR-001-979) Hours

[CA0125-PO] The Constellation Architecture shall provide launch opportunities for at least four (TBR-001-193) consecutive days for crewed missions.

Rationale: This requirement reflects an approach meant to afford a high assurance of crew launch in a given month. Four (TBR-001-193) days provides a balance between launch assurance and a reasonable duration for CEV consumables. This is the driving design case for CEV/CLV. The uncrewed ISS cargo mission is encompassed within this capability and does not require a separate requirement.

[CA0037-PO] The Constellation Architecture shall be prepared to launch again within 26 days (the beginning of the next TLI opportunity) following a missed opportunity.

Rationale: It is important to provide the capability to recycle the vehicles and mission elements in time to meet the next lunar launch window in the event of a missed window. The lunar launch windows are typically four days long and occur every 30 days. Recycle capability should include limited corrective maintenance actions as well as recycle from a weather delay.

[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.

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, Human-System Integration Requirements document.

[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., CEV and CLV) 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 all 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 frame work of the commonality database.

[CA5710-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; and tools and test equipment for in-flight maintenance.

[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 Document, 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.

[CA0550-PO] **Draft** 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 6 - 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)

3.2.14 RESERVED

3.2.15 ENVIRONMENTAL CONDITIONS

[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.

[CA0048-PO] The Constellation Architecture shall meet its requirements during and after exposure to the environments defined in CxP 70023, Constellation Architecture 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: CEV/CLV/GS, CEV/ISS, CEV/CLV, CEV/CaLV-EDS/LSAM, CEV/LSAM, CaLV/LSAM/GS, and CaLV/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 Architecture 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.

3.3 DESIGN AND CONSTRUCTION STANDARDS

3.3.1 ELECTRICAL

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

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

[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.

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.

[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. TDRSS, Range Safety), and other vehicles (e.g. ISS).

[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.

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.

[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., CEV integrated with CLV) 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.

[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.

[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.

[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.

[CA3005-PO] The Constellation Architecture shall comply with NASA-STD-(I)-6016, Standard Material and Process 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.

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 (HSIR), 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

[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.

[CA0383-PO] The Constellation Architecture shall protect systems and information as specified in the CxP 70070-ANX05, Book 1, Constellation Program Management Plan, Annex 5: Security Management Plan.

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.

3.3.6 EVA STANDARDS

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

Rationale: Requirements that are driven by EVA but common across the Constellation architecture are included in CxP 70130, Constellation Program Extravehicular Activity (EVA) 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 ephemeredes, planetary geometries, solar radiation assumptions, etc. The planned delivery and baselining of this document is for SDR.

[CA5618-PO] The Constellation Architecture shall use a single, continuous (TBR-001-518) reference time scale traceable to Coordinated Universal Time (UTC) in accordance with CxP 70142, Constellation Program Navigation Standards Specification Document.

Rationale: A single time reference will allow (1) multiple systems to be synchronized and (2) internal and external data to be exchanged and integrated. Traceability to UTC is required to exchange/integrate data with external entities such as C&TN that use UTC as a time reference. The word continuous requires a time representation that does not have discontinuities related to leap seconds or year-end roll-over, the details of which are to be resolved in consultation with Mission Systems, C&TN, and the NASA HQ Time and Frequency NASA Advisory Council.

3.3.8 OTHER STANDARDS

[CA5915-PO] The Constellation Architecture shall comply with the requirements from CxP (TBD-001-1002), SR&QA Technical Requirements document.

Rationale: Safety requirements to design based on lessons learned are mandated for NASA programs and projects.

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

Rationale: This standard ensure that uniform engineering practices, methods and essential criteria are employed in the design of ground support equipment (GSE) used within NASA.

3.3.9 TEST STANDARDS

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

Rationale: CxP 70036, Constellation 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 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, which ever is greater, as part of the equipment's certification program.

3.4 EXTERNAL INTERFACES

[CA5936-PO] The Constellation Architecture shall interface with the National Oceanic and Atmospheric Administration per (TBD-001-1022).

Rationale: NOAA includes the National Weather Service (NWS) and National Centers for Environmental Prediction (NCEP) that provide centers for monitoring and prediction of earth weather, aviation weather, marine weather, and space weather (solar-geophysical forecasts, solar x-ray flux, and space weather forecasts provided by Geostationary Operational Environmental Satellites (GOES)). This weather information is necessary for all phases of mission operations.

[CA5937-PO] The Constellation Architecture shall interface with the Department of Defense Manned Spaceflight Support Office per (TBD-001-1023).

Rationale: The DoD Manned Spaceflight Support Office (DDMS) has the responsibility for astronaut rescue and recovery, contingency landing site support, payload security, medical support, coordination of airlift/sealift for contingency operations, as well as other support services required in the event of a shuttle emergency. To carry out these responsibilities, DDMS receives and validates NASA requests for DoD support. The support office then selects assets best able to provide the required support, tasks selected units through appropriate command channels, and provides tactical control of those DoD forces supporting a specific Space Shuttle mission. The DoD weather program provides meteorology, oceanography, and space weather. This weather information is required for all phases of mission operations.

[CA5938-PO] The Constellation Architecture shall interface with Foreign Government per (TBD-001-1024).

Rationale: CxP vehicle landing is planned within the CONUS, however, Earth landing on water or land (not necessarily CONUS) may follow any event during the mission that requires an abort or early return to Earth, e.g., unanticipated circumstances that put the crew at risk or prevent mission completion.

[CA5939-PO] The Exploration Systems Mission Directorate will interface with the Space Operations Mission Directorate per (TBD-001-1025).

Rationale: During CEV/ISS proximity and docked operations, MCCS will require an interface to the ISS Mission Control Center for CEV command, telemetry, voice and video capability. For the crewed CEVs, communication will be established between ISS and CEV crews during approach/docking and undocking/departure maneuvers, in order to confirm nominal performance or alert crews to off-nominal situations. For pressurized cargo CEVs, this will allow the ISS crew and MCCS to monitor approach/docking and undocking/departure maneuvers in order to assert control over these processes and even initiate aborts if warranted.

[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 the Eastern Test Range in accordance with NPR 8715.5, Range Safety Program.

Rationale: The Eastern Range provides wind tower, balloon and wind profiler data for launch operations. The Eastern Range Operations Control Center (ROCC) (run 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.

[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 (TBD-001-1028).

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

[CA5943-PO] The Constellation Architecture shall interface to USSTRATCOM per (TBD-001-1029).

Rationale: USSTRATCOM provides state vector data for orbital debris and space vehicles. USSTRATCOM also generates conjunction assessments for collision avoidance. USSTRATCOM is responsible for tracking objects larger than 10 centimeters orbiting Earth.

[CA5944-PO] The Constellation Architecture shall interface to the Air Force Satellite Control Network (AFSCN) per (TBD-001-1030).

Rationale: AFSCN provides S-band tracking services outside of the Communications and Tracking Network.

[CA0077-HQ] The CEV shall interface with ISS per CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document.

Rationale: The CEV and ISS share physical and functional interfaces which are identified in CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document.

[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 Communication and Tracking (C&T) Networks Interface Requirements Document (IRD).

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 Communication and Tracking (C&T) Networks Interface Requirements Document (IRD). These are critical as the Constellation Architecture is dependent on the C&TN assets for communication.

3.5 PHYSICAL CHARACTERISTICS

[CA0023-PO] The Constellation Architecture shall conform to a Control Mass for all flight Systems (TBD-001-089).

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 CREW EXPLORATION VEHICLE (CEV)

3.7.1.1 CEV DESCRIPTION

The CEV 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. The CEV System will be used in all phases of the Constellation Program. Initially, the CEV 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, the CEV 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 CEV REQUIREMENTS

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

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

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

Rationale: The CEV launches on the human-rated CLV. Thus, the CEV is the designated Constellation System, per CxP 70007,Constellation Design Reference Missions and Operational Concepts Document, 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, NASA's Exploration Systems Architecture Study, which indicates that using CEV rather than the LSAM balances performance, cost and risk for the Constellation Program.

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

Rationale: The requirement is consistent with CxP 70007, Constellation Design Reference Missions and Operational Concepts Document, which indicates that the CEV is the Constellation System designated to deliver the crew and cargo to the ISS. Design considerations for the CEV must include features that are essential for the crew and cargo to safely launch atop the CLV to the ISS orbit and interface with ISS.

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

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

3.7.1.2.1 CEV MISSION SUCCESS

[CA0088-PO] The CEV shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Sortie mission to no greater than 1 in 50 (TBR-001-058).

Rationale: The 1 in 50 (TBR-001-058) means a .02 (or 2%) probability of LOM due to the CEV 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.

[CA3023-PO] The CEV 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 the CEV 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.

[CA0399-PO] The CEV shall limit their contribution to the risk of loss of mission (LOM) for an ISS Crewed mission to no greater than 1 in 250 (TBR-001-056).

Rationale: The 1 in 250 (TBR-001-056) means a .004 (or .4%) probability of LOM due to the CEV during any ISS Crewed 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.

[CA3022-PO] The CEV shall limit their contribution to the risk of loss of mission (LOM) for an ISS Cargo mission to no greater than 1 in (TBD-001-513).

Rationale: The 1 in (TBD-001-513) means a (TBD-001-513) (or (TBD-001-513)%) probability of LOM due to the CEV 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.

3.7.1.2.2 CEV CREW SURVIVAL

[CA4154-PO] The CEV shall perform the functions necessary to return the crew to the surface of the Earth in at least 120 (TBR-001-980) 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 120 (TBR-001-980) hours is coupled to the CEV and EVA System requirements to sustain the crews' life for the length of time to return the crew to Earth. As the CEV may lose pressure during the lunar loiter time, the vehicle may need to function with an unpressurized cabin for longer than 120 (TBR-001-980) hours.

[CA0274-PO] The CEV 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 SM separation through landing. This mode includes simple, inexpensive SW and 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, RCS jet firings, parachute deployment, and landing attenuation. This mode may use primary RCS, power and GNC 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 GNC 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.

[CA0984-PO] The CEV 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.

[CA0194-PO] The CEV shall provide for crew survival, without permanent crew disability, for at least 36 (TBR-001-045) hours with the hatch closed following a landing in the water.

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 (TBR-001-045) 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.

[CA0983-PO] The CEV 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 CEV must be recovered and the limits for post-landing CEV 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.

[CA3259-PO] The CEV shall provide visual aids for search and recovery independent of ambient lighting conditions per standard (TBD-001-568).

Rationale: Visual aids (e.g. flashing light beacons and dye bags) are necessary in 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.

[CA0532-PO] The CEV shall sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 120 (TBR-001-1006) hours.

Rationale: The 120 (TBR-001-1006) hours is associated with the maximum expected time frame the CEV needs to sustain the life of suited crew members during the unpressurized trip back to Earth. One key assumption that is being made is that the LSAM can be used as a lifeboat for scenarios where CEV unpressurized cabin event occurs during the trip to the moon. For ISS missions, the amount of time needed to return the crew will be much less - on the order of a few hours.

[CA3108-PO] The CEV 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 CEV 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 crew member 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 CEV Volume provided to have sets of crew members retrieve and don their suits serially.

[CA3138-PO] The CEV shall provide fire detection and suppression for the CEV 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.

[CA0493-PO] The CEV shall provide a habitable environment for the assigned crew for a single event of at least 2 (TBR-001-002) hours in duration while the CEV 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.

[CA0325-PO] The CEV 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.

3.7.1.2.2.1 CEV CREW SURVIVAL PROBABILITIES

[CA5913-PO] The CEV shall limit the risk of loss of crew (LOC) during a pad or ascent abort 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. 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): Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA0501-PO] The CEV shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Sortie mission to no greater than 1 in 200 (TBR-001-057).

Rationale: The 1 in 200 (TBR-001-057) means a .005 (or .5%) probability of LOC due to the CEV 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.

[CA3040-PO] The CEV 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 the CEV 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.

[CA0398-PO] The CEV shall limit their contribution to the risk of loss of crew (LOC) for an ISS Crew mission to no greater than 1 in 1700 (TBR-001-055).

Rationale: The 1 in 1700 (TBR-001-055) means a .00059 (or .059%) probability of LOC due to the CEV 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.

3.7.1.2.2.2 CEV EMERGENCY EGRESS, ABORTS AND RETURN FOR SURVIVABILITY

[CA0334-PO] The CEV 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] The CEV 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, 6 suited flight crew plus 2 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.

[CA0466-PO] The CEV shall provide for unassisted emergency egress for suited crew upon landing within (TBD-001-146) 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.

[CA0333-PO] The CEV shall perform aborts from the time the CEV 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 CEV 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 CEV 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.

[CA0579-PO] The CEV 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 CEV 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.

[CA0498-PO] The CEV shall abort without relying on thrust from the CLV.

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

[CA0522-PO] The CEV shall automatically initiate an ascent abort sequence upon notification of FTS indication.

Rationale: If flight termination is required for the launch vehicle, the CEV 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 Crew Exploration Vehicle

- To - Crew Launch Vehicle Interface Requirements Document.

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

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

[CA5234-PO] The CEV 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.

[CA5439-PO] The CEV shall automatically perform abort.

Rationale: In cases where response time constraints impact crew safety risk requirements, the CEV 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.

[CA0416-PO] The CEV 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 CEV. 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 CEV can complete the orbit transfer to the LRO, participate in RPODU activities, perform the TEI and complete Earth entry. For ISS missions, the CEV can perform undocking and proximity operations and entry activities using only internal equipment.

[CA5237-PO] The CEV shall return the crew from Lunar Rendezvous Orbit (LRO) to the surface of the Earth within 118 (TBR-001-063) hours from docking with LSAM.

Rationale: This requirement allocates a portion of the 130 (TBR-001-005) hours that the Constellation Architecture needs for early return of the crew to earth. The 118 (TBR-001-063) hour clock begins with completion of the CEV/LSAM docking activities and includes time for crew transfer and TEI preparation. The 12 (TBR-001-205) hours not covered by this requirement allows for the LSAM ascent and RPOD with the CEV.

3.7.1.2.3 CEV CREW SIZE

[CA0447-PO] The CEV 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 the CEV with no crew on it and also size the different crew compliments. Establishes the maximum crew launch capability required to support all defined phases of Exploration. Lower-level requirements will specify crew size for particular DRMs.

[CA0347-PO] **Draft** The CEV shall transport at least 6 (TBR-001-082) crew members 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 CEV is launched on the CLV to satisfy this requirement. Specifics of the Mars assembly and departure orbit are yet to be determined at this time.

3.7.1.2.4 CEV CARGO DELIVERY AND RETURN

[CA0868-PO] The CEV 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, 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.

[CA5155-PO] The CEV 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.

[CA0547-PO] The CEV shall provide 0.57 (TBR-001-750) m3 (20 ft3) of volume allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure elements during the cruise and lunar orbit phases of 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 the CEV. Specific objectives for each lunar sortie and outpost mission will be defined in a separate ESMD document. The mass associated with this requirement is to be determined. The support of cargo capability is secondary in priority to design and layout of propulsion systems.

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

Rationale: This requirement establishes the need for CEV 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 CEV transporting crew to and from ISS. The CEV will support pressurized cargo delivery for ISS logistical resupply. Automated rendezvous and docking will be needed because of the uncrewed configuration.

[CA0864-PO] The CEV 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 CEV 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] The CEV 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 CEV 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] The CEV shall deliver at least 2850 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 (16.5 ft) diameter CEV would have a

8.58 m3 (303 ft3) available volume limit for cargo and this volume limit would limit the mass storage of the CEV to 2,850 kg (6,283 lbm). TDS18B assumed that secondary structure mass would be accounted for in the vehicle weight. CEV Mass Delivered supports ISS upmass requirements for payloads, crew supplies and other consumables.

[CA5233-PO] The CEV shall return at least 2,858 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 (16.5 ft) diameter CEV would have a 8.58 m3 (303 ft3) available volume limit for Cargo and this volume limit would limit the mass storage of the CEV to 2.858 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 CEV Return Mass based upon center of gravity location and the related vehicle passive stability. CEV Mass Delivered supports ISS up-mass requirements for payloads, crew supplies and other consumables.

[CA0565-HQ] The CEV 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.

3.7.1.2.5 CEV MISSION RATES AND DURATIONS

[CA3164-PO] The CEV shall provide a habitable environment for a crew of four for a minimum of 18 (TBR-001-128) days during each lunar mission.

Rationale: Defines the number of days that CEV is required to provide support for the crew based on the maximum mission duration including contingencies and docked operations with LSAM. Includes 13.7 days for nominal mission timeline with crew, plus 4.3 days contingency, and assumes CEV supports crew during CEV-LSAM docked operations.

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

Rationale: Lunar missions call for the CEV 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 Document, 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 CEV will need to maintain its orbit and operational functionality throughout this loiter duration without crew intervention.

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

Rationale: Typical ISS mission durations are 180 days. The CEV 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 CEV may not be attached to the ISS during the entire crew increment due to ISS mission operations (such as CEV relocation to another port).

3.7.1.2.6 CEV ARCHITECTURE DEFINITION

[CA0351-PO] The CEV 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 CLV launches will set up CEV to rendezvous with systems previously inserted into orbit (e.g. ISS and CaLV+EDS), overall mission planning may be severely constrained if night launches are not allowed. CEV will not constrain CLV ability to launch regardless of ambient lighting conditions.

[CA3204-PO] The CEV shall perform the orbit transfer from the Ascent Target to the Earth Rendezvous Orbit (ERO) for crewed lunar missions.

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

[CA3207-PO] The CEV 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 CEV 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 CEV 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 CEV for Earth return. The CEV may transfer to an intermediate orbit between arrival into Lunar Destination Orbit and departure to LRO.

[CA5240-PO] The CEV shall perform an orbit transfer from Low Lunar Orbit to the LSAM in Lunar Rendezvous Orbit (LRO) in 6 (TBR-001-205) hours or less after the decision to return has been made.

Rationale: This requirement allocates a portion of the 130 (TBR-001-005) 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 the CEV to LRO.

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

Rationale: The CEV 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 the CEV will be used to control/monitor the vehicle during the ascent, but is not required for success. The CEV cannot rely on other Constellation Systems (i.e., CLV) for communication to the Missions Systems during ascent.

[CA3209-PO] The CEV 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 Document. The CEV includes the propulsion system and propellant to perform the TEI from LRO.

[CA0191-PO] The CEV shall perform the orbit transfer from the Ascent Target to ISS.

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

[CA0324-PO] The CEV shall return to Earth on land at designated CONUS landing sites.

Rationale: Returning to land at designated CONUS landing sites reduces risk and cost by reducing necessary recovery force assets, increasing proximity to U.S. medical facilities, increasing security, ensuring a prepared landing site free of hazards (as specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), section 3.5), and supporting vehicle reuse.

[CA0494-PO] The CEV 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] The CEV shall provide for at least 2 (TBR-001-206) EVA operations of at least 4 (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), CEV 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 CEV 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 CEV 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 decent to lunar surface and a contingency EVA for crew survival to transfer the crew from LSAM to CEV. Four (TBR-001-207) hours is anticipated to be the longest duration in space EVA and is consistent with the crew transfer.

[CA3168-PO] The CEV 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 CEV via contingency EVA, the CEV cabin will have to be depressurized either by ground command or by an EVA crewmember operating an external depress valve/control.

[CA0373-PO] **Draft** The CEV 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 CEV Earth entry. Three days independent crew flight time in the CEV represents a trade between CEV lifetime and MTV propulsive diversion requirements.

[CA5148-PO] The CEV shall provide the infrastructure necessary for at least 3 (TBR-001-208) CEV vehicles operating in-space concurrently.

Rationale: Multiple CEV vehicles will be operated in-space concurrently for ISS and for lunar missions. CEV 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).

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

Rationale: For CEV 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 the CEV 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.

3.7.1.2.6.1 CEV CONTROL MASS

[CA0827-PO] The CEV shall have a Control Mass of 22,072 kg (48,570 lbm) at the Lunar Ascent Target.

Rationale: The Control Mass for CEV was determined by the CEV DAC-2 analysis. Mass control is required for the concurrent design of multiple Systems which have an overall performance or mission goal. This mass is consistent with CEV delivery to the Lunar Ascent Target. The control mass applies to the CEV crew module and service module and spacecraft adapter total mass, including cargo. This mass includes all pertinent CEV design mass growth allocation and flight performance reserves necessary to accomplish the mission.

[CA4134-PO] The CEV shall have a Control Mass of 28,059 kg (61860 lbm) at Lift-Off for the Lunar Mission.

Rationale: The Control Mass for the CEV at Lift-Off is based on the CEV 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 CEV Crew Module, Service Module, Spacecraft Adapter and Launch Abort System masses. This Control Mass is needed with the Program Reserve to size CLV Mass Delivered requirements.

[CA4135-PO] The CEV shall jettison the LAS not later than 30 seconds after Upper Stage Engine ignition command.

Rationale: The LAS jettison time is required to properly define the mass interface between the CLV and CEV. Because the LAS is jettisoned during ascent, the CLV LEO injection capability is a function to the mass of the LAS and the timing of the LAS jettison.

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

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

[CA4163-PO] The CEV shall have a Control Mass of 25,331 kg (55,830 lbm) at Lift-Off for the ISS Mission.

Rationale: The Control Mass for the CEV at Lift-Off is based on the CEV 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 CEV 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 CLV Mass Delivered requirements.

[CA4164-PO] The CEV shall have a Control Mass of 19,301 kg (42,540 lbm) at the ISS Ascent Target.

Rationale: The Control Mass for the CEV at Lift-Off is based on the CEV 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 CEV Crew Module, Service Module and Spacecraft Adapter masses for the ISS mission. This Control Mass is needed with the Program Reserve to size CLV Mass Delivered requirements.

3.7.1.2.6.2 CEV DELTA-V

[CA0829-PO] The CEV shall provide a minimum translational delta-V of 1760 (TBR-001-148) m/s (5776 ft/s) for lunar missions.

Rationale: The minimum translational delta-V requirement is based on analysis. This number is based on the Lunar Outpost mission and includes the delta-V necessary for orbit circularization from the ascent target, RPOD with the CaLV/LSAM in ERO, altitude maintenance during the lunar surface stay, aligning the CEV parking orbit with the LSAM ascent orbit at worst case orientation, performing a TEI sequence with a 90 degree plane change, and executing 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.

[CA0406-PO] **Draft** The CEV 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.

3.7.1.2.7 CEV SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA0436-PO] The CEV shall provide two fault tolerance to catastrophic hazards except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance must be achieved without the use of EVA, emergency operations or emergency systems.

> *Rationale:* CEV shall be designed such that no two faults will have the effect of causing a catastrophic hazard leading to the permanent disability or loss of the Crew. The CEV design will therefore provide 2 fault tolerance protection (or DFMR) for functions or capabilities required for elimination of catastrophic hazards as well as providing protection against catastrophic hazardous effects from any CEV 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.

[CA0435-PO] The CEV shall be single fault tolerant for critical hazards and loss of mission, except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance must be achieved without the use of EVA, 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.

[CA0437-PO] The CEV 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 CEV COMMAND AND CONTROL

[CA3254-PO] The CEV shall generate commands.

> *Rationale:* To perform Command and Control of Integrated Systems, the CEV will need to be able to initiate the sending of commands to other Constellation Systems.

[CA0134-PO] The CEV 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.

[CA3249-PO] The CEV 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.

[CA3255-PO] The CEV shall execute commands which are addressed to the CEV.

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

[CA3110-PO] The CEV shall accept Control of Automation.

Rationale: Other Constellation Systems and the crew will need to select, initiate, inhibit, override, and terminate automation on the CEV during various operational phases. Reference NPR 8705.2, Human-Rating Requirements for Space Systems, Sections 3.2.7 (34445), 3.3.5 (34451).

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

Rationale: Vehicle systems must be designed so that more than one crew member is not required to operate the vehicle. There may be circumstances where crewmembers are unconscious or incapacitated leaving only a single crew member capable of vehicle control. Work stations should provide redundant capability from which to command systems and manually operate the vehicle if necessary.

[CA5039-PO] The CEV shall provide (TBD-001-220) bytes 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. 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 CxP 70073-02, Constellation Program Management Systems Requirements, Volume 2: Data Management Requirements. The amount of space required for each system will change with mission type. CEV 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, System Requirements for the Crew Exploration Vehicle (CEV) Element.

[CA5040-PO] The CEV 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 CEV HEALTH AND STATUS

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

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

[CA0427-PO] The CEV shall provide Health and Status information to the crew.

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

[CA0438-PO] The CEV shall detect system faults which 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 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element. 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] The CEV 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 non-recoverable failures. Faults subject to isolation are further specified by the CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element.

[CA5466-PO] The CEV 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, System Requirements for the Crew Exploration Vehicle (CEV) Element. This requirement does not preclude procedural recovery from other faults or failures.

3.7.1.2.10 CEV COMMUNICATIONS AND COMMUNICATIONS SECURITY

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

Rationale: The CEV needs to accept changes to sequences, commands and data parameters already stored on-board, when the Ground or Missions systems initiate such reconfiguration actions. Reconfiguration actions may impact procedures, operations time-lines, or on-board algorithms which operate on commandable data items to support mission activities.

[CA3280-PO] The CEV shall communicate using an independent, dissimilar, voice only system.

Rationale: CEV needs an independent voice communication capability to improve crew safety and mission success. CEV must be able to communicate with other in space systems as well as with Earth during contingencies when the prime voice system is unavailable.

[CA5904-PO] The CEV 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.

[CA0470-PO] The CEV shall transmit and receive in any attitude with geometric antenna coverage of 90% (TBR-001-335) for low-rate data as defined by CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV), Section 3.6.1.2.

Rationale: The CEV needs a reliable communications link that does not depend on active antenna pointing. CEV must communicate with MS through C&TN as CEV 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 CEV design trades, with the goal of achieving the highest possible coverage. Link data rate is specified in CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV). 90% (TBR-001-335) coverage is based on analysis in IDAC2, TDS SIG-13-201.

[CA3288-PO] The CEV shall communicate simultaneously with ISS and Mission Systems when within 30 (TBR-001-917) km (16.2 nmi) of ISS.

Rationale: The CEV must communicate with MS to provide situational awareness and to enable ground commanding. The CEV 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 CEV design trades. The relative range was determined based on IDAC2 and CEV design trades as well as ISS visiting vehicle requirements.

[CA3287-PO] The CEV shall communicate simultaneously with Mission Systems, and with 2 (TBR-001-126) other Constellation in-space systems that are within 800 (TBR-001-165) km (432 nmi) of CEV.

Rationale: Simultaneous communication is required so that the CEV can communicate with LSAM for rendezvous and docking operations and communicate with MS to provide situational awareness and enable ground commanding. Two (TBR-001-126) systems is based on the lunar outpost DRM in which the CEV will communicate with the outpost and an ascending/descending LSAM as well as with MS. The number of in-space systems will be determined by analysis of Constellation FFBDs and by analysis of LSAM and CEV design trades. The relative range was determined based on IDAC2, TDS SIG-12-003.

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

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

[CA0511-PO] The CEV 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 CEV design and defined in CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element.

3.7.1.2.11 CEV GN&C

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

Rationale: This requirement ensures the safety of the crew by providing the CEV 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 Document.

[CA5921-PO] The CEV shall perform separation functions with the CLV.

Rationale: This requirement is necessary to identify ownership of the separation function. The actual separation function (CEV Service Module from the CEV Spacecraft Adapter) resides entirely with the CEV.

[CA4128-PO] The CEV shall perform attitude control of the CEV/LSAM mated configuration after CaLV EDS undocking through CEV/LSAM separation in LLO.

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

[CA0497-PO] The CEV 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] The CEV shall perform navigation and attitude determination during all mission phases including pre-launch.

Rationale: Navigation and attitude determination are required onboard the CEV 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 pre-launch activities through touch down and recovery including aborts, even when CEV is not the controlling vehicle.

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

Rationale: On-board computations of rendezvous maneuvers are necessary for successful rendezvous execution and provide operational flexibility and efficiency. When the CEV 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 CEV chaser operations with the target LSAM in LLO.

[CA0368-PO] The CEV shall perform rendezvous trajectory operations to within a range of 1 (TBR-001-145) km to the target vehicle independent of lighting conditions.

Rationale: The CEV relative navigation design will preserve mission flexibility by performing proximity operations, docking, and undocking at anytime pass with the exception of small lighting exclusion periods where the lighting environment (including absence of sunlight) is too harsh for the relative navigation sensors and pilot to operate. This requirement is applicable in both Earth and lunar orbits.

[CA0462-PO] The CEV 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 CEV/ISS or CEV/LSAM docking activities or mated operations. It may be executed prior to CEV gaining structural attachment enough to allow CEV/ISS or CEV/LSAM interface to withstand attitude control loads or after the mated configuration is achieved.

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

Rationale: The duration defined allows for a quick get-away 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.

[CA0059-PO] The CEV shall function as the maneuvering vehicle during RPODU operations with the LSAM/CaLV EDS mated configuration in LEO.

Rationale: Because of launch vehicle constraints, it is necessary to launch CEV separately from the LSAM. Two launches make an Earth orbit rendezvous between the CEV and the LSAM/CaLV EDS necessary. The CEV is crewed during RPOD with LSAM/CaLV 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 CEV is needed to support abort scenarios for return to Earth.

[CA0131-PO] The CEV 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 CEV in LLO. The CEV will be uncrewed during RPOD operations with LSAM, so the CEV 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 CEV functions as the maneuvering vehicle is covered in a separate requirement (CA0369-PO).

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

Rationale: For nominal missions the CEV 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 CEV within planned as well as reserve performance. In this scenario, the CEV is remotely commanded to perform rendezvous maneuvers, including proximity operations. The LSAM then completes the final approach and docking maneuver as the maneuvering vehicle, with the CEV performing the target role. This is not intended as a separate delta-v requirement for CEV. It is intended to ensure that the CEV software and any RPOD hardware are capable of operating as the maneuvering vehicle for this contingency case.

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

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

[CA0133-PO] The CEV 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 CEV, the crew will transfer from the LSAM to the CEV. The CEV will then undock from LSAM and prepare to return to Earth. The CEV 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.

[CA0081-PO] The CEV 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 Document. CEV crew sizes of 0 and 1, as specified in CA0388, drive the required levels of automation on the CEV for ISS RPODU.

[CA0329-PO] The CEV shall perform a guided entry that results in landing within 5 (TBR-001-040) km (2.7 nmi) of the intended target at a designated CONUS landing site.

Rationale: Improved landing target accuracy increases the number of available landing sites and entry opportunities, thus reducing mission planning constraints and increasing crew survivability. Meeting this accuracy is dependent on having day of landing meteorological data available for the designated landing site. 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.

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

Rationale: Since the CEV is uncrewed as the LSAM undocks and departs for the lunar surface, CEV 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.

3.7.1.2.12 CEV RELIABILITY AND AVAILABILITY

[CA0178-PO] The CEV shall have a launch availability of no less than 98% (TBR-001-041) per launch attempt, exclusive of weather, starting at (TBD-001-505) hours for "LCC Call to Station" and ending at close of day-of-launch window.

Rationale: This requirement addresses CEV hardware readiness (exclusive of weather). Part of the decomposition of the hardware probability of launch requirement that assures lunar mission timelines can be met.

3.7.1.2.13 CEV MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

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

Rationale: During CEV 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.

3.7.1.2.14 CEV HABITABILITY AND HUMAN FACTORS

[CA0426-PO] The CEV Net Habitable Volume shall be no less than 10.76 m3 (380 ft3).

Rationale: Establishing a minimum net habitable volume ensures that the CEV 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.

[CA0288-PO] The CEV shall control cabin pressure to a selectable setpoint between 103 (TBR-001-923) kPa (14.9 psia) to 58 (TBR-001-501) kPa (8.4 psia) with 0.7 (TBR-001-500) kPa (0.1 psia) increments.

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 18 kPa (2.5 psia) ppO2 crew limit. This is to have common approach to cabin pressure management across Constellation architecture.

[CA3105-PO] The CEV 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-001-106) cm (0.25 in) to allow the crew time to don suits per CA3058-PO.

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 pre-breathe, 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 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.

[CA3133-PO] The CEV shall control cabin oxygen partial pressure to a selectable setpoint between 18 (TBR-001-124) kPa (2.6 psia) ppO2 and 21 (TBR-001-911) kPa (3.1 psia) ppO2 with 0.7 (TBR-001-912) 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.

[CA3061-PO] The CEV shall limit the maximum oxygen concentration within the pressurized cabin to 30% (TBR-001-109) by volume.

Rationale: The CEV and CaLV share functional interfaces which are identified in CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).

[CA5711-PO] The CEV shall return the CEV 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.

[CA0886-PO] The CEV shall provide not less than two vestibule pressurization cycles per mission.

Rationale: The responsibility for vestibule pressurization must be allocated between the CEV and LSAM and between the CEV and ISS. This requirement allocates responsibility for two pressurization cycles to CEV. Primary and contingency vestibule pressurization should account for each docking in which the crewed CEV is the active vehicle. The LSAM will perform the vestibule pressurization when the crewed LSAM docks with the CEV. 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.

[CA3106-PO] The CEV shall maintain the cabin environment at a pressure to support pre-breathe as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section (TBD-001-962), with an equivalent cabin hole diameter of 0.64 (TBR-001-106) 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. They 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 pre-breathe, 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 (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.

[CA3140-PO] The CEV shall provide oxygen and nitrogen storage to survive from the largest gas consumable combination of two pressure events. (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, pre-breathe, cabin depress and cabin repress to 70 (TBR-001-127) 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 pre-breathe. 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.

3.7.1.2.15 CEV ENVIRONMENTAL CONDITIONS

[CA5555-PO] The CEV 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] The CEV 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.

[CA0374-PO] The CEV 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 CEV 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 CEV also need to be considered for the integrated vehicle configurations: CEV/LSAM, CEV/LSAM/CaLV-EDS, CEV/CLV, CEV/CLV/GS and CEV/ISS.

3.7.1.3 RESERVED

3.7.1.4 CEV EXTERNAL INTERFACES

[CA0429-PO] The CEV shall interface with the CLV per CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document.

Rationale: The CEV and CLV share physical and functional interfaces which are identified in CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document.

[CA0800-PO] The CEV shall interface with the LSAM per CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

Rationale: The CEV and LSAM share physical and functional interfaces which are identified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

[CA0361-PO] The CEV shall interface with CaLV per CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).

Rationale: The CEV and CaLV share physical and functional interfaces which are identified in CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).

[CA0894-PO] The CEV shall interface with Mission Systems per CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: The CEV and Mission Systems share physical and functional interfaces which are identified in CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD).

[CA0893-PO] The CEV shall interface with Ground Systems per CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).

Rationale: The CEV and Ground Systems share physical and functional interfaces which are identified in CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).

[CA0896-PO] The CEV shall interface with the Communications and Tracking Network per CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV).

Rationale: The CEV and C&TN share physical and functional interfaces which are identified in CxP 70118-01, Constellation Program Systems to Communication and

Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV).

[CA0895-PO] The CEV shall interface with EVA Systems per CxP 70033, Constellation Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document.

Rationale: The CEV and EVA systems share physical and functional interfaces which are identified in the CEV to EVA Interface Requirements Document.

3.7.1.5 CEV PHYSICAL CHARACTERISTICS

[CA5933-PO] The CEV shall (TBD-001-1019) include a Service Module (SM) that is configurable as a standalone Element.

Rationale: This requirement allows flexibility in the applicability of the CEV 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.

[CA0386-HQ] The CEV 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, CEV 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 CEV development effort when compared with establishing a new design without flight heritage. The dimensions of the CEV will be based on the optimal size for meeting mission requirements.

3.7.2 CREW LAUNCH VEHICLE (CLV)

3.7.2.1 CLV DESCRIPTION

The CLV is the launch vehicle for the CEV. 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 the CEV has separated during ascent.

3.7.2.2 CLV REQUIREMENTS

3.7.2.2.1 CLV MISSION SUCCESS

[CA5916-PO] The CLV 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.

[CA1065-PO] The CLV shall limit their contribution to the risk of loss of mission (LOM) for any mission to no greater than 1 in 500 (TBR-001-174).

Rationale: The 1 in 500 (TBR-001-174) means a 0.002 (or 0.2 %) probability of loss of CLV 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 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.

[CA5805-PO] The CLV shall provide two fault tolerance to catastrophic hazards except for areas approved to use DFMR. The fault tolerance must be achieved w/o the use of emergency operations or emergency systems.

Rationale: The CLV 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 CLV design will therefore provide 2 fault tolerance protection (or DFMR) to catastrophic hazards as well as providing protection against catastrophic hazardous effects from failure of any CLV 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 CLV 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. The requirement to be 2FT for catastrophic hazards without relying on abort when applied to a launch vehicle is enveloping the fault tolerance for mission success. As such, this requirement is more conservative than the 1FT to mission success.

3.7.2.2.2 CLV CREW SURVIVAL

[CA5435-PO] The CLV shall automatically determine the need for an abort.

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

[CA0258-PO] The CLV 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 compliments JPR 8080.5, JSC Design and Procedural Standards, section G-2, which mandates separation of redundant systems, subsystems, and elements.

3.7.2.2.2.1 CLV CREW SURVIVAL PROBABILITIES

[CA5914-PO] The CLV shall limit the risk of loss of crew (LOC) during a pad or ascent abort to no greater than 1 in (TBD-001-948).

> *Rationale:* The 1 in (TBD-001-948) means a (TBD-001-948) (or (TBD-001-948)%) probability of LOC during any ascent abort. 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): Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

[CA3163-PO] The CLV shall limit their contribution to the risk of loss of crew (LOC) for crewed missions to no greater than 1 in (TBD-001-219).

> *Rationale:* The 1 in (TBD-001-219) means a (TBD-001-219) (or (TBD-001-219)%) probability of LOC due to the CLV during a 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.

3.7.2.2.2.2 CLV EMERGENCY EGRESS, ABORTS AND RETURN FOR SURVIVABILITY

[CA5159-PO] The CLV shall provide unassisted emergency egress for 6 (TBR-001-211) ground crew conducting pre-launch activities within the CLV during pre-launch 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 CLV exit point.

> *Rationale:* For contingency situations, ground crew will need the capability to safely egress the CLV. This should drive CLV internal access requirements, design of CLV interior egress paths and GSE to allow ground crew conducting pre-launch activities

within the CLV to exit without additional assistance. This requirement assumes that all CLV unique GSE required by Ground Crew for CLV internal activities is designed and provided by CLV. The egress time is from the initiation of egress until the last ground crew exits the CLV. 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 RESERVED

[CA5512-PO] The nominal CLV Lunar flight rate shall be 2 per year with a maximum rate of 3 per year.

Rationale: This requirement is the Lunar Sortie crewed CLV rate of the Constellation Architecture flight rate requirement and accommodates the flight rates necessary to sustain the Lunar Sortie program and drives system design to meet launch processing schedules. Anticipate two Sorties with a maximum of three, then transitioning to the Lunar Outpost. The nominal rate is intended to be applied to variable resources; however, in order to preserve the ability to add a flight when budgets permit, long lead or fixed resources should apply the maximum rate.

3.7.2.2.6 CLV ARCHITECTURE DEFINITION

[CA3202-PO] The CLV shall launch the CEV from the launch site to the Ascent Target.

Rationale: Establishes the function of the CLV for Lunar and ISS missions. The CLV is tasked to safely transport the CEV from the Earth's surface to the Ascent Target at which point the CEV will separate from the CLV/CEV integrated vehicle and continue to ERO for Lunar missions or to ISS per CxP 70007, Constellation Design Reference Missions and Operational Concepts Document. The split of ascent mission phase between the CEV and CLV is based on results from NASA-TM-2005-214062, Exploration Systems Architecture Study Report.

[CA5713-PO] The CLV shall refurbish the reusable elements of the CLV.

Rationale: Upon arrival back to earth, the First Stage element of the CLV will be recovered, refurbished and reflown utilizing the same processes of the STS RSRMs.

[CA5677-PO] The CLV 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 CLV launches will involve rendezvous with CEV previously inserted into orbit, overall mission planning may be severely constrained if night launches are not allowed.

[CA1023-PO] The CLV shall provide liftoff clearance between the CLV 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 CLV and CEV access arms, umbilicals and the SRM nozzle. Specific clearance envelopes will be defined in the CLV/GS and the CEV/GS IRDs.

[CA0389-HQ] The CLV 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 CLV 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 CLV designers to leverage. In addition, CLV 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 CLV development effort when compared with developing a new design without flight heritage.

[CA3221-PO] The CLV 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] The CLV shall change the planned ascent trajectory based on guidance target updates provided prior to launch.

Rationale: CLV 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.

3.7.2.2.6.1 CLV CONTROL MASS

[CA4138-PO] The CLV shall launch a CEV with a Gross Lift-off Weight of 29,728 kg (65,540 lbm) for Lunar missions.

Rationale: The Gross Lift-off Weight that CLV must accommodate for lunar missions is part of the Mass Delivered requirement. This requirement includes a CEV Control Mass at Lift-off and a Program Mass Reserve.

[CA1005-PO] The CLV shall deliver at least 23,700 kg (52,250 lbm) from Earth to the Lunar Ascent Target defined in CLV Lunar Mission Ascent Target table.

Rationale: The CLV Mass Delivered is the guaranteed mass delivered by the CLV to the Lunar Ascent Target based on CLV DAC-1 analysis. 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 CEV 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. The CLV Mass Delivered is required to size the CLV to ensure it is capable of delivering the CEV to the ISS Ascent Target. This Mass Delivered requirement is related to the CEV Control Mass requirement and the LAS jettison time requirement.

Table 7 - CLV LUNAR MISSION ASCENT TARGET

Orbit Injection Parameter	Lunar Mission
Apogee	185.2 km (100 nmi)
Perigee	-55.6 km (-30 nmi)
Inclination	28.5 (TBR-001-936) deg
Insertion Altitude	101.9 (TBR-001-982) km (55 nmi)

[CA1000-PO] The CLV shall deliver at least 20,355 kg (44,780 lbm) from Earth to the ISS Ascent Target defined in the CLV ISS Mission Ascent Target table.

Rationale: The CLV Mass Delivered is the guaranteed mass delivered by the CLV to the ISS Ascent Target based on the CLV DAC-1 analysis. Mass delivered requirements are necessary for the concurrent design of multiple Systems which have an overall performance or mission goal. This requirement includes a CEV 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. The ISS Mass Delivered quantities are derived from analysis of the CLV design for the Lunar Exploration mission. The CLV Mass Delivered is required to size the CLV to ensure it is capable of delivering the CEV to the ISS Ascent Target. This Mass Delivered requirement is related to the LAS jettison time requirement.

Table 8 - CLV ISS MISSION ASCENT TARGET

Orbit Injection Parameter:	ISS Mission
Apogee	185.2 (TBR-001-653) km (100 nmi)
Perigee	-55.6 (TBR-001-935) km (-30 nmi)
Inclination	51.6 deg
Insertion Altitude	101.9 (TBR-001-983) km (55 nmi)

[CA4165-PO] The CLV shall accommodate a CEV Gross Lift-off Weight of 26,348 kg (58,070 lbm) for the ISS missions.

Rationale: The Gross Lift-off Weight that CLV must accommodate for ISS missions is part of the Mass Delivered requirement. This requirement includes a CEV Control Mass at Lift-off and a Program Mass Reserve.

3.7.2.2.6.2 RESERVED

3.7.2.2.7 CLV SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA5825-PO] The CLV shall automatically shutdown CLV 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 LOV/LOC conditions when there is not sufficient time to request shutdown from CEV or Mission Systems. The failure to shutdown will lead to a LOV/LOC condition. There are known failure modes for various CLV 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 CEV 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] The CLV 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.

[CA5919-PO] The CLV shall be capable of uninstalling or physically disabling devices fitted to the CLV 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."

[CA0566-PO] The CLV 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] The CLV shall execute authenticated USAF FCO-initiated FTS command signals.

Rationale: For crewed CLV or CaLV 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 CLV or CaLV 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 OK for auto-initiation of FTS events for crewed vehicles.

[CA1054-PO] The CLV shall generate an indication upon receipt of each Flight Termination command.

Rationale: This requirement provides for the generation of the CEV 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] The CLV 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 and relative motion simulations.

[CA1056-PO] The CLV 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.

3.7.2.2.8 CLV COMMAND AND CONTROL

[CA3256-PO] The CLV 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] The CLV shall execute commands which are addressed to the CLV.

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

[CA3112-PO] The CLV shall accept Control of Automation.

Rationale: Other Constellation systems will need to select, initiate, inhibit, override, and terminate automation on the CLV during various operational phases. Reference NPR 8705.2, Human-Rating Requirements for Space Systems, Section 3.2.7 (34445).

[CA1029-PO] The CLV 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).

3.7.2.2.9 CLV HEALTH AND STATUS

[CA5816-PO] The CLV 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) System Requirements Document (SRD). FDIR is a redundancy management tool necessary to manage fault tolerance.

[CA3118-PO] The CLV shall generate Health and Status information.

Rationale: Provides for generation of Health and Status information on internal operations of the CLV. Full definition of the specific data is provided in CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD) and multiple CLV/System IRDs.

[CA1084-PO] The CLV 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) System Requirements Document (SRD). Crew abort can be initiated by LOC, LOV, or LOM conditions. For CLV, 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 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] The CLV 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) System 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] The CLV 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) System 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).

3.7.2.2.10 CLV COMMUNICATIONS AND COMMUNICATIONS SECURITY

[CA5906-PO] The CLV shall accept reconfiguration of stored commands, sequences and data prior to lift-off.

Rationale: The CLV needs to accept changes to sequences, commands and data parameters already stored on-board, when the Ground Systems initiates such reconfiguration actions. Reconfiguration actions may impact procedures, operations time-lines, or on-board algorithms which operate on commandable data items to support mission activities.

[CA5912-PO] The CLV shall be able to communicate simultaneously with the CEV, Mission Systems, and Ground Systems.

Rationale: Simultaneous communications is required so that the CLV can communicate with both the CEV via hardline and Ground Systems before launch. Before launch, Mission Systems will be receiving CLV data as well but it will be via Ground Systems. After launch, the CLV needs to be able to communicate with the CEV, Mission Systems, and Ground Systems; some long term engineering telemetry will not be sent to Mission Systems during launch and ascent.

3.7.2.2.11 CLV GN&C

[CA3143-PO] The CLV shall perform navigation and attitude determination from pre-launch through CLV upper stage separation from the CEV.

Rationale: Navigation and attitude determination are required to successfully execute the ascent phase to meet mission objectives.

[CA1017-PO] The CLV shall launch CEV to the Ascent Target with accuracy defined in the Orbital Injection Accuracy table.

Rationale: 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 the CEV onboard delta-V maneuvering capability and CLV upper stage impact footprint. Failure to achieve the accuracy on a specific mission may be acceptable if the CEV 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 9 - ORBITAL INJECTION ACCURACY

Delivery Orbit Parameter	ISS Mission	Exploration Mission
Semi major axis	+/- 9.26 (TBR-001-984) km (5 nmi)	+/- 9.26 (TBR-001-987) km (5 nmi)
Apogee	+/- 12.96 (TBR-001-985) km (7 nmi)	+/- 12.96 (TBR-001-988) km (7 nmi)
Orbit plane	+/- 0.05 (TBR-001-986) deg	+/- 0.05 (TBR-001-989) deg

3.7.2.2.12 CLV RELIABILITY AND AVAILABILITY

[CA1066-PO] The CLV shall have a launch availability of no less than 98% (TBR-001-041) per crew launch attempt, starting at "LCC Call to Station" and ending at close of day-of-launch window.

Rationale: Part of the decomposition of the probability of launch requirement that assures lunar mission timelines can be met. This requirement addresses CLV hardware readiness. Hardware readiness and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements.

[CA1068-PO] The CLV shall have a launch availability of no less than 95% (TBR-001-966) per crew launch attempt due to natural environments as specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), starting at "LCC Call to Station" and ending at close of day-of-launch window.

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 CEV 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-001-966) launch availability for CLV with respect to weather was selected to improve launch availability 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 ERTT panel December 20, 2005.

[CA1008-PO] The CLV shall provide launch opportunities for at least four (TBR-001-193) consecutive days for crewed missions.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. The CLV should be designed so that servicing can be completed for the next day's launch attempt or be designed to last at least four (TBR-001-193) days without servicing.

[CA5323-PO] The CLV 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 be 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.

[CA0072-PO] The CLV shall have a 10 (TBR-001-140) 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 the launch window. TDS04-016 showed the 10 minute window exists every calendar day for Flight Day 3 rendezvous.

3.7.2.2.13 RESERVED

3.7.2.2.14 RESERVED

3.7.2.2.15 CLV ENVIRONMENTAL CONDITIONS

[CA5557-PO] The CLV 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] The CLV 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.

[CA1069-PO] The CLV 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 CLV 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 CLV integrated vehicle configurations: CEV/CLV, and CEV/CLV/GS.

3.7.2.3 RESERVED

3.7.2.4 CLV EXTERNAL INTERFACES

[CA0898-PO] The CLV shall interface with Mission Systems per CxP 70053, Constellation Program Crew Launch Vehicle (CLV) to Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: The CLV and Mission Systems share physical and functional interfaces which are identified in CxP 70053, Constellation Program Crew Launch Vehicle (CLV) to Mission Systems (MS) Interface Requirements Document (IRD).

[CA0897-PO] The CLV shall interface with Ground Systems per CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD).

Rationale: The CLV and Ground Systems share physical and functional interfaces which are identified in CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD).

[CA0899-PO] The CLV shall interface with the Communication and Tracking Networks per CxP 70118-02, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 2: Crew Launch Vehicle (CLV).

Rationale: The CLV and C&TN share physical and functional interfaces which are identified in the CxP 70118-02, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 2: Crew Launch Vehicle (CLV).

[CA0430-PO] The CLV shall interface with the CEV per CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document.

Rationale: The CLV and CEV share physical and functional interfaces which are identified in the CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document.

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 CEV 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 CEV 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 Document, 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 Report, which indicates that using LSAM rather than the LSAM for lunar surface operations during Lunar Outpost Cargo missions balances performance, cost and risk for the Constellation Program. LSAM uses the same interface to CaLV and subsystems required for surface descent operations as LSAM.

3.7.3.2.1 LSAM MISSION SUCCESS

[CA0504-PO] **Draft** 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.

[CA3036-PO] **Draft** 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.

[CA3042-PO] **Draft** 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

[CA5193-PO] **Draft** 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-CEV rendezvous timeline plan.

[CA5194-PO] **Draft** 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 CEV volume provided to have sets of crewmembers retrieve and don their suits serially.

[CA5191-PO] **Draft** 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 CEV, and carry out the external transfer of the crew from LSAM to CEV is 7 (TBR-001-214) hours. The 7 (TBR-001-214) hours is derived from the 3 hour nominal LSAM-CEV rendezvous timeline plan and the 4 (TBR-001-244) hour EVA timeline to transfer the crew from LSAM to CEV.

[CA3139-PO] **Draft** 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.

3.7.3.2.2.1 LSAM CREW SURVIVAL PROBABILITIES

[CA0503-PO] **Draft** 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.

[CA3041-PO] **Draft** 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 the CEV. 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.

[CA5238-PO] **Draft** The LSAM shall return the crew from the surface of the moon to docking with the CEV in the Lunar Rendezvous Orbit in 12 (TBR-001-179) hours or less for Lunar Sortie and Lunar Outpost crew missions.

Rationale: This requirement allocates a portion of the 130 (TBR-001-005) hours that LSAM needs to provide for crew return to earth.

[CA5316-PO] The LSAM shall return the crew to the CEV 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 the CEV.

3.7.3.2.3 RESERVED

3.7.3.2.4 LSAM CARGO DELIVERY AND RETURN

[CA4140-PO] The LSAM shall deliver at least 21,552 (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 the CEV at the time of CaLV 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.

[CA0062-PO] **Draft** 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.

[CA5156-PO] **Draft** 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 TBR value is based on the crewed Apollo mission cargo return capability.

[CA0090-PO] **Draft** 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.

[CA0137-PO] **Draft** 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.

3.7.3.2.5 LSAM MISSION RATES AND DURATIONS

[CA0839-PO] **Draft** 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/CaLV EDS mated configuration, needs to survive on-orbit (e.g., withstand micrometeoroids and preserve propellant) while awaiting the launch of the CEV. The duration of the loiter is based on the interaction between the CEV 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 CEV/LSAM/CaLV EDS RPOD activities and TLI preparations.

[CA0842-PO] **Draft** 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.

[CA4150-PO] **Draft** 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 Document, 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.

3.7.3.2.6 LSAM ARCHITECTURE DEFINITION

[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.

[CA3286-PO] **Draft** 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.

[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 Document, 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 Report.

[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 Document, 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 Report, which indicates that using LSAM rather than the CEV 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 CEV (Earth return vehicle) remains in orbit while the LSAM travels to the lunar surface, the LSAM must rendezvous with includes a propulsion system capable of safely ascending from the lunar surface to the designated lunar orbit. This requirement is based on the results documented in NASA-TM-2005-214062, Exploration Systems Architecture Study Report, which indicates that using LSAM rather than the CEV for crewed lunar surface operations balances performance, cost and risk for the Constellation Program.

[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.

[CA5195-PO] The LSAM shall provide for at least 1 (TBR-001-217) in-space 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) in-space EVA operation is based on the Contingency EVA transfer of the crew from LSAM to the CEV.

[CA0394-HQ] The LSAM shall include a crew airlock.

Rationale: An LSAM airlock will be used to address the following concerns:

i. Dust Control: A significant issue during Apollo was the quantity of dust that was brought into the Lunar Module (LM) after each EVA.

ii. Split-Crew Operations: An airlock will allow 2 EVA crewmembers to explore the surface while the other two crewmembers remain in the LSAM performing IVA tasks in a shirt-sleeve environment.

iii. 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.

[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).

3.7.3.2.6.1 LSAM CONTROL MASS

[CA0836-PO] **Draft** The LSAM shall have a Control Mass of 45,000 (TBR-001-075) kg (99,180 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 CaLV. The Control Mass includes at least 500 kg (1,100 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 CaLV Mass Delivered requirement.

[CA5231-PO] **Draft** 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 CaLV Mass Delivered requirement.

3.7.3.2.6.2 LSAM DELTA-V

[CA4141-PO] The LSAM shall provide a least 1900 (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.

[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/CEV 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.

[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 2671 (TBR-001-571) m/s (8,764 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

[CA0891-PO] **Draft** The LSAM shall be two fault tolerant to catastrophic hazards, except for areas approved to use Design for Minimum Risk criteria. The fault tolerance should be achieved without the use of EVA, emergency operations or emergency systems.

Rationale: The LSAM shall be designed such that no two faults will have the effect of causing a catastrophic hazard leading to the permanent disability or loss of the crew.

The LSAM design will therefore provide 2 fault tolerance protection (or DFMR) for functions or capabilities required for elimination of catastrophic hazards as well as providing protection against catastrophic hazardous effects from any LSAM 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.

[CA0890-PO] **Draft** The LSAM shall be single fault tolerant for critical hazards or loss of mission, except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance should be achieved without the use of EVA, 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.

[CA5399-PO] **Draft** 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

[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 crew member is not required to operate the vehicle. There may be circumstances where crewmembers are unconscious or incapacitated leaving only a single crew member capable of vehicle control. Work stations should provide redundant capability from which to command systems and manually operate the vehicle if necessary.

[CA3272-PO] **Draft** 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.

[CA3250-PO] **Draft** 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.

[CA3258-PO] **Draft** 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.

[CA3111-PO] **Draft** 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).

[CA3277-PO] **Draft** The LSAM shall execute 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 CEV). In addition, the verification that the command is intended to be executed on the system will support the multi-hop routing capability.

[CA5440-PO] **Draft** 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.

[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.

3.7.3.2.9 LSAM HEALTH AND STATUS

[CA0431-PO] **Draft** 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.

[CA3115-PO] **Draft** 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.

[CA5469-PO] **Draft** The LSAM shall detect system faults which 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.

[CA5470-PO] **Draft** 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).

[CA5471-PO] **Draft** 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

[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 on-board, when the Ground or Missions systems initiate such reconfiguration actions. Reconfiguration actions may impact procedures, operations time-lines, or on-board 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.

[CA3289-PO] The LSAM shall communicate simultaneously with Mission Systems, and with 2 (TBR-001-129) other Constellation in-space 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 CEV for rendezvous and docking operations and communicate with MS to provide situational awareness and enable ground commanding. LSAM must also communicate with DSS and CEV during lunar ascent and descent for lunar outpost missions. Two (TBR-001-129) systems is based on the driving case of the lunar outpost DRM in which the LSAM will communicate with a CEV 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 CEV design trades. The relative range was determined based on IDAC2, TDS SIG-12-003.

[CA3281-PO] **Draft** The LSAM shall communicate using an independent, dissimilar, voice only system for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: LSAM needs an independent voice communication capability to improve crew safety and mission success. LSAM must be able to communicate with other in space systems as well as with Earth when the prime voice system is unavailable.

[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 Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), 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, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements

Document (IRD). 90% (TBR-001-755) coverage is based on analysis in IDAC2, TDS SIG-13-201.

[CA0517-PO] **Draft** 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 CEV 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.

[CA5054-PO] **Draft** 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 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.

3.7.3.2.11 LSAM GN&C

[CA5278-PO] The LSAM shall provide on-board, 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.

[CA3144-PO] **Draft** 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 is required when LSAM is the controlling vehicle post TLI as well as in LEO prior to CLV launch in order to verify system integrity.

[CA5293-PO] The LSAM shall provide target vehicle interfaces in the LSAM/CaLV EDS mated configuration during RPODU operations with CEV in LEO for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The LSAM provides the docking interface and the relative navigation and relative attitude estimation interfaces such as physical targets and radiometric tracking for RPODU with CEV.

[CA5273-PO] The LSAM 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. 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.

[CA5290-PO] The LSAM shall perform attitude control of the CEV/LSAM mated configuration after separating from the CaLV EDS for Lunar Sortie and Lunar Outpost crew missions.

Rationale: As the CEV/LSAM mated configuration is separating from the CaLV EDS, the LSAM will begin to take control of the CEV/LSAM mated configuration for Trans-Lunar Coast. Since LSAM will control the mated configuration and it has the best view of the departing CaLV EDS, it will perform the active control functions for the mated configuration.

[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 Document. 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 Report, which indicates that using LSAM rather than the CaLV or the CEV for the TCMs balances performance, cost and risk for the Constellation Program.

[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 Document. The CaLV 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 Report, which indicates that using CaLV rather than the LSAM or the CEV for the TLI balances performance, cost and risk for the Constellation Program.

[CA3251-PO] **Draft** The LSAM shall compute rendezvous maneuvers for lunar orbit operations for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: On-board 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 CEV in the event of loss-of-communications with Mission Systems. Additionally this capability is required to return the LSAM to the CEV from an aborted lunar landing.

[CA5285-PO] The LSAM shall perform maneuvering vehicle functions during undocking and departure proximity operations from CEV 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 CEV prior to descent to the lunar surface.

[CA3145-PO] **Draft** The LSAM shall compute maneuvers associated with lunar descent and landing beginning with DOI.

Rationale: LSAM onboard maneuver computations are required for when LSAM onboard navigation knowledge is better than that available on the ground (e.g. maneuvers occurring on the backside of the Moon).

[CA0284-PO] **Draft** 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 exploration 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.

[CA0418-PO] **Draft** 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 exploration 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.

[CA0135-PO] The LSAM shall function as the maneuvering vehicle during RPOD operations with the CEV in LLO prior to crew transfer back to the CEV.

Rationale: Upon return from the lunar surface, the LSAM will dock with the CEV in LLO. The LSAM will be crewed, so it will function as the maneuvering vehicle for RPOD with the uncrewed CEV. 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).

[CA5275-PO] The LSAM shall function as the target vehicle while performing RPOD with CEV in LLO for Lunar Sortie and Lunar Outpost crew missions.

Rationale: For nominal missions the CEV 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 the CEV 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, the CEV performs all or part of RPOD.

[CA5284-PO] The LSAM shall function as the target vehicle during undocking and departure proximity operations from CEV after crew transfer to CEV.

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 the CEV. This requirement conforms to the principle that the crewed vehicle should be in control of the rendezvous and docking process.

3.7.3.2.12 LSAM RELIABILITY AND AVAILABILITY

[CA5532-PO] **Draft** 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/CaLV will be launched at least 1 day prior to the CEV/CLV lunar launch, when applicable. The lunar injection windows are typically four days long and occur every 30 (TBR-001-919) days.

[CA5605-PO] **Draft** The LSAM shall have a launch availability of no less than (TBD-001-064)% per launch attempt, starting at "LCC Call to Station" and ending at close of day-of-launch window.

Rationale: This requirement is a child of CA5600-PO. Part of the decomposition of the probability of launch requirement that assures lunar mission timelines can be met. This requirement addresses CaLV hardware readiness. Hardware readiness and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements.

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.

3.7.3.2.14 LSAM HABITABILITY AND HUMAN FACTORS

[CA5385-PO] **Draft** 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.

[CA0813-PO] **Draft** The LSAM shall provide a habitable environment for a crew of 4 for a minimum of 180 (TBR-001-033) hours during each lunar mission, beginning prior to separation from the CEV 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 CEV. 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 CEV to LSAM crew support systems prior to undocking, etc...)

[CA3165-PO] **Draft** 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 the CEV in lunar rendezvous orbit.

Rationale: Defines the duration for which the LSAM will need to support the crew during ascent prior to docking with the CEV. 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 the CEV, thus, requiring the CEV 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.

[CA0814-PO] **Draft** 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 CEV 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.

[CA3062-PO] **Draft** 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.

[CA3135-PO] **Draft** 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 CEV docking partial pressures to the ppO2 crew limit. This is to have common approach to cabin pressure management across Constellation architecture.

[CA3137-PO] **Draft** 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 CEV 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 CEV.

[CA3107-PO] **Draft** 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-001-106) 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 pre-breathe, 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.

[CA3181-PO] **Draft** The LSAM shall maintain the cabin environment at a pressure to support pre-breathe as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section (TBD-001-962), with an equivalent cabin hole diameter of 0.64 (TBR-001-106) 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 pre-breathe, 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 pre-breathe 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.

3.7.3.2.15 LSAM ENVIRONMENTAL CONDITIONS

[CA5556-PO] **Draft** 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.

[CA5561-PO] **Draft** 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.

[CA0815-PO] **Draft** 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: CEV/LSAM, CEV/LSAM/CaLV-EDS, LSAM/CaLV, and LSAM/CaLV/GS.

3.7.3.3 RESERVED

3.7.3.4 LSAM EXTERNAL INTERFACES

[CA0901-PO] **Draft** 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).

[CA0902-PO] **Draft** 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).

[CA0904-PO] **Draft** The LSAM shall interface with the Communication and Tracking Networks per CxP 70118-03, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), 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 Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 3: Lunar Surface Access Module (LSAM).

[CA0903-PO] **Draft** 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).

[CA0900-PO] **Draft** The LSAM shall interface with the CaLV per CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).

> *Rationale:* The LSAM and CaLV 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).

[CA0432-PO] The LSAM shall interface with the CEV per CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

Rationale: The LSAM and CEV share physical and functional interfaces which are identified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

3.7.3.5 RESERVED

3.7.4 CARGO LAUNCH VEHICLE (CaLV)

3.7.4.1 CaLV DESCRIPTION

The CaLV provides the heavy lift capability for the Constellation Program. The CaLV 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 CLV upper stage). The EDS serves as the CaLV third stage with a role in injecting the LSAM/EDS stack into the LEO staging orbit where the LSAM/EDS and CEV rendezvous and dock. The EDS performs the trans-lunar injection (TLI) burn for the LSAM and CEV after which it is jettisoned.

3.7.4.2 CaLV REQUIREMENTS

[CA3212-PO] **Draft** The CaLV 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 CaLV 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.

[CA3215-PO] **Draft** The CaLV shall launch cargo into a (TBD-001-565) Earth orbit for Mars missions.

Rationale: Defines functional requirement for CaLV 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 CaLV MISSION SUCCESS

[CA5930-PO] **Draft** The CaLV 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.

[CA0487-PO] **Draft** The CaLV 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 CaLV 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.

[CA0486-PO] **Draft** The CaLV 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 CaLV 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.

3.7.4.2.2 CaLV CREW SURVIVAL

[CA5436-PO] **Draft** The CaLV shall automatically determine the need for an abort.

Rationale: In cases where response time constraints impact crew safety risk requirements, the CaLV should be able to automatically determine the need to abort. Abort determination is based on independent sensor information from the CaLV 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.

[CA5160-PO] **Draft** The CaLV shall provide the ground crew unassisted emergency egress during pre-launch activities within 2 (TBR-001-169) minutes.

Rationale: For contingency situations, the ground crew will need the capability to egress the launch pad for safety reasons. This should drive design of egress paths to allow the ground crew to egress without additional ground crew assistance.

3.7.4.2.2.1 CaLV CREW SURVIVAL PROBABILITIES

[CA0485-PO] **Draft** The CaLV 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 CaLV CARGO DELIVERY

[CA0282-PO] **Draft** The CaLV 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 CaLV crewed Lunar missions requirements CA0847-PO/CA0049-PO or the CaLV Lunar Outpost Cargo mission requirement CA0848-PO.

3.7.4.2.5 CaLV MISSION RATES AND DURATIONS

[CA0850-PO] **Draft** The CaLV 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 CaLV EDS, in the LSAM /CaLV 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 CEV. The duration of the loiter is based on the interaction between the CEV 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 CEV/LSAM/CaLV EDS RPOD activities and TLI preparations.

3.7.4.2.6 CaLV ARCHITECTURE DEFINITION

[CA0049-PO] **Draft** The CaLV shall launch LSAM from the launch site to the Earth Rendezvous Orbit (ERO) for Lunar Sortie Crew and Lunar Outpost Crew missions

Rationale: Establishes the CaLV 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 CEV docks with LSAM in the Earth Rendezvous Orbit (ERO). The architecture design solution of launching LSAM on the CaLV separate from the crewed CLV/CEV launch was a result of NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study.

[CA5678-PO] **Draft** The CaLV 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.

[CA3217-PO] **Draft** The CaLV shall provide liftoff clearance between the CaLV 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 CaLV and LSAM access arms, umbilicals and SRM nozzles.

Specific clearance envelopes will be defined in the CaLV/GS and the LSAM/GS IRDs.

[CA0391-HQ] The CaLV shall utilize twin shuttle-derived 5-segment SRBs along with a core stage that employs 5 modified RS-68 engines for first stage propulsion.

Rationale: The CaLV will take advantage of the flight proven propulsion systems components developed for the Space Shuttle and EELV (Evolved Expendable Launch Vehicle). These launch vehicle components, which have supported over 100 Space Shuttle missions and numerous EELV missions, have extensive test/flight experience databases available for CaLV designers to leverage. In addition, CaLV 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 CaLV development effort when compared with developing a new design without flight heritage.

[CA5714-PO] **Draft** The CaLV shall refurbish the reusable elements of the CaLV.

Rationale: Upon arrival back to earth, the first stage RSRM element of the CaLV will be recovered, refurbished and reflown utilizing the same processes of the STS RSRMs.

3.7.4.2.6.1 CaLV CONTROL MASS

[CA0848-PO] **Draft** The CaLV shall deliver at least 54,600 (TBR-001-077) kg (120,272 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 CaLV crewed Lunar missions requirements or the CaLV Mars Cargo mission requirement.

[CA0847-PO] **Draft** The CaLV 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/CEV mated configuration, which is the sum of the Control Masses for the LSAM and the CEV, and a Program Mass Reserve. This Mass Delivered requirement combined with the functional requirement defines the required performance of the CaLV for crewed lunar missions. This requirement may be enveloped by the CaLV Lunar Outpost cargo mission requirement or the CaLV Mars Cargo mission requirement.

3.7.4.2.6.2 CaLV DELTA-V

[CA0051-PO] **Draft** The CaLV 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 CEV 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 CaLV disposal or attitude control.

3.7.4.2.7 CaLV SAFETY

[CA5918-PO] The CaLV 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] The CaLV shall be capable of uninstalling or physically disabling devices fitted to the CaLV 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".

[CA5432-PO] **Draft** The CaLV shall generate an indication upon receipt of each Flight Termination command.

Rationale: This requirement provides for the generation of the CEV 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.

[CA5433-PO] **Draft** The CaLV 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.

[CA0874-PO] **Draft** The CaLV 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.

[CA5403-PO] **Draft** The CaLV 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.

[CA5806-PO] **Draft** The CaLV 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 CaLV 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 CaLV design will therefore provide 2 fault tolerance protection (or DFMR) to catastrophic hazards as well as providing protection against catastrophic hazardous effects from failure of any CaLV 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 CaLV 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.

3.7.4.2.8 CaLV COMMAND AND CONTROL

[CA3276-PO] The CaLV shall execute commands which are addressed to the CaLV.

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

[CA3257-PO] **Draft** The CaLV 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.

[CA3113-PO] The CaLV shall accept control of automation.

Rationale: Other Constellation systems will need to select, initiate, inhibit, override, and terminate automation on the CaLV during various operational phases. Reference NPR 8705.2A, Human-Rating Requirements for Space Systems, section 3.2.7 (34445).

[CA3302-PO] The CaLV 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 the CEV 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.

[CA3292-PO] **Draft** The CaLV 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).

[CA5431-PO] **Draft** The CaLV shall execute authenticated USAF FCO-initiated FTS command signals.

Rationale: For crewed CLV or CaLV 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 CLV or CaLV 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 OK for auto-initiation of FTS events for crewed vehicles.

3.7.4.2.9 CaLV HEALTH AND STATUS

[CA3124-PO] **Draft** The CaLV shall generate Health and Status information.

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

[CA5472-PO] **Draft** The CaLV 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.

[CA5473-PO] **Draft** The CaLV 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)D. 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).

[CA5474-PO] **Draft** The CaLV 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 CaLV COMMUNICATIONS AND COMMUNICATIONS SECURITY

[CA5911-PO] **Draft** The CaLV shall be able to communicate simultaneously with the LSAM, Mission Systems, and Ground Systems.

Rationale: Simultaneous communications is required so that the CaLV can communicate with both the LSAM via hardline and Ground Systems before launch. Before launch, Mission Systems will be receiving CaLV and LSAM data as well but it will be via Ground Systems. After launch, the CaLV 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.

[CA5044-PO] **Draft** The CaLV 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 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.

3.7.4.2.11 CaLV GN&C

[CA3146-PO] **Draft** The CaLV 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.

[CA3216-PO] **Draft** The CaLV 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 CaLV maneuvering capability and mission timelines. A large error at injection cutoff might be acceptable if there were sufficient delta-V budget in the CaLV.

[CA3225-PO] **Draft** The CaLV 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/CEV. 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.

[CA3186-PO] **Draft** The CaLV 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/CEV 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.

[CA3224-PO] **Draft** The CaLV 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.

[CA0128-PO] **Draft** The CaLV EDS shall perform attitude control of the LSAM/CaLV EDS mated configuration prior to CEV docking for Lunar Sortie and Lunar Outpost crew missions.

Rationale: The CaLV 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 CaLV EDS/LSAM Operation in LEO in CxP 70007, Constellation Design Reference Missions and Operational

Concepts Document. CaLV EDS controls the LSAM/CaLV EDS mated configuration as the target during RPOD with CEV.

[CA5292-PO] The CaLV EDS shall perform target vehicle control in the LSAM/CaLV EDS mated configuration during RPODU operations with CEV in LEO.

Rationale: The CaLV EDS is performing guidance, navigation, and control for the LSAM/CaLV EDS mated configuration, so it is natural that it would perform the target vehicle control during RPODU with CEV in ERO. The undocking portion of this requirement protects for the case of CEV undocking from LSAM/CaLV EDS due to an abort of the nominal mission.

[CA0129-PO] The CaLV 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 Document. The CaLV 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 Report, which indicates that using CaLV EDS rather than the LSAM or the CEV for the TLI balances performance, cost and risk for the Constellation Program.

[CA0183-PO] The CaLV EDS shall perform attitude control of the LSAM/CaLV EDS/CEV mated configuration for Lunar Sortie Crew and Lunar Outpost Crew missions.

Rationale: CaLV 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 CaLV EDS undocking from the CEV/LSAM.

3.7.4.2.12 CaLV RELIABILITY AND AVAILABILITY

[CA0413-PO] **Draft** The CaLV shall have a launch availability of no less than (TBD-001-064) per launch attempt, starting at "LCC Call to Station" and ending at close of day-of-launch window.

Rationale: Part of the decomposition of the probability of launch requirement that assures lunar mission timelines can be met. This requirement addresses CaLV hardware readiness. Hardware readiness and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements.

[CA0414-PO] **Draft** The CaLV shall have a launch availability of no less than (TBD-001-002) per launch attempt due to natural environments, starting at "LCC Call to Station" and ending at close of day-of-launch window.

Rationale: Part of the decomposition of the probability of launch requirement that assures lunar mission timelines can be met. This requirement addresses CaLV capability to meet minimal weather constraints. Hardware readiness and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements.

[CA5533-PO] The CaLV/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 CaLV will be launched at least 1 day prior to the CEV lunar launch, when applicable. The lunar injection windows are typically four days long and occur every 30 (TBR-001-919) days.

[CA5259-PO] **Draft** The CaLV 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.

[CA5265-PO] **Draft** The CaLV 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.

3.7.4.2.13 CaLV MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[CA5804-PO] **Draft** The CaLV shall be refurbished by Ground Systems.

Rationale: Upon arrival back to earth, the first stage SRB element of the CaLV will be recovered, refurbished and reflown utilizing the same processes of the STS SRBs.

3.7.4.2.14 RESERVED

3.7.4.2.15 CaLV ENVIRONMENTAL CONDITIONS

[CA5355-PO] **Draft** The CaLV 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 CaLV 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 CaLV integrated vehicle configurations: CaLV/LSAM/GS, CaLV/LSAM, and CaLV/LSAM/CEV.

[CA5558-PO] **Draft** The CaLV 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.

[CA5563-PO] **Draft** The CaLV 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 CaLV EXTERNAL INTERFACES

[CA0908-PO] **Draft** The CaLV shall interface with Mission Systems per CxP 70112, Constellation Program Cargo Launch Vehicle (CaLV) to Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: The CaLV and MS 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).

[CA0907-PO] **Draft** The CaLV shall interface with Ground Systems per CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) to Ground Systems Interface Requirements Document (IRD)

Rationale: The CaLV and GS share physical and functional interfaces which are identified in CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) to Ground Systems Interface Requirements Document (IRD).

[CA0905-PO] **Draft** The CaLV shall interface with the CEV per CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).

Rationale: The CaLV and CEV share physical and functional interfaces which are identified in CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).

[CA0909-PO] **Draft** The CaLV shall interface with the Communication and Tracking Networks per CxP 70118-04, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 4: Cargo Launch Vehicle (CaLV).

Rationale: The CaLV and C&TN share physical and functional interfaces which are identified in CxP 70118-04, Constellation Program Systems to Communication and

Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 4: Cargo Launch Vehicle (CaLV).

[CA0906-PO] **Draft** The CaLV shall interface with the LSAM per CxP 70109, Constellation Program Lunar Surface Access Module (LSAM) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).

Rationale: The CaLV and LSAM 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).

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 the CEV, CLV, CaLV, LSAM, and cargo, post-landing, recovery and deintegration services for the CEV CM, and cargo including search and rescue and supports CEV refurbishment and maintenance, if required. Ground Systems also provides post-landing and recovery services for the CLV 1st stage and CaLV SRBs. Ground Systems includes 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 Services" for examples).

[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 CEV 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 CLV first stage and CaLV boosters.

[CA0858-PO] Ground Systems shall provide ground-based imagery of flight vehicles during launch operations, ascent, descent, and landing.

Rationale: During critical mission phases (launch operations, ascent, descent, and landing) 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.

[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 in-space 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 an in-space flight vehicle (e.g. CEV/LSAM).

[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 fight systems/vehicles (e.g. CEV and LSAM)

[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 CEV Crew Module in the event CEV Crew Module lands at a site other than a designated landing site.

Rationale: In the event that the CEV 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 CEV Crew Module.

3.7.5.2.1 GS MISSION SUCCESS

[CA0860-PO] Ground Systems shall limit their contribution to the risk of Loss of Mission (LOM) for ISS missions to no greater than 1 in (TBD-001-094).

Rationale: The 1 in (TBD-001-094) means a (TBD-001-094) (or (TBD-001-094)%) probability of LOM due to the Ground Systems during any ISS 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.

[CA3028-PO] **Draft** Ground 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-001-530).

Rationale: The 1 in (TBD-001-530) means a (TBD-001-530) (or TBD-001-530 %) probability of LOM due to the Ground 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.

The risk of loss of mission (LOM), induced by Ground Operations, entails the probability that the ground system or process will cause an event on the pad making the vehicle unusable for the intended mission. This includes a delay in launch of the manned portion of the lunar mission which results in a failure of the EDS/LSAM in orbit. Mission delays are not included if the original vehicles intended for the mission are still usable.

[CA3029-PO] Ground Systems shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Crewed mission to no greater than 1 in (TBD-001-533).

Rationale: The 1 in (TBD-001-533) means a (TBD-001-533) (or (TBD-001-533)%) probability of LOM due to the Ground Systems during any Lunar 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.

3.7.5.2.2 GS CREW SURVIVAL

[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 crew member exits the CEV and ending when the last crew member 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.

[CA3033-PO] Ground Systems shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Crewed mission to no greater than 1 in (TBD-001-546).

Rationale: The 1 in (TBD-001-546) means a (TBD-001-546) (or (TBD-001-546)%) probability of LOC due to the Ground Systems during any Lunar 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.

[CA3031-PO] Ground Systems shall limit their contribution to the risk of loss of crew (LOC) for an ISS Crew mission to no greater than 1 in (TBD-001-539).

Rationale: The 1 in (TBD-001-539) means a (TBD-001-539) (or (TBD-001-539)%) probability of LOC due to the Ground Systems during any ISS 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.

[CA0151-PO] Ground Systems shall provide safe haven for a maximum of 14 (TBR-001-261) 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.

[CA0337-PO] Ground Systems shall provide a maximum of 12 (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.

[CA0146-PO] Ground Systems shall locate and rescue the flight crew in the event CEV 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; (1) In the event of launch abort (after lift-off and prior to earth orbit insertion), (2) In the event of an early return (after Earth orbit insertion), (3) 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.

[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.

[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% (12hrs) =36hrs) to ensure crew survivability in the event of delays in real-time recovery operations. The CEV Crew Module provides for 36 hours of post-landing life support to the crew (CA0194-PO).

[CA5408-PO] Ground Systems shall provide two fault tolerance to catastrophic hazards, 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: Ground Systems shall be designed such that no two faults will have the effect of causing a catastrophic hazard leading to the permanent disability or loss of crew. The Ground Systems design will therefore provide 2 fault tolerance protection (or DFMR) for functions or capabilities required for elimination of catastrophic hazards as well as providing protection against catastrophic hazardous effects from any Ground Systems element or component regardless if the element or component is necessary for crew survival or mission success. The Constellation Program will define levels of fault tolerance that are satisfied by multiple systems and the allocations to those systems.

[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.

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 CLV no later than 1 (TBR-001-020) day after the launch of the CaLV.

Rationale: Lunar missions involve the simultaneous operations of two flight vehicles. With a 1 (TBR-0001-020) day interval, the Ground System must be able to support pre-launch and launch operations immediately following the launch of the CaLV.

[CA5690-PO] Ground Systems shall provide a daily launch opportunity for not less than 4 (TBR-001-193) consecutive days for CLV missions.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. 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 four days without servicing.

[CA5702-PO] Ground Systems shall provide a daily launch opportunity for not less than 4 (TBR-001-193) consecutive days for CaLV missions.

Rationale: If initial launch attempt is scrubbed for weather, hardware, or other issues, additional launch attempt opportunities are needed. 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 four days without servicing.

3.7.5.2.6 GS ARCHITECTURE DEFINITION

[CA0444-PO] Ground Systems shall provide Earth weather services for pre-launch, launch, SRB recovery and CEV CM pad abort recovery activities.

Rationale: Where there is a gap between Constellation Architecture needs and available earth weather capabilities, the Ground Systems shall generate the necessary data for pre-launch and launch activities. This includes acquisition (via Ground Systems Earth-based assets) of weather data, the acquisition of weather data from non-Ground Systems external sources, and the necessary processing of that data for use by the Constellation Architecture.

[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.

[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

[CA0855-PO] Ground Systems shall refurbish the CLV SRB reusable elements.

Rationale: Upon arrival back to earth, the first stage SRB element of the CLV will be recovered, refurbished and reflown utilizing the same processes of the STS SRBs.

[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 CEV Crew Module. This requirement also covers the systems and GSE needed to disassemble the CLV first stage and CaLV boosters in preparation for transport to a refurbishment facility.

[CA5712-PO] Ground Systems shall refurbish the CaLV SRB reusable elements.

Rationale: Upon arrival back to earth, the first stage SRB element of the CaLV will be recovered, refurbished and reflown utilizing the same processes of the STS SRBs.

3.7.5.2.7 GS SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA5406-PO] Ground Systems shall be single fault tolerant for critical hazards and loss of missions, except for areas approved to use Design for Minimum Risk Criteria.

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.

3.7.5.2.8 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 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 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 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 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

[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 six other Constellation flight systems.

Rationale: Simultaneous communications is required so that Ground System can communicate with a CEV and CLV on the launch pad and during launch and ascent, while communicating with Mission Systems. Lunar missions will also require Ground Systems to be able to communicate with a LSAM and CaLV / EDS at the launch pad, and during launch and ascent, while a CEV and CLV is being prepared for launch. Finally Ground Systems may have to support integration and testing of two other Constellation flight systems (an example might be supporting the integration of a CLV for an upcoming ISS mission) at the same time.

[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 on-board 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.

3.7.5.2.11 RESERVED

3.7.5.2.12 GS RELIABILITY AND AVAILABILITY

[CA3064-PO] Ground Systems shall have a launch availability of no less than (TBD-001-041)% per crew launch attempt, starting at "LCC Call to Station" and ending at close of day of launch window.

Rationale: Part of the decomposition of the probability of launch requirement that assures lunar mission timelines can be met. This requirement addresses Ground Operations hardware readiness. Hardware readiness and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements.

3.7.5.2.13 GS MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[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.

[CA5803-PO] Ground Systems shall refurbish the reusable elements of the CLV.

Rationale: Upon arrival back to earth, the first stage SRB element of the CLV will be recovered, refurbished and reflown utilizing the same processes of the STS SRBs.

3.7.5.2.14 RESERVED

3.7.5.2.15 GS ENVIRONMENTAL CONDITIONS

[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.

[CA3018-PO] Ground Systems shall prevent 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), Paragraphs 3.1.11, 3.2.12.

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 CEV 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.

3.7.5.3 RESERVED

3.7.5.4 GS EXTERNAL INTERFACES

[CA0910-PO] Ground Systems shall interface with the CEV per CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).

Rationale: Ground Systems and CEV share physical and functional interfaces which are identified in CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).

[CA0911-PO] Ground Systems shall interface with the CLV per CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD).

Rationale: Ground Systems and CLV share physical and functional interfaces which are identified in CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems 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).

[CA0913-PO] **Draft** Ground Systems shall interface with CaLV per CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) to Ground Systems Interface Requirements Document (IRD).

Rationale: Ground Systems and CaLV share physical and functional interfaces which are identified in CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) 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 (EVA) Systems to Ground Systems (GS) 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 (EVA) Systems to Ground Systems (GS) Interface Requirements Document (IRD).

[CA0916-PO] Ground Systems shall interface with the Communication and Tracking Networks per CxP 70118, CxP to Communication and Tracking Networks Interface Requirements Document

Rationale: The Ground Systems and C&TN share physical and functional interfaces which are identified in CxP 70118, CxP to Communication and Tracking Networks Interface Requirements Document.

3.7.5.5 RESERVED

3.7.6 MISSION SYSTEMS (MS)

3.7.6.1 MS DESCRIPTION

Mission Systems includes the Mission Control Center in Houston 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

[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).

[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.

[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).

[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.

3.7.6.2.1 MS MISSION SUCCESS

[CA3026-PO] Mission Systems shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Sortie Crew mission to no greater than 1 in (TBD-001-524).

> *Rationale:* The 1 in (TBD-001-524) means a (TBD-001-524) (or (TBD-001-524)%) probability of LOM due to Mission Systems during any Lunar Sortie 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.

[CA3030-PO] **Draft** 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.

[CA3027-PO] **Draft** 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.

[CA3025-PO] Mission Systems shall limit their contribution to risk of loss of mission (LOM) for an ISS Crew mission to no greater than 1 in (TBD-001-521).

Rationale: The 1 in (TBD-001-521) means a (TBD-001-521) (or (TBD-001-521)%) probability of LOM due to Mission Systems during any ISS 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.

[CA3024-PO] Mission Systems shall limit their contribution to the risk of loss of mission (LOM) for an ISS Cargo mission to no greater than 1 in (TBD-001-518).

Rationale: The 1 in (TBD-001-518) means a (TBD-001-518) (or (TBD-001-518)%) probability of LOM due to the Mission Systems during any ISS 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.

3.7.6.2.2 MS CREW SURVIVAL

[CA3034-PO] Mission Systems shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Sortie mission to no greater than 1 in (TBD-001-549).

Rationale: The 1 in (TBD-001-549) means a (TBD-001-549) (or (TBD-001-549)%) probability of LOC due to Mission Systems during any Lunar Sortie 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.

[CA3035-PO] **Draft** 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.

[CA3032-PO] Mission Systems shall limit their contribution to the risk of loss of crew (LOC) for an ISS Crew mission to no greater than 1 in (TBD-001-543).

Rationale: The 1 in (TBD-001-543) means a (TBD-001-543) (or (TBD-001-543)%) probability of LOC due to Mission Systems during any ISS 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.

[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.

[CA0163-PO] Mission Systems shall provide updates to the predicted landing footprint to recovery forces within 20 (TBR-001-981) 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.

3.7.6.2.3 MS CREW SIZE

[CA5128-PO] Mission Systems shall provide training of 4 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 6 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 DURATIONS

[CA5524-PO] Mission Systems shall provide the capacity to operate the missions as defined in the Systems Flight Rates table for ISS and human exploration programs.

Rationale: The Mission System 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 Systems Flight Rate table is located in Section

3.2.5 of this document associated with CA0036-HQ. The flight rates in the table reflect the expected nominal flight rate plus a surge capacity accounted for by the maximum flight rate in conjunction with the minimum interval. Budgets will determine opportunities for flight rate surges. The nominal rate is intended to be applied to variable resources; however, in order to preserve the ability to add a flight when budgets permit, long lead or fixed resources should apply the maximum rate. The following assumptions are incorporated into the flight rate plan: 1. Intervals are measured from launch to launch of each system. 2. ISS crew rotations and lunar missions may be conducted concurrently. 3. Lunar Sortie and Lunar Outpost missions may be conducted concurrently. 4. There will not be more than one vehicle launching or landing per day.

3.7.6.2.6 MS ARCHITECTURE DEFINITION

[CA5900-PO] Mission Systems shall provide the reconfiguration system for data and flight software.

Rationale: Successful Constellation mission preparation and execution requires system flight software and data that are arranged and formatted into specific configurations applicable to mission activities. Given the configuration management and operational assignment services will be provided by Mission Systems, the operational configurations of these flight software and data should be made available by Mission Systems in order to ensure validity and consistency for operational needs during mission preparation and execution.

[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 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

[CA5407-PO] Mission Systems shall provide two fault tolerance to catastrophic hazards, 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: Mission Systems shall be designed such that no two faults will have the effect of causing a catastrophic hazard leading to the permanent disability or loss of crew. Mission Systems design will therefore provide 2 fault tolerance protection (or DFMR) for functions or capabilities required for elimination of catastrophic hazards as well as providing protection against catastrophic hazardous effects from any Mission Systems element or component regardless if the element or component is necessary for crew survival or mission success. The Constellation Program will define levels of fault tolerance that are satisfied by multiple systems and the allocations to those systems.

[CA5405-PO] Mission Systems shall be single fault tolerant for critical hazards and 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.

3.7.6.2.8 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.

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 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

[CA3285-PO] Mission Systems shall concurrently monitor and control at least 3 (TBR-001-222) active and 3 (TBR-001-245) quiescent vehicles operating in-space.

Rationale: Multiple CEV 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 CEVs in quiescent mode, CaLV/EDS/Crew LSAM/CEV, 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 in-space vehicles 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.

[CA5903-PO] Mission Systems shall generate reconfigurable automated sequences.

Rationale: Reconfigurable automated sequences need to be uplinked to CEV and LSAM for future onboard execution. They may be uplinked to EDS as well.

[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 ICDs.

[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.

[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 on-board 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.

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.

[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 launch availability of no less than (TBD-001-021)% per crew launch attempt, starting at 24 hours prior to launch and ending at close of day of launch window.

Rationale: Part of the decomposition of the probability of launch requirement that assures lunar mission timelines can be met. This requirement addresses MCC hardware readiness. Hardware readiness and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements.

[CA5135-PO] Mission Systems shall provide for operations of crewed missions no later than 1 (TBR-001-020) day after the launch of the CaLV.

Rationale: Lunar missions involve the simultaneous operations of two flight vehicles. With a 1 (TBR-0001-020) day interval, the Mission System must be able to support pre-launch and launch operations immediately following the launch of the CaLV.

3.7.6.2.13 MS MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[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).

[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 Crew Exploration Vehicle - 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 prelaunch packing within vehicle constraints. Mission Systems will be responsible for planning the transfer of hardware from the CEV 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 CEV 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).

[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 Crew Exploration Vehicle - 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 the CEV 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 CEV 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).

3.7.6.2.14 RESERVED

3.7.6.2.15 RESERVED

3.7.6.3 RESERVED

3.7.6.4 MS EXTERNAL INTERFACES

[CA0920-PO] Mission Systems shall interface with CaLV per CxP 70112, Constellation Program Cargo Launch Vehicle (CaLV) to Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: Mission Systems and CaLV 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).

[CA0922-PO] Mission Systems shall interface with the Communication and Tracking Networks per CxP 70118, Constellation Program Systems to Communication and

Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 6: Mission Systems (MS).

Rationale: Mission Systems and Communication and Tracking Networks share physical and functional interfaces which are identified in CxP 70118, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 6: Mission Systems (MS).

[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).

[CA0918-PO] Mission Systems shall interface with the CLV per CxP 70053, Constellation Program Crew Launch Vehicle (CLV) to Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: Mission Systems and CLV share functional interfaces which are identified in CxP 70053, Constellation Program Crew Launch Vehicle (CLV) to Mission Systems (MS) Interface Requirements Document (IRD).

[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).

[CA0917-PO] Mission Systems shall interface with the CEV per CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD).

Rationale: Mission Systems and CEV share physical and functional interfaces which are identified in CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD).

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

[CA0862-PO] **Draft** 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

[CA0863-PO] **Draft** 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

[CA3290-PO] **Draft** DAV shall communicate simultaneously with Mission Systems and with 3 (TBR-001-136) other Constellation in-space systems that are within 800 (TBR-001-165) km (432 nmi) of DAV.

Rationale: Simultaneous communication is required between systems on the lunar surface during lunar outpost operations. DAV must communicate with systems on the surface, in lunar orbit, and with MS. Three (TBR-001-136) systems is based on the lunar outpost DRM case in which the outpost will communicate with a CEV in LLO, an LSAM and a lunar surface rover. The number of simultaneous systems is determined by analysis of Constellation FFBDs and DRMs.

[CA3282-PO] **Draft** 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 other in space systems as well as with Earth when the prime voice system is unavailable.

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 EXTRA VEHICULAR ACTIVITIES (EVA) SYSTEMS

3.7.9.1 EVA SYSTEMS DESCRIPTION

EVA Systems 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. EVA Systems 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 (e.g. integral to the pressure suit), and ground support systems.

3.7.9.2 EVA SYSTEMS REQUIREMENTS

[CA4127-PO] EVA Systems shall perform at least 2 (TBR-001-163) in-space EVA operations of at least 4 (TBR-001-223) hours duration on Lunar missions.

Rationale: In keeping with Constellation Program Need, Goals and Objectives, EVA Systems needs to provide an in-space 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 EVA Systems needs to provide an in-space EVA capability using the CEV 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) in space 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 CEV. Four (TBR-001-223) hours is anticipated to be the longest duration in space EVA and is consistent with the crew transfer.

3.7.9.2.1 EVA SYSTEMS MISSION SUCCESS

[CA5946-PO] EVA Systems shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Sortie Mission to no greater than 1 in (TBD-001-1048).

Rationale: The 1 in (TBD-001-1048) means a (TBD-001-1048) (or (TBD-001-1048)%) probability of LOM due to EVA Systems 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 SYSTEMS CREW SURVIVAL

[CA3003-PO] EVA Systems shall sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 120 (TBR-001-1006) hours while receiving consumables from the vehicle.

Rationale: In order to return the crew without permanent disability, the life of the crewmember needs to be sustained. The maximum duration for the CEV to return to Earth from any point in a lunar mission is 120 (TBR-001-1006) hours. The worst case would be sustaining the crew for the full time in their suits. For ISS missions, the amount of time needed to return the crew is assumed to be much less. EVA System represents the most straightforward solution to crew survival in this contingency situation.

[CA5170-PO] EVA System shall provide for the suited crew to perform an unassisted emergency egress from the CEV upon landing within (TBD-001-146) minutes starting from when the decision to egress the CEV 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 design of seat restraints, spacecraft aids, and space suit mobility components.

[CA5203-PO] EVA Systems 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 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.

[CA5169-PO] EVA Systems 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 crew member exiting the CEV to the last crew member 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 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.

3.7.9.2.2.1 EVA SYSTEMS CREW SURVIVAL PROBABILITIES

[CA5945-PO] EVA Systems shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Sortie Mission to no greater than 1 in (TBD-001-1047).

Rationale: The 1 in (TBD-001-1047) means a (TBD-001-1047) (or (TBD-001-1047)%) probability of LOC due to EVA Systems 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 RESERVED

3.7.9.2.6 RESERVED

3.7.9.2.7 EVA SYSTEMS SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA5410-PO] EVA Systems shall provide two fault tolerance to catastrophic hazards except for areas approved for Design for Minimum Risk. The fault tolerance must be achieved without the use of emergency operations or emergency systems.

Rationale: EVA Systems shall be designed such that no two faults will have the effect of causing a catastrophic hazard leading to the permanent disability or loss of the Crew. EVA Systems design will therefore provide 2 fault tolerance protection (or DFMR) for functions or capabilities required for elimination of catastrophic hazards as well as providing protection against catastrophic hazardous effects from any EVA system or component regardless if the system or component is necessary for crew survival or mission success. The Constellation Program will define levels of fault tolerance that are satisfied by multiple systems and the allocations to those systems.

[CA5409-PO] EVA Systems shall be single fault tolerant for critical hazards and loss of mission except for areas approved for Design for Minimum Risk. 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.

[CA5400-PO] EVA Systems 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.

3.7.9.2.8 RESERVED

3.7.9.2.9 EVA SYSTEMS HEALTH AND STATUS

[CA3121-PO] EVA Systems shall generate Health and Status information.

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

[CA3122-PO] EVA Systems shall provide Health and Status information to the crew.

Rationale: Provides for processing of H&S information on internal operations of the EVA for use by the EVA crew.

[CA5467-PO] EVA Systems shall detect system faults which 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, Extravehicular Activity (EVA) Systems 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] EVA 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). Faults subject to isolation are further specified by CxP 72002, Extravehicular Activity (EVA) Systems 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).

[CA4125-PO] EVA 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. Faults subject to recovery are further specified by the EVA Systems 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 SYSTEMS COMMUNICATIONS AND COMMUNICATIONS SECURITY

[CA5909-PO] EVA Systems shall communicate simultaneously with four (TBR-001-556) Constellation Systems during a Lunar Sortie mission.

Rationale: Simultaneous communications is required so that a crew member on EVA can communicate with up to three other crew members on EVA and Mission Systems simultaneously. By specifying four Constellation systems, this also covers the case where an EVA crew member needs to be able to communicate with another EVA crew member, the LSAM, and Mission Systems simultaneously; this covers the case where a crew member may be in the LSAM. The TBR will be resolved by working with APO to develop a lunar communications architecture based on a lunar surface concept of operations.

[CA5910-PO] EVA Systems shall communicate simultaneously with six (TBR-001-557) Constellation Systems during a Lunar Outpost mission.

Rationale: Simultaneous communications is required so that a crew member on EVA can communicate with other crew members 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.

[CA5046-PO] **Draft** EVA Systems shall provide (TBD-001-221) bytes 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. 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. EVA 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 Systems SRD.

[CA5047-PO] **Draft** EVA Systems 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.

[CA3283-PO] EVA Systems shall communicate using an independent, dissimilar, voice only system.

Rationale: EVA Systems needs an independent voice communication capability to improve crew safety and mission success. EVA Systems must have a secondary, "back up" ability to communicate with CEV, LSAM, and DSS, both in-space and on the lunar surface when the prime voice system is unavailable.

3.7.9.2.11 RESERVED

3.7.9.2.12 EVA SYSTEMS RELIABILITY AND AVAILABILITY

[CA3063-PO] EVA Systems shall have a launch availability of no less than (TBD-001-562)% per crew launch attempt, starting at "LCC Call to Station" and ending at close of day of launch window.

Rationale: This requirement addresses EVA Systems hardware readiness. Part of the decomposition of the hardware probability of launch requirement that assures lunar mission timelines can be met. This requirement addresses EVA Systems hardware readiness. Hardware readiness and the design to minimize weather related launch constraints are technically very different activities, thus the separation of the requirements.

3.7.9.2.13 EVA SYSTEMS MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[CA5184-PO] EVA Systems 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 vs. 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. EVA Systems should be designed to allow for the capability for change out and repair of on-orbit replaceable units.

[CA5182-PO] EVA Systems flight hardware shall not require preventive maintenance or repair during a single ISS mission.

Rationale: This requirement addresses the desire to design EVA 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.

3.7.9.2.14 EVA SYSTEMS HABITABILITY AND HUMAN FACTORS

[CA5168-PO] EVA Systems shall provide for unassisted donning and doffing of space suit systems.

Rationale: Unassisted donn/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.

[CA3058-PO] EVA Systems shall provide spacesuits that can be donned by the full crew in 1 (TBR-001-113) hour.

Rationale: The full crew must get into their suits while the vehicle ECLSS system feeds the leak. The 1 hour is the current ECLSS time requirement to feed the leak. The TBR is associated with the exact time requirement for the EVA System to don the spacesuits, as time will also be dictated by the time to retrieve the suits, prebreathe time required once the crew has donned their suits (to prevent DCS once the cabin and suit pressure have dropped after the 1 hour time has elapsed), and the suit donning sequence used. It may be more appropriate given the limited CEV volume space available, that suit retrieval and donning will be performed by sets of crewmembers rather than the entire compliment of crewmembers simultaneously. Given these factors, the suit donning time requirement for the EVA System spacesuit will likely be shorter than 1 hour.

[CA5659-PO] EVA Systems 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 EMU and is the pressure recommended in the Explorations Atmospheres Working Group. Definition of this pressure is required to define what the CEV 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 SYSTEMS ENVIRONMENTAL CONDITIONS

[CA5188-PO] EVA Systems 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: CEV/LSAM/EVA, CEV/EVA, and LSAM/EVA.

[CA5559-PO] EVA Systems 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] EVA Systems 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 SYSTEMS EXTERNAL INTERFACES

[CA0924-PO] EVA Systems shall interface with the LSAM per CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) to Extravehicular Activity (EVA) Interface Requirements Document (IRD).

Rationale: The CEV 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).

[CA0925-PO] EVA Systems shall interface with GS per CxP 70104, Constellation Program Extravehicular Activity (EVA) Systems to Ground Systems (GS) Interface Requirements Document (IRD).

Rationale: EVA Systems and Ground Systems share physical and functional interfaces which are identified in CxP 70104, Constellation Program Extravehicular Activity (EVA) Systems to Ground Systems (GS) Interface Requirements Document (IRD).

[CA0923-PO] EVA Systems shall interface with the CEV per CxP 70033, Constellation Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document.

Rationale: EVA Systems and CEV share physical and functional interfaces which are identified in the CxP 70033, Constellation Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document.

3.7.9.5 RESERVED

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. Analysis- 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.

D. Demonstration – Verification by demonstration is a qualitative exhibition of functional performance (i.e., serviceability, accessibility, transportability and human engineering features) usually accomplished with no or minimal instrumentation.

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.

I. Inspection – 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:

a. Construction

b. Workmanship

c. Physical condition

d. 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 CLV shall use a J2X engine).

Inspection also may be used to determine closure status of verification activities being performed at Level 3 to support closures at Level 2 when the data is not analyzed at Level 2, 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 Environmental Qualification and Acceptance Testing requirements (CEQATR) Document.

-or- Mandatory qualification tests are as specified in CxP 70036, Constellation Environmental Qualification and Acceptance Testing requirements (CEQATR) Document.

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.

[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.

[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.

[CA0014V-HQ] **Draft** The capability to establish a Lunar Outpost located within 5 degrees of the lunar South Pole (TBR-001-009) shall be verified by analysis. The analysis shall review the Constellation Architecture lunar crew and cargo delivery capacity and site selection criteria in (TBD-001-009) NASA HQ controlled document. The analysis shall be considered successful when it shows that crew and cargo delivery capability is sufficient for the establishment of a Lunar Outpost at the selected location and the location meets the selection criteria.

Rationale: This is an overarching verification requirement that can be satisfied once the flow-down requirements to the elements are satisfied.

[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 resources 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.

[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.

[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:

Ability for the crew to depress (external and internal to vehicle) and repress the lunar surface vehicle cabin (internal to vehicle).

Compliance to EVA specifications per CxP 70130, Constellation Program Extravehicular Activity (EVA) Design and Construction Specification, section (TBD-001-703).

Provide consumables to support full complement of EVA crewmembers.

Egress and ingress paths with pressure suits to and from the lunar surface vehicle.

Communication (voice, suit and biomed data).

The demonstration shall consist of the following:

Walk back tests subjected to the appropriate mission profile.

Interface tests with appropriate mockups and simulators.

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 perform 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.

[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.

[CA0889V-PO] **Draft** 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.

[CA0011V-HQ] **Draft** 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 resources 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.

[CA0404V-PO] **Draft** (TBD-001-1031)

Rationale: (TBD-001-1031)

[CA0074V-PO] **Draft** (TBD-001-1032)

Rationale: (TBD-001-1032)

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 a (TBR-001-951) probability that LOM for a Lunar Sortie is no greater than 1 in 20 (TBR-001-007).

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 a (TBD-001-920) probability that LOM for a Lunar Outpost Crew is no greater than 1 in (TBD-001-034).

Rationale: NR

[CA3038V-HQ] **Draft** 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 a (TBD-001-925) probability that LOM for a Lunar Outpost Cargo mission is not greater than 1 in (TBD-001-058).

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 a (TBR-001-900) probability that LOM for ISS Crew mission is no greater than 1 in 200 (TBR-001-017).

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 a (TBD-001-922) probability that LOM for an ISS Cargo Mission is no greater than 1 in 200 (TBR-001-967).

Rationale: NR

[CA3039V-HQ] **Draft** 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 a (TBD-001-923) probability that LOM for a Mars mission is not greater than 1 in (TBD-001-050).

Rationale: NR

4.2.2 CREW SURVIVAL

[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

[CA0028V-PO] The ability of the Constellation Systems to return the crew to the Earth 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.

[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, System Requirements for the Crew Exploration Vehicle (CEV) Element and review of CxP 72002, Extravehicular Activity (EVA) Systems Requirements Document (SRD) and CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD), CxP 70117, Constellation Program System Requirements for the Missions Systems (MS) Element, and CxP 72006, Ground Systems Requirements Document (SRD). The verification shall be considered successful when the inspection shows that CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD), CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element, CxP 72002, Extravehicular Activity (EVA) Systems Requirements Document (SRD), CxP 70117, Constellation Program System Requirements for the Missions Systems (MS) Element, and CxP 72006, Ground Systems Requirements Document (SRD) requirements are closed.

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 Requirements Document (SRD), CxP (TBD-001-1068), Ground Systems Land Landing and Recovery SSRD, CxP (TBD-001-1069) Ground Systems Water Landing and Recovery SSRD 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, System Requirements for the Crew Exploration Vehicle (CEV) Element for closure of crew survival capability for contingency landing to meet SAR time constraints. The analysis shall consist of status review of allocated requirements (CEV provide visual aids, CEV provide comm. With MS for 36 hr, GS rescue the crew within 24 hr, GS recover CEV CM other than at designated landing site, GS perform SAR, and GS perform 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, System Requirements for the Crew Exploration Vehicle (CEV) Element, CxP 72006, Ground Systems Requirements Document (SRD) CxP (TBD-001-1068), Ground Systems Land Landing and Recovery SSRD, and CxP (TBD-001-1069) Ground Systems Water Landing and Recovery SSRD 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

4.2.2.1 CREW SURVIVAL PROBABILITIES

[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 a (TBD-001-946) probability that LOC for an ISS Crew Mission is no greater than 1 in 10 (TBR-001-959).

Rationale: NR

[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 (a (TBD-001-1021) probability) that LOC for a Lunar Sortie is no greater than 1 in 100 (TBR-001-014).

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 a (TBD-001-921) probability that LOC for a Lunar Outpost Crew mission is no greater than 1 in (TBD-001-036).

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 a (TBR-001-905) probability that LOC for an ISS Crew Mission is no greater than 1 in 1000 (TBR-001-015).

Rationale: NR

[CA3037V-HQ] **Draft** 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 a (TBD-001-924) probability that LOC for a Mars mission is not greater than 1 in (TBD-001-054).

Rationale: NR

4.2.2.2 EMERGENCY EGRESS, ABORTS, AND EARLY RETURN FOR SURVIVABILITY

[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 crew members and collecting the task time for crew egress from the CEV 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] Ground crew capability for unassisted emergency egress to a safe haven during pre-launch 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 ground crew members and collecting the task time for ground crew egress from the CEV 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 determines that 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

[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.

[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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[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, CA3199-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.

[CA0352V-HQ] The ability of the Constellation architecture to return the crew within 130 (TBR- 001-005) 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 CEV 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 130 (TBR- 001-005) hours. The analysis shall be considered successful when the consolidated timeline is no greater than 130 (TBR-001-005) 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.

4.2.3 CREW SIZE

[CA0203V-HQ] The capability to deliver crew sizes ranging from 2 to 4 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

[CA0020V-HQ] The Constellation Architecture ability to provide for at least 4 (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 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 Outpost provides a habitable environment for 4 (TBR-001-010) crew members per mission.

Rationale: Analysis. The analysis must determine that the Lunar Outpost not only has sufficient room to physically accommodate 4 (TBR-001-010) crewmembers and their supplies (food, water, clothes, etc.) but that the outpost can provide the utilities (power, ECLS, etc.) required to support 4(TBR-001-010) crewmembers, and also provides for the crew's well-being during the rotation period. (exercise, communication, recreation, etc.)

[CA0388V-HQ] Constellation Architecture delivery/return crew size requirement shall be verified by inspection. The inspection shall confirm closure of CEV crew size requirement. The verification shall be considered successful when the inspection shows that the CEV crew size is 0 through 6.

Rationale: Currently this Level 2 verification will require that CEV have and properly close a Level 3 crew size requirement of 0 through 6.

[CA0010V-PO] **Draft** The capability to transport 6 (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) 6 (TBR-001-082) crew members, plus, reconfiguration capability to cover in-between configurations and (TBD-001-637). Verification shall be considered successful when the analysis shows that the CEV 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 6 (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.)

4.2.4 CARGO DELIVERY AND RETURN

[CA0209V-HQ] The Constellation Architecture Mass Delivered requirement to the lunar surface for crewed missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 inspection shows that the Mass Delivered capability of the Constellation Architecture is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-475) of the simulations with a 90% confidence.

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.

[CA0211V-HQ] The Constellation Architecture Mass Returned requirement from the lunar surface to the Earth for crewed missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 Mass Returned capability of the Constellation Architecture is equal to or greater than the Mass Returned requirement for 99.73% (TBR-001-473) of the simulations with a 90% confidence.

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.

[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 and 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 CEV 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 the CEV and the available volume in the CEV after the return mission objectives and crew requirements are accounted for.

[CA0002V-HQ] **Draft** The Constellation Architecture Mass Delivered requirement to the lunar surface for uncrewed Lunar Outpost Cargo missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 calculated Mass Delivered capability of the Constellation Architecture is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-300) of the simulations with a 90% confidence.

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.

[CA0212V-HQ] **Draft** (TBD-001-1033)

Rationale: (TBD-001-1033)

[CA0823V-PO] **Draft** (TBD-001-1034)

Rationale: (TBD-001-1034)

4.2.5 MISSION RATES AND DURATIONS

[CA5604V-PO] Performing concurrent operations of multiple in-space 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 Constellation vehicles and mission operations. The analysis shall consist of a review that the as-built vehicles, infrastructure, simulators, and mission control center system (MCCS) satisfy the requirements to perform concurrent in-space vehicle operations. The vehicles, infrastructure, simulators, MCCS will be identified and characterized in CxP 72000, 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 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV), CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Missions Systems (MS) Interface Requirements Document (IRD) and CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) to Mission Systems Interface Requirements Document (IRD). The verification shall be considered successful when the analysis and testing shows that the CxP 72000, 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 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV), CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Missions Systems (MS) Interface Requirements Document (IRD) and CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) to Mission Systems Interface Requirements Document (IRD) requirements pertaining to the vehicles, infrastructure, simulators, and MCCS are ready to support concurrent operations of multiple in-space vehicles.

Rationale: NR

[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 and analysis. Inspection shall determine that each individual system of the Constellation Architecture has closed their respective flight rate requirement. Analysis shall assess: 1). The time required to integrate the flight systems into mission configurations, and 2). The availability of Constellation launch facilities. Verification shall be considered successful when inspection determines each system has successfully closed its respective flight rate requirement, and analysis shows: 1) The individual flight systems can be integrated into mission configurations in time to meet mission objectives and 2) The scheduled usage of the launch facilities can accommodate scheduled mission rates.

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.

[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

[CA5289V-PO] **Draft** 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 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 Outpost provides a habitable environment for the full crew compliment 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.

[CA0073V-HQ] **Draft** (TBD-001-1035)

Rationale: (TBD-001-1035)

[CA0047V-PO] **Draft** (TBD-001-1036)

Rationale: (TBD-001-1036)

4.2.6 ARCHITECTURE DEFINITION

[CA5247V-PO] **Draft** (TBD-001-1037)

Rationale: (TBD-001-1037)

[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 3 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.

[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 Requirements Document (SRD), CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD), CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element, 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 Requirements Document (SRD), CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD), CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element, 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 CONUS landing sites shall be verified by inspection of relevant CEV analysis supporting section 3.7 requirements verification, and Ground Systems analysis supporting CxP 70028, Constellation

Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD) requirements verification. Verification shall be considered successful when inspection shows completion of relevant CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) 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.

[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.

[CA3211V-PO] **Draft** 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.

[CA0281V-HQ] The accomplishment of crewed lunar missions with two launches consisting of one CaLV/LSAM launch and a separate CLV/CEV launch shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations for the CaLV/LSAM launch and the CLV/CEV launch. 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 results show that there is a 99.73% (TBR-001-974) probability with a confidence of 90% (TBR-001-975) that the crewed lunar missions can be accomplished using two launches, one CaLV and one CLV.

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.

[CA0353V-PO] **Draft** (TBD-001-1038)

Rationale: (TBD-001-1038)

[CA0405V-HQ] **Draft** The capability of the Constellation Architecture to support Lunar Outpost crew rotation with 1 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 crew members.

Rationale: Analysis is required to determine if the mission design can meet this requirement.

[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: CEV Contingency EVA Operation, CEV External EVA Translation Path, LSAM EVA translation paths, CEV lunar contingency capability, CEV ISS contingency capability, CEV Cabin depress, CEV Cabin repress, CEV depress capability external to vehicle, CEV egress path, CEV ingress path, CEV stabilization aids, EVA mobility, EVA Sustain Life, EVA System protect crew from environment, EVA System to provide crew stability, CxP 70130, Constellation Program Extravehicular Activity (EVA) 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.

[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 (CEV depress/repress), CA3166-PO (CEV Lunar EVA Capability), CA4127 (EVA System 2 EVAs), CA3167-PO (compliance with EVA 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.

[CA0022V-HQ] **Draft** (TBD-001-600)

Rationale: (TBD-001-600)

[CA0287V-PO] **Draft** (TBD-001-651)

Rationale: (TBD-001-651)

[CA0407V-PO] **Draft** (TBD-001-1039)

Rationale: (TBD-001-1039)

[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 presents 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 presents of the lunar dust environment.

[CA0465V-HQ] **Draft** (TBD-001-1065)

Rationale: (TBD-001-1065)

[CA3184V-PO] The delivery of the crew and cargo from the Earth to ISS using the CLV and CEV shall be verified by inspection. The inspection shall consist of a status review of the child requirement CA3202-PO (The CLV shall launch the CEV from the launch site to the Ascent Target) and a status review of CA0191-PO (The CEV 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 shows the vehicle successfully achieves the required orbit and satisfies the RPOD requirements of CxP 70031, Constellation Program Crew Exploration Vehicle

- To - International Space Station Interface Requirements Document, 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.

[CA3214V-PO] **Draft** The utilization of the CaLV 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 CaLV 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 CaLV 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.

[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.

4.2.7 SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[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 CLV 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 possible conditions.

[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.

[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, System Requirements for the Crew

Exploration Vehicle (CEV) Element, 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 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, System Requirements for the Crew Exploration Vehicle (CEV) Element, 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 Requirements Document (SRD) are closed. Analysis shall be considered successful when 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)).

> *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), a process for accepting risk levels above the guidelines, and (TBD-001-263).

[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 NPD 8710.3, NASA Policy for Limiting Orbital Debris Generation Sections 1, 2, and 7 (TBR-001-970).

> *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.

[CA0214V-PO] The two fault tolerance for catastrophic hazard shall be verified by analysis. The analysis shall review the results System-level 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 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.

[CA0213V-PO] The single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the results of the system-level hazard analyses, FMEA/CILs, and the integrated architecture hazard analysis for 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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 and then top down for the integrated systems.

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 Document. 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

1) 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, and

2) 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.

4.2.9 HEALTH AND STATUS

[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 is 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):

- is provided for each Constellation system
- is obtained by each Constellation system
- is observed by crew surrogates in each Constellation system which will house crew
- is provided and obtained in each mission phase, state and mode
- 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

- defined by (TBD-001-372) document(s)
- for each Constellation system
- to each Constellation system
- to crew surrogates in each Constellation system which will house crew
- for each mission phase, state and mode for both nominal and off-nominal conditions
- 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.

[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:

- detected by each affected Constellation system,
- isolated by each affected Constellation system,
- recovered from by each affected Constellation system.

Rationale: At Constellation Level II a Demonstration of the provision of fault detection, isolation and recovery

- defined by (TBD-001-268) document(s)
- by applicable Constellation systems
- for each mission phase, state and mode
- 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.

4.2.10 COMMUNICATIONS AND COMMUNICATIONS SECURITY

[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 Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 6: Mission Systems (MS), CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Missions Systems (MS) Interface Requirements Document (IRD) and CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) to Mission Systems 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. Demonstration 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, and 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.

[CA0296V-HQ] The communication capabilities of the Constellation Architecture shall be verified by Test and Analysis.

A test on flight or flight-like components shall be performed under simulated conditions in the SIL 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.

The verification shall be considered successful when the analysis and testing find that all of the Systems can communicate as required by IRD's at the expected system load (TBD-001-348) for all mission phases and in accordance with the C3I specification for the link class. Analysis will be used to determine appropriate link margins required as part of the testing criteria and as a tool to show that appropriate communications protocol and data format are being followed.

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 hard-line and RF communications links. Systems broadcasting as part of the Constellation architecture shall conform to the broadcasting portion of the C3I specification. Testing with a system load is called out because network systems that recover bandwidth are susceptible to general degradation on overload. Testing this condition would verify load-shedding algorithms or typify behavior

[CA3021V-PO] The capability of the Constellation Architecture to provide access to system digital data as specified 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, and d) simulated data flow between ISS and one Cx system (e.g. CEV). In each case the demonstration shall include attempts to access data by authorized users and non-authorized users.

The verification shall be considered successful when the demonstration shows a) distributed communication between system for three mission phases, 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, and 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.

[CA0476V-HQ] The ability of the Constellation Architecture to support simultaneous communication between at least 9 (TBR-001-119) systems 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 time-line, multiple system communications scenarios shall be identified. Each of these sets of interconnected systems shall be tested using flight or flight-like components with nominal loads and heavy (TBD-001-960) loads for a duration of 20 (TBR-001-337) minutes 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 9 (TBR-001-119) system can simultaneously exchange data at the maximum data rate of the specified systems or simulated systems for a period of 20 (TBR-001-337) minutes without apparent degradation, b) analysis shows that no degradation is predicted if the test time were indefinite, and c) analysis shows that forward and received link margins are sufficient to support communication at nominal distances for the representative systems.

> *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 9 (TBR-001-119) systems transferring information at their maximum rate to stress test the system. A variety of data types shall be needed to show that all types are supported sufficiently well.

[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 of 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, and 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.

[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)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, and

(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.

1) An analysis shall be conducted on the Constellation Architecture communications infrastructure, audio implementation, and motion imagery implementation for at least 3 (TBR-001-260) 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 and if the audio and imagery will be routed to the ground for release.

2) A demonstration of simulated space-originated audio and high resolution motion imagery shall be performed. The source signals shall be connected to a ground system portion of the space-to-ground path within the Constellation Architecture systems and not directly to the release interface. The source can be live or recorded signals. Monitoring of the audio and imagery signals shall be performed at the end-user site or patched to a monitoring system.

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 at least three (TBR-001-260) mission scenarios, and b) the demonstration shows that the monitored signals are recognizable as the source information.

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.

4.2.11 GUIDANCE, NAVIGATION, AND CONTROL

[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.

[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 CEV 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.

[CA0529V-PO] **Draft** 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-001-044) for landing on the lunar surface has been met.

Rationale: NR

[CA0356V-PO] **Draft** 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

[CA3141V-PO] **Draft** 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

[CA0826V-PO] **Draft** 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

4.2.12 RELIABILITY AND AVAILABILITY

[CA0123V-PO] The ability of the Constellation Architecture to meet an 88% (TBR-001-021) probability of launch per crew launch attempt, starting at "LCC Call to Station" and ending at close of day of launch window shall be verified by analysis and inspection. 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 and Maintainability (R&M) 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 availability children requirements. Verification shall be considered successful when analysis and inspection shows that the probability of launch per crew launch attempt is at least 88% (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 is required for all missions, but CEV lunar missions are assumed to be the driver, to enable rendezvous with the EDS and maintenance of mission schedule and lunar phase constraints. This requirement decomposes into other "probability of go" requirements that need to be placed on the separate elements: CEV hardware ready; CEV abort landing site requirements met; CLV hardware ready; CLV weather related launch constraints, and the ground systems readiness are met. The decomposition of this requirement is shown in the Launch Probability and Contributing Conditional Probabilities table. This requirement is inclusive of both the probability of delay and the probable duration of such delay to perform review, repair or replacements.

[CA5600V-PO] The ability of the Constellation Architecture to meet a (TBD-001-517) probability of launch per uncrewed launch attempt, starting at "LCC Call to Station" and ending at close of day of launch window 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 and Maintainability (R&M) Plan. Verification shall be considered successful when analysis shows that the probability of launch per uncrewed launch attempt is at least (TBD-001-517) with an uncertainty of not greater than (TBD-001-631).

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 beginning "LCC Call to Station" and ending at close of day-of-launch window.

[CA0038V-PO] The ability of the CEV to launch within one (TBR-001-020) day of the CaLV shall be verified by analysis. Analysis shall assess Level 3 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 CaLV and the CEV within one (TBR-001-020) day 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.

[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

[CA0125V-PO] The ability for the Constellation Architecture to provide launch opportunities for four (TBR-001-193) 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 four consecutive days. The verification shall be considered successful when the analysis results show that the Constellation Architecture can provide launch opportunities for at least four (TBR-001-193) consecutive days for crewed missions.

Rationale: Analysis of the various plans and lower-level analysis reports is sufficient for verification work.

[CA0037V-PO] The ability of Constellation Architecture to be prepared to conduct a Lunar Mission at the beginning of the next lunar launch window shall be verified by analysis. Analysis shall assess Level 3 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.

[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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. 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 Requirements Document (SRD) or GS-SSRD. The push down of the LSAM requirements to the SRD does not effect the CARD 4.7 verification statement. The verification of LSAM will be in the SRD 4.2 and SSRD 4.7 sections.

4.2.13 MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[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, and demonstration of the CA design. The analysis will consist of a review of each project (CEV, CLV, CaLV, LSAM, EVA) 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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. The demonstration shall consist of late pad access operations within a specified time as defined in the requirement to meet late stow for time critical cargo by L-12 (TBR-001-964) hours. Verification shall be considered complete when the analysis and demonstration have 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] Ensuring that the Constellation Architecture includes all required tools for on-orbit maintenance and reconfiguration shall be verified by inspection. The inspection shall consist of a review of allocated children verification results. The verification shall be considered successful when all allocated children verifications have been closed.

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.

[CA5710V-PO] The ability of the Constellation Architecture to provide the infrastructure to maintain systems through their operational life cycles shall be verified by analysis. 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 verification shows that the Constellation Architecture provides 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; and tools and test equipment for in-flight maintenance.

[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 (CLV/CaLV/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 (CLV/CaLV/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:

1) Accepted by the receiving LRU.

2) Is accomplished without LRU removal.

3) Is confirmed via C3I cross checking (i.e. ack, checksum)

Rationale: Demonstrations using flight quality assets, operational baseline, and C3I infrastructure provides assurance of 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.

[CA0550V-PO] **Draft** 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.

4.2.14 RESERVED

4.2.15 ENVIRONMENTAL CONDITIONS

[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.

[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: 1) Allocation of the natural environments requirements to the lower tier systems and their verification methods and details, and 2) 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: CEV/CLV/GS, CEV/ISS, CEV/CLV, CEV/CaLV-EDS/LSAM, CEV/LSAM, CaLV/LSAM/GS, and CaLV/LSAM.

The verification shall be considered successful when the inspection and integrated analysis show: 1) The natural environment requirements and verification have been allocated to the lower tier systems in accordance section 4 of the DSNE, 2) Lower tier verifications have been completed and 3) 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 CCxP 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.

4.3 DESIGN AND CONSTRUCTION STANDARDS

4.3.1 ELECTRICAL

[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 28 VDC and CxP 70050-02, Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28 VDC 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 28 VDC and CxP 70050-02, Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28 VDC. The CARD 3.7.x.4 Interface Requirements require multi-System integrated testing that will include power interface testing.

[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: 1) The submitted bonding verification data have been approved, 2) 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.

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: 1) during the test all systems successfully complete functional and operational performance requirements 2) 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.

[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: 1) During the test all systems successfully complete functional and operational performance requirements 2) 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.

[CA0555V-PO] Compatibility with the external electromagnetic environment shall be verified by test, inspection and analysis. The test shall verify that the integrated systems meets 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 insure that each system has complied with Constellation E3 requirements. Verification is considered successful when 2 items are satisfied:

1) The analysis and test results verify that the systems are compatible with the external electromagnetic environment.

2) 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.

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.

[CA3187V-PO] Compliance with CxP 70135, Constellation Program Structural Design and Verification Requirements, shall be verified (1) for each system by inspection and (2) for the integrated systems (for example, CEV integrated with CLV) 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.

(2) Analysis and test shall be used to verify that the integrated systems (for example, CEV integrated with CLV) meet the agreed to requirements of CxP 70135, Structural Design and Verification Requirements. The systems shall include the following integrated configurations: CEV/CLV/GS, CEV/ISS, CEV/CLV, CEV/CaLV-EDS/LSAM, CEV/LSAM, CaLV/LSAM/GS, and CaLV/LSAM. Verification that the integrated systems meet the agreed to requirements of CxP 70135, 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.

[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.

[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.

[CA3237V-PO] Compliance with Sections 1 through 4 of NASA-STD-5017, Design and Development Requirements for Mechanisms, shall be verified (1) for each system by inspection and (2) for the integrated systems (for example, CEV integrated with CLV) 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, CEV integrated with CLV) 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: CEV/CLV/GS, CEV/ISS, CEV/CLV, CEV/CaLV-EDS/LSAM, CEV/LSAM, CaLV/LSAM/GS, and CaLV/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.

[CA3005V-PO] Compliance with NASA-STD-(I)-6016, Standard Material and Process 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 Material and Process 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.

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: No additional rationale required.

4.3.5 COMMUNICATIONS STANDARDS

[CA5800-PO] Compliance to the CxP 70022, C3I Interoperability Standards Book Volume 1, 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.

[CA0383V-PO] The protection of systems and information as specified in the CxP 70070-ANX05, Constellation Program Management Plan, Annex 5: Security Management Plan, Book 1: 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 70070-ANX05, Constellation Program Management Plan, Annex 5: Security Management Plan, Book 1: Functional Security Requirements for Program Systems and Elements; Applicability Matrix for Functional Security Requirements, are met.

Rationale: All requirements specified for the Constellation Architecture and every System in CxP 70070-ANX05, Constellation Program Management Plan, Annex 5: Security Management Plan, Book 1: Functional Security Requirements for Program Systems and Elements; 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 70070-ANX05, Constellation Program Management Plan, Annex 5: Security Management Plan, Book 1: Functional Security Requirements for Program Systems and Elements; Applicability Matrix for Functional Security Requirements, can result in unacceptable residual security risk. CxP 70070-ANX05, Constellation Program Management Plan, Annex 5: Security Management Plan, Book 1: Functional Security Requirements for Program Systems and Elements; 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.

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 (EVA) 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 (EVA) 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 CEV, EVA and LSAM. Although the CxP 70130, Constellation Program Extravehicular Activity (EVA) 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 (EVA) 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 a reference time scale, traceable to UTC in accordance with CxP 70142, Constellation Program Navigation Standards Specification Document shall be verified by inspection. The inspection shall be accomplished by comparing time reference methods and assumptions to those documented in the navigation standards specification. The verification shall be considered successful when the inspection shows the time reference functional capability is traceable to UTC and in accordance with those in CxP 70142, Constellation Program Navigation Standards Specification Document.

Rationale: NR

4.3.8 OTHER STANDARDS

[CA5915V-PO] Constellation Architecture compliance with design standards of CxP (TBD-001-1002), SR&QA Technical Requirements Document shall be verified by analysis. The analysis shall consist of a review by the program board approval of the design certification of all Constellation Architecture hardware and software. This supporting hardware and software will be verified complete and ready to support by successfully completing the design certification review for the specific end items. The verification shall be considered successful when the analysis shows that the Constellation SRD certificates incorporate all SR&QA Technical requirements.

Rationale: NR

[CA5680V-PO] Constellation Architecture compliance with design standards of NASA-STD-5005B (TBR-001-961) will be verified by analysis. The analysis shall consist of a review by the program board approval of the design certification of all Constellation Architecture GSE hardware that is to be utilized for ground processing. This supporting hardware will be verified complete and ready to support by successfully completing the design certification review for the specific end items of Ground Support Equipment. The verification shall be considered successful when the analysis shows that the Constellation SRD certificates incorporate all requirements for the use of ground support hardware on flight elements.

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 1) 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 and 2) 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 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 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 it's functional and performance requirements after exposure to these test environments.

4.4 EXTERNAL INTERFACES

[CA5936V-PO] (TBD-001-1055)

Rationale: (TBD-001-1055)

[CA5937V-PO] (TBD-001-1056)

Rationale: (TBD-001-1056)

[CA5938V-PO] (TBD-001-1057)

Rationale: (TBD-001-1057)

[CA5939V-PO] (TBD-001-1058)

Rationale: (TBD-001-1058)

[CA5940V-PO] (TBD-001-1059)

Rationale: (TBD-001-1059)

[CA5941V-PO] (TBD-001-1060)

Rationale: (TBD-001-1060)

[CA5942V-PO] (TBD-001-1061)

Rationale: (TBD-001-1061)

[CA5943V-PO] (TBD-001-1062)

Rationale: (TBD-001-1062)

[CA5944V-PO] (TBD-001-1063)

Rationale: (TBD-001-1063)

[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 Crew Exploration Vehicle - To - International Space Station Interface Requirements Document, 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 77084, 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 the CEV 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 Crew Exploration Vehicle - To - International Space Station Interface Requirements Document, have been satisfied, and (b) when integrated multi-system test objectives for the Constellation Architecture and ISS interfaces established by CxP 77084, 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.

[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 70018-02, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 2: Crew Launch Vehicle (CLV) 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 77084, 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., CEV/CLV) and in-space vehicle stacks that will be assembled for the first time in space (e.g., CEV/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 70018-02, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 2: Crew Launch Vehicle (CLV) have been satisfied, and

(b) Integrated multi-system test objectives for the Constellation Architecture and Communications and Tracking Network interfaces established by CxP 77084, 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.

4.5 PHYSICAL CHARACTERISTICS

[CA0023V-PO] The Control Mass requirement for the Constellation Architecture flight Systems shall be verified by inspection. The inspection shall consist of a review of the verifications performed for lower level Systems requirements. The verification shall be considered successful when the inspection shows that all requirements for Control Masses and gross liftoff weight capabilities have been successfully verified and that the CLV mass delivered numbers were successfully verified using the required LAS jettison time.

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 CREW EXPLORATION VEHICLE (CEV)

4.7.1.1 CEV DESCRIPTION

4.7.1.2 CEV REQUIREMENTS

[CA0056V-PO] The requirement for the CEV to return crew and cargo from the LRO to the Earth surface for crewed lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 results show there is a 99.73% (TBR-001-397) probability with a confidence of 90% (TBR-001-xxx) that the CEV 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 the CEV to deliver crew and cargo from the Earth surface to the Lunar Destination Orbit (LDO) for lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 results show there is a 99.73% (TBR-001-397) probability that the CEV 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5312V-PO] The ability of the CEV to deliver the crew and pressurized cargo from the Earth surface to ISS shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include earth orbit, entry, and landing capabilities. 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 99.73% (TBR-001-375) probability that the CEV can deliver the crew and pressurized cargo from the Earth surface to the ISS and meet the RPOD requirements of the CEV/ISS IRD.

> *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 being used to deliver crew and pressurized cargo from the Earth surface to the ISS.

[CA3203V-PO] The ability of the CEV to return the crew and pressurized cargo from ISS to Earth surface shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include earth orbit, entry, and landing capabilities. 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 99.73% (TBR-001-375) probability with a 90% confidence that the CEV 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.1.2.1 CEV MISSION SUCCESS

[CA0088V-PO] Lunar Sortie LOM due to the CEV 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 (a (TBD-001-1012) probability) that LOM for a Lunar Sortie mission due to the CEV is no greater than 1 in 50 (TBR-001-058).

Rationale: NR

[CA3023V-PO] Lunar Outpost Crew LOM due to the CEV 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 a (TBD-001-932) probability that LOM for a Lunar Outpost Crew mission due to CEV is not greater than 1 in (TBD-001-515).

Rationale: NR

[CA0399V-PO] ISS Crew LOM due to the CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70087, Constellation Program Reliability and Maintainability (R&M) Plan. Verification shall be successful when the analysis shows (a TBR-001-956 probability) that LOM for an ISS Crew mission due to the CEV is no greater than 1 in 250 (TBR-001-056).

Rationale: NR

[CA3022V-PO] ISS Cargo Mission LOM due to the CEV 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 (a TBD-001-931 probability) that LOM for an ISS Cargo Mission due to the CEV is no greater than 1 in (TBD-001-513).

Rationale: NR

4.7.1.2.2 CEV CREW SURVIVAL

[CA4154V-PO] The ability of the CEV to return the crew to Earth with an unpressurized cabin for at least 120 (TBR-001-1006) hours shall be verified by analysis. The analysis shall consist of a review of documentation that the CEV System can provide those critical functions necessary to return the CEV and crew back to Earth while the CEV 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 120 (TBR-001-980) hours.

Rationale: This is an overarching CEV Project parent verification requirement that can be satisfied once the flow-down requirements to the CEV 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 CEV 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 120 (TBR-001-980) hours with an unpressurized cabin.

[CA0274V-PO] The CEV Emergency Entry mode capabilities shall be verified by Analysis. The analysis shall review the performance of the CEV software and hardware intended to support the entry and landing of an earth returning crew in an Emergency Entry mode situation. The analysis shall be considered successful when it shows a probability of 99.73% (TBR-001-308) with a 90% confidence 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0984V-PO] The crew survival during landing touchdown shall be verified by test and analysis. The test shall verify that the CEV can withstand the loads associated with landing impact, considering the wind speed, trajectory, and sea conditions. The test shall include instrumentation of the internal CEV 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 the CEV 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 insure 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.

[CA0194V-PO] The CEV crew survival following a landing on water shall be verified by analysis.

The analysis shall assess that the CEV design for power, ventilation, and thermal conditioning provides a physical environment that does not lead to crew loss or permanent disability of suited crew, as specified in CxP 70024, Constellation Human-Systems Integration Requirements (HSIR), for up to 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), Section 3.5.19.

The analysis shall audit the CEV provision of food, potable water, waste management, and emergency supplies for up to 36 hours with the hatch closed following a landing on water.

The verification shall be considered successful when the analysis shows the CEV provides for suited crew survival, without permanent disability, for up to 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.

[CA0983V-PO] The CEV structural integrity and ability to float shall be verified by analysis. The analysis shall indicate the CEV 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 the CEV floats and maintains structural integrity for a minimum of 36 hours and shall also indicate any time beyond the 36 hour minimum in which the CEV 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 flotation duration in the analysis will define the length of time within which the CEV must be recovered and the limits for post-landing CEV 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.

[CA3259V-PO] CEV visual aids for contingency landings shall be verified by inspection. The inspection shall consist of review of allocated requirements from CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element. The verification shall be considered successful when the inspection determines that the CEV System complies with (TBD-001-568) Standard for SAR visual aids.

Rationale: This is an overarching CEV project parent verification requirement that can be satisfied once the flow-down requirements to the CEV projects are satisfied.

The inspection documentation can be satisfied by the CEV System providing the requirements that address the functions (whether in CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element or CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD)).

[CA0532V-PO] The ability of the CEV to sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 120 (TBR-001-1006) hours shall be verified by analysis.

The analysis shall consist of documentation that the CEV System can provide the following simultaneous functions while the CEV habitable volume is depressurized:

- Breathing gas quantity, flowrates, and scrubbing to the suited crew for 120 (TBR-001-1006) hours to meet medical standards as defined per CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section 3.2.1 Natural and Induced Envrionments, Atmosphere and Section 3.5.4.3 Environmental Loads, and in accordance with suit pressure defined in CA5659.

- Thermal conditioning to the suited crew for 120 (TBR-001-1006) 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.

- Power to the suited crew for 120 (TBR-001-1006) hours per CxP 70033, Constellation Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document.

- Nutritional, medical, and hydration needs to the suited crew for 120 (TBR-001-1006) hours to meet medical standards as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).

- Communication (voice, suit and biomed data) with the suited crew for 120 (TBR-001-1006) hours as defined in CxP 70033, Constellation Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document.

- Seat ingress and harness securing with a pressurized suited crewmember and ability to readjust harness upon re-entry when suit becomes unpressurized.

- Ability for interfacing CEV systems to operate and remove ammonia/body contaminates in return breathing gas for 120 (TBR-001-1006) hours. The verification shall be considered successful when the analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized for 120 (TBR-001-1006) 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.

[CA3108V-PO] The ability of the CEV to provide suit stowage such that a suit can be accessed within 2 (TBR-001-157) minutes per crew member 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 CEV volume mockup, with the suits stowed in the designated CEV 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 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 the CEV. Since there are primarily 3 factors involved (CEV 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 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 the CEV detects events indicating fire and limits propagation of a fire in the pressurized volume of the CEV. The analysis shall utilize results from CEV children requirements compliance with CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element 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 CEV. 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 the CEV 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.

[CA0493V-PO] The CEV habitable environment during an ISS isolation event shall be verified by analysis.

The analysis shall assess that the CEV 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 the CEV is still docked to the ISS, but the crew is isolated from the ISS.

The analysis shall audit the CEV 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 the CEV provides a habitable environment for the assigned crew for a single event of at least 2 hours in duration while the CEV 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.

[CA0325V-PO] The capability to provide Earth landing throughout all mission phases shall be verified by analysis using a NASA-accredited digital orbital and entry simulation. 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. Verification shall be considered successful when analysis of all scenarios with system and environmental dispersions shows a 99.73% (TBR-001-309) probability with a 90% confidence of achieving a survivable Earth landing within appropriate abort targeting constraints.

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.

4.7.1.2.2.1 CEV CREW SURVIVAL PROBABILITIES

[CA5913V-PO] 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 a (TBD-001-1000) probability that LOC for an ISS Crew Mission is no greater than 1 in (TBD-001-947).

[CA0501V-PO] Lunar Sortie LOC due to CEV 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 (a (TBD-001-957) probability) that LOC for a Lunar Sortie due to the CEV is not greater than 1 in 200 (TBR-001-057).

Rationale: NR

[CA3040V-PO] Lunar Outpost Crew LOC due to the CEV 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 a (TBD-001-939) probability that LOC for a Lunar Outpost Crew mission due to the CEV is not greater than 1 in (TBD-001-559).

Rationale: NR

[CA0398V-PO] ISS Crew LOC due to the CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70087, Constellation Program Reliability and Maintainability (R&M) Plan. Verification shall be successful when the analysis shows a (TBD-001-955) probability that LOC for an ISS Crew mission due to the CEV is no greater than 1 in 1700 (TBR-001-055).

Rationale: NR

4.7.1.2.2.2 CEV EMERGENCY EGRESS, ABORTS AND RETURN FOR SURVIVABILITY

[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 CEV by performing a minimum of two runs with two different sets of suited crew members and collecting the task time for crew egress from CEV. 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, CLV and CEV system documentation review that meets unobstructed egress for the suited crew through the closure in the allocated CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) 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 CEV project verification requirement that can be satisfied once the flow-down requirements to the CEV projects are satisfied. The inspection documentation can be satisfied by the CEV System providing the requirements that address the functions (whether in the SRR, ICD or IRD),

[CA0335V-PO] The CEV 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 crew members and collecting the task time for crew egress from CEV. 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 CEV 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 Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems 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-001-202) 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: N/A

[CA0466V-PO] The CEV 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 CEV and performing a minimum of two runs with two different sets of suited crew members and collecting the task time for crew egress from CEV. 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 CEV supports the capability for unassisted emergency egress for suited crew upon landing.

Rationale: NR

[CA0333V-PO] The CEV 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 CEV 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. Analysis for ascent aborts shall be conducted using NASA-accredited digital simulations with dispersed parameters for all flight phases to mission destination. The verification testing shall be considered successful when the all test results successfully return the crew to a land or water landing. The verification analysis shall be considered successful when the analysis shows that there is a 95% (TBR-001-311) probability of crew survival for aborts.

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.

[CA0579V-PO] The ability of the CEV to land outside the Downrange Exclusion Zone during ISS mission shall be verified by analysis. The analysis shall be conducted in a NASA-accredited digital simulation, including models of the ascent vehicle and separation dynamics. The verification shall be considered successful when the analysis shows that there is a 95% (TBR-001-321) probability that the CEV 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.

[CA0498V-PO] The ability of the CEV to perform aborts without CLV thrust shall be verified by analysis. The analysis shall show that all ascent aborts can by accomplished without the use of CLV thrust using a NASA-accredited digital simulation including models of the Crew launch vehicle.

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.

[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:

1) Telemetry shows the presence of the FTS indication.

2) That the FTS indication is valid.

3) That the CEV automatically initiates the Ascent Abort Sequence.

4) That the abort sequence initiated by the CEV 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.

[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:

1) The CEV performs the abort determination function(s) through an internal algorithm using internal or external data sources.

2) The CxP Architecture elements receive notification from the CEV of the need for an abort through the C3I infrastructure.

3) 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.

[CA5234V-PO] The ability of the CEV to perform abort landings within allowable areas shall be verified by analysis. The analysis shall be conducted in a NASA-accredited digital simulation, including models of the ascent vehicle, separation dynamics, and CEV dynamics. The verification shall be considered successful when the analysis shows that there is a 95% (TBR-001-467) probability that the CEV 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.

[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:

1) 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).

2) 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.

[CA0416V-PO] The ability of the CEV 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 be performed using a NASA-accredited digital simulation, including models of navigation subsystems that impact the ability of the vehicle to navigate independent of MS, and models of systems and elements on which the CEV depends to perform this task. The analysis shall include Monte Carlo dispersions of mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis shows there is a 99.73% (TBR-001-314) probability with a 90% confidence that the CEV 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 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 the CEV depends to complete the task, including CLV, EDS, and LSAM vehicles.

[CA5237V-PO] The CEV expedited return from lunar orbit capability shall be verified by analysis and test. The analysis shall be conducted using a NASA-accredited digital simulation with dispersed parameters. The testing shall be conducted using a SIL (or equivalent) with models of the CEV as well as the LSAM in lunar orbit. The verification shall be considered successful when the test shows that the CEV can return the crew from lunar orbit to the Earth surface within 118 (TBR-001-063) hours under nominal conditions. The analysis shall be considered successful when the results show that there is a 99.73% (TBR-001-972) probability of successful with a 90% confidence for return of the CEV 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 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.

4.7.1.2.3 CEV CREW SIZE

[CA0447V-PO] The capability to transport crews of 0, 1, 2, 3, 4, 5 and 6 into LEO with a single launch shall be verified by analysis. The analysis shall include the following functions: Flight performance/upmass, center of gravity, 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) min and max crews, plus, 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 the CEV can perform the transportation of the specified number of crew within its performance limits.

Rationale: NR

[CA0347V-PO] **Draft** (TBD-001-1040)

Rationale: (TBD-001-1040)

4.7.1.2.4 CEV CARGO DELIVERY AND RETURN

[CA0868V-PO] The CEV Mass Returned requirement from the Lunar Rendezvous Orbit (LRO) to Earth for crewed lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 calculated Mass Returned capability of the CEV is equal to or greater than the Mass Returned requirement for 99.73% (TBR-001-331) of the simulations with a 90% confidence.

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.

[CA5155V-PO] The ability of the CEV 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 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.

[CA0547V-PO] CEV 0.57 (TBR-001-750) m3 (20 ft3) of volume, (TBD-001-390) kg ((TBD-001-390) lb) mass, and (TBD-001-391) services allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure elements during the cruise and lunar orbit phases of lunar missions shall be verified by analysis. The analysis shall consist of a review of programmatic manifesting documentation. The verification shall be considered successful when the analysis shows that all of the programmatic manifesting documentation meet CEV 0.57 (TBR-001-750) m3 (20 ft3) of volume, (TBD-001-390) kg ((TBD-001-390) lb) mass, and (TBD-001-391) services allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure elements during the cruise and lunar orbit phases of lunar missions.

[CA3182V-PO] The CEV requirement to deliver cargo from the Earth to ISS in an uncrewed configuration shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations for the CEV/CLV ascent and CEV on-orbit

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.

[CA0864V-PO] The CEV pressurized Mass Delivered requirement from Earth to ISS for crewed missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 Mass Delivered capability of the CEV is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-330) of the simulations with a 90% confidence.

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.

[CA0865V-PO] The CEV Mass Returned requirement from ISS to Earth for crewed missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 calculated Mass Returned capability of the CEV is equal to or greater than the Mass Returned requirement for 99.73% (TBR-001-920) of the simulations with a 90% confidence.

Rationale: NR

[CA0866V-PO] The CEV pressurized Cargo Mass Delivered requirement from Earth to the ISS for ISS Cargo Missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 calculated Mass Delivered capability of the CEV is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-921) of the simulations with a 90% confidence.

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.

[CA5233V-PO] The CEV Mass Returned requirement from ISS to Earth for uncrewed Cargo missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 Mass Returned capability of the CEV is equal to or greater than the Mass Returned requirement for 99.73% (TBR-001-922) of the simulations with a 90% confidence.

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.

[CA0565V-PO] The ability of the CEV to deliver a volume of 10.76 (TBR-001-035) m3 (380 ft3) of pressurized 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 the requirement during each cargo mission.

The ability of the CEV 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.

4.7.1.2.5 CEV MISSION RATES AND DURATIONS

[CA3164V-PO] The CEV's provision of a habitable environment for a lunar mission shall be verified by analysis. The analysis shall assess that the CEV 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 4 crew for a minimum of 18 (TBR-001-128) days. The analysis will be supported by component and subsystem tests and analyses. The verification shall be considered successful when the analysis shows the CEV provides a habitable environment for up to 4 crew for a minimum of 18 (TBR-001-128) days in duration for a lunar mission.

Rationale: Analysis supported by subsystem and component tests and analyses is sufficient to verify that the CEV can support a habitable environment for a crew of 4 for 18 (TBR-001-128) days. The analysis will include an audit of consumable supplies.

[CA0082V-PO] The ability for the CEV 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 the CEV can loiter uncrewed in LLO for at least 210 days.

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.

[CA0060V-HQ] The ability of the CEV to remain at the ISS for 210 days shall be verified by analysis. Verification shall include analysis of component lifetimes (including planned preventive maintenance) and consumables margins. The verification shall be considered successful when the analysis shows that CEV can remain at the ISS for 210 days.

Rationale: NR

4.7.1.2.6 CEV ARCHITECTURE DEFINITION

[CA0351V-PO] The CEV 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, System Requirements for the Crew Exploration Vehicle (CEV) Element, CxP 72006, Ground Systems Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. 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 CEV Architecture independent of ambient lighting conditions.

Rationale: NR

[CA3204V-PO] The CEV orbital transfer from the Ascent Target to the Earth Rendezvous Orbit (ERO) for crewed lunar missions shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations for the CEV orbit transfer mission phase. 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 results show there is a 99.73% (TBR-001-376) probability with a 90% confidence that the vehicle can successfully perform the orbit transfer from Ascent Target to ERO 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.

[CA3207V-PO] The ability of the CEV to perform the orbit transfer from LLO to LRO for crewed lunar missions shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include multi-body gravity effects. The analysis shall include Monte Carlo dispursions on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-971) probability that the CEV 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5240V-PO] The CEV 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 analysis shall be performed using NASA-accredited digital flight simulations for the CEV orbit transfer mission phase. The simulation shall include timing of the orbit transfer maneuver. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters, and trans-lunar and multi-body gravity effects. The verification analysis shall be considered successful when the analysis shows that there is a 99.73% (TBR-001-471) chance of successful orbit transfer from LLO to LRO in 6 (TBR-001-205) hours or less in the presence of dispersions with a confidence of 90% (TBR-001-973).

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.

[CA5319V-PO] The CEV 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 analysis shall be performed using NASA-accredited digital flight simulations for the CEV orbit transfer mission phase. The simulation shall include Navigation System performance, specifically in the case where no ground update of state vector is performed. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The analysis will review the software's capability to successfully perform this function without updates from MS. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-507) probability with a 90% confidence 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 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.

[CA3209V-PO] The ability of the CEV to perform TEI for crewed lunar missions shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include multi-body gravity effects experienced during trans-Earth coast. 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 99.73% (TBR-001-380) probability with a 90% confidence that the CEV can perform the TEI 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.

[CA0191V-PO] The CEV orbital transfer from the Ascent Target to ISS requirement shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations for the CEV orbit transfer mission phase. 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 results show there is a 99.73% (TBR-001-480) probability with a 90% confidence that the vehicle can successfully perform the orbit transfer from Ascent Target to ISS.

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.

[CA0324V-PO] The capability to land at designated CONUS locations shall be verified by analysis. The analysis shall be performed using a NASA-accredited digital orbital and entry simulation. Analysis will cover LEO and Lunar DRMs to designated CONUS sites, and will include performance from SM separation to landing. Verification shall be considered successful when analysis of DRMs with system and environmental dispersions shows a 99.73% (TBR-001-472) probability with a 90% confidence of achieving a nominal entry and landing at each of the designated CONUS sites (as appropriate to the specific DRM) within targeting constraints.

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.

[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 the CEV 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 the CEV to perform EVAs on lunar missions at least 2 (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 CEV System can provide the following functions while the CEV habitable volume is depressurized:

- Ability for the crew to depress (external and internal to vehicle) and repress the vehicle cabin (internal to vehicle).

- Atmospheric consumables to repress the vehicle two times to from 0 psia to standard cabin pressure as specified in CA0288-PO.

- Compliance to EVA specifications per CxP 70130, Constellation Program Extravehicular Activity (EVA) Design and Construction Specification, section (TBD-001-1051).

- Internal volume to egress and ingress the vehicle with a full complement of crewmembers

- Provide consumables to support 4 crewmembers for 2 (TBR-001-206) EVAs (4 (TBR-001-207) hours per EVA)

- Translation paths to and stabilization for Contingency and Unscheduled EVA tasks

- Hatch operable with pressure suits

- Egress and ingress paths with pressure suits. The analysis shall prove that the CEV System can provide the following functions for 16 (TBR-001-538) hours for 4 crewmembers while the CEV habitable volume is depressurized:

- EVA System oxygen quantity and flow rates

- EVA System breathing gas scrubbing

- EVA System fluid flow rates and temperatures

- EVA System power

- Communication (voice, suit and biomed data) with EVA System

- Provide the functions simultaneously during the 4 hour EVA for 2 EVA crewmembers with an umbilical length of 30 (TBR-001-409) feet and 2 EVA crewmembers with an umbilical length of 10 (TBR-001-410) feet. The demonstration shall consist of neutral buoyancy evaluations, with the CEV 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 CEV 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 CEV. The test shall consist of CEV 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 CEV at ambient conditions for the following sequences.

1. Four suits (and crewmembers) will be connected to all short umbilical positions with the suits performing simultaneously.

2. 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:

- The analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized.

- The demonstration reflects crew subjective acceptability for CEV ingress, egress, vehicle displays and controls, translations, worksite stability, and worksite tasks as documented in the Crew Consensus report.

- The test data confirms all CEV and EVA System conform to CEV/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 CEV Project are satisfied. The analysis of functions will confirm that CEV has levied and closed out the next lower level requirements. The analysis documentation can be satisfied by the CEV System providing the requirements that address the functions (whether in the CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element or CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD)), provide evidence as to how the CEV 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 2 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 the CEV simultaneously. Note that the 4 hour prebreathe period may be performed by all 4 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 CEV control, etc) with a full complement of crewmembers and in the CEV 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 CEV or EVA system certification that a full set of suits and CEV 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 the CEV 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 the CEV System can provide the following functions:

- Ability to depress the vehicle to vacuum through an external method

- Adherence to CxP 70130, Constellation Program Extravehicular Activity (EVA) Design and Construction Specification, section (TBD-001-468)

The demonstration shall consist of neutral buoyancy evaluations, with a CEV external mockup outfitted with the external repress mechanism, translation path and all external appendages as identified in the CEV 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 CEV 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 CEV System providing the requirements that address the functions (whether in CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element or CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD)), provide evidence as to how the CEV 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 CEV 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.

[CA0373V-PO] **Draft** (TBD-001-1041)

Rationale: (TBD-001-1041)

[CA5148V-PO] The ability of CEV project to provide the infrastructure necessary to concurrently operate at least 3 (TBR-001-208) CEV in-space 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 3 (TBR-001-208) CEVs in-space. Analysis consists of a review of the CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element and IRDs which describe CEV infrastructure necessary to identify and control specific vehicles (e.g. CEV-1, CEV-2). Verification shall be considered successful when the analysis and test confirms the infrastructure necessary to concurrently operate at least 3 (TBR-001-208) CEV in-space vehicles.

Rationale: This is an overarching CEV project verification requirement that can be satisfied once the flow-down requirements to the CEV projects are satisfied. The analysis can be satisfied by the CEV providing the requirements that address the functions (whether in CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element, ICD or IRD).

[CA4152V-PO] The ability of the CEV 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 CEV System can provide the following functions:

- The exterior of the CEV complies to EVA specifications as invoked per CxP 70130, Constellation Program Extravehicular Activity (EVA) Design and Construction Specification compliance applicability.

- EVA translation paths as specified per CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD). The demonstration shall consist of neutral buoyancy evaluations, with the CEV mockups outfitted with external translation paths, and all external appendages as identified in the CEV 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 CEV translations as documented in the Crew Consensus report.

Rationale: This is an overarching CEV Project parent verification requirement that can be satisfied once the flow-down requirements to the CEV 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 CEV during the ISS mission phases will be performed from the ISS airlock using ISS resources. Thus, the CEV 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 the CEV (mission success or contingency EVA for ISS phases), then those will need to be added. The analysis documentation can be satisfied by the CEV System providing the requirements that address the functions (whether in CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element or CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD)), provide evidence as to how the CEV 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.

4.7.1.2.6.1 CEV CONTROL MASS

[CA0827V-PO] The Control Mass requirement of the CEV 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 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 the CEV 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 the CEV 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 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 the CEV at Lift-Off for Lunar Missions is less than or equal to the required Control Mass.

Rationale: NR

[CA4135V-PO] The LAS jettison time shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations for the CLV/CEV ascent phase. 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 results show there is a 99.73% (TBR-001-963) probability that the vehicle can successfully perform the LAS jettison within the required amount of time following the CLV Upper Stage ignition.

Rationale: NR

[CA4139V-PO] The Control Mass requirement of the CEV at the time of CaLV 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 the CEV at the time of CaLV rendezvous is less than or equal to the required Control Mass.

Rationale: NR

[CA4163V-PO] The Control Mass requirement of the CEV 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 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 the CEV 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 the CEV 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 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 the CEV at the ISS Ascent Target is less than or equal to the required Control Mass.

Rationale: NR

4.7.1.2.6.2 CEV DELTA-V

[CA0829V-PO] The CEV translational Delta-V requirement shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight and performance simulations. 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 calculated translational Delta-V of the CEV is equal to or greater than the translational Delta-V requirement for 99.73% (TBR-001-474) of the simulations with a 90% confidence.

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.

[CA0406V-PO] **Draft** (TBD-001-1042)

Rationale: (TBD-001-1042)

4.7.1.2.7 CEV SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA0436V-PO] The two fault tolerance for catastrophic hazard shall be verified by analysis. The analysis shall review the results of the CEV 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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.

[CA0435V-PO] The single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the CEV 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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 bottoms up at the system level.

[CA0437V-PO] The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the CEV 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 CEV COMMAND AND CONTROL

[CA3254V-PO] The generation of commands by the CEV shall be verified by Test. The Test shall use the flight CEV 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 the CEV. (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 the CEV in every applicable mission phase, state and mode

Rationale: A Test of the generation of CEV commands

- defined by (TBD-001-742) document(s)
- by the flight CEV or flight equivalent hardware
- 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 the CEV.

[CA0134V-PO] The CEV crew interface to generate commands shall be verified by Test. The Test shall use the flight CEV 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-001-325) 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-001-325) document(s):

- are generated by crew surrogates in the CEV in each applicable mission phase, state and mode
- the crew displays reflect the status and effects of the commands.

Rationale: A Test of the execution of CEV commands

- defined by (TBD-001-325) document(s)

- by the flight CEV 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-001-325) 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 CEV.

[CA3249V-PO] The CEV crew interface to generate commands shall be verified by Test. The Test shall use the flight CEV 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):

- are generated by crew surrogates in the CEV in each applicable mission phase, state and mode

- and that the crew displays reflect the status of the commands.

Rationale: A Test of the generation of CEV commands

- defined by (TBD-001-750) document(s)

- by crew surrogates in the CEV

- on the flight CEV 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 the CEV.

[CA3255V-PO] The execution of commands by the CEV which are addressed to the CEV shall be verified by Test. The Test shall use the flight CEV 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 the CEV. (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 CEV 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):

- are executed by the CEV 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.

- are rejected by the CEV when not valid in the current state in each applicable mission phase, state and mode or not properly addressed to the CEV.

Rationale: A Test of the execution of CEV commands

- defined by (TBD-001-759) document(s)

- by the flight CEV 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 the CEV.

[CA3110V-PO] The requirement for the CEV 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:

1) The vehicle's running function is halted by the authorized Constellation System assuming vehicle control.

2) When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

3) 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.

[CA0448V-PO] The capability to control the CEV system by a single crew member 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 crew member can monitor and operate all critical functions of the CEV 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 CEV 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 CEV 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 crew member can operate all critical functions of the CEV 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.

[CA5039V-PO] CEV shall provide (TBD-001-220) bytes of digital storage for recording digital data received from other Constellation Systems. The provision of (TBD-001-220) 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 a) the inspection shows that (TBD-001-220) bytes are allocated for the storage of digital data received from other Constellation Systems, and b) the demonstration shows that the receiving system records at least (TBD-001-220) 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.

[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, and 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 CEV HEALTH AND STATUS

[CA0428V-PO] The generation of health and status information by the CEV shall be verified by Test.

The Test shall use the flight CEV 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 the CEV. (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):

- is generated by the CEV in each applicable mission phase, state and mode.
- agrees with the actual health and status of the CEV.

Rationale: A Test of the generation of CEV health and status data

- defined by (TBD-001-330) document(s)
- by the flight CEV 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 the CEV.

[CA0427V-PO] The provision of health and status data by the CEV to the crew shall be verified by Test.

The Test shall use the flight CEV 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):

- is observed by crew surrogates in the CEV in each applicable mission phase, state and mode.

- agrees with the actual health and status of the CEV.

Rationale: A Test of the provision of CEV health and status data

- defined by (TBD-001-287) document(s)

- by the flight CEV or flight equivalent hardware

- to crew surrogates in the CEV

- 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 the CEV.

[CA0438V-PO] The provision of fault detection by the CEV shall be verified by Test. The Test shall use the flight CEV 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 the CEV 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 the CEV in every applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the CEV

- for the faults and fault scenarios identified by (TBD-001-906) document(s)

- by the flight CEV or flight equivalent hardware

- 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 the CEV shall be verified by Test. The Test shall use the flight CEV 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 the CEV 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 the CEV in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the CEV

- for the faults and fault scenarios identified by (TBD-001-452) document(s)

- by the flight CEV or flight equivalent hardware

- 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 the CEV shall be verified by Test. The Test shall use the flight CEV 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 the CEV 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 the CEV in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the CEV

- for the faults and fault scenarios identified by (TBD-001-454) document(s)
- by the flight CEV or flight equivalent hardware
- 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 CEV COMMUNICATIONS AND COMMUNICATIONS SECURITY

[CA5901V-PO] The CEV capability to reconfigure stored commands, sequences and data shall be verified by demonstration. The demonstration shall use the flight CEV or flight equivalent hardware in simulated mission conditions. The CEV 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 the CEV and that they properly reflect the updated values.

Rationale: A demonstration of the CEV 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.

[CA3280V-PO] The use of a dissimilar voice communication system by CEV as specified shall be verified by Analysis and Demonstration. The analysis shall be performed on the CEV voice communication systems. The demonstration shall be performed on the CEV 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, and b) the analysis shows the dissimilar system is independent when compared to the prime CEV 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.

[CA5904V-PO] The CEV capability to execute reconfigurable automation sequences shall be verified by demonstration. The demonstration shall use the flight CEV or flight equivalent hardware in simulated mission conditions. The command sequences identified in (TBD-001-996) documents shall be executed by the CEV. 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:

- the command sequences have been executed without human intervention

- the end state of the CEV at the end of the sequence execution is the same as if the commands had been executed manually

- the reconfigured command sequences execute the updated commands

- sequences are only executed when they are valid in the current state and are rejected otherwise

Rationale: A demonstration of the CEV 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.

[CA0470V-PO] The ability of the CEV to transmit and receive with geometric antenna coverage of 90% (TBR-001-335), excluding non-CEV structural blockage and re-entry plasma, for low rate data as defined by the CxP 70118, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Section 3.6.1.2 shall be verified by test and analysis.

The antenna to be used by the CEV 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, excluding non-CEV structural blockage and re-entry plasma, as mounted on the CEV. The analysis shall also determine the needed signal strength and quality to provide 90% (TBR-001-335) coverage. A field test shall be conducted on and installed antenna in a simulated CEV 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 (1) the analysis of mounted antenna coverage for low rate data, excluding non-CEV structural blockage and re-entry plasma, is shown to be greater than 90% (TBR-001-335), (2) 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 and (3) 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.

[CA3288V-PO] Simultaneous communication by CEV with ISS and MS as specified shall be verified by analysis and test.

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.

The verification shall be considered a success when a) testing shows the system can simultaneously exchange data at the maximum data rates with the specified systems for a period of 20 (TBR-001-405) minutes without apparent degradation, b) analysis shows that no degradation is predicted if the test time were indefinite with data maintained at the maximum data rate, and c) 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. 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.

[CA3287V-PO] Simultaneous communication by CEV with MS and 2 (TBR-001-126) other systems in space 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. The verification shall be considered a success when a) testing shows the system can simultaneously exchange data at the maximum data rates with the specified systems for a period of 20 (TBR-001-418) minutes without apparent degradation b) analysis shows that no degradation is predicted if the test time were indefinite with data maintained at the maximum data rate, and c) 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. 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.

[CA0344V-PO] The CEV 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 will be analyzed. The flight unit or similar units will be tested under simulated communications for the required period of time with sufficient radiated power to maintain communication with the communication infrastructure(s) measuring power consumption. 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 CEV with no more than 2 (TBR-001-541) breaks of no more than 2 (TBR-001-312) minutes each during a worst case landing location scenario, and c) testing shows CEV communication with Mission Systems for the 36 hour duration can be maintained in a simulated recovery exercise.

> *Rationale*: Communication coverage is critical to CEV 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 and operation of the actual hardware are necessary to guarantee lack of manufacturing defects. Recovery exercises will show the links necessary are in place.

[CA0511V-PO] The recording of critical data for reconstruction of catastrophic events by the CEV shall be verified by Test. The Test shall use the flight CEV 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-001-291) document(s) shall be recorded by the CEV. (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 critical data identified in (TBD-001-291) document(s):

- is available for retrieval after the flight hardware has been subjected to the environmental conditions specified in the CEV SRD.

Rationale: A Test of the recording of critical data for reconstruction of catastrophic events:

- defined by (TBD-001-291) document(s)

- by the flight CEV 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-001-291) 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.

4.7.1.2.11 CEV GN&C

[CA5819V-PO] The ability of the CEV to perform TCMs during TLC shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include multi-body gravity effects experienced during the TLC. 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 99.73% (TBR-001-377) probability that the CEV can perform the TCMs during TLC.

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.

[CA5921V-PO] The ability for the CEV to separate from the CLV shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations of the integrated CLV/CEV. 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 results shows a 99.73% (TBR-001-977) probability with a confidence of 90% (TBR-001-978) that the CEV can separate from the CLV.

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.

[CA4128V-PO] The CEV performance of attitude control of the CEV/LSAM mated configuration after CaLV EDS undocking through CEV/LSAM separation in LLO shall be verified by analysis. The CEV attitude control analysis shall be conducted in a NASA-accredited digital simulation. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, and environmental parameters for both CEV and LSAM. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access

Module (LSAM) Interface Requirements Document (IRD) is greater than 99.73% (TBR-001-509) with a 90% confidence.

Rationale: It is assumed that the integrated CEV/LSAM attitude limits will be documented in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

[CA0497V-PO] The capability to manually control the CEV 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 CEV 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] The CEV 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 CEV. The dynamic simulation, analysis, and hardware-in-the-loop tests shall verify the accuracy of the CEV 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, System Requirements for the Crew Exploration Vehicle (CEV) Element for the navigation and attitude determination capability has been met.

Rationale: NR

[CA3248V-PO] The CEV 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 CEV 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, System Requirements for the Crew Exploration Vehicle (CEV) Element have been met.

Rationale: NR

[CA0368V-PO] The capability of the CEV to rendezvous, conduct proximity operations, dock and undock, independent of lighting conditions shall be verified by analysis and test. The verification shall consist of analysis and test for final approach and docking, and analysis of rendezvous and proximity operations terminating at final approach.

The final approach and docking tests shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 30.5 (TBR-001-435) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor measurements and relative vehicle state estimates. The facility shall include flight or flight-like replicas of the target docking adapter with any required reflectors or target-cooperative hardware. The demonstration shall be conducted under the range of lighting conditions of table (TBD-001-292). The tests shall be considered successful when the simulation achieves docking contact conditions for all tests with initial conditions inside the docking corridor defined by (TBD) ISS-CEV IRD and (TBD) CEV/ISS IRD requirements.

The final approach and docking analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of CEV docking sensors driven by simulated sensor input such as video, reflector responses, target returns, etc. The analysis shall include Monte Carlo dispersions on lighting and initial condition parameters. The final approach and docking analysis shall be considered successful when the analysis shows that the probability of successful docking is greater than 99.73% (TBR-001-436) with a 90% confidence.

The rendezvous and proximity operations analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of any sensors relying on lighting (such as start trackers, or camera-based sensors) as well as models of environmental lighting conditions throughout the rendezvous. The analysis shall include Monte Carlo dispersions on lighting and initial condition parameters. The analysis shall be considered successful when the results show that the probability of achieving a relative state inside the final approach corridor with relative sensor acquisition are greater than 99.73% (TBR-001-437) with a 90% confidence.

[CA0462V-PO] The ability of the CEV 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 be conducted using a NASA-accredited digital simulation including models of the CEV, LSAM/CaLV EDS, and the ISS vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters, and environmental parameters and shall span nominal attitude and attitude rates. The analysis shall also include undocking cases initiated prior to and after rigidization of the docking mechanism is complete. The analysis shall be considered successful when 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 99.73% (TBR-001-319) with a 90% confidence for the following emergency undocking scenarios: (1) CEV undocking from LSAM/CaLV EDS, (2) CEV undocking from LSAM, and (3) CEV undocking from ISS. The test shall be conducted with the CEV docking interface hardware in conjunction with both LSAM and ISS docking interface hardware. The test shall be conducted with CEV, LSAM, and ISS docking interface hardware in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the CEV, LSAM, CaLV 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 the CEV 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: (1) CEV undocking from LSAM/CaLV EDS, (2) CEV undocking from LSAM, and (3) CEV 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 CEV undocking.
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> Rationale: Rationale for undocking hardware tests: The mechanical docking subsystems are critical to mission success for all CEV 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 the CEV 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 4 consecutive runs.

[CA0059V-PO] The ability of the CEV to actively accomplish rendezvous, proximity operations, dock, and undock with the LSAM/EDS shall be verified by test, demonstration and analysis. Docking and undocking tests and demonstrations shall be conducted with the CEV and EDS/LSAM docking interface hardware. Final approach and separation tests and demonstrations shall be conducted with the relative navigation sensor hardware. Rendezvous, proximity operations and docking/separation tests and analysis shall be conducted using certified digital simulations.

Docking Hardware The docking/undocking interface hardware verification shall include capture envelope testing, and demonstration of the docking/undocking hardware with simulated closed loop control.

The capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV and EDS/LSAM in a 6-DOF test facility. The docking test shall be successful when it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. The undocking test shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and LSAM that are within the specifications of CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements.

The docking/undocking hardware demonstration shall be conducted in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the CEV and EDS/LSAM navigation, guidance and control software. The docking demonstration shall be considered successful when docking is achieved under both (1) automated simulation control and (2) pilot-in-the-loop control. The docking demonstration shall be conducted with nominal vehicle health status and under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. The undocking demonstration shall be considered successful when the simulation results show that undocking separation and relative angular rates are within bounds specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements.

Relative Navigation Sensors Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 30.48 (TBR-001-441) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect docking. Testing shall be conducted under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. Testing shall be considered successful when the simulation achieves docking contact conditions for all tests with initial conditions inside the docking corridor defined by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements.

Relative navigation sensor demonstration shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 30.48 (TBR-001-441) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor measurements and relative vehicle state estimates. The vehicle simulation will accept and react to inputs from a pilot-in-the-loop. The demonstration shall be conducted under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. The demonstration shall be considered successful when the simulation achieves docking contact conditions for all demonstrations with initial conditions inside the docking corridor defined by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements.

SIL (or equivalent) Avionics The rendezvous, proximity operations, docking, and undocking tests shall be conducted within a SIL (or equivalent). The SIL (or equivalent) simulation shall include models of the LSAM/EDS vehicle attitude control systems and dynamics. These tests shall include one or more rendezvous and docking tests as well as one or more undocking tests conducted under nominal conditions. The rendezvous and docking test shall be considered successful when required docking contact conditions are demonstrated with no violations of trajectory or vehicle constraints. The undocking test shall be considered successful when undocking and departure proximity operations are demonstrated without re-contact and without violations of vehicle or trajectory constraints.

Analysis The rendezvous, proximity operations, docking and undocking analysis shall be conducted using a NASA-accredited digital simulation including models of both the CEV and LSAM/EDS vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. Analysis shall be performed for rendezvous, proximity operations, and docking as well as undocking and departure proximity operations. The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.73% (TBR-001-442) with a 90% confidence. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without re-contact is greater than 99.73% (TBR-001-443) with a 90% confidence.

Rationale: Rationale for docking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all CEV missions. These mechanisms must be characterized and verified to confirm the docking envelope and 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 docking/undocking test simulation must include models of both maneuvering (CEV) 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 can not be controlled in the operational environment.

[CA0131V-PO] The ability for the CEV to perform target vehicle functions during RPOD with the LSAM shall be verified by inspection, docking mechanism tests, CEV attitude control tests, and CEV attitude control analysis.

CEV design documentation shall be inspected to show that any CEV hardware required for proper functioning of the LSAM sensors or navigation system is present and mounted in accordance with the CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

The docking capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV and EDS/LSAM in a 6-DOF test facility. The docking test shall be successful when it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

The CEV 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 vehicle, including LSAM thruster plumes. One or more tests shall be conducted for all nominal LSAM approach trajectories. The attitude hold tests shall be considered successful when the results show that CEV attitude errors and angular rate errors remain within the limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements.

The CEV attitude control analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of environmental attitude disturbances, as well as models of the LSAM vehicle, including LSAM thruster plumes. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, environmental parameters and LSAM plume impingement parameters. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) is greater than 99.73% (TBR-001-444) with a 90% confidence.

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 CEV missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Much of the remaining test and analysis depends 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 (CEV) 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 can not be controlled in the operational environment.

[CA0369V-PO] The ability of the CEV to actively accomplish rendezvous, proximity operations, and docking, with the LSAM in LLO shall be verified by test, demonstration and analysis. Docking tests and demonstrations shall be conducted with the CEV and LSAM docking interface hardware. Final approach tests and demonstrations shall be conducted with the relative navigation sensor hardware. Rendezvous, proximity operations and docking tests and analysis shall be conducted using certified digital simulations.

The docking interface hardware verification shall include capture envelope testing, and demonstration of the docking hardware with simulated closed loop control. The docking capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for LSAM and CEV in a 6-DOF test facility. The docking test shall be successful when it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements.

The docking hardware demonstration shall be conducted in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the LSAM and CEV navigation, guidance and control software. The docking demonstration shall be conducted with nominal vehicle health status. The docking demonstration shall be considered successful when docking is achieved using real-time control inputs.

Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 10.36 (TBR-001-451) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect docking. Testing shall be considered successful when the simulation achieves docking contact conditions for all tests with initial conditions inside the docking corridor defined by (TBD-001-1003) LSAM-CEV IRD requirements.

Relative navigation sensor demonstration shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 10.36 (TBR-001-451) m (100 ft) of the approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor measurements and relative vehicle state estimates. The vehicle simulation will accept and implement real-time control inputs. The demonstration shall be considered successful when the simulation achieves docking contact conditions for all demonstrations with initial conditions inside the docking corridor defined by (TBD-001-1003) CEV-LSAM IRD requirements.

The rendezvous, proximity operations, and docking shall be conducted within a SIL (or equivalent). The LSAM SIL simulation shall include models of the CEV vehicle attitude control systems and dynamics. These tests shall include one or more rendezvous and docking tests conducted under nominal conditions. The rendezvous and docking test shall be considered successful when required docking contact conditions are demonstrated with no violations of trajectory or vehicle constraints.

The rendezvous, proximity operations and docking analysis shall be conducted using a NASA-accredited digital simulation including models of both the LSAM and CEV vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. Analysis shall be performed for rendezvous, proximity operations, and docking. The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.73% (TBR-001-450) with a 90% confidence.

Rationale: Rationale for docking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all CEV missions. These mechanisms must be characterized and verified to confirm the docking envelope and 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 docking/undocking test simulation must include models of both maneuvering (CEV) 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 can not be controlled in the operational environment.

[CA0187V-PO] The CEV performance of attitude control of the CEV/LSAM mated configuration after docking in LLO shall be verified by analysis. The CEV attitude control analysis shall be conducted in a NASA-accredited digital simulation. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, and environmental parameters for both CEV and LSAM. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) is greater than 99.73% (TBR-001-508) with a 90% confidence.

Rationale: It is assumed that the integrated CEV/LSAM attitude limits will be documented in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD). Note that this is an integrated performance requirement and may need a new CARD requirement to cover it.

[CA0133V-PO] The ability of the CEV to actively accomplish undocking with the LSAM in LLO shall be verified by test, demonstration and analysis. Undocking tests and demonstrations shall be conducted with the CEV and LSAM docking interface hardware. Separation tests and demonstrations shall be conducted with the relative navigation sensor hardware. Separation tests and analysis shall be conducted using certified digital simulations.

Docking/Undocking Hardware: the docking/undocking hardware testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV and LSAM in a 6-DOF test facility. The undocking tests shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and LSAM that are within the specifications of (TBD-001-655) LSAM-CEV IRD requirements.

Relative Navigation Sensors: Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the first 30.48 (TBR-001-542) m (100 ft) of the post-undocking separation. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect undocking and separation. Testing shall be conducted under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. Initial conditions for the tests shall be derived from the range of undocking separation forces and moments determined from the hardware tests. Testing shall be considered successful when the simulation achieves safe separation without re-contact for all tests.

SIL (or equivalent) Avionics: The undocking tests shall be conducted within a SIL (or equivalent). The SIL (or equivalent) simulation shall include models of the LSAM vehicle attitude control systems and dynamics. These tests shall include one or more undocking tests conducted under nominal conditions. The undocking test shall be considered successful when undocking and departure proximity operations are demonstrated without re-contact and without violations of vehicle or trajectory constraints.

Analysis: The undocking analysis shall be conducted using a NASA-accredited digital simulation including models of both the CEV and LSAM vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. Analysis shall be performed for undocking and departure proximity operations. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without re-contact is greater than 99.73% (TBR-001-449) with a 90% confidence.

Rationale: Rationale for docking/undocking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all CEV 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 (CEV) 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 can not be controlled in the operational environment.

[CA0081V-PO] The ability of the CEV to actively accomplish rendezvous, proximity operations, dock, and undock with the ISS shall be verified by test, demonstration and analysis. Docking and undocking tests and demonstrations shall be conducted with the CEV and ISS docking interface hardware. Final approach and separation tests and demonstrations shall be conducted with the relative navigation sensor hardware. Rendezvous, proximity operations and docking/separation tests and analysis shall be conducted using certified digital simulations.

The docking/undocking interface hardware verification shall include capture envelope testing, and demonstration of the docking/undocking hardware with simulated closed loop control. The docking/undocking capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV and ISS in a 6-DOF test facility.

The docking test shall be successful when it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. The undocking test shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and ISS that are within the specifications of CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. The docking/undocking hardware demonstration shall be conducted in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the CEV and ISS navigation, guidance and control software. The docking demonstration shall be considered successful when docking is achieved under both (1) automated simulation control, (2) CEV pilot-in-the-loop control, and (3) remote pilot-in-the-loop control (from ISS). The docking demonstration shall be conducted with nominal vehicle health status and under (TBD-001-325) range of lighting conditions spanning the operational range of the sensors. The undocking demonstration shall be considered successful when the simulation results show that undocking separation and relative angular rates are within bounds specified in CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 100 (TBR-001-246) ft of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect docking. Testing shall be conducted under (TBD-001-325) range of lighting conditions spanning the operational range of the sensors. Testing shall be considered successful when the simulation achieves docking contact conditions for all tests with initial conditions inside the docking corridor defined by CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. Relative navigation sensor demonstration shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 100 (TBR-001-246) ft of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor measurements and relative vehicle state estimates. The vehicle simulation will accept and react to inputs from a pilot-in-the-loop, both on board CEV and remote pilot commanding from ISS. The demonstration shall be conducted under (TBD-001-325) range of lighting conditions spanning the operational range of the sensors. The demonstration shall be considered successful when the simulation achieves docking contact conditions for all demonstrations with initial conditions inside the docking corridor defined by CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. The rendezvous, proximity operations, docking, and undocking tests shall be conducted within the a SIL (or equivalent). The SIL (or equivalent) simulation shall include models of the ISS vehicle attitude control systems and dynamics. These tests shall include one or more rendezvous and docking tests as well as one or more undocking tests conducted under nominal conditions. The rendezvous and docking test shall be considered successful when required docking contact conditions are demonstrated with no violations of trajectory or vehicle constraints. The undocking test shall be considered successful when undocking and departure proximity operations are demonstrated without re-contact and without violations of vehicle or trajectory constraints. The rendezvous, proximity operations, docking and undocking analysis shall be conducted using a NASA-accredited digital simulation including models of both the CEV and ISS vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. Analysis shall be performed for rendezvous, proximity operations, and docking as well as undocking and departure proximity operations. The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.73% (TBR-001-247) with a 90% confidence. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without re-contact is greater than 99.73% (TBR-001-248) with a 90% confidence.

> *Rationale*: Rationale for docking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all CEV missions. These mechanisms must be characterized and verified to confirm the docking envelope and separation dynamics. Much of the remaining test and analysis depends on the results of this testing.
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> 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.
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> 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 (CEV) 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.
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> 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 can not be controlled in the operational environment.

[CA0329V-PO] Guided entry landing accuracy shall be verified by analysis using a NASA-accredited digital entry simulation. Verification shall be considered successful when analysis of nominal direct and skip entry DRMs with system and environment dispersions shows a 99.73% (TBR-001-310) probability with a 90% confidence of achieving the required landing target accuracy at each of the designated CONUS landing sites (as appropriate to the specific DRM).

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.

[CA5286V-PO] The ability of the CEV to perform target vehicle functions during undocking and departure proximity operations from LSAM prior to lunar descent shall be verified by analysis. The analysis shall be performed using a NASA-accredited digital simulation of the CEV and LSAM vehicles. The analysis shall focus on the ability of the CEV to maintain attitude such that the relative navigation of the vehicles ensures no recontact. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, and environmental parameters for both CEV and LSAM. The verification shall be considered successful when the analysis shows that there is a 99.73% (TBD-001-901) probability with a 90% confidence that the CEV can support target vehicle functions during LSAM undock and departure proximity operations.

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. In this case, the verification will demonstrate that the passive CEV 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.

4.7.1.2.12 CEV RELIABILITY AND AVAILABILITY

[CA0178V-PO] The ability of CEV to have a launch availability of no less than 98% at a 50% confidence (TBR-001-041) exclusive of weather and range safety shall be verified by analysis. Analysis shall assess the CEV level 3 reliability analysis, maintainability planning, and the level 3 Logistics Support Plan (LSP). Verification shall be considered successful when analysis verifies the CEV launch availability of no less than 98% at a 50% confidence exclusive of weather and range safety.

Rationale: The CEV 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 "LCC Call to Station" and ending at close of day-of-launch window.

4.7.1.2.13 CEV MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[CA5495V-PO] The ability of CEV to sustain operations as defined in the DRM using only onboard equipment and spares without resupply or support from personnel other than the crew shall be verified by analysis. Analysis shall verify CEV conformance with CxP 70132, Constellation Program Commonality Plan, CxP 70087, Constellation Reliability and Maintenance (R&M) Plan, the CEV Logistics Support Plan (LSP), and the related Logistics Support Analysis Records (LSAR). Analysis shall be updated based upon ground testing. Verification shall be considered successful when analysis shows that CEV provides infrastructure to maintain systems through their operational life cycles 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.

4.7.1.2.14 CEV HABITABILITY AND HUMAN FACTORS

[CA0426V-PO] Net habitable volume shall be verified by analysis. The analysis shall review the design of the CEV and shall assess the net habitable volume using JSC 63557 (TBR-001-960), 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 CEV 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.

[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 the CEV over the range of 103 (TBR-001-923) to 58 (TBR-001-501) kPa (14.9 to 8.4 psia), in 0.7 (TBR-001-500) kPa (0.1 psia) increments.

Rationale: This is to allow the CEV to adjust between the primary operating atmospheric pressure setpoints - ISS at 102 kPa (14.8 psia), CEV at 70 kPa (10.2 psia).

[CA3105V-PO] The CEV 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 pre-breathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained during suit donning.

A test in the CEV 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 CEV 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.

[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 the CEV over the range of 18 (TBR-001-124) to 21 (TBR-001-911) kPa (2.6 to 3.1 psia), in 0.7 (TBR-001-912) kPa (0.1 psia) increments.

> *Rationale*: This is to verify the CEV will adjust the oxygen partial pressure setpoints to maintain the oxygen concentration within limits established to minimize material flammability concerns.

[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 CEV 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 CEV cabin. This also verifies that the materials flammability is not an issue at 30% (TBR-001-109) oxygen concentration.

[CA5711V-PO] Returning the CEV pressurized volume to a habitable environment following a contamination event shall be verified by analysis.

The analysis shall verify that the CEV 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 the CEV returns the CEV 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.

[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 CEV Gas Storage and vestibule pressurization shall show that the CEV 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 CEV can execute at least two vestibule pressurization cycles per mission.

Rationale: Analysis to calculate the quantity of nitrogen and oxygen, based on the CEV vestibule design and consumable requirements, coupled with the inspection of the storage hardware compliance data is sufficient.

[CA3106V-PO] The CEV 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 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 requirements for pre-breathe 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 pre-breathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained to support pre-breathe.

A test in the CEV 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 CEV can maintain cabin pressure to allow crew pre-breathe.

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.

[CA3140V-PO] The quantity of consumables required for 2 pressure events shall be verified by analysis.

The analysis shall determine the quantity of consumables resources required for the following cases: EVA (for lunar missions only) which includes gas for suit donning, suit purge, pre-breathe, cabin depress and cabin repress to 70 (TBR-001-127) kPa (10.2 psia); contaminated atmosphere event which includes gas for emergency breathing apparatus if applicable, and cabin depress/repress to initial pressure if applicable; unrecoverable cabin leak which includes gas required to maintain cabin at 55 kPa (8 psia) while crew dons suits, purges suit loop, and performs pre-breathe. The analysis shall determine which combination of 2 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 the CEV can provide consumables for 2 pressure events.

> *Rationale*: Analysis to calculate the quantity of nitrogen and oxygen for the worst two scenarios, based on the CEV vehicle design and consumable requirements, coupled with the inspection of the storage hardware compliance data is sufficient to verify this requirement.

4.7.1.2.15 CEV ENVIRONMENTAL CONDITIONS

[CA5555V-PO] CEV 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:

- Review of the induced environmental verifications submitted against all of the CEV/System IRD requirements.

- Review of the induced environment verifications submitted against CxP

72000, System Requirements for the Crew Exploration Vehicle (CEV) Element 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 CEV 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 1) the proper induced

environments have been considered, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA5560V-PO] CEV induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

- Review of the induced environmental verifications submitted against all of the CEV/System IRD requirements.

- Review of the induced environment verifications submitted against CxP

72000, System Requirements for the Crew Exploration Vehicle (CEV) Element 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 (IEDS). The verification shall be considered successful when the analysis shows that the CEV 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 1) the proper induced environments have been met, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA0374V-PO] Compliance of the CEV 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: 1) Development of a Natural Environment Requirements Sensitivity and Applicability Matrices (NERSAMs), defined in section 4 of the DSNE, and 2) 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: CEV/LSAM, CEV/LSAM/CaLV-EDS, CEV/CLV, CEV/CLV/GS, CEV/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: 1) The NERSAM has been completed in accordance with section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), 2) 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), 3) Lower tier verifications have been completed and 4) The CEV 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.

4.7.1.3 RESERVED

4.7.1.4 CEV EXTERNAL INTERFACES

[CA0429V-PO] The CEV interfaces with the CLV shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CEV Project Office to demonstrate that the CEV-to-CLV interface requirements defined within 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 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV and CLV 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 CEV/CLV 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 CEV interface verification requirements defined within CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document, have been satisfied and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 CEV Project Office to confirm that all of the CEV-to-CLV interface requirements specified in CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document have been satisfied. Integrated testing of the CEV and CLV 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 CEV and CLV 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] The CEV 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 CEV Project Office to demonstrate that the CEV-to-LSAM interface requirements defined within the CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) 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 CEV 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 CEV/LSAM in-space 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 in-space vehicle stack and the ground support and mission control systems. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD), have been satisfied, and (b) when the 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 CEV Project Office to confirm that all of the CEV-to-LSAM interface requirements specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD)have been satisfied. Integrated testing of the CEV 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 in-space CEV/LSAM vehicle stack for part of the lunar transit, integrated testing will include configurations with and without the EDS. Since the first time the CEV 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.

[CA0361V-PO] The CEV interfaces with the CaLV EDS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CEV Project Office to demonstrate that the CEV-to-CaLV EDS interface requirements defined within the CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) 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 CEV and CaLV 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 CaLV EDS. Testing shall also include a multi-system integrated test of the integrated CEV/LSAM/CaLV EDS in-space 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 in-space vehicle stack and the ground support and mission control systems. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD), have been satisfied, and (b) when the 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 CEV Project Office to confirm that all of the CEV-to-EDS interface requirements specified in the IRD have been satisfied. Integrated testing of the CEV 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 in-space CEV/EDS vehicle stack, integrated testing will include configurations with the LSAM. Since the first time the CEV 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.

[CA0894V-PO] The CEV 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 CEV Project Office to demonstrate that the CEV-to-MS interface requirements defined within the CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) 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 CEV 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 CEV, GS, and MS. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied and (b) when the 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 CEV Project Office to confirm that all of the CEV-to-MS interface requirements specified in the IRD have been satisfied. Integrated testing between the CEV 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.

[CA0893V-PO] The CEV 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 CEV Project Office to demonstrate that the CEV-to-GS interface requirements defined within the CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) 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 CEV 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 CEV and GS. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD) have been satisfied, and (b) when the 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 CEV Project Office to confirm that all of the CEV-to-GS interface requirements specified in the IRD have been satisfied. Integrated testing between the CEV 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.

[CA0896V-PO] The CEV 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 CEV Project Office to demonstrate that the CEV interface requirements defined within CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV) 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 CEV 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 CEV interface verification requirements defined within CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV) have been satisfied, and

(b) when the 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 CEV Project Office to confirm that all of the CEV-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrated testing between the CEV 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.

[CA0895V-PO] The CEV 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 CEV Project Office to demonstrate that the CEV-to-EVA interface requirements defined within CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV 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 CEV, GS, and EVA systems. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 CEV Project Office to confirm that all of the CEV-to-EVA interface requirements specified in the IRD have been satisfied. Integrated testing between the CEV 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.

4.7.1.5 CEV PHYSICAL CHARACTERISTICS

[CA5933V-PO] The ability of the CEV SM to be configured as a standalone Element shall be verified by analysis. The analysis shall consist of a review of the avionics, power, thermal, GN&C, C&T, structural and mass/volume capabilities of the CEV SM to show that it has the performance available for robotic missions. The analysis shall review the CEV SM design in a standalone configuration for compatibility with mission specific avionics kits, the addition of a fairing, and Architecture capabilities (e.g., communications, ground operations). The verification shall be considered successful when the analysis shows that the SM can be configured to meet independent mission needs.

Rationale: Analysis will confirm sufficient mission resources and margins for performing the desired missions. CEV capability assessment will confirm that the vehicle will provide the support services that are needed for completion of the mission.

[CA0386V-HQ] The outer mold-line of the CEV shall be verified by inspection. The inspection shall consist of the review of CEV 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 the CEV is in compliance with CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line.

Rationale: NR

4.7.2 CREW LAUNCH VEHICLE (CLV)

4.7.2.1 CLV DESCRIPTION

4.7.2.2 CLV REQUIREMENTS

4.7.2.2.1 CLV MISSION SUCCESS

[CA5916V-PO] The single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the CLV 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 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 documents. It looks top down and bottoms up at the system level.

[CA1065V-PO] Loss of CLV 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 (a (TBD-001-1013) probability) that loss of CLV missions is not greater than 1 in 500 (TBR-001-174).

Rationale: NR

[CA5805V-PO] The two fault tolerance for catastrophic hazard shall be verified by analysis. The analysis shall review the results of the CLV 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 documents. It looks top down and bottoms up at the system level.

4.7.2.2.2 CLV CREW SURVIVAL

[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:

1) The CLV performs the abort determination function(s) through an internal algorithm using internal or external data sources.

2) The CxP Architecture elements receive notification from the CLV of the need for an abort through the C3I infrastructure.

3) The profiles, boundaries, modes, variable ranges and accuracy specified in (TBD-001-783) 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-001-783) 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.

[CA0258V-PO] The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the CLV 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.

4.7.2.2.2.1 CLV CREW SURVIVAL PROBABILITIES

[CA5914V-PO] 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 a (TBD-001-1001) probability that LOC for an ISS Crew Mission is no greater than 1 in (TBD-001-948).

[CA3163V-PO] CLV LOC for a crewed 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 (a (TBD-001-915) probability) that LOC for CLV is not greater than 1 in (TBD-001-219).

Rationale: NR

4.7.2.2.2.2 CLV EMERGENCY EGRESS, ABORTS AND RETURN FOR SURVIVABILITY

[CA5159V-PO] The unassisted emergency egress for six (TBR-001-211) ground crew from internal CLV 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 crew members and collecting the task time for ground crew egress from initiation of the egress event to the last person being external to CLV. 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 CLV 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 CLV 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 CLV exit point.

Rationale: NR

4.7.2.2.3 RESERVED

4.7.2.2.4 RESERVED

4.7.2.2.5 RESERVED

[CA5512V-PO] The ability of the CLV to attain the nominal and maximum flight rate for the Lunar missions shall be verified by analysis. The analysis shall assess the integrated schedule and facilities required to deliver, process, and launch the CLV. The verification shall be considered successful when the analysis determines the CLV is capable of 2 flights per year with capacity for 3.

Rationale: In order to support CLV delivery, assembly and integration, testing requires facilities and integrated schedules of processing flows to accommodate flight hardware and associated support equipment to process and launch up to 3 flights per year will need to be developed.

4.7.2.2.6 CLV ARCHITECTURE DEFINITION

[CA3202V-PO] The delivery of the CEV from the launch site to Ascent Target shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations of the integrated CLV/CEV. 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 results show a 99.73% (TBR-001-374) probability with a 90% confidence that the CEV can achieve the Ascent Target.

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.

[CA5713V-PO] CLV to provide refurbishment of the CLV First Stage reusable elements 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. These facility, facility systems and GSE requirements will be identified and characterized in the CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD). The verification shall be considered successful when the analysis shows that the CxP 72034, Crew Launch Vehicle (CLV) System Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that support refurbishment of CLV First Stage flight elements have been satisfied per the design certification review.

[CA5677V-PO] The CLV 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) System Requirements Document (SRD), CxP 72006, Ground Systems Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. 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 CLV Architecture independent of ambient lighting conditions.

[CA1023V-PO] The liftoff clearance between the CLV integrated stack vehicle and the launch facility shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations of the integrated stack dynamics, the launch facility, and the ability to compute the minimum clearance between the closest elements of the facility and the CLV integrated stack. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters, and structure location. The verification shall be considered successful when the analysis results show that there is a 99.7% (TBR-001-385) probability that the CLV integrated stack can maintain the liftoff clearance with respect to the launch facility as defined in the CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD).

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.

[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 CLV design shall be verified by inspection. The inspection shall consist of the review of CLV 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 CLV 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 CLV design shall be verified by inspection. The inspection shall consist of the review of CLV 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 CLV design

[CA3221V-PO] The ability of the CLV 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 CLV flight hardware and a certified flight-like communication system. The verification shall be considered successful when test results show the CLV can accurately change ascent trajectory based on design parameter updates.

Rationale: Data exchange between the CLV 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 CLV 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 CLV flight hardware and a certified flight-like communication system. The verification shall be considered successful when test results show the CLV can accurately change ascent trajectory based on updates provided prior to launch.

Rationale: Data exchange between the CLV 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.

4.7.2.2.6.1 CLV CONTROL MASS

[CA4138V-PO] The capability of the CLV to accommodate the Gross Lift Off Weight of the CEV shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 a 99.73% (TBR-001-1020) probability that the CLV can accommodate the Gross Lift Off Weight of the CEV.

Rationale: NR

[CA1005V-PO] The CLV Mass Delivered requirement from Earth to the Ascent Target for crewed lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 calculated Mass Delivered capability of the CLV is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-407), with a 90% confidence, of the simulations during the worst performing month.

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.

[CA1000V-PO] The CLV Mass Delivered requirement from Earth to the Ascent Target for crewed lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on vehicle and environmental parameters. The verification shall be considered successful when the analysis shows that the calculated Mass Delivered capability of the CLV is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-406) with a 90% confidence for an on-time launch during the worst performing month.

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.

[CA4165V-PO] That CLV is accommodating the Gross Lift Off Weight of CLV is verified by inspection. The requirement is considered successful when the CEV Gross Lift-off Weight in the input deck of the digital simulation used for CLV Mass Delivered requirement for ISS is equal to the CEV Gross Lift-off Weight requirement.

Rationale: NR

4.7.2.2.6.2 RESERVED

4.7.2.2.7 CLV SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA5825V-PO] The ability of the CLV to automatically shutdown CLV 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 CLV elements to detect the faults. The verification shall be considered successful when the analysis shows that the CLV can detect the faults that lead to catastrophic conditions that will occur in 2 seconds and the required CLV 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 CLV flight termination systems shall be verified by demonstration. The demonstration shall use the flight CLV 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 CLV 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 CLV 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 CLV. They may be attached to and destroy dummy hardware as long as the CLV 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 CLV 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 CLV flight termination systems. The verification shall be considered successful when the inspection conclusively shows that the CLV cannot be launched with crew when the auto initiate capability of the CLV flight termination systems is installed or enabled. The demonstration shall use the flight CLV 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 CLV 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 CLV flight termination systems.

[CA0566V-PO] The CLV 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 Manual, 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 CLV 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: A) 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.

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-001-852) 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:

1) Telemetry shows that the (CLV) generated an indication upon each FTS command.

2) The telemetry shows that the indication of each FTS command was received by the CxP destination (i.e. CEV)

3) That the combined environments will not induce a false indication from the (CLV).

Rationale: A) Testing is considered the best means for requirement verification. FTS testing is the established precedence for verification.

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-001-343) 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 CLV 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 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 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.

4.7.2.2.8 CLV COMMAND AND CONTROL

[CA3256V-PO] The execution of commands by the CLV which are valid in the current state shall be verified by Test. The Test shall use the flight CLV 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 CLV. (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):

- are executed by the CLV when valid in the current state in each applicable mission phase, state and mode

- are rejected by the CLV when not valid in the current state in each applicable mission phase, state and mode.

Rationale: A Test of the execution of CLV commands

- defined by (TBD-001-734) document(s)

- by the flight CLV 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-001-734) 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 CLV.

[CA3275V-PO] The execution of commands by the CLV which are addressed to the CLV shall be verified by Test.

The Test shall use the flight CLV 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 CLV. (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 CLV 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):

- are executed by the CLV when addressed to the CLV

- are processed by the CLV 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 CLV.

Rationale: A Test of the execution of CLV commands

- defined by (TBD-001-763) document(s)

- by the flight CLV 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-001-763) 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 CLV.

[CA3112V-PO] The requirement for the CLV 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:

1) The vehicle's running function is halted by the authorized Constellation System assuming vehicle control.

2) When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

3) 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.

[CA1029V-PO] The CLV Autonomous Lift-Off and Ascent Operations requirement verification shall be satisfied by demonstration. A) Demonstrations shall be performed using the flight (CLV) assets and Crew Surrogates under simulated flight conditions during integrated ground exercises. B) Demonstrations using the flight/flight-like assets (CLV) 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:

1) Demonstrated autonomous operation is accomplished.

2) Additional adjustments are not required.

3) External intervention was not necessary.

> *Rationale*: A) Demonstrations using Flight Assets and the CxP Architecture provide the best environment to demonstrate autonomous functions. B) Demonstrations during simulations and training exercises are necessary to reduce the risk of being unable to perform the autonomous operation during flight.
>
> The (TBD-001-422) 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.

4.7.2.2.9 CLV HEALTH AND STATUS

[CA5816V-PO] The provision of fault detection by the CLV shall be verified by Test.

The Test shall use the flight CLV 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 CLV 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 CLV in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the CLV

- for the faults and fault scenarios identified by (TBD-001-1008) document(s)

- by the flight CLV or flight equivalent hardware

- for each mission phase, state and mode is 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.

[CA3118V-PO] The generation of health and status information by the CLV shall be verified by Test. The Test shall use the flight CLV 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 CLV. (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):

- is generated by the CLV in each applicable mission phase, state and mode.

- agrees with the actual health and status of the CLV.

Rationale: A Test of the generation of CLV health and status data:

- defined by (TBD-001-708) document(s)

- by the flight CLV 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-001-708) 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 CLV.

[CA1084V-PO] The provision of fault detection by the CLV shall be verified by Test. The Test shall use the flight CLV 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 CLV 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 CLV in every applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the CLV

- for the faults and fault scenarios identified by (TBD-001-346) document(s)

- by the flight CLV or flight equivalent hardware

- 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 CLV shall be verified by Test. The Test shall use the flight CLV 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 CLV 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 CLV in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the CLV

- for the faults and fault scenarios identified by (TBD-001-424) document(s)

- by the flight CLV or flight equivalent hardware

- 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 CLV shall be verified by Test. The Test shall use the flight CLV 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 CLV 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 CLV in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the CLV

- for the faults and fault scenarios identified by (TBD-001-347) document(s)

- by the flight CLV or flight equivalent hardware

- 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.

4.7.2.2.10 CLV COMMUNICATIONS AND COMMUNICATIONS SECURITY

[CA5906V-PO] The CLV capability to reconfigure stored commands, sequences and data shall be verified by demonstration. The demonstration shall use the flight CLV or flight equivalent hardware in simulated mission conditions. The CLV 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 CLV and that they properly reflect the updated values.

Rationale: A demonstration of the CLV 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 CLV with the CEV, 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 CLV launch operation scenarios. The test shall consist of simulations of the communications for nominal and off-nominal CLV 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 CLV can simultaneously exchange data with the CEV, Mission Systems, and Ground Systems for CLV pre-launch and launch operations correctly and without apparent degradation for both nominal and maximum data rates for each scenario at least twice, and 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 CLV 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.

4.7.2.2.11 CLV GN&C

[CA3143V-PO] The CLV 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 CLV. The dynamic simulation, analysis, and hardware-in-the-loop tests shall verify the accuracy of the CLV 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) System Requirements Document (SRD) for the navigation and attitude determination capability from pre-launch through CLV upper stage separation from the CEV has been met.

Rationale: NR

[CA1017V-PO] The ability of the CLV to deliver the CEV to Ascent Target shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations of the integrated CLV/CEV. The analysis shall include Monte Carlo dispersions on the mass properties, engine performance, GN&C parameters, and environmental parameters. The verification shall be considered successful when the analysis results show that there is a 99.73% (TBR-001-482) probability with a 90% confidence that the vehicle achieves orbit with the specified accuracies.

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.

4.7.2.2.12 CLV RELIABILITY AND AVAILABILITY

[CA1066V-PO] The ability of the CLV to meet a 98% (TBR-001-041) availability of launch per crew launch attempt, starting at "LCC Call to Station" and ending at close of day of launch window 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 and Maintainability (R&M) Plan. Verification shall be considered successful when analysis shows that the availability of launch per crew launch attempt is at least 98% (TBR-001-041)) with an uncertainty of not greater than (TBD-001-345) %.

Rationale: The CLV 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 "LCC Call to Station" and ending at close of day-of-launch window.

[CA1068V-PO] The ability of the CLV to a meet a 95% (TBR-001-966) launch availability 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 requirements and the Induced Environments Design Specification. The envelope defining the extents of the compiled data from these sources should then defined as the weather constraints for launch availability assessments. The defined weather constraints shall subsequently be analyzed against the 95% (TBR-001-966) weather conditions for a given launch window and determine that the CLV can launch within these conditions with no more than (TBD-001-345) % uncertainty. The verification shall be considered successful when the analysis concludes within the (TBD-001-345) confidence interval that the CLV has a launch probability of 95% (TBR-001-966) with respect to the natural environment.

Rationale: The assessment of the launch availability with respect to the natural environment must consider associated induced effects of the launch configuration, i.e. CEV 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.

[CA1008V-PO] The ability for the CLV to provide launch opportunities for four (TBR-001-193) consecutive days for crewed missions shall be verified by analysis. The analysis shall assess the Integrated Logistics Support Plan, the CLV 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 four consecutive days. The verification shall be considered successful when the analysis results show that the CLV can provide launch opportunities for at least four (TBR-001-193) consecutive days for crewed 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.

[CA5323V-PO] The requirement for the CLV to have a 90 (TBR-001-181) min planar launch window per crewed launch opportunity for Lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and day-of-launch environmental effects The verification shall be considered successful when the analysis results show a 99.73% (TBR-001-487) probability with a 90% confidence that the CaLV can launch within at least a 90 (TBR-001-181) min planar launch window 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.

[CA0072V-PO] The requirement for the CLV to have a 10 (TBR-001-140) minute planar launch window per crewed launch opportunity for ISS missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and day-of-launch environmental effects. The verification shall be considered successful when the analysis results show a 99.73% (TBR-001-372) probability with a 90% confidence that the CLV can launch (planar) within at least a 10 (TBR-001-140) minute window for ISS 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.

4.7.2.2.13 RESERVED

4.7.2.2.14 RESERVED

4.7.2.2.15 CLV ENVIRONMENTAL CONDITIONS

[CA5557V-PO] CLV 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:

- Review of the induced environmental verifications submitted against all of the CLV/System IRD requirements.

- Review of the induced environment verifications submitted against CxP 72034, Crew Launch Vehicle (CLV) System 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 (IEDS). The verification shall be considered successful when the analysis shows that the CLV 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 1) the proper induced environments have been considered, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA5562V-PO] CLV induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

- Review of the induced environmental verifications submitted against all of the CLV/System IRD requirements.

- 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 (IEDS). The verification shall be considered successful when the analysis shows that the CLV 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 1) the proper induced environments have been met, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA1069V-PO] Compliance of the CLV 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:

1) Allocation of the natural environments requirements to the lower tier systems and their verification methods and details, and

2) 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: CEV/CLV/GS, CEV/CLV, and CLV/GS. The verification shall be considered successful when the inspection and integrated analysis show:

1) The natural environment requirements and verification have been allocated to the lower tier systems in accordance section 4 of the DSNE

2) Lower tier verifications have been completed and

3) The CLV 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.

4.7.2.3 RESERVED

4.7.2.4 CLV EXTERNAL INTERFACES

[CA0898V-PO] The CLV 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 CLV Project Office to demonstrate that the CLV-to-MS interface requirements defined within the CxP 70053, Constellation Program Crew Launch Vehicle (CLV) 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 CLV 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 CLV, GS, and MS. Verification shall be considered successful when (a) Analysis confirms that all of the CLV interface verification requirements defined within CxP 70053, Constellation Program Crew Launch Vehicle (CLV) to Mission Systems (MS) Interface Requirements Document (IRD) have been satisfied, and (b) when the 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 CLV Project Office to confirm that all of the CLV-to-MS interface requirements specified in the IRD have been satisfied. Integrated testing between the CLV 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.

[CA0897V-PO] The CLV 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 CLV Project Office to demonstrate that the CLV-to-GS interface requirements defined within the CxP 70052, Constellation Program Crew Launch Vehicle (CLV) 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 CLV 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 CLV and GS. Verification shall be considered successful when

(a) Analysis confirms that all of the CLV interface verification requirements defined within CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD) have been satisfied, and

(b) when the integrated avionics, software, and multi-system test objctives 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 CLV Project Office to confirm that all of the CLV-to-GS interface requirements specified in the IRD have been satisfied. Integrated testing between the CLV 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.

[CA0899V-PO] The CLV 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 CLV Project Office to demonstrate that the CLV interface requirements defined within the CxP 70118-02, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 2: Crew Launch Vehicle (CLV) 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 CLV 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 CLV interface verification requirements defined within CxP 70118-02, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 2: Crew Launch Vehicle (CLV) have been satisfied, and

(b) when the 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 CLV Project Office to confirm that all of the CLV-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrated testing between the CLV 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.

[CA0430V-PO] The CLV interfaces with the CEV shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CLV Project Office to demonstrate that the CLV-to-CEV 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 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CLV and CEV 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 CLV/CEV 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 CEV interface verification requirements defined within CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 CLV Project Office to confirm that all of the CLV-to-CEV interface requirements specified in CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document have been satisfied. Integrated testing of the CLV and CEV 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 CLV and CEV 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.

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 analysis shall be performed using a NASA-accredited digital flight simulation, which shall include lunar orbit, descent, and landing capabilities. 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 99.73% (TBR-001-375) probability 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

[CA0504V-PO] **Draft** 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 (a TBD-001-959) probability) that LOM for a Lunar Sortie mission due to the LSAM is no greater than 1 in 75 (TBR-001-060).

Rationale: NR

[CA3036V-PO] **Draft** 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 (a (TBD-001-919) probability) that LOM for a Lunar Outpost Crew mission due to LSAM is not greater than 1 in (TBD-001-557).

Rationale: NR

[CA3042V-PO] **Draft** 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 (a (TBD-001-942) probability) that 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

[CA5193V-PO] **Draft** 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:

- LSAM minimum system operation with an unpressurized cabin for 3 (TBR-001-171) hours

- LSAM launch off lunar surface and rendezvous with CEV

- LSAM ECLSS cooling to all minimum systems with an unpressurized cabin for 3 (TBR-001-171) hours

- LSAM alarm annunciation to crew inside pressure suit

- 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)

- (TBD-001-945) Others

- 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

[CA5194V-PO] **Draft** 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 crew-members (six crew-members 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 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-001-172) minutes.

Rationale: NR

[CA5191V-PO] **Draft** 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:

- EVA System oxygen quantity for 7 (TBR-001-214) hours

- EVA System oxygen flow rates for 7 (TBR-001-214) hours

- EVA System breathing gas scrubbing for 7 (TBR-001-214) hours

- EVA System fluid flow rates and temperatures for 7 (TBR-001-214) hours

- EVA System power for 7 (TBR-001-214) hours

- EVA System nutritional, medical, and hydration needs for 7 (TBR-001-214) hours

- Communication (voice, suit and biomed data) with EVA System for 7 (TBR-001-214) hours

- Seat ingress and harness securing with a pressurized suit for lunar ascent and CEV docking (if required)

- Ability for interfacing CEV 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 4 crewmembers.

Rationale: NR

[CA3139V-PO] **Draft** 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.

4.7.3.2.2.1 LSAM CREW SURVIVAL PROBABILITIES

[CA0503V-PO] **Draft** 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 (a (TBD-001-958) probability) that LOC for a Lunar Sortie mission due to the LSAM is no greater than 1 in 250 (TBR-001-059).

Rationale: NR

[CA3041V-PO] **Draft** 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 (a (TBD-001-941) probability) that 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 CEV/LSAM vehicle to a safe CM entry point from any point between TLI and CEV/LSAM separation. The lunar descent analysis shall be perfumed on aborts during lunar descent using a NASA-accredited digital simulation and shall include models of the LSAM stage separation as well as the CEV in lunar orbit. The testing shall be conducted with within a SIL (or equivalent) facility and shall include testing of LSAM abort trajectory maneuvers with the CEV/LSAM vehicle, testing of Ascent stage abort maneuvers during LSAM descent, and testing of the LSAM capability to separate and stabilize the CEV/LSAM vehicle while mated to the CaLV, including during the TLI maneuver. The trajectory analysis verification shall be considered successful when the analysis shows that LSAM propellant is sufficient to return the CEV/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 the CEV is not less than 95% (TBR-001-468). 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 CEV/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 CEV. The LSAM/CaLV separation testing shall be considered successful when the results show that the LSAM can separate from the CaLV without recontact and stabilize the mated CEV/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.

[CA5238V-PO] **Draft** The LSAM expedited return from lunar surface to docking with CLV LRO shall be verified by analysis and test. The analysis shall be conducted using a NASA-accredited digital simulation with dispersed parameters. The testing shall be conducted using a SIL (or equivalent) with models of the LSAM ascent stage as well as the CEV in lunar orbit. The verification shall be considered successful when the analysis test shows that the LSAM ascent stage can return the crew to the orbiting CEV within 12 (TBR-001-179) hours under nominal conditions. The analysis shall be considered successful when the results show that there is a 99.73% probability with a 90% confidence of successful return of the CEV to low lunar orbit within 12 (TBR-001-179) hours in the presence of dispersions.

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 CEV independent of communications with MS shall be verified by analysis. The analysis shall be performed using a NASA-accredited digital simulation, including models of LSAM and CEV navigation subsystems that impact the ability of the vehicle to navigate independent of

MS. The analysis shall include Monte Carlo dispersions mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis shows there is a 99.73% (TBR-001-463) probability with a 90% confidence that the LSAM can return the crew to the CEV independent of communications with MS.

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.

4.7.3.2.3 RESERVED

4.7.3.2.4 LSAM CARGO DELIVERY AND RETURN

[CA4140V-PO] The LSAM Mass Delivered requirement during the TLC and the LOI shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 calculated Mass Delivered of the LSAM is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-924) of the simulations with a 90% confidence.

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.

[CA0062V-PO] **Draft** 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 the results of NASA accredited digital flight simulations. 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 Return Mass Capability of the LSAM is equal to or greater than the Return Mass requirement for 99.73% (TBR-001-303) of the simulations with a 90% confidence.

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.

[CA5156V-PO] **Draft** 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:

- LSAM provisions for returning cargo volume of at least (TBR-001-167) from the lunar orbit to earth for Lunar Sortie missions

- 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).

[CA0090V-PO] **Draft** 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 the results of NASA accredited digital flight simulations. 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 calculated Mass Delivered of the LSAM is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-475) of the simulations with a 90% confidence.

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.

[CA0137V-PO] **Draft** The LSAM Mass Delivered requirement to the lunar surface for uncrewed Outpost Cargo missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 calculated Mass Delivered capability of the LSAM is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-300) of the simulations with a 90% confidence.

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.

4.7.3.2.5 LSAM MISSION RATES AND DURATIONS

[CA0839V-PO] **Draft** The ability for the LSAM to loiter in LEO at least (TBD-001-975) days after orbit insertion shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include high-order earth gravity effects. 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-001-327) probability with a 90% confidence 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0842V-PO] **Draft** 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

[CA4150V-PO] **Draft** 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 compliment for a duration of at least 7 days.

Rationale: NR

4.7.3.2.6 LSAM ARCHITECTURE DEFINITION

[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 analysis shall be performed using the results of NASA-accredited digital flight simulations, including lighting models that have been validated against test data. The analysis shall include Monte Carlo dispersions of lighting conditions, mass properties, engine performance, vehicle consumables, and GN&C parameters. The verification shall be considered successful when the test results show that the selected navigation sensors can operate within expected lighting conditions, and when the analysis shows that there is a 99.73% (TBR-001-543) probability with a 90% confidence that 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3286V-PO] **Draft** 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.

[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 will be performed using a NASA-accredited digital flight simulation, which 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 99.73% (TBR-001-378) probability with a 90% confidence that the LSAM to deliver the crew and cargo from LDO to the lunar surface.

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.

[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 analysis will be performed using a NASA-accredited digital flight simulation, which 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 99.73% (TBR-001-379) probability with a 90% confidence that the LSAM to deliver the crew and cargo from the lunar surface to LRO.

> *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.

[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 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 restart. The verification shall be considered successful when the analysis shows the probability of system restart is (TBD-001-315) and that the steady-state thrust after restart is (TBD-001-1010). 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 steady-state thrust 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. Test provides the necessary quantitative data that confirms the propulsion system performs as required.

[CA5195V-PO] The ability of the LSAM to perform at least 1 (TBR-001-217) in-space 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 CEV docking.

- Ability for the crew to depress the vehicle cabin

- Compliance to EVA specifications per CxP 70130, Constellation Program Extravehicular Activity (EVA) Design and Construction Specification

- Internal volume to egress and ingress the vehicle with a full complement of crew-members

- Provide consumables to support 4 crewmembers for 1 EVA (4 (TBR-001-244) hours per EVA)

- Translation paths to and stabilization for Contingency and Unscheduled EVA tasks

- Hatch operable with pressure suits

- 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 4 crewmembers while the LSAM habitable volume is depressurized:

- EVA System oxygen quantity and flow rates

- EVA System breathing gas scrubbing

- EVA System fluid flow rates and temperatures

- EVA System power

- Communication (voice, suit and biomed data) with EVA System

- Provide the functions simultaneously during the 4 (TBR-001-244) hour EVA for 2 EVA crewmembers with an umbilical length of 30 (TBR-001-529) feet and 2 IVA crewmembers with an umbilical length of 10 (TBR-001-530) feet.

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.

1. Four suits (and crewmembers) will be connected to all short umbilical positions with the suits performing simultaneously.

2. 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:

- 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)

- 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.

- 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) in-space EVA operation is based on the Contingency EVA transfer of the crew from LSAM to the CEV.

[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.

[CA5149V-PO] The ability of LSAM project to provide the infrastructure necessary to concurrently operate at least 2 (TBR-001-218) LSAM in-space 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 2 (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 2 (TBR-001-218) LSAM in-space 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).

4.7.3.2.6.1 LSAM CONTROL MASS

[CA0836V-PO] **Draft** 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 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 LSAM total predicted mass is less than or equal to the required Control Mass.

Rationale: N/R

[CA5231V-PO] **Draft** 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 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 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

[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. This analysis shall be performed using the results of NASA accredited digital flight and performance simulations. 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 calculated translational delta-V of the LSAM is equal to or greater than the delta-V requirement for 99.73% (TBR-001-504) of the simulations with a 90% confidence.

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.

[CA0837V-PO] The LSAM translational Delta-V requirement for the LSAM/CEV mated configuration shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight and performance simulations. 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 calculated Delta-V of the LSAM for the LSAM/CEV mated configuration is greater than or equal to the translational Delta-V requirement for 99.73% (TBR-001-325) of the simulations with a 90% confidence.

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.

[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. This analysis shall be performed using the results of NASA accredited digital flight and performance simulations. 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 calculated translational delta-V of the LSAM is equal to or greater than the translational delta-V requirement for 99.73% (TBR-001-505) of the simulations with a 90% confidence.

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.

[CA4145V-PO] The LSAM translational delta-V requirement for the Lunar Outpost cargo missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight and performance simulations. 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 calculated translational delta-V of the LSAM is equal to or greater than the delta-V requirement for 99.73% (TBR-001-506) of the simulations with a 90% confidence.

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.

4.7.3.2.7 LSAM SAFETY

[CA0891V-PO] **Draft** The two fault tolerance for catastrophic hazard shall be verified by analysis. The analysis shall review the results of the LSAM 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

Rationale: Verification for 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 and CxP 70038, Constellation Program Hazard Analyses Methodology. It looks top down and bottoms up at the system level.

[CA0890V-PO] **Draft** The single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the LSAM 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

Rationale: Verification for 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 and the CxP 70038, Constellation Program Hazard Analyses Methodology. It looks top down and bottoms up at the system level.

[CA5399V-PO] **Draft** 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 bottoms up at the system level.

4.7.3.2.8 LSAM COMMAND AND CONTROL

[CA5801V-PO] The capability to control the LSAM system by a single crew member 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 crew member 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 does 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 crew member 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.

[CA3272V-PO] **Draft** 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)

- by 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-001-640) 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 CaLV.

[CA3250V-PO] **Draft** 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.

[CA3258V-PO] **Draft** 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):

- are executed by the LSAM when valid in the current state in each applicable mission phase, state and mode

- 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)

- by 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-001-738) 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.

[CA3111V-PO] **Draft** 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:

1) The vehicle's running function is halted by the authorized Constellation System assuming vehicle control.

2) When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

3) 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.

[CA3277V-PO] **Draft** 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):

- are executed by the LSAM when addressed to the LSAM

- 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 CaLV commands

- defined by (TBD-001-772) document(s)

- by 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-001-772) 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.

[CA5440V-PO] **Draft** 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:

1) 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).

2) All possible profiles, boundaries, variable ranges and accuracy are verified within the specified (TBD-001-799) 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-001-799) 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.

[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:

1) The LSAM performs the abort determination function(s) through an internal algorithm using internal or external data sources.

2) The CxP Architecture elements receive notification from the LSAM of the need for an abort through the C3I infrastructure.

3) The profiles, boundaries, modes, variable ranges and accuracy within the specified (TBD-001-780) 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-001-780) 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.

4.7.3.2.9 LSAM HEALTH AND STATUS

[CA0431V-PO] **Draft** 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):

- is generated by the LSAM in each applicable mission phase, state and mode.

- 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)

- by 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-001-331) 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.

[CA3115V-PO] **Draft** 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):

- is observed by crew surrogates in the LSAM in each applicable mission phase, state and mode. -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.

[CA5469V-PO] **Draft** 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

- for the faults and fault scenarios identified by (TBD-001-459) document(s)

- by the flight LSAM or flight equivalent hardware

- 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.

[CA5470V-PO] **Draft** 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

- for the faults and fault scenarios identified by (TBD-001-1016) document(s)

- by the flight LSAM or flight equivalent hardware

- 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.

[CA5471V-PO] **Draft** 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

- for the faults and fault scenarios identified by (TBD-001-461) document(s)

- by the flight LSAM or flight equivalent hardware

- 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

[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:

- the command sequences have been executed without human intervention
- the end state of the LSAM at the end of the sequence execution is the same as if the commands had been executed manually
- the reconfigured command sequences execute the updated commands
- 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.

[CA3289V-PO] Simultaneous communication by LSAM with MS and 2 (TBR-001-129) other systems in space 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. The verification shall be considered a success when a) testing shows the system can simultaneously exchange data at the maximum data rates with the specified systems for a period of 20 (TBR-001-422) minutes without apparent degradation b) analysis shows that no degradation is predicted if the test time were indefinite with data maintained at the maximum data rate, and c) 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. 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.

[CA3281V-PO] **Draft** The use of a dissimilar voice communication system by LSAM as specified shall be verified by Analysis and Demonstration. The analysis shall be performed on the LSAM voice communication systems. The demonstration shall be performed on the LSAM 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, and b) the analysis shows the dissimilar system is independent when compared to the prime LSAM 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.

[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 (1) the analysis of mounted antenna coverage for low rate data is shown to be greater than 90% (TBR-001-755) of all attitudes, (2) 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 and (3) 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.

[CA0517V-PO] **Draft** 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):

- is recorded by the LSAM in each applicable mission phase, state and mode.
- 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)
- by 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-001-336) 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.

[CA5054V-PO] **Draft** 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, and 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.

4.7.3.2.11 LSAM GN&C

[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.

[CA3144V-PO] **Draft** 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

[CA5293V-PO] The requirement for LSAM to provide target vehicle interfaces in the LSAM/CaLV EDS mated configuration during CEV RPODU in LEO shall be verified by inspection and test. CEV design documentation shall be inspected to show that any LSAM hardware required for proper functioning of the CEV sensors or navigation system is present and mounted in accordance with CxP 70034, Constellation Program

Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

The docking and undocking hardware testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV 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 the CEV and LSAM that are within the specifications of CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) 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 CEV.

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 depends on the results of this testing.

[CA5273V-PO] The capability of the LSAM to rendezvous, conduct proximity operations, dock and undock, independent of lighting conditions shall be verified by analysis and test. The verification shall consist of analysis and test for final approach and docking, and analysis of rendezvous and proximity operations terminating at final approach.

The final approach and docking tests shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 30.48 (TBR-001-441) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor measurements and relative vehicle state estimates. The facility shall include flight or flight-like replicas of the target docking adapter with any required reflectors or target-cooperative hardware. The demonstration shall be conducted under the range of lighting conditions of table (TBD-001-292). The tests shall be considered successful when the simulation achieves docking contact conditions for all tests with initial conditions inside the docking corridor defined by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

The final approach and docking analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of LSAM docking sensors driven by simulated sensor input such as video, reflector responses, target returns, etc. The analysis shall include Monte Carlo dispersions on lighting and initial condition parameters. The final approach and docking analysis shall be considered successful when the analysis shows that the probability of successful docking is greater than 99% (TBR-001-968).

The rendezvous and proximity operations analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of any sensors relying on lighting (such as start trackers, or camera-based sensors) as well as models of environmental lighting conditions throughout the rendezvous. The analysis shall include Monte Carlo dispersions on lighting and initial condition parameters. The analysis shall be considered successful when the results show that the probability of achieving a relative state inside the final approach corridor with relative sensor acquisition is greater than 99% (TBR-001-968).

Rationale: "Final approach testing incorporates sensor-in-the-loop testing under realistic lighting conditions. This is a critical test to verify that the system perform as expected under the harshest lighting conditions. That is, it is necessary top show that the RPODU system is robust to any variations in sensor performance due to lighting conditions.

The simulation analysis for final approach and docking allows a larger set of test cases with appropriate variations to be run and evaluated in a statistically meaningful way.

Simulation analysis must be used for the longer range rendezvous and proximity operations because no test environment is capable of incorporating the clode-loop RPODU system. The simulation analysis also allows for a statistically meaningful number of cases with appropriate variations."

[CA5290V-PO] The LSAM's performance of attitude control of the CEV/LSAM mated configuration after separating from the CaLV EDS shall be verified by analysis. The LSAM attitude control analysis shall be conducted in a NASA-accredited digital simulation. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, and environmental parameters for both CEV and LSAM. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CEV/LSAM IRD is greater than 99.73% (TBR-001-520) with a 90% confidence.

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.

[CA3205V-PO] The ability of the LSAM to perform TCMs during TLC shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include trans-lunar and multi-body gravity effects. 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 99.73% (TBR-001-377) probability with a 90% confidence that the LSAM can perform the TCMs during TLC.

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.

[CA0461V-PO] The capability of the LSAM to perform the LOI into LDO for lunar missions shall be verified by analysis. The analysis shall be performed using a NASA-accredited digital flight simulation, which shall include lunar gravity effects. 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 shows there is a 99.73% (TBR-001-318) probability with 90% (TBR-001-969) confidence that the LSAM can perform the LOI into LDO for 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.

[CA3251V-PO] **Draft** 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

[CA5285V-PO] The ability of the LSAM to actively accomplish undocking with the CEV prior to lunar descent shall be verified by test, demonstration and analysis. Undocking tests and demonstrations shall be conducted with the CEV and LSAM docking interface hardware. Separation tests and demonstrations shall be conducted with the relative navigation sensor hardware. Separation tests and analysis shall be conducted using certified digital simulations. The undocking hardware testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV and LSAM in a 6-DOF test facility. The undocking tests shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and LSAM that are within the specifications of (TBD-001-655) LSAM-CEV IRD requirements. Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the first 30.48 (TBR-001-542) m (100 ft) of the post-undocking separation. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect undocking and separation. Initial conditions for the tests shall be derived from the range of undocking separation forces and moments determined from the hardware tests. Testing shall be considered successful when the simulation achieves safe separation without re-contact for all tests. The undocking tests shall be conducted within a SIL (or equivalent). The SIL (or equivalent) simulation shall include models of the CEV vehicle attitude control systems and dynamics. These tests shall include one or more undocking tests conducted under nominal conditions. The undocking test shall be considered successful when undocking and departure proximity operations are demonstrated without re-contact and without violations of vehicle or trajectory constraints. The undocking analysis shall be conducted using a NASA-accredited digital simulation including models of both the CEV and LSAM vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. Analysis shall be performed for undocking and departure proximity operations. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without re-contact is greater than 99.73% (TBR-001-449) with a 90% confidence.

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 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 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 can not be controlled in the operational environment.

[CA3145V-PO] **Draft** 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

[CA0284V-PO] **Draft** 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 analysis shall be performed using a NASA-accredited digital flight simulation, which shall include lunar gravity effects and a model of the lunar surface accurate enough to analyze the requirement. 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 shows there is a 99.73% (TBR-001-534) probability with a 90% confidence 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0418V-PO] **Draft** 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 analysis shall be performed using a NASA-accredited digital flight simulation, which shall include lunar gravity effects and a model of the lunar surface accurate enough to analyze the requirement. 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 shows there is a 99.73% (TBR-001-316) probability with a 90% confidence 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA0135V-PO] The ability of the LSAM to actively accomplish rendezvous, proximity operations, and docking, with the CEV in LRO shall be verified by test, demonstration and analysis. Docking tests and demonstrations shall be conducted with the CEV and EDS/LSAM docking interface hardware. Final approach tests and demonstrations shall be conducted with the relative navigation sensor hardware. Rendezvous, proximity operations and docking tests and analysis shall be conducted using certified digital simulations.

Docking Hardware: The docking interface hardware verification shall include capture envelope testing, and demonstration of the docking hardware with simulated closed loop control.

The docking capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for LSAM and CEV in a 6-DOF test facility. The docking test shall be successful when it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements.

The docking hardware demonstration shall be conducted in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the LSAM and CEV navigation, guidance and control software. The docking demonstration shall be conducted with nominal vehicle health status and under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. The docking demonstration shall be considered successful when docking is achieved under both (1) automated simulation control and (2) pilot-in-the-loop control.

Relative navigation sensor demonstration shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 30.5 (TBR-001-441) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor measurements and relative vehicle state estimates. The vehicle simulation will accept and react to inputs from a pilot-in-the-loop. The demonstration shall be conducted under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. The demonstration shall be considered successful when the simulation achieves docking contact conditions for all demonstrations with initial conditions inside the docking corridor defined by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements.

SIL (or equivalent) Avionics: The rendezvous, proximity operations, and docking shall be conducted within a SIL (or equivalent). The LSAM SIL simulation shall include models of the CEV vehicle attitude control systems and dynamics. These tests shall include one or more rendezvous and docking tests conducted under nominal conditions. The rendezvous and docking test shall be considered successful when required docking contact conditions are demonstrated with no violations of trajectory or vehicle constraints.

Analysis: The rendezvous, proximity operations and docking analysis shall be conducted using a NASA-accredited digital simulation including models of both the LSAM and CEV vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. Analysis shall be performed for rendezvous, proximity operations, and docking. The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.73% (TBR-001-452) with a 90% confidence.

> *Rationale*: Rationale for docking hardware tests and demonstrations: The mechanical docking subsystems are critical to mission success for all CEV missions. These mechanisms must be characterized and verified to confirm the docking envelope and 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 docking test simulation must include models of

both maneuvering (CEV) 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 can not be controlled in the operational environment.

[CA5275V-PO] The ability for the LSAM to function as the target vehicle during RPOD with CEV in LLO prior to crew transfer back to CEV shall be verified by test and analysis. LSAM 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 CEV vehicle, including CEV thruster plumes. One or more tests shall be conducted for each contingency CEV proximity operations trajectory. The attitude hold tests shall be considered successful when the results show that LSAM attitude errors and angular rate errors remain within the limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. The LSAM attitude control analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of environmental attitude disturbances, as well as models of the CEV vehicle, including CEV thruster plumes. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, environmental parameters and CEV plume impingement parameters. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) is greater than 99.73% (TBR-001-453) with a 90% confidence.

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 (CEV) 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 can not be controlled in the operational environment.

[CA5284V-PO] The ability for the LSAM to perform target vehicle functions during undocking with the CEV shall be verified by inspection, docking mechanism tests, LSAM attitude control tests, and LSAM attitude control analysis.

LSAM design documentation shall be inspected to show that any LSAM hardware required for proper functioning of the CEV sensors or navigation system is present and mounted in accordance with CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

The undocking hardware testing shall consist of ground tests, using flight-equivalent docking adaptors for LSAM and CEV in a 6-DOF test facility. The undocking tests shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and LSAM that are within the specifications of CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).

The LSAM 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 CEV vehicle, including CEV thruster plumes. One or more tests shall be conducted for all nominal CEV separation trajectories. The attitude hold tests shall be considered successful when the results show that LSAM attitude errors and angular rate errors remain within the limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) for separation.

The LSAM attitude control analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of environmental attitude disturbances, as well as models of the CEV vehicle, including CEV thruster plumes. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, environmental parameters and CEV plume impingement parameters. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) during LSAM undocking and separation is greater than 99.73% (TBR-001-454) with a 90% confidence.

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 CEV.

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 depends 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 (CEV) 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.

4.7.3.2.12 LSAM RELIABILITY AND AVAILABILITY

[CA5532V-PO] **Draft** The ability 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. Analysis shall assess the tasks and activities required to reprocess and ready the LSAM to launch after a missed launch window. Analysis shall be considered successful when the analysis shows the LSAM can be reprocessed and readied for launch 4 (TBR-001-183) days prior to the next lunar injection window occurs.

Rationale: Processing flows, schedules, and launch manifest will be needed to determine whether LSAM can be launched as often as required.

[CA5605V-PO] **Draft** The ability of the LSAM to meet a (TBD-001-064) % availability of launch per launch attempt, starting at "LCC call to station" and ending at the close of the day-of-launch window 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 and Maintainability (R&M) Plan. Verification shall be considered successful when analysis shows that the availability of launch per crew launch attempt is at least (TBD-001-064) % with an uncertainty of not greater than (TBD-001-1009).

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 beginning "LCC Call to Station" and ending at close of day-of-launch window.

4.7.3.2.13 LSAM MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[CA5505V-PO] The ability of LSAM to sustain operations as defined in the DRM using only onboard equipment and spares without resupply or support from personnel other than the crew shall be verified by analysis. Analysis shall verify LSAM conformance with CxP 70132, Constellation Program Commonality Plan, CxP 70087, Constellation Program Reliability and Maintenance (R&M) Plan, LSAM Logistics Support Plan (LSP), and the related Logistics Support Analysis Reports (LSAR). Analysis shall be updated based upon ground testing. Verification shall be considered successful when analysis shows that LSAM provides infrastructure to maintain systems through their operational life cycles 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.

4.7.3.2.14 LSAM HABITABILITY AND HUMAN FACTORS

[CA5385V-PO] **Draft** 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-001-960), 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.

[CA0813V-PO] **Draft** 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 4 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 4 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 4 for 180 (TBR-001-033) hours. The analysis will include an audit of consumable supplies.

[CA3165V-PO] **Draft** 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 4 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 4 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 4 for 12 (TBR-001-131) hours. The analysis will include an audit of consumable supplies.

[CA0814V-PO] **Draft** 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 - CEV at 70 kPa (10.2 psia), LSAM at 55 kPa (8.0 psia).

[CA3062V-PO] **Draft** 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.

[CA3135V-PO] **Draft** 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.

[CA3137V-PO] **Draft** 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.

[CA3107V-PO] **Draft** 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 pre-breathe 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.

[CA3181V-PO] **Draft** 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 pre-breathe 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 pre-breathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained to support pre-breathe.

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 pre-breathe.

A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA suit donning and pre-breathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained to support pre-breathe.

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.

4.7.3.2.15 LSAM ENVIRONMENTAL CONDITIONS

[CA5556V-PO] **Draft** 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:

- Review of the induced environmental verifications submitted against all of the LSAM/System IRD requirements

- 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 (IEDS).

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 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 1) the proper induced environments have been considered, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA5561V-PO] **Draft** LSAM induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

- Review of the induced environmental verifications submitted against all of the LSAM/System IRD requirements.

- 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 1) the proper induced environments have been met, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA0815V-PO] **Draft** 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: 1) Development of a Natural Environment Requirements Sensitivity and Applicability Matrices (NERSAMs), defined in section 4 of the DSNE, and 2) 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: CEV/LSAM, CEV/LSAM/CaLV-EDS, LSAM/CaLV, LSAM/CaLV/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: 1) The NERSAM has been completed in accordance with section 4 of the DSNE, 2) The natural environment requirements and verification have been allocated to the lower tier systems in accordance section 4 of the DSNE, 3) Lower tier verifications have been completed and 4) 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.

4.7.3.3 RESERVED

4.7.3.4 LSAM EXTERNAL INTERFACES

[CA0901V-PO] **Draft** 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, and (b) when the 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.

[CA0902V-PO] **Draft** 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, and (b) when the 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 CLV 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.

[CA0904V-PO] **Draft** 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 CLV interface requirements defined within the CxP 70118-03, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), 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 CLV 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 Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 3: Lunar Surface Access Module (LSAM), have been satisfied, and

(b) when the 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.

[CA0903V-PO] **Draft** 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, and

(b) when the 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.

[CA0900V-PO] **Draft** The LSAM interfaces with the CaLV 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-CaLV 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 CaLV (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 CaLV/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, and

(b) when the 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-CaLV interface requirements (including EDS) specified in the IRD have been satisfied. Integrated testing of the LSAM and CaLV 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 CaLV 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.

[CA0432V-PO] The LSAM interfaces with the CEV 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-CEV interface requirements defined within the CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan, and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the LSAM and CEV 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 CEV/LSAM in-space 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 in-space 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 Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface

Requirements Document (IRD), have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-CEV interface requirements specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) have been satisfied. Integrated testing of the LSAM and CEV 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 in-space LSAM/CEV 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 CEV 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.

4.7.3.5 RESERVED

4.7.4 CARGO LAUNCH VEHICLE (CaLV)

4.7.4.1 CaLV DESCRIPTION

4.7.4.2 CaLV REQUIREMENTS

[CA3212V-PO] **Draft** The ability of the CaLV to launch a LSAM into a Trans-Lunar trajectory shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations of the CaLV dynamics. 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 results show a 99.73% (TBR-001-382) probability with a 90% confidence that the CaLV 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA3215V-PO] **Draft** The CaLV cargo launch into (TBD-001-565) Earth orbit for Mars missions requirement shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations of the CaLV's cargo delivery capability. 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 results show a 99.73%

(TBR-001-383) probability with a 90% confidence that the CaLV can successfully deliver cargo into (TBD-001-565) Earth orbit.

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.

4.7.4.2.1 CaLV MISSION SUCCESS

[CA5930V-PO] **Draft** The CaLV single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the CaLV 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.

[CA0487V-PO] **Draft** Lunar mission LOM due to the CaLV 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 (a (TBR-001-954) probability) that LOM for Lunar missions due to the CaLV is not greater than 1 in 125 (TBR-001-054).

Rationale: NR

[CA0486V-PO] **Draft** Lunar mission LOM due to the CaLV 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 (a (TBR-001-953) probability) that LOM for a Lunar mission due to the CaLV EDS is no greater than 1 in 250 (TBR-001-053).

Rationale: NR

4.7.4.2.2 CaLV CREW SURVIVAL

[CA5436V-PO] **Draft** 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:

1) The CaLV performs the abort determination function(s) through an internal algorithm using internal or external data sources.

2) The CxP Architecture elements receive notification from the CaLV of the need for an abort through the C3I infrastructure.

3) 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.

[CA5160V-PO] **Draft** CaLV 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 crew members and collecting the task time for ground crew egress to ground level. The analysis shall consist of the Ground System, EVA, CaLV and CEV system documentation review that meets unobstructed egress for the suited crew through the closure in the allocated GS-EVA IRD, GS-CaLV IRD, GS-CEV IRD, CEV-EVA IRD, and Ground Ops 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

4.7.4.2.2.1 CaLV CREW SURVIVAL PROBABILITIES

[CA0485V-PO] **Draft** Lunar mission LOC due to the CaLV 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 (a (TBR-001-952) probability) that LOC for Lunar missions due to the 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 CaLV CARGO DELIVERY

[CA0282V-PO] **Draft** The CaLV Mass Delivered from the Earth surface to LEO for Mars exploration missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 Mass Delivered capability of the CaLV is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-479) of the simulations with a 90% confidence.

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.

4.7.4.2.5 CaLV MISSION RATES AND DURATIONS

[CA0850V-PO] **Draft** The ability for the CaLV EDS to loiter in LEO at least (TBD-001-975) days after orbit insertion shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include high-order earth gravity effects. 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-001-397) probability with a 90% confidence that the CaLV can loiter for at least (TBD-001-975) days after orbit insertion.

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.

4.7.4.2.6 CaLV ARCHITECTURE DEFINITION

[CA0049V-PO] **Draft** The delivery of the LSAM from the launch site to the ERO shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations. 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 results show that there is a 99.73% (TBR-001-902) probability with a 90% confidence that the LSAM reaches ERO.

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.

[CA5678V-PO] **Draft** The CaLV+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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. 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

[CA3217V-PO] **Draft** The liftoff clearance between the CaLV integrated stack vehicle and the launch facility shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations of the integrated stack dynamics, the launch facility, and the ability to compute the minimum clearance between the closest elements of the facility and the CaLV integrated stack. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters, and structure location. The verification shall be considered successful when the analysis results show that there is a 99.73% (TBR-001-385) probability with a 90% confidence that the CaLV 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 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 CaLV design shall be verified by inspection. The inspection shall consist of the review of CaLV configuration drawings. The verification shall be considered successful when the inspection shows that shuttle-derived 5-segment SRBs and RS-68's are utilized in the CaLV design.

Rationale: The incorporation of the shuttle-derived 5-segment SRBs and RS-68 engines in the CaLV design shall be verified by inspection. The inspection shall consist of the review of CaLV configuration drawings. The verification shall be considered successful when the inspection shows that shuttle-derived 5-segment SRBs and RS-68's are utilized in the CaLV design.

[CA5714V-PO] **Draft** CaLV to provide refurbishment of the CaLV RSRM reusable elements 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. These facility, facility systems and GSE requirements will be identified and characterized in the CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD). The verification shall be considered successful when the analysis shows that the CxP 72004, Cargo Launch Vehicle (CaLV) Systems Requirements Document (SRD) requirements pertaining to the facilities, facility systems and GSE that support refurbishment of CaLV RSRM flight elements have been satisfied per the design certification review.

4.7.4.2.6.1 CaLV CONTROL MASS

[CA0848V-PO] **Draft** The CaLV 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. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 Mass Delivered capability of the CaLV is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-322) of the simulations with a 90% confidence.

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.

[CA0847V-PO] **Draft** The CaLV 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. This analysis shall be performed using the results of NASA accredited digital flight simulations. 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 Mass Delivered capability of the CaLV EDS is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-329) of the simulations with a 90% confidence.

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.

4.7.4.2.6.2 CaLV DELTA-V

[CA0051V-PO] **Draft** The CaLV EDS translational delta-V requirement for the TLI for crewed Lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight and performance simulations. 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 calculated translational delta-V of the CaLV EDS is equal to or greater than the translational delta-V requirement for 99.73% (TBR-001-402) of the simulations with a 90% confidence.

Rationale: Establishes the CaLV 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 CEV docks with LSAM in the Earth Rendezvous Orbit (ERO).

4.7.4.2.7 CaLV SAFETY

[CA5918V-PO] The auto initiate capability of the CaLV flight termination systems shall be verified by demonstration. The demonstration shall use the flight CaLV 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 CaLV 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 CaLV 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 CaLV. They may be attached to and destroy dummy hardware as long as the CaLV 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 CaLV 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 CaLV flight termination systems. The verification shall be considered successful when the inspection conclusively shows that the CaLV cannot be launched with crew when the auto initiate capability of the CaLV flight termination systems is installed or enabled. The demonstration shall use the flight CaLV 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 CaLV 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 CaLV flight termination systems.

[CA5432V-PO] **Draft** 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:

1) Telemetry shows that the CaLV generated an indication upon each FTS command.

2) The telemetry shows that the indication of each FTS command was received by the CxP destination (i.e. CEV)

3) That the combined environments will not induce a false indication from the CaLV.

Rationale: A) Testing is considered the best means for requirement verification. FTS testing is the established precedence for verification.

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-001-634) 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.

[CA5433V-PO] **Draft** 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 is 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.

[CA0874V-PO] **Draft** The CaLV 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.

[CA5403V-PO] **Draft** The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the CaLV 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.

[CA5806V-PO] **Draft** The two fault tolerance for catastrophic hazard shall be verified by analysis. The analysis shall review the results of the CaLV 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 documents. It looks top down and bottoms up at the system level.

4.7.4.2.8 CaLV COMMAND AND CONTROL

[CA3276V-PO] The execution of commands by the CaLV which are addressed to the CaLV shall be verified by Test.

The Test shall use the flight CaLV 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 CaLV. (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 CaLV 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):

- are executed by the CaLV when addressed to the CaLV

- are processed by the CaLV 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 CaLV.

Rationale: A Test of the execution of CaLV 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 CaLV.

[CA3257V-PO] **Draft** The execution of commands by the CaLV which are valid in the current state shall be verified by Test.

The Test shall use the flight CaLV 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 CaLV. (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):

- are executed by the CaLV when valid in the current state in each applicable mission phase, state and mode

- are rejected by the CaLV when not valid in the current state in each applicable mission phase, state and mode

Rationale: A Test of the execution of CaLV commands

- defined by (TBD-001-426) document(s)

- by the flight CaLV 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-001-426) 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 CaLV.

[CA3113V-PO] The requirement for the CaLV 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:

1) The vehicle's running function is halted by the authorized Constellation System assuming vehicle control.

2) When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

3) 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.

[CA3302V-PO] The CaLV Automated Lift-Off and Flight Operations requirement verification shall be satisfied by Test. A) Tests shall be performed using the flight (CaLV) 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:

1) The automated lift-off and ascent/flight functions identified in (TBD-001-414) document(s) are tested.

2) When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task.

3) The profiles, boundaries, modes, variable ranges and accuracy are verified as specified in the (TBD-001-414) document(s).

Rationale: A) 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) 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-001-414) 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.

[CA3292V-PO] **Draft** The CaLV Autonomous Lift-off and Ascent Operations requirement shall be verified by demonstration. A) Demonstrations shall be performed using the flight (CaLV) assets and Crew Surrogates under simulated flight conditions during integrated ground testing. B) Demonstrations using the flight/flight-like assets (CaLV) 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:

1) Demonstrated autonomous operation is accomplished.

2) Additional adjustments are not required.

3) External intervention was not necessary.

Rationale: A) Demonstrations using Flight Equivalent Assets and actual CxP architecture provide the best environment to demonstrate autonomous functions. B) Demonstrations during simulations and training exercises are necessary to reduce the risk of being unable to perform the autonomous operation during flight.

[CA5431V-PO] **Draft** The CaLV 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-001-755) 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: A) 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. B) 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 CaLV HEALTH AND STATUS

[CA3124V-PO] **Draft** The generation of health and status information by the CaLV shall be verified by Test. The Test shall use the flight CaLV 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 CaLV. (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):

- is generated by the CaLV in each applicable mission phase, state and mode.
- agrees with the actual health and status of the CaLV.

Rationale: A Test of the generation of CaLV health and status data

- defined by (TBD-001-711) document(s)
- by the flight CaLV 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-001-711) 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 CaLV.

[CA5472V-PO] **Draft** The provision of fault detection by the CaLV shall be verified by Test. The Test shall use the flight CaLV 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 CaLV 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 CaLV in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the CaLV:

- for the faults and fault scenarios identified by (TBD-001-432) document(s)

- by the flight CaLV or flight equivalent hardware

- 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.

[CA5473V-PO] **Draft** The provision of fault isolation by the CaLV shall be verified by Test. The Test shall use the flight CaLV 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 CaLV 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 CaLV in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the CaLV

- for the faults and fault scenarios identified by (TBD-001-435)- document(s)

- by the flight CaLV or flight equivalent hardware

- 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.

[CA5474V-PO] **Draft** The provision of fault recovery by the CaLV shall be verified by Test. The Test shall use the flight CaLV 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 CaLV 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 CaLV in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the CaLV

- for the faults and fault scenarios identified by (TBD-001-438) document(s)

- by the flight CaLV or flight equivalent hardware

- 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 CaLV COMMUNICATIONS AND COMMUNICATIONS SECURITY

[CA5911V-PO] **Draft** Simultaneous communication by the CaLV 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 CaLV launch operation scenarios. The test shall consist of simulations of the communications for nominal and off-nominal CaLV 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 CaLV can simultaneously exchange data with the LSAM, Mission Systems, and Ground Systems for CaLV pre-launch and launch operations correctly and without apparent degradation for both nominal and maximum data rates for each scenario at least twice, and 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 CaLV 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.

[CA5044V-PO] **Draft** CaLV 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, and 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.

4.7.4.2.11 CaLV GN&C

[CA3146V-PO] **Draft** The CaLV 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 CaLV. The dynamic simulation, analysis, and hardware-in-the-loop tests shall verify the accuracy of the CaLV 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 CaLV Verification document (TBD-001-943) navigation capability has been met.

Rationale: NR

[CA3216V-PO] **Draft** The ability of the CaLV to meet orbital injection accuracies shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations of the CaLV maneuvering capability and mission timelines. 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 results show that there is a 99.73% (TBR-001-384) probability with a 90% confidence that the CaLV can achieve the orbital injection accuracies defined in Table (TBD-001-566).

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.

[CA3225V-PO] **Draft** The ability of the CaLV 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 CaLV flight hardware and a certified flight-like communication system. The verification shall be considered successful when test results show the CaLV can accurately change ascent trajectory based on updates provided prior to launch.

Rationale: Data exchange between the CaLV 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.

[CA3186V-PO] **Draft** The ability of the CaLV 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 CaLV EDS flight hardware and a certified flight-like communication system. The verification shall be considered successful when test results show the CaLV can accurately change TLI based on updates prior to launch.

Rationale: Data exchange between the CaLV 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.

[CA3224V-PO] **Draft** The ability of the CaLV to change the planned ascent trajectory design parameter updates prior to launch shall be verified by test. The test shall be performed using CaLV flight hardware and a certified flight-like communication system.

The verification shall be considered successful when test results show the CaLV can accurately change ascent trajectory prior to launch.

Rationale: Data exchange between the CaLV 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.

[CA0128V-PO] **Draft** The CaLV EDS performance of attitude control of the LSAM/CaLV EDS mated configuration prior to CEV docking shall be verified by analysis. The CaLV EDS attitude control analysis shall be conducted in a NASA-accredited digital simulation. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, and environmental parameters for both CaLV EDS and LSAM. 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% (TBR-001-521) with a 90% confidence.

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.

[CA5292V-PO] The capability of the CaLV EDS to provide attitude control of the mated CaLV EDS/LSAM vehicle during CEV RPODU shall be verified by test and analysis. The CaLV 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 CEV vehicles, including CEV thruster plumes. One or more tests shall be conducted for all nominal CEV RPODU trajectories. The attitude hold tests shall be considered successful when the results show that CaLV attitude errors and angular rate errors remain within the limits specified by CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD). The CaLV EDS attitude control analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of environmental attitude disturbances, as well as models of the LSAM and CEV vehicles, including CEV thruster plumes. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, environmental parameters and CEV plume impingement parameters. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD), during CEV RPODU is greater than 99.73% (TBR-001-455) with a 90% confidence.

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 can not be controlled in the operational environment.

[CA0129V-PO] The use of the CaLV EDS to perform TLI shall be verified by inspection and analysis. The inspection shall review verification results for CA0051-PO. The analysis shall be performed using a NASA-accredited digital flight simulation, which shall include trans-lunar and multi-body gravity effects, and vehicle subsystem models. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the inspection and analysis results show there is a 99.73% (TBR-001-306) probability with a 90% confidence that the CaLV 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 CaLV EDS performance of attitude control of the LSAM/CaLV EDS/CEV mated configuration shall be verified by analysis. The CaLV EDS attitude control analysis shall be conducted in a NASA-accredited digital simulation. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, and environmental parameters for both CEV and LSAM. 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 Surface Access Module (LSAM) - To - Cargo Launch Vehicle (CaLV) - To - Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD) is greater than 99.73% (TBR-001-522) with a 90% confidence.

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.

4.7.4.2.12 CaLV RELIABILITY AND AVAILABILITY

[CA0413V-PO] **Draft** The ability of the CaLV to meet a 98% (TBR-001-041) availability of launch per launch attempt, starting at "LCC call to station" and ending at the close of the day-of-launch window 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 and Maintainability (R&M) Plan. Verification shall be considered successful when analysis shows that the availability of launch per crew launch attempt is at least 98% (TBR-001-041) with an uncertainty of not greater than (TBD-001-407) % (TDS# SIG-01-004).

Rationale: Level 3 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 beginning "LCC Call to Station" and ending at close of day-of-launch window.

[CA0414V-PO] **Draft** The ability of the CaLV to a meet a (TBD-001-002)% launch availability 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 requirements 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 availability assessments. The defined weather constraints shall subsequently be analyzed against the (TBD-001-002)% weather conditions for a given launch window and determine that the CaLV can launch within these conditions with no more than (TBD-001-1018)% uncertainty. The verification shall be considered successful when the analysis concludes within the (TBD-001-1018) confidence interval that the CaLV has a launch probability of (TBD-001-002)% with respect to the natural environment.

Rationale: The assessment of the launch availability with respect to the natural environment must consider associated induced effects of the launch configuration, i.e. CEV 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.

[CA5533V-PO] The ability of the CaLV/EDS to launch again 4 days (TBR-001-493) prior to the next lunar injection window following a missed window shall be verified by analysis. Analysis shall assess the tasks and activities required to reprocess and ready the CaLV/EDS to launch after a missed launch window. Analysis shall be considered successful when the analysis shows the CaLV/EDS can be reprocessed and readied for launch 4 days prior to the next lunar injection window occurs.

Rationale: Processing flows, schedules, and launch manifest will be needed to determine whether CaLV/EDS can be launched as often as required.

[CA5259V-PO] **Draft** The requirement for the CaLV to have a (TBD-001-572) minute launch window per cargo launch opportunity for Lunar missions shall be verified by analysis. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and day-of-launch environmental effects. The verification shall be considered successful when the analysis results show a 99.73% (TBR-001-489) probability with a 90% confidence that the CaLV 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

[CA5265V-PO] **Draft** The requirement for the CaLV to have a (TBD-001-573) minute launch window per crewed launch opportunity for Lunar missions shall be verified by analysis. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and day-of-launch environmental effects. The verification shall be considered successful when the analysis results show a 99.73% (TBR-001-485) probability with a 90% confidence that the CaLV 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 lack of access to the flight-like mission environment, analysis with an accredited simulation is sufficient for verification work.

4.7.4.2.13 CaLV MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[CA5804V-PO] **Draft** The ability of the CaLV elements 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 CaLV refurbish able elements design to the GS design for compatibility. The verification shall be considered successful when the analysis shows that the CaLV elements can be refurbished in the GS facilities, facility systems and GSE that support refurbishment, as attested by the design certification review.

Rationale: NR

4.7.4.2.14 RESERVED

4.7.4.2.15 CaLV ENVIRONMENTAL CONDITIONS

[CA5355V-PO] **Draft** Compliance of the CaLV 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:

1) Allocation of the natural environments requirements to the lower tier systems and their verification methods and details, and

2) 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: CEV/LSAM/CaLV-EDS/GS, CEV/LSAM/CaLV-EDS, CEV/LSAM/CaLV/GS, CEV/LSAM/CaLV, LSAM/CaLV/GS and LSAM/CaLV. The verification shall be considered successful when the inspection and integrated analysis show:

1) The natural environment requirements and verification have been allocated to the lower tier systems in accordance section 4 of the DSNE,

2) Lower tier verifications have been completed and

3) The CaLV 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.

[CA5558V-PO] **Draft** CaLV 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:

- Review of the induced environmental verifications submitted against all of the CaLV/System IRD requirements.

- 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 (IEDS).

The verification shall be considered successful when the analysis shows that the CaLV 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 1) the proper induced environments have been considered, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA5563V-PO] **Draft** CaLV induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts:

- Review of the induced environmental verifications submitted against all of the CaLV/System IRD requirements.

- Review of the induced environment verifications submitted against CaLV/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 CaLV 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 1) the proper induced environments have been met, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

4.7.4.3 RESERVED

4.7.4.4 CaLV EXTERNAL INTERFACES

[CA0908V-PO] **Draft** The CaLV 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 CLV Project Office to demonstrate that the CaLV-to-MS interface requirements defined within CxP 70012, 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 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CaLV 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 CaLV, GS, and MS. Verification shall be considered successful when (a) Analysis confirms that all of the CaLV interface verification requirements defined within CxP 70012, Constellation Program Cargo Launch Vehicle (CaLV) to Mission Systems (MS) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 CaLV Project Office to confirm that all of the CaLV-to-MS interface requirements specified in the IRD have been satisfied. Integrated testing between the CaLV 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.

[CA0907V-PO] **Draft** The CaLV 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 CaLV 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 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CaLV 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 CaLV and GO systems. Verification shall be considered successful when (a) Analysis confirms that all of the CaLV interface verification requirements defined within CxP 70105, Constellation Program Cargo Launch Vehicle (CaLV) to Ground Systems Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 CaLV Project Office to confirm that all of the CaLV-to-GO interface requirements specified in the IRD have been satisfied. Integrated testing between the CaLV 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.

[CA0905V-PO] **Draft** The CaLV EDS interfaces with the CEV shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CaLV Project Office to demonstrate that the CaLV EDS-to-CEV interface requirements defined within the CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CaLV EDS and CEV 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 CaLV EDS. Testing shall also include a multi-system integrated test of the integrated CEV/LSAM/CaLV EDS in-space 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 in-space vehicle stack and the ground support and mission control systems. Verification shall be considered successful when (a) Analysis confirms that all of the CaLV interface verification requirements defined within CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Planhave 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 CEV Project Office to confirm that all of the CaLV EDS-to-CEV interface requirements specified in the IRD have been satisfied. Integrated testing of the EDS and CaLV 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 in-space CEV/EDS vehicle stack, integrated testing will include configurations with the LSAM. Since the first time the CEV 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.

[CA0909V-PO] **Draft** The CaLV 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 CaLV Project Office to demonstrate that the CaLV interface requirements defined within CxP 70118-04, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 4: Cargo Launch Vehicle (CaLV) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CaLV 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 CaLV interface verification requirements defined within CxP 70118-04, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 4: Cargo Launch Vehicle (CaLV) have been satisfied, and

(b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 CaLV Project Office to confirm that all of the CaLV-to-Communications and Tracking Network interface requirements specified in the IRD have been satisfied. Integrated testing between the CaLV 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.

[CA0906V-PO] **Draft** The CaLV 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 CaLV Project Office to demonstrate that the LSAM-to-CaLV 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 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CaLV (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 CaLV/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 CaLV 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, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 CaLV Project Office to confirm that all of the CaLV-to-LSAM interface requirements (including EDS) specified in the IRD have been satisfied. Integrated testing of the LSAM and CaLV 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 CaLV 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.

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 test. 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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. An operational acceptance test shall be performed to demonstrate 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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems

- Sub-Systems Requirements Document requirements pertaining to the performance the ground processing of flight elements and cargo have been satisfied per the design certification review. The verification for test shall be considered successful when the operational acceptance test 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

[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 CEV 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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. The verification for analysis shall be considered successful when the analysis shows that the CxP 72006, Ground Systems Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems

- Sub-Systems Requirements Document requirements pertaining to the facilities, facility systems and GSE that are needed to locate, safe, retrieve, and transport the CLV first stage and CaLV 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 during launches 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 CxP 72006, Ground Systems Requirements Document (SRD). 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

[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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. 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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document 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 in-space flight vehicle has been successfully mated, powered and operated.

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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. The physical demonstration shall be performed by lifting a dummy load of similar size, weight, C/G 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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document 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 design certification 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

[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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. The verification shall be considered successful when the test and analysis shows that the personnel, CxP 72006, Ground Systems Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document 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 CEV Crew Module in the event CEV 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 Requirements Document (SRD)CxP 72006, Ground Systems Requirements Document (SRD), Land Landing and Recovery SSRD, Water Landing and Recovery SSRD 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, System Requirements for the Crew Exploration Vehicle (CEV) Element for closure of crew survival capability for contingency landing to meet SAR time constraints. The analysis shall consist of status review of allocated requirements (CEV 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, System Requirements for the Crew Exploration Vehicle (CEV) Element, CxP 72006, Ground Systems Requirements Document (SRD) and SSRD's 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

4.7.5.2.1 GS MISSION SUCCESS

[CA0860V-PO] ISS mission LOM due to Ground 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 (a (TBD-001-926) probability) that LOM for an ISS mission due to Ground Systems is no greater than 1 in (TBD-001-094).

Rationale: NR

[CA3028V-PO] **Draft** Lunar Outpost Cargo LOM due to the Ground 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 (a (TBD-001-934) probability) that LOM for a Lunar Outpost Cargo mission due to Ground Systems is not greater than 1 in (TBD-001-530).

Rationale: NR

[CA3029V-PO] Lunar Crewed LOM due to the Ground 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 (a (TBD-001-935) probability) that LOM for a Lunar Crewed mission due to Ground Systems is not greater than 1 in (TBD-001-533).

Rationale: NR

4.7.5.2.2 GS CREW SURVIVAL

[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 CEV and launch support structure by performing a minimum of two runs with two different sets of suited crew members and collecting the task time for crew egress from CEV 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, CLV and CEV system documentation review that meets unobstructed egress for the suited crew through the closure in the allocated CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD), CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD), CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD), CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD), 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).

[CA3033V-PO] Lunar Crewed LOC due to the Ground 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 (a (TBD-001-938) probability) that LOC for a Lunar Crewed mission due to Ground Systems is not greater than 1 in (TBD-001-546).

Rationale: NR

[CA3031V-PO] ISS Crew LOC due to the Ground 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 (a (TBD-001-937) probability) that LOC for an ISS Crew mission due to Ground Systems is not greater than 1 in (TBD-001-539).

Rationale: NR

[CA0151V-PO] Ground Systems to provide safe haven for 14 (TBR-001-261) 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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. The verification shall be considered successful when the analysis shows that the CxP 72006, Ground Systems Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document requirements pertaining to the facilities, facility systems and GSE that support safe haven for 14 (TBR-001-261) ground personnel and crew at the launch pad have been satisfied per the design certification review.

Rationale: NR

[CA0337V-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 CEV and launch support structure by performing a minimum of two runs with two different sets of suited crew members and collecting the task time for crew egress from CEV 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, CLV and CEV system documentation review that meets unobstructed egress for the suited crew through the closure in the allocated GCxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD), CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD), CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD), CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD), 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-001-144) min and the allocated children requirements have been closed.

Rationale: NR

[CA0146V-PO] Ground Systems rescue of the flight crew in the event CEV 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 Requirements Document (SRD), CxP (TBD-001-1068), Ground Systems Land Landing and Recovery SSRD, CxP (TBD-001-1069) Ground Systems Water Landing and Recovery SSRD, 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, System Requirements for the Crew Exploration Vehicle (CEV) Element for closure of crew survival capability for contingency landing to meet SAR time constraints. The test shall consist of a CEV 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 Requirements Document (SRD), CxP (TBD-001-1068), Ground Systems Land Landing and Recovery SSRD, and CxP (TBD-001-1069) Ground Systems Water Landing and Recovery SSRD are 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 CEV project providing the requirements that address the functions within CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element.

[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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems

- Sub-Systems Requirements Document. 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

[CA5146V-PO] Ground Systems rescue of the crew within 24 hrs 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 Requirements Document (SRD), CxP (TBD-001-1068), Ground Systems Land Landing and Recovery SSRD, CxP (TBD-001-1069) Ground Systems Water Landing and Recovery SSRD 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, System Requirements for the Crew Exploration Vehicle (CEV) Element 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 (CEV 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, System Requirements for the Crew Exploration Vehicle (CEV) Element, CxP 72006, Ground Systems Requirements Document (SRD), CxP (TBD-001-1068), Ground Systems Land Landing and Recovery SSRD and CxP (TBD-001-1069) Ground Systems Water Landing and Recovery SSRD 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 hrs following a landing outside of the designated landing sites.

Rationale: NR

[CA5408V-PO] The two fault tolerance for catastrophic hazards shall be verified by analysis. The analysis shall review the results of the system-level hazard analyses, FMEA/CILs, and the integrated architecture hazard analysis for 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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 bottoms up at the system level and then top down for the integrated systems.

[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:

1) The Ground Systems performs the abort determination function(s) through an internal algorithm using internal or external data sources.

2) The CxP Architecture Systems receive notification from the Ground Systems of the need for an abort through the C3I infrastructure.

3) The profiles, boundaries, modes, variable ranges and accuracy specified in (TBD-001-792) Document(s) are verified.

Rationale: A) 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-001-792) 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 CLV no later than 1 (TBR-001-020) day interval after the launch of CaLV 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 Requirements Document (SRD) and GS-SSRD. The verification shall be considered successful when the analysis shows that the CxP 72006, Ground Systems Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document requirements pertaining to the facilities, facility systems and GSE that support operation of the CLV no later that 1 (TBR-001-020) day interval after the launch of CaLV 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 4 (TBR-001-193) consecutive days for CLV missions shall be verified by inspection. The inspection shall consist of examining the allocated CxP 72006, Ground 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 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 (TBR-001-193) consecutive days for CLV 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 (TBR-001-193) consecutive days for CaLV missions shall be verified by inspection. The inspection shall consist of examining the allocated CxP 72006, Ground 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 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 (TBR-001-193) consecutive days for CaLV 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.

4.7.5.2.6 GS ARCHITECTURE DEFINITION

[CA0444V-PO] Ground Systems Earth weather services for pre-launch, launch, SRB recovery, and CEV CM pad aborts 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 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

[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 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

[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 Requirements Document (SRD). The demonstration shall be performed by lifting a dummy loads of similar size, weight, C/G 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 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

[CA0855V-PO] Ground Systems to provide refurbishment of CLV SRB reusable elements 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. 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 GS-SRD and GS-SSRD requirements pertaining to the facilities, facility systems and GSE that support refurbishment of CLV SRB flight elements have been satisfied per the design certification review.

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 Requirements Document (SRD). The verification shall be considered successful when the analysis shows that CxP 72006, Ground 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 design certification review.

Rationale: NR

[CA5712V-PO] Ground Systems to provide refurbishment of CaLV SRB reusable elements 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. These facility, facility systems and GSE requirements will be identified and characterized in the CxP 72006, Ground Systems Requirements Document (SRD) an CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. The verification shall be considered successful when the analysis shows that the CxP 72006, Ground Systems Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document requirements pertaining to the facilities, facility systems and GSE that support refurbishment of CaLV SRB flight elements have been satisfied per the design certification review.

Rationale: NR

4.7.5.2.7 GS SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA5406V-PO] The single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the results of the system-level hazard analyses, FMEA/CILs, and the integrated architecture hazard analysis for 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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 bottoms up at the system level and then top down for the integrated systems

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)

- by the operational Ground Systems hardware and software

- 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):

- is generated by the Ground Systems in each applicable mission phase, state and mode.

- 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)

- by the operational Ground Systems hardware and software

- 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)

- by the operational Ground Systems hardware and software

- 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)

- by the operational Ground Systems hardware and software

- 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)

- by the operational Ground Systems hardware and software

- 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

[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:

- the reconfigurable automated sequences have been successfully received and the reconfiguration product generated

- the reconfigurable automated sequences contain data and commands valid for use by other Constellation Systems

- 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 six other Constellation flight systems 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 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) six generic simulated Constellation flight elements and, (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. And, 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; and 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 6. 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 (NISN).

[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, and 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.

4.7.5.2.11 RESERVED

4.7.5.2.12 GS RELIABILITY AND AVAILABILITY

[CA3064V-PO] The ability of the Ground Systems to meet a (TBR-001-041)% availability of launch per crew launch attempt, starting at "LCC Call to Station" and ending at close of day of launch window 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 and Maintainability (R&M) Plan. Verification shall be considered successful when analysis shows that the availability of launch per crew launch attempt is at least (TBR-001-041)% .

> *Rationale*: Ground systems will be responsible for verifying that all fixed and variable resources needed to support beginning "LCC Call to Station" and ending at close of day-of-launch window will be available and ready.

4.7.5.2.13 GS MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[CA5934V-PO] The ability of the Ground Systems to provide the infrastructure to maintain systems through their operational life cycles shall be verified by analysis. The 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 CxP 70064, Constellation Program Supportability Plan. The verification shall be considered successful when the analysis shows that the Ground Systems provide the infrastructure to maintain systems through their operational life cycles.

[CA5803V-PO] The ability of the CLV elements 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 CLV refurbish able elements design to the GS design for compatibility. The verification shall be considered successful when the analysis shows that the CLV elements can be refurbished in the GS facilities, facility systems and GSE that support refurbishment, as attested by the design certification review.

Rationale: NR

4.7.5.2.14 RESERVED

4.7.5.2.15 GS ENVIRONMENTAL CONDITIONS

[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:

- Review of the induced environmental verifications submitted against all of the GS/System IRD requirements.

- Review of the induced environment verifications submitted against CxP

72006, Ground Systems - System 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 1) the proper combined natural and induced environments have been considered, 2) sensitivities to these environments, and 3) 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:

- Review of the induced environmental verifications submitted against all of the GS/System IRD requirements.

- Review of the induced environment verifications submitted against CxP

72006, Ground Systems - System 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 CCxP 70143, Constellation Program Induced Environment Design Specification can provide verification including assurance that 1) the proper induced environments have been met, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA3018V-PO] The lightning protection 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 that Constellation systems are protected against catastrophic or hazardous failures from direct lightning attachment during ground operations, shipping and transportation, refurbishment, and/or other related operations.

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.

[CA5112V-PO] The Ground Systems capability to launch the Flight Systems independent of ambient lighting conditions shall be verified by test and analysis. An operational acceptance test shall be performed to demonstrate that the facility, facility systems and GSE will be able to provide launch 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 Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. The verification shall be considered successful when the analysis and test shows 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:

1) Allocation of the natural environments requirements to the lower tier systems and their verification methods and details, and

2) 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:

1) 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),

2) Lower tier verifications have been completed and

3) 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 requires 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.

4.7.5.3 RESERVED

4.7.5.4 GS EXTERNAL INTERFACES

[CA0910V-PO] The GS interfaces with the CEV 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 CEV-to-GS interface requirements defined within CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV 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 CEV 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 Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-

CEV interface requirements specified in the IRD have been satisfied. Integrated testing between the CEV 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 was adequate.

[CA0911V-PO] The GS interfaces with the CLV 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-CLV interface requirements defined within CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CLV 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 CLV and Ground Systems. Verification shall be considered successful when (a) Analysis confirms that all of the GS interface verification requirements defined within CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-CLV interface requirements specified in the IRD have been satisfied. Integrated testing between the CLV 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.

[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 77084, 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, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 was adequate.

[CA0913V-PO] **Draft** The GS interfaces with the CaLV shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CaLV Project Office to demonstrate that the GS-to-CaLV 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 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CaLV 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 CaLV 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, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-CaLV interface requirements specified in the IRD have been satisfied. Integrated testing between the CaLV 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 was 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 77084, 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, and (b) when the integrated avionics, software, and multi-system test objectives established by CCxP 77084, 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 (EVA) Systems to Ground Systems (GS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, 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 (EVA) Systems to Ground Systems (GS) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 5: Ground Systems (GS) have been satisfied. Testing shall include those series of tests established by CxP 77084, 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 70092 have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 was adequate.

4.7.5.5 RESERVED

4.7.6 MISSION SYSTEMS (MS)

4.7.6.1 MS DESCRIPTION

4.7.6.2 MS REQUIREMENTS

[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 4 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

[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 Simultation 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 has the capability to generate contingency Earth return analysis, plans and procedures has been accredited per CxP 70076, Constellation Program Modeling and Simultation Management Requirements - Level II.

Rationale: Analysis of the various lower-level analysis requirements results is sufficient for verifying this requirement.

[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 4 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 and test show at the Operational readiness review (used to verify the tools, facilities, and processes) that the tools and facilities are ready to support mission analysis and execution product development and viewing.

Rationale: NR

[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 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. 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

4.7.6.2.1 MS MISSION SUCCESS

[CA3026V-PO] Lunar Sortie 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 (a (TBD-001-932) probability) that LOM for a Lunar Sortie mission due to Mission Systems is not greater than 1 in (TBD-001-524).

Rationale: NR

[CA3030V-PO] **Draft** 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 (a (TBD-001-936) probability) that LOM for a Lunar Outpost Crew mission due to Mission Systems is not greater than 1 in (TBD-001-536).

Rationale: NR

[CA3027V-PO] **Draft** 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 (a (TBD-001-930) probability) that LOM for a Lunar Outpost Cargo mission due to Mission Systems is not greater than 1 in (TBD-001-527).

Rationale: NR

[CA3025V-PO] ISS 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 (a (TBD-001-910) probability) that LOM for an ISS Crew mission due to Mission Systems is not greater than 1 in (TBD-001-521).

Rationale: NR

[CA3024V-PO] ISS 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 (a (TBD-001-909) probability) that LOM for an ISS Cargo mission due to Mission Systems is not greater than 1 in (TBD-001-518).

Rationale: NR

4.7.6.2.2 MS CREW SURVIVAL

[CA3034V-PO] Lunar Sortie LOC 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 (a (TBD-001-912) probability) that LOC for a Lunar Sortie mission due to Mission Systems is not greater than 1 in (TBD-001-549).

Rationale: NR

[CA3035V-PO] **Draft** 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 (a (TBD-001-913) probability) that LOC for a Lunar Outpost Crew mission due to Mission Systems is not greater than 1 in (TBD-001-552).

Rationale: NR

[CA3032V-PO] ISS Crew LOC 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 (a (TBD-001-911) probability) that LOC for an ISS Crew mission due to Mission Systems is not greater than 1 in (TBD-001-543).

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:

1) The Mission Systems performs the abort determination function(s) through an internal algorithm using internal or external data sources.

2) The CxP Architecture Systems receive notification from the Mission Systems of the need for an abort through the C3I infrastructure.

3) All possible profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-789) Document(s).

Rationale: A) 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-001-789) 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.

[CA0163V-PO] Mission Systems landing footprint location services for the CEV 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 the CEV 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 CEV landing footprint location, as specified in the CxP 70117, Constellation Program System Requirements for the Mission Systems (MS) Element, has been met within 20 (TBR-001-981) minutes after the declaration of an entry contingency.

Rationale: NR

4.7.6.2.3 MS CREW SIZE

[CA5128V-PO] Training for 4 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 (PTT's, Mock-ups, etc.), facilities and mission control center systems satisfy the requirements to train 4 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 (PTT's, Mock-ups, etc.), facilities and mission control center systems meet Lunar Sortie mission related training objectives for 4 member crews (each for prime and backup).

Rationale: NR

[CA5129V-PO] Training for 6 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 (PTT's, Mock-ups, etc.), facilities and mission control center systems satisfy the requirements to train 6 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 (PTT's, Mock-ups, etc.), facilities and mission control center systems meet ISS missions related training objectives for 6 member crews (each for prime and backup).

Rationale: NR

4.7.6.2.4 RESERVED

4.7.6.2.5 MS MISSION RATES AND DURATIONS

[CA5524V-PO] The ability of the Mission System to provide a Flight Rate which will sustain the ISS and Human exploration programs shall be verified by inspection and analysis. Inspection shall determine that the Mission System has closed their respective flight rate requirement. Analysis shall assess: 1). The time required to integrate the flight systems into mission configurations, and 2). The availability of Constellation launch facilities. Verification shall be considered successful when inspection determines each system has successfully closed its respective flight rate requirement, and analysis shows: 1) The individual flight systems can be integrated into mission configurations in time to meet mission objectives and 2) The scheduled usage of the launch facilities can accommodate scheduled mission rates.

Rationale: Processing flows, schedules, and launch manifest will be needed to determine whether Mission Systems can support flight rates necessary to sustain the ISS and Human exploration as required.

4.7.6.2.6 MS ARCHITECTURE DEFINITION

[CA5900V-PO] The Mission Systems reconfiguration system for data and flight software shall be verified by demonstration. The demonstration shall examine the output products generated by the reconfiguration system to support a lunar landing from launch through CEV recovery. (Exhaustive verification (tests) of each output product and the value it contains 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 reconfiguration system generates all of the products expected to support the lunar landing DRM and that the products contain expected values as defined in the (TBD-001-1046) documents.

Rationale: A demonstration of the Mission Systems reconfiguration system in support of the lunar landing DRM is sufficient to demonstrate that the reconfiguration system functions properly. (This does not verify the actual output products themselves - these must be verified separately for each mission.) The (TBD-001-1046) documents will be the engineering source data (SRDs, IRDs, trade studies, analyses, flight procedures, flight rules, etc.) generated throughout the design process which specify for each Constellation System what data is subject to reconfiguration and what the range of potential values are.

[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 a 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

[CA5407V-PO] The two fault tolerance for catastrophic hazards shall be verified by analysis. The analysis shall review the results of the system-level hazard analyses, FMEA/CILs, and the integrated architecture hazard analysis for 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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 bottoms up at the system level and then top down for the integrated systems.

[CA5405V-PO] The single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the results of the system-level hazard analyses, FMEA/CILs, and the integrated architecture hazard analysis for 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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 bottoms up at the system level and then top down for the integrated systems

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)

- by the operational Mission Systems hardware and software

- 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.

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):

- is generated by the MS in each applicable mission phase, state and mode.

- 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)

- by the operational MS hardware and software

- 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)

- by the operational Mission Systems hardware and software

- 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)

- by the operational Mission Systems hardware and software

- 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)

- by the operational Mission Systems hardware and software

- 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

[CA3285V-PO] Concurrently monitoring and controlling at least 3 active and 3 quiescent in-space vehicles shall be verified by analysis and test. The testing shall consist of an End-to-End data flow that exercises command, health and status monitoring, voice and video services of concurrent mission operations. The analysis shall consist of a review that the as-built simulators and Mission Control Center systems (MCCS) satisfy the requirements to monitor and control 3 active and 3 quiescent vehicles concurrently. These simulators and MCCS will be identified and characterized in CxP 70117, Constellation Program System Requirements for the Missions Systems (MS) Element, CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Missions Systems (MS) Interface Requirements Document (IRD) and CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) to Mission Systems Interface Requirements Document (IRD). The verification shall be considered successful when the analysis and testing shows that CxP 70117, Constellation Program System Requirements for the Missions Systems (MS) Element, CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Missions Systems (MS) Interface Requirements Document (IRD) and CxP 70113, Constellation Program Lunar Surface Access Module (LSAM) to Mission Systems Interface Requirements Document (IRD). requirements pertaining to the simulators and MCCS are ready to concurrently monitor and control at least 3 active and 3 quiescent in-space vehicles.

Rationale: Tests are needed that are specific to the system and its characteristic data. 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.

[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:

- the command sequences have been successfully generated

- the command sequences contain commands valid for execution on other Constellation Systems

- 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.

[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-001-742) document(s) is processed by Mission Systems in each applicable mission phase, state and mode as specified in (TBD-001-742) document(s).

Rationale: A Test of the processing of telemetry by Mission Systems - defined by (TBD-001-646) document(s) - by the operational Mission Systems hardware and software - 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.

[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 4 different voices, 2 male and 2 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.

[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, and 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.

4.7.6.2.11 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

[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 meet a (TBD-001-564)% availability of launch per crew launch attempt, starting at 24 hours prior to launch and ending at close of day of launch window 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 and Maintainability (R&M) Plan. Verification shall be considered successful when analysis shows that the availability of launch per crew launch attempt is at least 98%) with an uncertainty of not greater than (TBD-001-363)%.

Rationale: Mission systems will be responsible for verifying that all fixed and variable resources needed to support beginning starting at 24 hours prior to launch and ending at close of day of launch window.

[CA5135V-PO] Operations for the CEV no later than 1 (TBR-001-020) day after the launch of the CaLV 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 the CEV no later that 1 (TBR-001-020) day after the launch of the CaLV. 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 CEV no later than 1 (TBR-001-020) day after the launch of the CaLV for Lunar Sortie missions.

Rationale: NR

4.7.6.2.13 MS MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[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

[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

[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

4.7.6.2.14 RESERVED

4.7.6.2.15 RESERVED

4.7.6.3 RESERVED

4.7.6.4 MS EXTERNAL INTERFACES

[CA0920V-PO] The MS interfaces with the CaLV 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 CaLV-to-MS interface requirements defined within CxP 70012, 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 CCxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CaLV 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 CaLV, GS, and MS. Verification shall be considered successful when (a) Analysis confirms that all of the MS interface verification requirements defined within CxP 70012, Constellation Program Cargo Launch Vehicle (CaLV) to Mission Systems (MS) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-CaLV interface requirements specified in the IRD have been satisfied. Integrated testing between the CaLV 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 was adequate.

[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 Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 6: Mission Systems (MS) have been satisfied. Testing shall include those series of tests established by CxP 77084, 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 70092 have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 was 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 77084, 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, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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.

[CA0918V-PO] The MS interfaces with the CLV 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-CLV interface requirements defined within CxP 70053, Constellation Program Crew Launch Vehicle (CLV) to Mission Systems (MS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CLV 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 CLV, 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 Crew Launch Vehicle (CLV) to Mission Systems (MS) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-CLV interface requirements specified in the IRD have been satisfied. Integrated testing between the CLV 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.

[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 77084, 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, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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 was adequate.

[CA0917V-PO] The MS interfaces with the CEV 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-CEV interface requirements defined within CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Missions Systems (MS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV 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 CEV, 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 Crew Exploration Vehicle (CEV) to Missions Systems (MS) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-CEV interface requirements specified in the IRD have been satisfied. Integrated testing between the CEV 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 was 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

[CA0862V-PO] **Draft** (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

[CA0863V-PO] **Draft** (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

[CA3290V-PO] **Draft** Simultaneous communication by DSS with MS and 3 (TBR-001-136) other systems in space 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. The verification shall be considered a success when a) testing shows the system can simultaneously exchange data at the maximum data rates with the specified systems for a period of 20 (TBR-001-420) minutes without apparent degradation b) analysis shows that no degradation is predicted if the test time were indefinite with data maintained at the maximum data rate, and c) 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. 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.

[CA3282V-PO] **Draft** The use of a dissimilar voice communication system by DSS as specified 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, and 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.

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 EXTRA VEHICULAR ACTIVITIES (EVA) SYSTEMS

4.7.9.1 EVA SYSTEMS DESCRIPTION

4.7.9.2 EVA SYSTEMS REQUIREMENTS

[CA4127V-PO] The ability of the EVA System to perform at least 2 (TBR-001-163) in-space 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):

- Provisions for life sustaining nutrition and hydration

- Provisions to collect human waste

- Body thermal control

- EVA System communication (voice, suit and biomed data) to the vehicle.

- CO_2 washout and trace contaminant control

- Certification for 8 hours pressurized operations with external space conditions (as defined in DSNE)

- Decompression Sickness (DCS) compliance to appropriate risk level for EVA

- Protection of the crew from the space environment

- Infrastructure to receive and route vehicle life support to EVA suits (umbilicals, vehicle panel interfaces)

- Suits to accommodate anthropometric ranges of crewmembers specified in HSIR

- Pressurized suit mobility and stability to translate and perform vehicle tasks

- Lighting for translation and worksites

- Tools (safety tethers, hand tools, tool tethers) to perform the tasks

- Camera equipment (if applicable to for the mission phase)

The demonstration shall consist of neutral buoyancy evaluations, with the CEV 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 CEV 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 CEV.

The test shall consist of CEV (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 CEV (LSAM) at ambient conditions for the following sequences. The test shall consist of CEV 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 CEV at ambient conditions for the following sequences.

1. Four suits (and crewmembers) will be connected to all short umbilical positions with the suits performing simultaneously.

2. 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 CEV 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 CEV (LSAM) and EVA System conform to CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) (CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) to Extravehicular Activity (EVA) Interface Requirements Document (IRD)) specifications of all four suits simultaneously. Note: CEV 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 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, System Requirements for the Crew Exploration Vehicle (CEV) Element, CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD), or CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) to Extravehicular Activity (EVA) Interface Requirements Document (IRD)) 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 2 (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 CEV control, etc) with a full complement of crewmembers and in the CEV 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 CEV LSAM) or EVA system certification that a full set of suits and CEV (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.

4.7.9.2.1 EVA SYSTEMS MISSION SUCCESS

[CA5946V-PO] Lunar Sortie LOM due to the EVA 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 (a (TBD-001-1050) probability) that LOM for a Lunar Sortie mission due to EVA Systems is not greater than 1 in (TBD-001-1048).

4.7.9.2.2 EVA SYSTEMS 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 120 (TBR-001-005) 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:

- EVA System provisions for life sustaining nutrition, hydration, and medicine for 120 (TBR-001-005) hours
- EVA System provisions to collect human waste for 120 (TBR-001-005) hours
- EVA System certified for 120 (TBR-001-005) hours of pressurized life at vacuum

- EVA System body thermal control for 120 (TBR-001-005) hours

- EVA System communication (voice, suit and biomed data) to the vehicle for 120 (TBR-001-005) hours.

- Seat ingress/securing with CEV in a pressurized suit and ability to adjust the harness during cabin repress upon re-entry

- EVA System pressurized mobility for vehicle operations to complete vehicle minimum performance needs to return to Earth

- CO2 washout and trace contaminant control for 120 (TBR-001-005) hours.

- 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

120 (TBR-001-005) 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, CEV-EVA IRD, etc), provide evidence as to how the EVA 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 affects 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 120 (TBR-001-005) hour in-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.

[CA5170V-PO] The suited crew capability for unassisted emergency egress out of the CEV after landing (including both land and water) within (TBD-001-146) minutes starting from when the decision to egress the CEV is made shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using EVA System and CEV by performing a minimum of two runs with two different sets of suited crew members egressing the CEV. 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 Systems and CEV system documentation review that meets unassisted egress for the suited crew through the closure in CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) Section (TBD-

001-815). The verification shall be considered successful when the analysis determines the demonstration meets unassisted emergency egress out of the CEV.

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 the CEV during pre-launch activities shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using EVA System and CEV by performing a minimum of two runs with two different sets of suited crew members and collecting the task time for crew egress from CEV 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 Systems and CEV system documentation review that meets unassisted egress for the suited crew through the closure in the CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) Section (TBD-001-814). The verification shall be considered successful when the analysis determines the demonstration meets unassisted emergency egress out of the CEV within 2 (TBR-001-173) min.

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 Systems providing the requirements that address the functions (whether in the SRR, ICD or IRD).

[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 EVA System, CEV and launch support structure by performing a minimum of two runs with two different sets of suited crew members and collecting the task time for crew egress from CEV 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 Systems, CLV and CEV system documentation review that meets unassisted egress for the suited crew through the closure in CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) Section (TBD-001-809), CxP 70052, Constellation Program Crew Launch Vehicle (CLV) to Ground Systems Interface Requirements Document (IRD) Section (TBD-001-810), CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD) Section (TBD-001-813), CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) Section (TBD-001-811), 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 min (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 Systems providing the requirements that address the functions (whether in the SRR, ICD or IRD).

4.7.9.2.2.1 EVA SYSTEMS CREW SURVIVAL PROBABILITIES

[CA5945V-PO] Lunar Sortie LOC due to the EVA 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 (a (TBD-001-1049) probability) that LOC for a Lunar Sortie mission due to EVA Systems is not greater than 1 in (TBD-001-1047).

4.7.9.2.3 RESERVED

4.7.9.2.4 RESERVED

4.7.9.2.5 RESERVED

4.7.9.2.6 RESERVED

4.7.9.2.7 EVA SYSTEMS SAFETY (SYSTEM, PUBLIC, AND PLANETARY)

[CA5410V-PO] The two fault tolerance for catastrophic hazard shall be verified by analysis. The analysis shall review the results of the EVA 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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 bottoms up at the system level.

[CA5409V-PO] The single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the CEV 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 per CxP 70038, Constellation Program Hazard Analyses Methodology.

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.

[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.

4.7.9.2.8 RESERVED

4.7.9.2.9 EVA SYSTEMS HEALTH AND STATUS

[CA3121V-PO] The generation of health and status information by the EVA shall be verified by Test. The Test shall use the flight EVA 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. (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):

- is generated by the EVA in each applicable mission phase, state and mode.
- agrees with the actual health and status of the EVA.

Rationale: A Test of the generation of EVA health and status data

- defined by (TBD-001-591) document(s)
- by the flight EVA 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-001-591) 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.

[CA3122V-PO] The provision of health and status data by the EVA to the crew shall be verified by Test. The Test shall use the flight EVA 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):

- is observed by crew surrogates in the EVA in each applicable mission phase, state and mode.
- agrees with the actual health and status of the EVA.

Rationale: A Test of the provision of EVA health and status data

- defined by (TBD-001-595) document(s)

- by the flight EVA or flight equivalent hardware

- to crew surrogates in the EVA

- 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.

[CA5467V-PO] The provision of fault detection by the EVA Systems shall be verified by Test. The Test shall use the flight EVA Systems 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 Systems 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 Systems in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault detection by the EVA Systems

- for the faults and fault scenarios identified by (TBD-001-456) document(s)

- by the flight EVA Systems or flight equivalent hardware

- 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 Systems shall be verified by Test. The Test shall use the flight EVA Systems 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 Systems 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 Systems in each applicable mission phase, state and mode.

Rationale: A Test of the provision of fault isolation by the EVA Systems

- for the faults and fault scenarios identified by (TBD-001-458) document(s)

- by the flight EVA Systems or flight equivalent hardware

- 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.

[CA4125V-PO] The provision of fault recovery by the EVA Systems shall be verified by Test. The Test shall use the flight EVA Systems 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 Systems 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 Systems in every applicable mission phase, state and mode.

Rationale: A Test of the provision of fault recovery by the EVA Systems

- for the faults and fault scenarios identified by (TBD-001-817) document(s)
- by the flight EVA Systems or flight equivalent hardware
- 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.

4.7.9.2.10 EVA SYSTEMS COMMUNICATIONS AND COMMUNICATIONS SECURITY

[CA5909V-PO] Simultaneous communication by the EVA 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 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, and 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 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 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, and 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.

[CA5046V-PO] **Draft** EVA 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 a) 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.

[CA5047V-PO] **Draft** EVA 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, and 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.

[CA3283V-PO] The use of a dissimilar voice communication system by EVA as specified shall be verified by Analysis and Demonstration. The analysis shall be performed on the EVA voice communication systems. The demonstration shall be performed on the EVA 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, and b) the analysis shows the dissimilar system is independent when compared to the prime EVA 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.

4.7.9.2.11 RESERVED

4.7.9.2.12 EVA SYSTEMS RELIABILITY AND AVAILABILITY

[CA3063V-PO] The ability of the EVA Systems to meet a 98% (TBR-001-041) availability of launch per crew launch attempt, starting at “LCC Call to Station” and ending at close of day of launch window 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 70879, CxP Reliability and Maintenance Plan. Verification shall be considered successful when analysis shows that the availability of launch per crew launch attempt is at least 98% (TBR-001-041) with an uncertainty of not greater than (TBD-001-1014)% (TDS# SIG-01-004).

Rationale: It will be necssary for the EVA systems to make certain that their system has the reliablility to be available to support beginning "LCC Call to Station" and ending at close of day-of-launch window.

4.7.9.2.13 EVA SYSTEMS MAINTAINABILITY, SUPPORTABILITY, AND LOGISTICS

[CA5184V-PO] The ability of the EVA System flight hardware to be designed for in-flight maintenance including replacement and repair of major end items shall be verified by analysis. A maintainability analysis shall be performed to determine the actions required to maintain the EVA and prevent loss of mission. These actions will then be compared to the allocated parameters for each mission phase. Verification shall be considered successful when analysis shows all required EVA maintenance actions can be accomplished in its operational environment.

Rationale: It is important to implement EVA designs that ere reliable, easy to repair and require minimum maintenance in-flight.

[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, and the EVA System FMEA. Verification shall be considered successful when analysis determines that the EVA System contains no limited-life items which must be replace during an ISS mission and does not require any preventive maintenance activities to be performed during an 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 Systems LSA. The EVA Systems FMEA will identify and 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.

4.7.9.2.14 EVA SYSTEMS HABITABILITY AND HUMAN FACTORS

[CA5168V-PO] The ability of the EVA System to provide for unassisted donning and doffing of space suit systems shall be verified by demonstration and analysis. The demonstration shall consist of 1-g suit donning and doffing evaluations using flight or training quality suits performed by six crewmembers with donning and doffing time collected. The crewmembers selected shall represent the anthropometric range as specified in the CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), within the constraints of the existing Astronaut Office cadre. The demonstration will use those donning aids available to the crew during flight, with the suit parts readily accessible to the crewmember, and will be performed without any assistance. The donning time will begin with the crewmembers in undergarments, shall include all parts of the EVA system necessary to sustain the crew for 120 hours in an unpressurized cabin, will end when the suit is ready for pressurization (suit sealed up) and the crew has subjectively determines adequate fit has been achieved. Doffing will begin with the suits in a ready for pressurization state, shall include all parts of the EVA system necessary to sustain the crew for 120 hours in an unpressurized cabin, and will end when the crewmembers are in undergarments, with assistance allowable after an item has been doffed in order to maintain proper handling of the suit components. The donning and doffing evaluation will be repeated by each crewmember up to five times. The analysis shall consist of examination of task time collected during the 1-g demonstration and applying a program approved in-space extrapolation factor as appropriate. The verification will be considered successful when the analysis proves that each crewmember can don the suit within the donning time identified in CA3058-

PO divided by 2, and is repeatable at least once during the demonstration and doffing time does not exceed 30 minutes.

Rationale: Although this requirement is specifically levying a suit system that does not require assistance to don and doff, a time limit must be established for the demonstration to keep the intent of the original requirement (as any suit system can be donned without assistance if given enough time). Requiring a suit system that can be donned without assistance in half the time as specified in CA3058-PO (EVA System donning time in the case of a vehicle emergency depressurization event) will help improve the success of the verification of CA3058-PO within the limited confines of the CEV and LSAM and so is useful to establish the time limit for this self donning and doffing requirement. It is assumed that, in the CEV and LSAM vehicle confines, approximately half the crew can perform donning simultaneously. Thus if it is shown that donning can be accomplished in half the time specified in CA3058-PO by a single crewmember, there will be high confidence that the CA3058-PO verification will be successful, and also ensures the intent of a self donning/doffing suit has been satisfied. Most likely, many parts of the suit can be donned by the entire crew in parallel regardless of vehicle volume (such as gloves), so this donning time verification requirement is likely slightly conservative which will help account for inefficiencies due to crew unfamiliarity with the hardware in flight. For suit doffing time, there is no cited emergency for the crew to quickly doff suits. However, it is believed that 30 minutes will ensure a crewmember can doff the suit without assistance within a reasonable time limit.

This requirement does not require the suits to be stowed in any specific manner, as the stowage of suits and suit parts are not within the responsibility of the EVA System Project (and, thus, the EVA System should not be penalized for any additional time required to unstow the equipment). Although it is difficult to specifically test the full anthropometric range (as individuals are usually not the smallest or largest in all dimensions), the intent is to include the anthropometric extremes within the available astronaut office cadre at the time (as those represent the most likely range of crewmembers who will be assigned to future Constellation flights). The best two of five runs was chosen as that represents a number of runs available for the crewmembers to overcome a learning curve with the hardware, but limits the project to proving compliance within a limited number of runs (representative of the amount of hardware experience that the crew might accumulate during training before flight). Six crewmembers represent the standard number of crewmembers used for crew consensus reports and, although a crew consensus report is not required for this verification, represents a generally minimum acceptable number of crewmembers to the Astronaut office, and should not be too large to result in undue test burden on the EVA System Project.

[CA3058V-PO] The ability of the EVA System to provide spacesuits that can be donned by the full crew in 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 CEV volume mockup, with the suits stowed in the designated CEV 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 in-space 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 retrieve, don, and pressurize the suits.

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 the CEV. Since there are 3 primary factors (CEV 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 in-space activities, 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 time available for the ECLSS feed the leak). Six crewmembers were chosen as the maximum necessary to satisfy overarching Constellation requirements for ISS missions.

[CA5659V-PO] The ability of EVA Systems 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 Systems pressure suit and all EVA Systems 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 the following function:

- 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 Systems 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 SYSTEMS ENVIRONMENTAL CONDITIONS

[CA5188V-PO] Compliance of the 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: CEV/LSAM/EVA, CEV/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:

1) The analysis has been completed to address the scope of section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE)

2) 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)

3) Lower tier verifications have been completed

4) 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] EVA 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: 1) Review of the induced environmental verifications submitted against all of the EVA/System IRD requirements. 2) 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 Specificationcan provide verification including assurance that 1) the proper induced environments have been considered, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

[CA5564V-PO] EVA induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts: 1) Review of the induced environmental verifications submitted against all of the EVA/System IRD requirements. 2) 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 (IEDS).

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 1) the proper induced environments have been met, 2) sensitivities to these environments, and 3) synergistic effects have each been properly addressed for all mission phases.

4.7.9.3 RESERVED

4.7.9.4 EVA SYSTEMS EXTERNAL INTERFACES

[CA0924V-PO] The EVA interfaces 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 interface requirements defined within CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) to Extravehicluar Activity (EVA) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, 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 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, GS, and EVA systems. Verification shall be considered successful when (a) Analysis confirms that all of the LSAM-to-EVA interface verification requirements defined within CxP 70107, Constellation Program Lunar Surface Access Module (LSAM) to Extravehicluar Activity (EVA) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-to-LSAM 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.

[CA0925V-PO] The EVA 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-to-GS interface requirements defined within CxP 70104, Constellation Program Extravehicular Activity (EVA) Systems to Ground Systems (GS) Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, 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 EVA interface verification requirements defined within CxP 70104, Constellation Program Extravehicular Activity (EVA) Systems to Ground Systems (GS) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-to-GS 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.

[CA0923V-PO] The EVA interfaces with the CEV 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-to-CEV interface requirements defined within CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV avionics, software, and fluid interfaces 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 CEV, GS, and EVA systems. Verification shall be considered successful when (a) Analysis confirms that all of the EVA-to-CEV interface verification requirements defined within CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, 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-to-CEV interface requirements specified in the IRD have been satisfied. Integrated testing between the CEV 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.

4.7.9.5 RESERVED

APPENDIX A - GLOSSARY AND ACRONYMS

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.

Where “(P)” is shown after the acronym or glossary term, the item is Pending approval of a proposed change.

Table A-1 - Acronyms

Acronym	Acronym Description
C&T	Communications & Tracking
C3I	Command, Control, Communications, Information
CA	Constellation Architecture
CaLV	Cargo Launch Vehicle
CARD	Constellation Architecture Requirements Document
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle
CM	Crew Module / Configuration Management
CONUS	Continental United States
Cx	Constellation
CxCB	Constellation Program Control Board
CxP	Constellation Program
CxPO	Constellation Program Office
CEQATR	Constellation Environment Qualification and Acceptance Testing
DAC	Design Analysis Cycle
DAEZ	Down-range Abort Exclusion Zone
DAV	Descent Ascent Vehicle
DC	Direct Current
DDMS	Data Distribution Management System
DDT&E	Design, Development, Test and Evaluation
DFMR	Design for Minimum Risk

Acronym	Acronym Description
DRM	Design Reference Mission
DSNE	Design Specification for Natural Environments
DSS	Destination Surface Systems
DTO	Development Test Objective
E3	Electromagnetic Environmental Effects
Ec	Expectation of Casualties
ECLS	Environment Control and Life Support
EDS	Earth Departure Stage
EEE	Electrical, Electronic, and Electromechanical
EMC	Electromagnetic Compatibility
ERO	Earth Rendezvous Orbit
ESAS	Exploration Systems Architecture Study
ESMD	Exploration Systems Mission Directorate
EVA	Extravehicular Activity
EOR (P)	Earth Orbit Rendezvous
FCO	Flight Control Officer
FDIR	Fault Detection, Isolation, and Recovery/Reconfiguration
FFBD	Functional Flow Block Diagram
FIPS PUB	Federal Information Processing Standard Publication
FTS	Flight Termination System
FCE	Flight Crew Equipment
FOD	Foreign Object Debris
FSE	Flight Support Equipment/Forward Skirt Extension
GFE	Government Furnished Equipment
GN&C	Guidance, Navigation, and Control
GSE	Ground Support Equipment
GS (P)	Ground Systems
HRR	Human Rating Requirements
HSIR	Human Systems Integration Requirements
IDAC	Integrated Design Analysis Cycle

Acronym	Acronym Description
ILS	Integrated Logistics Support
IMS	Integrated Master Schedule
IP	Internet Protocol
IRD	Interface Requirements Document
ISS	International Space Station
KSC	Kennedy Space Center
LAS	Launch Abort System
LCC	Launch Commit Criteria/Launch Control Center
LEO	Low Earth Orbit
LH2	Liquid Hydrogen
LLO	Low Lunar Orbit
LOC	Loss of Crew
LOI	Lunar Orbit Insertion
LOM	Loss of Mission
LOR (P)	Lunar Orbit Rendezvous
LOX	Liquid Oxygen
LRU	Line-Replaceable Unit
LSAM	Lunar Surface Access Module
LRO	Lunar Rendezvous Orbit
LDO	Lunar Destination Orbit
MCC	Mission Control Center
MEIT	Multi-Element Integrated Testing
MS (P)	Mission Systems
MTV	Mars Transfer Vehicle
M&P	Materials and Processes
NGO	Needs, Goals, and Objectives
NSS	NASA Safety Standard
NERSAM (P)	Natural Environment Requirement Sensitivity and Applicability Matrices
OMRSD	Operations and Maintenance Requirements and

Acronym	Acronym Description
	Specifications Document
OSE	Orbital Support Equipment
PRA	Probabilistic Risk Assessment
RCS	Reaction Control System
RF	Radio Frequency
RPODU	Rendezvous-Proximity Operation-Docking-Undocking
RPOD	Rendezvous-Proximity Operation-Docking
SA (P)	Single Access/Spacecraft Adaptor
SAR	Search and Rescue/System Acceptance Review
SM	Service Module
SRD	System Requirements Document
SSRB	Shuttle Solid Rocket Booster
STS	Space Transportation System
SRB	Solid Rocket Booster
SIL	Systems Integration Laboratory
SRM	Solid Rocket Motor
TBD	To Be Determined
TBR	To Be Resolved
TCM	Trajectory Correction Maneuver
TEI	Trans-Earth Injection
TLI	Trans-Lunar Injection
TLC	Trans-Lunar Coast
USAF	United States Air Force
UTC	Universal Time Code
V	Volt
V&V (P)	Verification and Validation
VDC	Volt Direct Current
VSE	Vision for Space Exploration

Table A-2 - Glossary

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 CEV prior to rendezvous with the LSAM would be considered catastrophic. A hazard that may cause loss of CEV 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., "The Crew Exploration Vehicle 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 Crew Launch Vehicle 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.

Glossary Term	Description
Communication & 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.
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.

Glossary Term	Description
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.
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.

Glossary Term	Description
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
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.

Glossary Term	Description
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).
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.
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.

Glossary Term	Description
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 CEV 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.
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.
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 CEV health while docked to ISS; for Lunar missions this mode ensures functionality to accomplish redocking between CEV and LSAM.

Glossary Term	Description
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 CEV CM for crew egress, egress of the flight crew, providing access to stowed items, flight element retrieval (CLV first stage, CaLV SRBs, CEV 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)
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 CLV/CEV, can be moved for protection from hazardous conditions until the hazard no longer exists.

Glossary Term	Description
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

APPENDIX B-1 - TBD MATRIX

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, if not already shown, will be updated at the Program Baseline Sync, scheduled for 2007.

Table B-1-1 - OPEN WORK - TBD

TBD #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-034	SR&QA	Update IDAC 2 analysis to include this mission	IDAC-3	CA0099-HQ	CARD_3.2.1
TBD-001-034	SR&QA	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA0099-HQ	CARD_3.2.1
TBD-001-036	SR&QA	Update IDAC 2 analysis to include this mission	IDAC-3	CA0474-HQ	CARD_3.2.2.1
TBD-001-036	SR&QA	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA0474-HQ	CARD_3.2.2.1
TBD-001-076	FPSIG	TDS for analysis by Flight Dynamics group	IDAC-5	CA5234-PO	CARD_3.7.1.2.2.2
TBD-001-089	FPSIG	Create a CxPO document, Control Mass Plan, which will include the reporting process to show that each of the Systems are meeting their Control Masses	SRR + 60 days	CA0023-PO	CARD_3.5
TBD-001-094	SR&QA SIG	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006.	CxP SRR	CA0860-PO	CARD_3.7.5.2.1
TBD-001-094	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA0860-PO	CARD_3.7.5.2.1
TBD-001-1002	SR&QA	This is a Design and Construction Standard. The document number will be filled in when available.	CxP PBS	CA5915-PO	CARD_3.3.8

TBD #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-1004	Flight Performance	Continuation of analysis to further define CaLV capability.	CaLV SRR	CA4139-PO	CARD_3.7.1.2.6.1
TBD-001-1005	FPSIG	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	CA4145-PO	CARD_3.7.3.2.6.2
TBD-001-1019	PTI	Analysis to study feasibility within cost, schedule, and risk for CEV development	CEV PDR	CA5933-PO	CARD_3.7.1.5
TBD-001-1022	IMO	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	CxP SDR	CA5936-PO	CARD_3.4
TBD-001-1023	IMO	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	CxP SDR	CA5937-PO	CARD_3.4
TBD-001-1024	IMO	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	CxP SDR	CA5938-PO	CARD_3.4
TBD-001-1025	IMO	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	CxP SDR	CA5939-PO	CARD_3.4
TBD-001-1026	IMO	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	CxP SDR	CA5940-PO	CARD_3.4
TBD-001-1028	IMO	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	CxP SDR	CA5942-PO	CARD_3.4
TBD-001-1029	IMO	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	CxP SDR	CA5943-PO	CARD_3.4
TBD-001-1030	IMO	Need Level 1 HQ to negotiate draft and sign MOUs with external organizations	CxP SDR	CA5944-PO	CARD_3.4
TBD-001-1047	SR&QA	Will be resolved through IDAC 3 analysis	CxP SDR	CA5945-PO	CARD_3.7.9.2.2.1
TBD-001-1048	SR&QA	Will be resolved through IDAC 3 analysis	CxP SDR	CA5946-PO	CARD_3.7.9.2.1

TBD #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-146	GOP	New study for IDAC-3 to validate post landing egress. 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	CA0466-PO	CARD_3.7.1.2.2.2
				CA5170-PO	CARD_3.7.9.2.2
TBD-001-146	GOMO SIG	Determine unassisted emergency egress time for suited crew post landing from initiation of egress to last crew member out of the hatch.	IDAC-3	CA0466-PO	CARD_3.7.1.2.2.2
				CA5170-PO	CARD_3.7.9.2.2
TBD-001-174	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006.	CxP SRR	CA1065-PO	CARD_3.7.2.2.1
TBD-001-204	C3I SIG	New study for IDAC-3 (CTN Data Volume Handling). Need to determine the total amount of data that needs to flow between Cx and CTN. Basis of study will start from SIG-13-111 (Communication Services) and possibly leverage the Data flow models found in SIG-13-109.	IDAC-3	CA3045-PO	CARD_3.8.2
TBD-001-204	C3I SIG	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	IDAC-3	CA3045-PO	CARD_3.8.2
TBD-001-205	C3I SIG	New study for IDAC-3 (CTN Data Volume Handling). Need to determine the total amount of data that needs to flow between Cx and CTN. Basis of study will start from SIG-13-111 (Communication Services) and possibly leverage the Data flow models found in SIG-13-109.	IDAC-3	CA0929-PO	CARD_3.8.2

TBD #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-206	C3I SIG	New study for IDAC-3 (CTN Data Volume Handling). Need to determine the total amount of data that needs to flow between Cx and CTN. Basis of study will start from SIG-13-111 (Communication Services) and possibly leverage the Data flow models found in SIG-13-109.	IDAC-3	CA0930-PO	CARD_3.8.2
TBD-001-206	C3I SIG	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	IDAC-3	CA0930-PO	CARD_3.8.2
TBD-001-209	C3I SIG	New study for IDAC3 (C&TN Data Volume Handling). Need to determine the total amount of data that needs to flow between Cx and ECANS. Basis of study will start from SIG-13-111 (Communication Services) and possibly leverage the Data flow models found in SIG-13-109.	IDAC-3	CA3044-PO	CARD_3.8.2
TBD-001-209	C3I SIG	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	IDAC-3	CA3044-PO	CARD_3.8.2
TBD-001-219	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2, IDAC-3	CA3163-PO	CARD_3.7.2.2.2.1
TBD-001-219	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3163-PO	CARD_3.7.2.2.2.1
TBD-001-220	C3I SIG	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	CA5039-PO	CARD_3.7.1.2.8

TBD #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-252	GOMO SIG	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	CARD_3.2.2.2
TBD-001-460	FPSIG	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	CARD_3.7.3.2.6
TBD-001-505	SLRM SIG	New TDS	IDAC-3	CA0178-PO	CARD_3.7.1.2.12
TBD-001-513	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006	IDAC-2	CA3022-PO	CARD_3.7.1.2.1
TBD-001-513	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3022-PO	CARD_3.7.1.2.1
TBD-001-515	SR&QA	Update IDAC 2 analysis to include this mission	IDAC-3	CA3023-PO	CARD_3.7.1.2.1
TBD-001-515	SR&QA	Future IDAC supporting Lunar Outpost DRM	Cx Lunar Outpost SRR	CA3023-PO	CARD_3.7.1.2.1
TBD-001-517	SLRM SIG	TDS for analysis	CaLV SRR	CA5600-PO	CARD_3.2.1 2
TBD-001-518	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA3024-PO	CARD_3.7.6.2.1
TBD-001-518	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3024-PO	CARD_3.7.6.2.1
TBD-001-521	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA3025-PO	CARD_3.7.6.2.1
TBD-001-521	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3025-PO	CARD_3.7.6.2.1

TBD #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-524	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA3026-PO	CARD_3.7.6.2.1
TBD-001-524	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3026-PO	CARD_3.7.6.2.1
TBD-001-533	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2, IDAC-3	CA3029-PO	CARD_3.7.5.2.1
TBD-001-533	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3029-PO	CARD_3.7.5.2.1
TBD-001-539	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA3031-PO	CARD_3.7.5.2.2
TBD-001-539	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3031-PO	CARD_3.7.5.2.2
TBD-001-543	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA3032-PO	CARD_3.7.6.2.2
TBD-001-543	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	Cx Lunar Transportation SRR	CA3032-PO	CARD_3.7.6.2.2
TBD-001-546	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2, IDAC-3	CA3033-PO	CARD_3.7.5.2.2
TBD-001-546	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3033-PO	CARD_3.7.5.2.2
TBD-001-549	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006	IDAC-2	CA3034-PO	CARD_3.7.6.2.2
TBD-001-549	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA3034-PO	CARD_3.7.6.2.2

TBD #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBD-001-559	SR&QA	Update IDAC 2 analysis to include this mission	IDAC3	CA3040-PO	CARD_3.7.1.2.2.1
TBD-001-559	SR&QA	Future IDAC supporting Lunar Outpost DRM	CxP Lunar Outpost SRR	CA3040-PO	CARD_3.7.1.2.2.1
TBD-001-562	SLRM SIG	Resolution per TDS-SIG-01-004	IDAC-2	CA3063-PO	CARD_3.7.9.2.12
TBD-001-562	SLRM SIG	Resolution per TDS-SIG-01-004 Extended through to IDAC-3	IDAC-3	CA3063-PO	CARD_3.7.9.2.12
TBD-001-563	SLRM SIG	TDS-SIG-01-004	IDAC-2	CA3064-PO	CARD_3.7.5.2.12
TBD-001-563	SLRM SIG	TDS-SIG-01-004 Extended through IDAC-3	IDAC-3	CA3064-PO	CARD_3.7.5.2.12
TBD-001-568	GOMO	Find an external standard for reference	CxP SRR Board	CA3259-PO	CARD_3.7.1.2.2
TBD-001-568	GOMO SIG	Determine proper Standard-xxx for SAR visual aids for CEV to design into vehicle that aids in recovery independent of ambiaent lighting conditions.	IDAC-3	CA3259-PO	CARD_3.7.1.2.2
TBD-001-851	FPSIG			CA5233-PO	CARD_3.7.1.2.4
TBD-001-851	FPSIG	TDS to CEV flight dynamics team to determine center-of-gravity envelope for stable entry	IDAC 3	CA5233-PO	CARD_3.7.1.2.4
TBD-001-947	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA5913-PO	CARD_3.7.1.2.2.1
TBD-001-948	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA5914-PO	CARD_3.7.2.2.2.1
TBD-001-984	FPSIG	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

APPENDIX B-2 - 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. Section 4 resolution plans, if not already shown, will be updated at the Program Baseline Sync, scheduled for 2007.

Table B-2-1 - OPEN WORK - TBR

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-002	ISS	ISS to determine possible failure scenarios and required safe haven time.	Cx SRR	CA0493-PO	CARD_3.7.1.2.2
TBR-001-004	FPSIG	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-001-007	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA0033-HQ	CARD_3.2.1
TBR-001-007	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA0033-HQ	CARD_3.2.1

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-010	ARDIG	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.		CA0020-HQ	CARD_3.2.3
TBR-001-010	ARDIG	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-001-014	SR&QA	Update IDAC 2 analysis	IDAC-3	CA0032-HQ	CARD_3.2.2.1
TBR-001-014	SR&QA	Update IDAC 3 analysis	CxP SDR	CA0032-HQ	CARD_3.2.2.1

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-015	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA0096-HQ	CARD_3.2.2.1
TBR-001-015	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA0096-HQ	CARD_3.2.2.1
TBR-001-017	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA0095-HQ	CARD_3.2.1
TBR-001-017	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA0095-HQ	CARD_3.2.1
TBR-001-018	G/MO SIG	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-001-021	SLRM SIG	TDS for IDAC-3	IDAC-3	CA0123-PO	CARD_3.2.12
				CA3065-PO	CARD_3.7.6.2.12
TBR-001-021	SLRM SIG	TDS for IDAC-2 Extended through to IDAC-3	IDAC-3	CA0123-PO	CARD_3.2.12
				CA3065-PO	CARD_3.7.6.2.12
TBR-001-035	PTI	Further analysis of ISS mission and CEV capability to accommodate cargo	IDAC-3	CA0565-HQ	CARD_3.7.1.2.4
TBR-001-040	FPSIG	TDS for CEV flight dynamics group to provide updated landing analysis based on maturing CEV design. As the flight software algorithms mature and the sensors are selected for the vehicle, more accurate simulations will be available to provide this data.	IDAC-5	CA0329-PO	CARD_3.7.1.2.11

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-045	Integrated Thermal/ ECLS SIG	ECLSS/Thermal performing feasibility assessment for supporting crew in suit with minimal cabin cooling in worst sea state external temp. environment.	CEV RAC-3	CA0194-PO	CARD_3.7.1.2.2
TBR-001-047	G/MO SIG	New study of SAR capabilities to validate this requirement. Must be coordinated with CEV study of 36 hours crew survival.	IDAC-3	CA5146-PO	CARD_3.7.5.2.2
TBR-001-047	G/MO SIG	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-3	CA5146-PO	CARD_3.7.5.2.2
TBR-001-055	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA0398-PO	CARD_3.7.1.2.2.1
TBR-001-055	SR&QA	Update IDAC-3 analysis	CxP SDR	CA0398-PO	CARD_3.7.1.2.2.1
TBR-001-056	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA0399-PO	CARD_3.7.1.2.1
TBR-001-056	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA0399-PO	CARD_3.7.1.2.1
TBR-001-057	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA0501-PO	CARD_3.7.1.2.2.1
TBR-001-057	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA0501-PO	CARD_3.7.1.2.2.1
TBR-001-058	SR&QA	Revise PRA analysis to include software and EVA allocation per CxCB direction on 9/5/2006. Provide results back to CxCB on 10/31/2006.	IDAC-2	CA0088-PO	CARD_3.7.1.2.1

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-058	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA0088-PO	CARD_3.7.1.2.1
TBR-001-063	FPSIG	Determined by differencing the final values for TBR-001-005 and TBR-001-179.	IDAC-3	CA5237-PO	CARD_3.7.1.2.2.2
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-001-1006	FPSIG	Review analyses performed by CEV Flight Dynamics team and ARDIG which show that 120 hours envelopes all of the early return cases.	IDAC-3	CA0532-PO	CARD_3.7.1.2.2
				CA3003-PO	CARD_3.7.9.2.2
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-001-1012	C3I SIG	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	CxP SDR	CA0928-PO	CARD_3.8.2
TBR-001-1014	C3I SIG	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	CxP SDR	CA0928-PO	CARD_3.8.2

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-1015	C3I SIG	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	CxP SDR	CA0928-PO	CARD_3.8.2
TBR-001-1016				CA0036-HQ	CARD_3.2.5
TBR-001-1017				CA0036-HQ	CARD_3.2.5
TBR-001-1018				CA0036-HQ	CARD_3.2.5
TBR-001-105	C3I SIG	New IDAC3 study based on SIG-13-101 (Master Link Book) and SIG-13-107 (BER) from IDAC2	IDAC-3	CA3043-PO	CARD_3.2.10
TBR-001-109	Integrated Thermal	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.	IDAC-3	CA3061-PO	CARD_3.7.1.2.14

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-113	EVA SIG	1. Perform feasibility assessment of time to don suits with CEV volume (EC5/ T. Hill completed 8/4/06) 2. Team Brainstorm on Options (XA/J. Patrick completed 8/11/06) 3. Determine prebreathe protocols for time assessment (SK/M. Gernhardt est. 9/22/06). 4. Ops Scenario Formulation of Brainstormed Options (DX/S. Bleisath est. 9/22/06) 5. Team review options with protocols, and determine time recommendations (EVA & ECLSS SIG lead est. 9/29/06) 6. Prepare time recommendations and Ops Concept package (EVA SIG est 10/6/06). 7. Review Ops Concept through panels/board (EVA SIG est 10/20/06). 8. Close TBRs with SECB/Cx CP (EVA SIG est 11/10/06).	121506	CA3058-PO	CARD_3.7.9.2.14
TBR-001-113	EVA SIG	Perform feasability assessment of the entire unpressurized survival scenario, which includes time to don suits with CEV volume, prebreathe protocols, suit pressures, etc.	IDAC3	CA3058-PO	CARD_3.7.9.2.14
TBR-001-114	C3I SIG	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	CxP SDR	CA0928-PO	CARD_3.8.2
TBR-001-115	C3I	New study for IDAC3 (C&TN Data Volume Handiling). Need to determine the total amount of data that needs to flow between Cx and ECANS. Basis of study will start from SIG-13-111 (Communication Services) and possibly leverage the Data flow models found in SIG-13-109.	IDAC-3	CA3046-PO	CARD_3.8.2

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-119	C3I SIG	New study for IDAC-3 on simultaneous communications	IDAC-3	CA0476-PO	CARD_3.2.10
TBR-001-122	G/MO SIG	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-001-124	Integrated Thermal/ ECLS SIG	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.	IDAC-3	CA3133-PO	CARD_3.7.1.2.14
TBR-001-126	C3I	New study for IDAC3 which will be an extension of SIG-13-103 (Rendezvous Communication)	IDAC-3	CA3287-PO	CARD_3.7.1.2.10
TBR-001-127	Integrated Thermal/ ECLS SIG	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.	IDAC-3	CA3140-PO	CARD_3.7.1.2.14
TBR-001-128	FP SIG	Should be led by FPSIG with ECLSS/TH support.	Cx SRR	CA3164-PO	CARD_3.7.1.2.5
TBR-001-128	FP SIG	Review results of studies done to date. Schedule meeting for week of 12/03/06. Determine any follow-on work required at that time or remove TBR.	SRR + 60 days	CA3164-PO	CARD_3.7.1.2.5
TBR-001-129	C3I	New study for IDAC3 which will be an extension of SIG-13-103 (Rendezvous Communication)	IDAC-3	CA3289-PO	CARD_3.7.3.2.10

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-134	G/MO SIG	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-001-137	NAV SIG	The 5 systems are consistent with the C3I requirements for communications to systems, but assumes no ISS missions simultaneously. Need to confirm the applicability and assumptions of this requirement before TBR may be removed. Requires coordination with C3I and ECANS. Jan/2007	Jan-31-2007	CA3179-PO	CARD_3.8.2
TBR-001-137	NAV SIG	The 5 systems are consistent with the C3I requirements for communications to systems, but assumes no ISS missions simultaneously. Need to confirm the applicability and assumptions of this requirement before TBR may be removed. Requires coordination with C3I and ECANS. Jan/2007	SRR+90 days	CA3179-PO	CARD_3.8.2
TBR-001-140	FPSIG	TDS to evaluate the proper window which will trade performance with launch probabilities.	IDAC-3	CA0072-PO	CARD_3.7.2.2.12
TBR-001-144	G/MO SIG	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	CA0337-PO	CARD_3.7.5.2.2
TBR-001-144	G/MO SIG	Determine time for 12 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 #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-148	FPSIG	Delta-V discussion at AWG/CxCB on Sept. 13 left TBR for further assessment	IDAC-3	CA0829-PO	CARD_3.7.1.2.6.2
TBR-001-149	FPSIG	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	FPSIG	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.	IDAC-4	CA1055-PO	CARD_3.7.2.2.7
TBR-001-157	EVA SIG	1. Perform feasibility assessment of time to don suits with CEV volume (EC5/ T. Hill completed 8/4/06) 2. Team Brainstorm on Options (XA/J. Patrick completed 8/11/06) 3. Determine prebreathe protocols for time assessment (SK/M. Gernhardt est. 9/22/06). 4. Ops Scenario Formulation of Brainstormed Options (DX/S. Bleisath est. 9/22/06) 5. Team review options with protocols, and determine time recommendations (EVA & ECLSS SIG lead est. 9/29/06) 6. Prepare time recommendations and Ops Concept package (EVA SIG est 10/6/06). 7. Review Ops Concept through panels/board (EVA SIG est 10/20/06). 8. Close TBRs with SECB/Cx CP (EVA SIG est 11/10/06).	CEV SRR	CA3108-PO	CARD_3.7.1.2.2

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-157	EVA SIG	Perform feasability assessment of the entire unpressurized survival scenario, which includes time to don suits with CEV volume, prebreathe protocols, suit pressures, etc.	IDAC3	CA3108-PO	CARD_3.7.1.2.2
TBR-001-159	FPSIG	Continuation of analysis to further define CaLV capability.	CaLV SRR	CA4139-PO	CARD_3.7.1.2.6.1
TBR-001-161	G/MO SIG	New study for IDAC-3 to assess the capabilities of the recovery forces and CEV to validate this requirement	IDAC-3	CA4122-PO	CARD_3.7.5.2
TBR-001-161	G/MO SIG	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	EVA SIG	1. Cursory timeline study of in-space scenario (only scenario of LSAM-CEV transfer) (DX/Bleisath completed) 2. Pull together presentation for quantity and duration based on methodology used for requirement development (EVA SIG, est. 10/6/06). 2. Present to SECB/Cx CP for TBR closure (EVA SIG, est. 10/27/06). Note that EVA duration may be dependent on future CEV design work (it will be part of the presentation as to whether the program wants to keep a TBR for duration based on this).	EVA SRR	CA4127-PO	CARD_3.7.9.2
TBR-001-163	EVA SIG	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.	IDAC3	CA4127-PO	CARD_3.7.9.2
TBR-001-166	FPSIG	Use CEV configuration analysis	IDAC-3	CA5155-PO	CARD_3.7.1.2.4

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-168	G/MO SIG	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	CA5159-PO	CARD_3.7.2.2.2.2
TBR-001-168	G/MO SIG	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	G/MO SIG	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-001-173	G/MO SIG	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-001-174	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA1065-PO	CARD_3.7.2.2.1
TBR-001-181	FPSIG	Mass delivered discussion at AWG/CxCB on Sept 13	September 13, 2006	CA5323-PO	CARD_3.7.2.2.12
TBR-001-191	Integrated Themal/ECLS SIG	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.	IDAC-3	CA5659-PO	CARD_3.7.9.2.14
TBR-001-193	FPSIG	Review of analysis already performed will continue to determine whether there are indeed reasonable launch opportunities on four consecutive days based on rendezvous times and lunar landing site opportunities.	IDAC-5	CA0125-PO	CARD_3.2.12

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
				CA1008-PO	CARD_3.7.2.2.12
				CA5690-PO	CARD_3.7.5.2.5
				CA5702-PO	CARD_3.7.5.2.5
TBR-001-202	GOMO	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	CA0335-PO	CARD_3.7.1.2.2.2
TBR-001-202	GOMO SIG	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-001-205	FPSIG	Need to review study already performed by LSAM project which indicates that 12 hours is the maximum time required from the point a decision is made to return to the Earth until the LSAM can reach the LRO. The CEV must transfer from whatever orbit it is loitering in to the LRO within that same amount of time.	IDAC-3	CA5237-PO	CARD_3.7.1.2.2.2
				CA5240-PO	CARD_3.7.1.2.6

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-206	EVA SIG	1. Determine prebreathe protocols for time assessment (SK/M. Gernhardt est. 9/22/06). 2. Ops Scenario Formulation of Brainstormed Options (DX/S. Bleisath est. 9/22/06) 3. Team review options with protocols, and determine time recommendations (EVA & ECLSS SIG lead est. 9/29/06) 4. Prepare time recommendations and Ops Concept package (EVA SIG est 10/6/06). 5. Review Ops Concept through panels/board (EVA SIG est 10/20/06).	CxP SRR Board	CA3166-PO	CARD_3.7.1.2.6
TBR-001-206	EVA SIG	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.	IDAC3	CA3166-PO	CARD_3.7.1.2.6
TBR-001-207	EVA SIG	1. Determine prebreathe protocols for time assessment (SK/M. Gernhardt est. 9/22/06). 2. Ops Scenario Formulation of Brainstormed Options (DX/S. Bleisath est. 9/22/06) 3. Team review options with protocols, and determine time recommendations (EVA & ECLSS SIG lead est. 9/29/06) 4. Prepare time recommendations and Ops Concept package (EVA SIG est 10/6/06). 5. Review Ops Concept through panels/board (EVA SIG est 10/20/06).	CxP SRR Board	CA3166-PO	CARD_3.7.1.2.6

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-207	EVA SIG	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.	IDAC3	CA3166-PO	CARD_3.7.1.2.6
TBR-001-208	GOMO	New study for IDAC-3 on Concurrent in-space vehicle operations requirement.	IDAC-3	CA5148-PO	CARD_3.7.1.2.6
TBR-001-208	GOMO SIG	Determine maximum number of CEVs to be operated in-space concurrently with overlapping missions, rates and intervals assumed in CA0036 and CA5604 requirements.	IDAC-3	CA5148-PO	CARD_3.7.1.2.6
TBR-001-211	GOMO	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	CA5159-PO	CARD_3.7.2.2.2.2
TBR-001-211	GOMO	Determine maximum number of ground crew that would be conducting pad operations at require emergency egress from pad to a safe haven.	IDAC-3	CA5159-PO	CARD_3.7.2.2.2.2
TBR-001-217	EVA SIG	1. Determine prebreathe protocols for time assessment (SK/M. Gernhardt est. 9/22/06). 2. Ops Scenario Formulation of Brainstormed Options (DX/S. Bleisath est. 9/22/06) 3. Team review options with protocols, and determine time recommendations (EVA & ECLSS SIG lead est. 9/29/06) 4. Prepare time recommendations and Ops Concept package (EVA SIG est 10/6/06). 5. Review Ops Concept through panels/board (EVA SIG est 10/20/06).	CxP SRR Board	CA5195-PO	CARD_3.7.3.2.6

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-217	EVA SIG	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	MOP	New study for IDAC-3 on Concurrent in-space vehicle operations requirement	IDAC-3	CA5149-PO	CARD_3.7.3.2.6
TBR-001-218	G/MO SIG	Determine maximum number of LSAMs to be operated in-space concurrently with overlapping missions, rates and intervals assumed in CA0036 and CA5604 requirements.	IDAC-3	CA5149-PO	CARD_3.7.3.2.6
TBR-001-222	C3I	New study for IDAC-3 on simultaneous communications.	IDAC-3	CA3285-PO	CARD_3.7.6.2.10
TBR-001-222	GOMO SIG	Determine number of active vehicles MS will have to operate in-space concurrently for worst case mission class overlap under assumptions CA0036 and CA5604 were developed.	IDAC-3	CA3285-PO	CARD_3.7.6.2.10
TBR-001-223	EVA SIG	1. Determine prebreathe protocols for time assessment (SK/M. Gernhardt est. 9/22/06). 2. Ops Scenario Formulation of Brainstormed Options (DX/S. Bleisath est. 9/22/06) 3. Team review options with protocols, and determine time recommendations (EVA & ECLSS SIG lead est. 9/29/06) 4. Prepare time recommendations and Ops Concept package (EVA SIG est 10/6/06). 5. Review Ops Concept through panels/board (EVA SIG est 10/20/06).	CxP SRR Board	CA4127-PO	CARD_3.7.9.2

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-223	EVA SIG	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	IDAC3	CA4127-PO	CARD_3.7.9.2
TBR-001-224	C3I	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)	IDAC3	CA4131-PO	CARD_3.8.2
TBR-001-225	C3I	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	CA4130-PO	CARD_3.8.2
TBR-001-245	C3I	New study for IDAC-3 on simultaneous communications.	IDAC-3	CA3285-PO	CARD_3.7.6.2.10
TBR-001-245	GOMO SIG	Determine number of quiescent vehicles MS will have to operate in-space concurrently for worst case mission class overlap under assumptions CA0036 and CA5604 were developed.	IDAC-3	CA3285-PO	CARD_3.7.6.2.10
TBR-001-261	GOMO SIG	Determine maximum number of ground and suited flight crew personnel requiring safe haven at the launch pad for emergency egress scenarios.	IDAC-3	CA0151-PO	CARD_3.7.5.2.2
TBR-001-262	GO / MO SIG	Update CxP 70070-ANX01 Program Management Plan, Annex 1, to describe process for Range Safety Program and issue appropriate CR to change that document.	1/15/2007	CA0100-HQ	CARD_3.2.7
TBR-001-335	C3I	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	IDAC-3	CA0470-PO	CARD_3.7.1.2.10

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-500	Integrated Thermal/ ECLS SIG	6 analysis 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.	IDAC-3	CA0288-PO	CARD_3.7.1.2.14
TBR-001-501	Integrated Thermal/ ECLS SIG	6 analysis 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.	IDAC-3	CA0288-PO	CARD_3.7.1.2.14
TBR-001-503	ARDIG	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-3	CA0822-HQ	CARD_3.2.4
TBR-001-512	FPSIG	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 #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-513	FPSIG	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	FPSIG	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-001-518	NAV SIG	There are two competing perspectives on the reference time scale, the use of UTC as is done today by the tracking networks and MCC, or the use of a time scale that does not incorporate leap seconds (such as GPS time). Coordinate between Operations Integration, MOD, ECANS and NASA HQ SCAWG on selection of the appropriate time scale.	IDAC-3 MID TERM	CA5618-PO	CARD_3.3.7
TBR-001-545	GO / MO SIG	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	CARD_3.7.1.2.2.2
TBR-001-556	C3I Interoperability	New study for IDAC3 that will leverage information from SIG-13-110 (Comm Frequency Plan) and SIG-13-103 (Rendezvous Comm). This study should also include inputs from the DRMs and FFBDs.	IDAC-3	CA5909-PO	CARD_3.7.9.2.10

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-557	C3I Interoperability	New study for IDAC3 that will leverage information from SIG-13-110 (Comm Frequency Plan) and SIG-13-103 (Rendezvous Comm). This study should also include inputs from the DRMs and FFBDs.	IDAC-3	CA5910-PO	CARD_3.7.9.2.10
TBR-001-571	FPSIG	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	CA4145-PO	CARD_3.7.3.2.6.2
TBR-001-571	FPSIG	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	CA4145-PO	CARD_3.7.3.2.6.2
TBR-001-653	Flight Performance	Continuation of CLV analysis work	IDAC-3	CA1000-PO	CARD_3.7.2.2.6.1
TBR-001-750	PTI	Work with Planetary Exploration Office, Ops Int, APO, ATA, CEV, and ISS to Identify potential payloads that could fly in the “SIM” Bay Develop concept of ops, proposed payload type, accommodations, mass, volume, and CEV resources: By October 15 Collect historical data on similar payloads By October 31 Perform trade study to define optimum services needed. By November 15 Propose requirements to SECB End of November Update CA 0547 if necessary.	CxP SRR Board	CA0547-PO	CARD_3.7.1.2.4

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-750	PTI	Analysis will be performed to determine volume allocation	IDAC-3	CA0547-PO	CARD_3.7.1.2.4
TBR-001-753		Will be resolved as part of IDAC-3	IDAC-3	CA0296-HQ	CARD_3.2.10
TBR-001-755	C3I SIG	New study for IDAC3 extending the results of SIG-13-108 (Communication Coverage) and SIG-13-105 (Reentry Communication)	IDAC-3	CA0887-PO	CARD_3.7.3.2.10
TBR-001-911	Integrated Thermal/ ECLS SIG	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.	IDAC-3	CA3133-PO	CARD_3.7.1.2.14
TBR-001-912	Integrated Thermal/ ECLS SIG	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.	IDAC-3	CA3133-PO	CARD_3.7.1.2.14
TBR-001-917	C3I Interoperability	New study for IDAC3 that will leverage information from SIG-13-110 (Comm Frequency Plan) and SIG-13-103 (Rendezvous Comm). This study should also include inputs from the DRMs and FFBDs.	IDAC-3	CA3288-PO	CARD_3.7.1.2.10
TBR-001-923	Integrated Thermal/ ECLS SIG	6 analysis 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.	IDAC-3	CA0288-PO	CARD_3.7.1.2.14

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-935	Flight Performance	Continuation of CLV analysis work	IDAC-3	CA1000-PO	CARD_3.7.2.2.6.1
TBR-001-936	Flight Performance	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	CA1005-PO	CARD_3.7.2.2.6.1
TBR-001-959	SR&QA	Update IDAC-3 Analysis	CxP SDR	CA5818-HQ	CARD_3.2.2.1
TBR-001-961	GO / MO SIG	A Working Group is established lead by Ground Systems with vehicle project representation to revise NASA Std 5005 to a revision C. An interim update process is planned with draft out for review in December 2006. Part of this revision will include determining the tailoring needed for individual projects' statements of work (SOWs) on applicability of the Revision C standards to each project/GSE.	SRR + 60 days	CA5680-PO	CARD_3.3.8
TBR-001-962	GO / MO SIG	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	CA0337-PO	CARD_3.7.5.2.2
TBR-001-964	GO / MO SIG	New study for IDAC-3 on late access for time critical cargo (no later than time on pad).	IDAC-3	CA5815-PO	CARD_3.2.13
TBR-001-966	SLRM SIG	Launch availability TDS	IDAC-3	CA1068-PO	CARD_3.7.2.2.12
TBR-001-967		Update IDAC-3 Analysis	CxP SDR	CA0097-HQ	CARD_3.2.1
TBR-001-979	GOMO SIG	New study for IDAC-5 on launch readiness duration for CaLV lunar cargo missions	IDAC-5	CA0071-PO	CARD_3.2.12
TBR-001-980	FPSIG	Review analyses performed by CEV Flight Dynamics team and ARDIG which show that 120 hours envelopes all of the early return cases.	IDAC-3	CA4154-PO	CARD_3.7.1.2.2

TBR #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
TBR-001-981	Mission Systems Project		MS SRR	CA0163-PO	CARD_3.7.6.2.2
TBR-001-982	Flight Performance	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	CA1005-PO	CARD_3.7.2.2.6.1
TBR-001-983	Flight Performance	Continuation of CLV analysis work	IDAC-3	CA1000-PO	CARD_3.7.2.2.6.1
TBR-001-984	Flight Performance	TDS to address allowable deviations based on CEV onboard delta-V maneuvering capability and CLV upper stage impact footprint	IDAC-3	CA1017-PO	CARD_3.7.2.2.11
TBR-001-985	Flight Performance	TDS to address allowable deviations based on CEV onboard delta-V maneuvering capability and CLV upper stage impact footprint	IDAC-3	CA1017-PO	CARD_3.7.2.2.11
TBR-001-986	Flight Performance	TDS to address allowable deviations based on CEV onboard delta-V maneuvering capability and CLV upper stage impact footprint	IDAC-3	CA1017-PO	CARD_3.7.2.2.11
TBR-001-987	Flight Performance	TDS to address allowable deviations based on CEV onboard delta-V maneuvering capability and CLV upper stage impact footprint	IDAC-4	CA1017-PO	CARD_3.7.2.2.11
TBR-001-988	Flight Performance	TDS to address allowable deviations based on CEV onboard delta-V maneuvering capability and CLV upper stage impact footprint	IDAC-4	CA1017-PO	CARD_3.7.2.2.11
TBR-001-989	Flight Performance	TDS to address allowable deviations based on CEV onboard delta-V maneuvering capability and CLV upper stage impact footprint	IDAC-4	CA1017-PO	CARD_3.7.2.2.11
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 #	Owner	Resolution Plan	Resolution Date	CARD No.	REQ. Para.
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

APPENDIX B-3 - OPEN CARD ACTIONS

CARD Open Work to be updated by Program Baseline Sync (PBS)

a) Ground Operations Integration Team (GOIT) / Stretch Requirement Incorporation – Objectives associated with ground and flight system supportability and operations will be added to the CARD as they are matured through PBS.
b) Unpressurized Cargo Requirement – To be updated per F. Bauer in accordance with the Cx SRR Board action.
c) GS/MS Inadvertent Action Requirement – Issue from traceability within CxP 70067-01, Constellation Program Human Rating Plan, Volume 1. Currently no requirement exists to eliminate ground-based inadvertent actions in accordance with NPR 8705.2, Human-Rating Requirements for Space Systems. Text update in work, to be completed prior to PBS.
d) JPR 8080.5 Review for complete allocation – To ensure all requirements from JPR 8080.5 are included in Program Documentation, a trace activity must be completed.
e) Workmanship Standards Review for complete allocation – Currently the CARD specifies some process/workmanship standards, but not all. Need to identify a comprehensive plan to address all Program Workmanship Standards.
f) Use of “In-Space” terminology - Based on the 11/3/06 Cx SRR pre-board presentation, an action was issued to address the definition of “in space” throughout the CARD. The action item response included the definition of space as any region beyond the Earth’s atmosphere or beyond the solar system that is above the altitude of 100 km or 62 miles. The term “in space” as used in the context of systems or vehicles will be replaced with either flight vehicle or surface system when applicable. When used in the context of EVA operations “in-space” will be replaced with either microgravity or surface EVA. Finally, when “in-space” is used in the context of operations/concurrent operations the term will be removed if it does not adequately cover the intent of the requirement or rationale or replaced with either flight vehicle or surface system.
g) VR TBD/TBR Resolution Plan incorporation – Open work identified at Cx SRR Board to update and incorporate all Section 4 TBD/TBR Resolution Plans.
h) Map to HQ EARD – Based on the pending release of Level 1 requirements in the Exploration Architecture Requirements Document, the CARD will have to be reviewed and updated for traceability.
i) Design Policy trace to program documentation/gap assessment (HIQAT Action) – Open work to fully identify allocations from Design Policy to other Program documentation, or determine how to best reflect the policy.
j) Validation Documentation – As part of CART, full requirements validation will be updated.
k) Traceability Review – Top-down traceability across Program documents will be completed (NGO to OpsCon to Functional Analysis to Requirements) to ensure complete allocations. This activity may identify holes in Initial Capability

allocations (such as Flight Crew Equipment) where new requirements need to be added.

l) SI/English Implementation updates – Open work exists with implementation of SI units across Level 2. Some exceptions are possible (such as units for pressure) and these will need to be updated in the CARD.
m) Document Consistency through CM process – Formal Document Quality Assurance (DQA) will be completed to ensure the CARD fulfills all Program Configuration Management mandates.
n) Section 2, Applicable and Reference Documents – The Applicable and Reference document tables in the CARD must be updated to reflect all documents referred to in the CARD.

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	
3.2	CA0001-HQ	X				CA0001V-HQ
	CA0003-HQ		X			CA0003V-HQ
	CA0004-HQ		X			CA0004V-HQ
	CA0005-HQ					
	CA0006-HQ		X			CA0006V-HQ
	CA0011-HQ		X			CA0011V-HQ
	CA0013-HQ	X				CA0013V-HQ
	CA0014-HQ		X			CA0014V-HQ
	CA0074-PO					CA0074V-PO
	CA0202-HQ	X	X	X	X	CA0202V-PO
	CA0404-HQ					CA0404V-PO
	CA0889-HQ	X				CA0889V-PO
	CA0892-HQ	X				CA0892V-PO
3.2.1	CA0033-HQ		X			CA0033V-HQ
	CA0095-HQ		X			CA0095V-PO
	CA0097-HQ		X			CA0097V-PO
	CA0099-HQ		X			CA0099V-PO
	CA3038-HQ		X			CA3038V-HQ
	CA3039-HQ		X			CA3039V-HQ
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
3.2.2.1	CA0032-HQ		X			CA0032V-HQ

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA0096-HQ		X			CA0096V-PO
	CA0474-HQ		X			CA0474V-PO
	CA3037-HQ		X			CA3037V-HQ
	CA5818-HQ		X			CA5818V-HQ
3.2.2.2	CA0027-PO	X	X			CA0027V-PO
	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
3.2.3	CA0010-HQ		X			CA0010V-PO
	CA0020-HQ		X			CA0020V-HQ
	CA0203-HQ	X				CA0203V-HQ
	CA0388-HQ	X				CA0388V-HQ
3.2.4	CA0002-HQ		X			CA0002V-HQ
	CA0209-HQ		X			CA0209V-HQ
	CA0211-HQ		X			CA0211V-HQ
	CA0212-HQ					CA0212V-HQ
	CA0822-HQ		X			CA0822V-HQ
	CA0823-HQ					CA0823V-PO
3.2.5	CA0036-HQ	X	X			CA0036V-PO
	CA0047-HQ					CA0047V-PO
	CA0073-HQ					CA0073V-HQ
	CA0207-HQ		X			CA0207V-HQ
	CA5289-PO		X			CA5289V-PO
	CA5604-PO		X		X	CA5604V-PO
3.2.6	CA0021-PO		X		X	CA0021V-PO
	CA0022-HQ		X			CA0022V-HQ
	CA0029-HQ	X				CA0029V-HQ
	CA0039-HQ	X				CA0039V-HQ
	CA0044-PO	X				CA0044V-PO
	CA0121-HQ	X				CA0121V-HQ
	CA0181-HQ	X				CA0181V-HQ

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA0281-HQ	X				CA0281V-HQ
	CA0287-PO		X			CA0287V-PO
	CA0316-PO	X				CA0316V-PO
	CA0353-PO					CA0353V-PO
	CA0405-HQ		X			CA0405V-HQ
	CA0407-PO					CA0407V-PO
	CA0465-HQ					CA0465V-HQ
	CA3175-PO	X				CA3175V-PO
	CA3184-PO	X				CA3184V-PO
	CA3211-PO	X				CA3211V-PO
	CA3214-HQ					
	CA5247-PO					CA5247V-PO
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
3.2.8	CA0449-PO		X	X		CA0449V-PO
3.2.9	CA0216-PO			X		CA0216V-PO
	CA0217-PO			X		CA0217V-PO
3.2.10	CA0296-HQ		X		X	CA0296V-HQ
	CA0476-PO		X		X	CA0476V-HQ
	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
3.2.11	CA0314-PO	X				CA0314V-PO

Section Number	Requirement Number	Method I	A	D	T	Verification Requirement
	CA0356-PO		X			CA0356V-PO
	CA0529-PO		X			CA0529V-PO
	CA0826-PO		X			CA0826V-PO
	CA3141-PO		X			CA3141V-PO
	CA5601-PO	X				CA5601V-PO
	CA5602-PO	X				CA5602V-PO
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
3.2.13	CA0550-PO		X			CA0550V-PO
	CA3293-PO			X		CA3293V-PO
	CA5710-PO		X			CA5710V-PO
	CA5814-PO		X	X		CA5814V-PO
	CA5815-PO		X	X		CA5815V-PO
	CA5935-PO	X				CA5935V-PO
3.2.14						
3.2.15	CA0048-PO	X	X			CA0048V-PO
	CA0991-PO		X		X	CA0991V-PO
	CA5552-PO	X	X			CA5552V-PO
3.3						
3.3.1	CA0817-PO	X	X			CA0817V-PO
	CA0990-PO	X				CA0990V-PO
3.3.1.1	CA0554-PO	X			X	CA0554V-PO
	CA0555-PO	X	X		X	CA0555V-PO
	CA5811-PO	X			X	CA5811V-PO
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
3.3.3						
3.3.4	CA0042-PO	X				CA0042V-PO
3.3.5	CA0383-PO	X				CA0383V-PO
	CA5800-PO	X				CA5800-PO
3.3.6	CA3167-PO	X				CA3167V-PO
3.3.7	CA3252-PO		X			CA3252V-PO
	CA5618-PO	X				CA5618V-PO
3.3.8	CA5680-PO		X			CA5680V-PO
	CA5915-PO		X			CA5915V-PO
3.3.9	CA4111-PO		X			CA4111V-PO
3.4	CA0069-HQ		X		X	CA0069V-HQ
	CA0077-HQ		X		X	CA0077V-HQ
	CA5936-PO					CA5936V-PO
	CA5937-PO					CA5937V-PO
	CA5938-PO					CA5938V-PO
	CA5939-PO					CA5939V-PO
	CA5940-PO					CA5940V-PO
	CA5941-PO					CA5941V-PO
	CA5942-PO					CA5942V-PO
	CA5943-PO					CA5943V-PO
	CA5944-PO					CA5944V-PO
3.5	CA0023-PO	X				CA0023V-PO
3.6						
3.7						
3.7.1						
3.7.1.1						
3.7.1.2	CA0056-PO		X			CA0056V-PO
	CA0091-PO		X			CA0091V-PO
	CA3203-PO		X			CA3203V-PO
	CA5312-PO	X				CA5312V-PO
3.7.1.2.1	CA0088-PO		X			CA0088V-PO

Section Number	Requirement Number	Method I	Method A	Method D	Method T	Verification Requirement
	CA0399-PO		X			CA0399V-PO
	CA3022-PO		X			CA3022V-PO
	CA3023-PO		X			CA3023V-PO
3.7.1.2.2	CA0194-PO		X			CA0194V-PO
	CA0274-PO		X			CA0274V-PO
	CA0325-PO		X			CA0325V-PO
	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
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
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
3.7.1.2.3	CA0347-PO					CA0347V-PO
	CA0447-PO		X			CA0447V-PO
3.7.1.2.4	CA0547-PO		X			CA0547V-PO

Section Number	Requirement Number	Method I	Method A	Method D	Method T	Verification Requirement
	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
	CA5155-PO		X			CA5155V-PO
	CA5233-PO		X			CA5233V-PO
3.7.1.2.5	CA0060-HQ		X			CA0060V-HQ
	CA0082-PO		X			CA0082V-PO
	CA3164-PO		X			CA3164V-PO
3.7.1.2.6	CA0191-PO		X			CA0191V-PO
	CA0324-PO		X			CA0324V-PO
	CA0351-PO		X			CA0351V-PO
	CA0373-PO					CA0373V-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			CA5240V-PO
	CA5319-PO		X			CA5319V-PO
3.7.1.2.6.1	CA0827-PO		X		X	CA0827V-PO
	CA4134-PO		X			CA4134V-PO
	CA4135-PO		X	X		CA4135V-PO
	CA4139-PO		X		X	CA4139V-PO
	CA4163-PO		X		X	CA4163V-PO
	CA4164-PO		X		X	CA4164V-PO
3.7.1.2.6.2	CA0406-PO					CA0406V-PO
	CA0829-PO		X			CA0829V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
3.7.1.2.7	CA0435-PO		X			CA0435V-PO
	CA0436-PO		X			CA0436V-PO
	CA0437-PO		X			CA0437V-PO
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
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
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
3.7.1.2.11	CA0059-PO		X	X	X	CA0059V-PO
	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
	CA0368-PO					
	CA0369-PO		X	X	X	CA0369V-PO
	CA0462-PO		X		X	CA0462V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	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
3.7.1.2.12	CA0178-PO		X			CA0178V-PO
3.7.1.2.13	CA5495-PO		X		X	CA5495V-PO
3.7.1.2.14	CA0288-PO				X	CA0288V-PO
	CA0426-PO		X			CA0426V-PO
	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
3.7.1.2.15	CA0374-PO	X	X			CA0374V-PO
	CA5555-PO	X	X			CA5555V-PO
	CA5560-PO	X	X			CA5560V-PO
3.7.1.3						
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
3.7.1.5	CA0386-HQ	X				CA0386V-HQ
	CA5933-PO		X			CA5933V-PO
3.7.2						

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
3.7.2.1						
3.7.2.2						
3.7.2.2.1	CA1065-PO		X			CA1065V-PO
	CA5805-PO		X			CA5805V-PO
	CA5916-PO		X			CA5916V-PO
3.7.2.2.2	CA0258-PO		X			CA0258V-PO
	CA5435-PO		X		X	CA5435V-PO
3.7.2.2.2.1	CA3163-PO		X			CA3163V-PO
	CA5914-PO		X			CA5914V-PO
3.7.2.2.2.2	CA5159-PO		X	X		CA5159V-PO
3.7.2.2.3						
3.7.2.2.4						
3.7.2.2.5	CA5512-PO					
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
	CA5713-PO		X			CA5713V-PO
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
3.7.2.2.6.2						
3.7.2.2.7	CA0566-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

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
3.7.2.2.8	CA1029-PO			X		CA1029V-PO
	CA3112-PO				X	CA3112V-PO
	CA3256-PO				X	CA3256V-PO
	CA3275-PO		X		X	CA3275V-PO
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
3.7.2.2.10	CA5906-PO			X		CA5906V-PO
	CA5912-PO		X		X	CA5912V-PO
3.7.2.2.11	CA1017-PO		X			CA1017V-PO
	CA3143-PO		X		X	CA3143V-PO
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
3.7.2.2.13						
3.7.2.2.14						
3.7.2.2.15	CA1069-PO	X	X			CA1069V-PO
	CA5557-PO	X	X			CA5557V-PO
	CA5562-PO	X	X			CA5562V-PO
3.7.2.3						
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
3.7.2.5						
3.7.3						
3.7.3.1						
3.7.3.2	CA3213-PO		X			CA3213V-PO
3.7.3.2.1	CA0504-PO		X			CA0504V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA3036-PO		X			CA3036V-PO
	CA3042-PO		X			CA3042V-PO
3.7.3.2.2	CA3139-PO	X	X		X	CA3139V-PO
	CA5191-PO			X		CA5191V-PO
	CA5193-PO		X			CA5193V-PO
	CA5194-PO		X	X		CA5194V-PO
3.7.3.2.2.1	CA0503-PO		X			CA0503V-PO
	CA3041-PO		X			CA3041V-PO
3.7.3.2.2.2	CA5236-PO		X		X	CA5236V-PO
	CA5238-PO		X		X	CA5238V-PO
	CA5316-PO		X			CA5316V-PO
3.7.3.2.3						
3.7.3.2.4	CA0062-PO		X			CA0062V-PO
	CA0090-PO		X			CA0090V-PO
	CA0137-PO		X			CA0137V-PO
	CA4140-PO		X			CA4140V-PO
	CA5156-PO		X			CA5156V-PO
3.7.3.2.5	CA0839-PO		X			CA0839V-PO
	CA0842-PO		X			CA0842V-PO
	CA4150-PO		X			CA4150V-PO
3.7.3.2.6	CA0394-HQ	X				CA0394V-PO
	CA0397-HQ		X		X	CA0397V-HQ
	CA3200-PO				X	CA3200V-PO
	CA3206-PO		X			CA3206V-PO
	CA3208-PO		X			CA3208V-PO
	CA3286-PO		X			CA3286V-PO
	CA5149-PO		X		X	CA5149V-PO
	CA5195-PO		X	X	X	CA5195V-PO
	CA5303-PO		X		X	CA5303V-PO
3.7.3.2.6.1	CA0836-PO		X		X	CA0836V-PO
	CA5231-PO		X		X	CA5231V-PO
3.7.3.2.6.2	CA0837-PO		X			CA0837V-PO
	CA4141-PO		X			CA4141V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA4143-PO		X			CA4143V-PO
	CA4145-PO		X			CA4145V-PO
3.7.3.2.7	CA0890-PO		X			CA0890V-PO
	CA0891-PO		X			CA0891V-PO
	CA5399-PO		X			CA5399V-PO
3.7.3.2.8	CA3111-PO				X	CA3111V-PO
	CA3250-PO		X		X	CA3250V-PO
	CA3258-PO				X	CA3258V-PO
	CA3272-PO				X	CA3272V-PO
	CA3277-PO				X	CA3277V-PO
	CA5434-PO		X		X	CA5434V-PO
	CA5440-PO				X	CA5440V-PO
	CA5801-PO		X	X		CA5801V-PO
3.7.3.2.9	CA0431-PO				X	CA0431V-PO
	CA3115-PO				X	CA3115V-PO
	CA5469-PO				X	CA5469V-PO
	CA5470-PO				X	CA5470V-PO
	CA5471-PO				X	CA5471V-PO
3.7.3.2.10	CA0517-PO				X	CA0517V-PO
	CA0887-PO		X		X	CA0887V-PO
	CA3281-PO		X	X		CA3281V-PO
	CA3289-PO		X		X	CA3289V-PO
	CA5054-PO			X		CA5054V-PO
	CA5902-PO			X		CA5902V-PO
	CA5905-PO			X		CA5905V-PO
3.7.3.2.11	CA0135-PO		X	X	X	CA0135V-PO
	CA0284-PO		X			CA0284V-PO
	CA0418-PO		X			CA0418V-PO
	CA0461-PO		X			CA0461V-PO
	CA3144-PO		X		X	CA3144V-PO
	CA3145-PO		X			CA3145V-PO
	CA3205-PO		X			CA3205V-PO
	CA3251-PO		X			CA3251V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA5273-PO		X		X	CA5273V-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
3.7.3.2.12	CA5532-PO		X			CA5532V-PO
	CA5605-PO		X			CA5605V-PO
3.7.3.2.13	CA5505-PO		X			CA5505V-PO
3.7.3.2.14	CA0813-PO		X			CA0813V-PO
	CA0814-PO				X	CA0814V-PO
	CA3062-PO		X		X	CA3062V-PO
	CA3107-PO		X		X	CA3107V-PO
	CA3135-PO				X	CA3135V-PO
	CA3137-PO		X		X	CA3137V-PO
	CA3165-PO		X			CA3165V-PO
	CA3181-PO		X		X	CA3181V-PO
	CA5385-PO		X			CA5385V-PO
3.7.3.2.15	CA0815-PO	X	X			CA0815V-PO
	CA5556-PO	X	X			CA5556V-PO
	CA5561-PO	X	X			CA5561V-PO
3.7.3.3						
3.7.3.4	CA0432-PO		X		X	CA0432V-PO
	CA0900-PO		X		X	CA0900V-PO
	CA0901-PO		X		X	CA0901V-PO
	CA0902-PO		X		X	CA0902V-PO
	CA0903-PO		X		X	CA0903V-PO
	CA0904-PO		X		X	CA0904V-PO
3.7.3.5						
3.7.4						
3.7.4.1						
3.7.4.2	CA3212-PO		X			CA3212V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA3215-PO		X			CA3215V-PO
3.7.4.2.1	CA0486-PO		X			CA0486V-PO
	CA0487-PO		X			CA0487V-PO
	CA5930-PO		X			CA5930V-PO
3.7.4.2.2	CA5160-PO		X	X		CA5160V-PO
	CA5436-PO		X		X	CA5436V-PO
3.7.4.2.2.1	CA0485-PO		X			CA0485V-PO
3.7.4.2.3						
3.7.4.2.4	CA0282-PO					
3.7.4.2.5	CA0850-PO		X			CA0850V-PO
3.7.4.2.6	CA0049-PO		X			CA0049V-PO
	CA0391-HQ	X				CA0391V-HQ
	CA3217-PO		X			CA3217V-PO
	CA5678-PO		X		X	CA5678V-PO
	CA5714-PO		X			CA5714V-PO
3.7.4.2.6.1	CA0847-PO		X			CA0847V-PO
	CA0848-PO		X			CA0848V-PO
3.7.4.2.6.2	CA0051-PO		X			CA0051V-PO
3.7.4.2.7	CA0874-PO	X				CA0874V-PO
	CA5403-PO		X			CA5403V-PO
	CA5432-PO				X	CA5432V-PO
	CA5433-PO			X		CA5433V-PO
	CA5806-PO		X			CA5806V-PO
	CA5918-PO			X		CA5918V-PO
	CA5920-PO	X		X		CA5920V-PO
3.7.4.2.8	CA3113-PO				X	CA3113V-PO
	CA3257-PO				X	CA3257V-PO
	CA3276-PO				X	CA3276V-PO
	CA3292-PO			X		CA3292V-PO
	CA3302-PO				X	CA3302V-PO
	CA5431-PO				X	CA5431V-PO
3.7.4.2.9	CA3124-PO				X	CA3124V-PO
	CA5472-PO				X	CA5472V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA5473-PO				X	CA5473V-PO
	CA5474-PO				X	CA5474V-PO
3.7.4.2.10	CA5044-PO			X		CA5044V-PO
	CA5911-PO		X		X	CA5911V-PO
3.7.4.2.11	CA0128-PO		X			CA0128V-PO
	CA0129-PO	X	X			CA0129V-PO
	CA0183-PO		X			CA0183V-PO
	CA3146-PO		X		X	CA3146V-PO
	CA3186-PO				X	CA3186V-PO
	CA3216-PO		X			CA3216V-PO
	CA3224-PO				X	CA3224V-PO
	CA3225-PO				X	CA3225V-PO
	CA5292-PO		X		X	CA5292V-PO
3.7.4.2.12	CA0413-PO		X			CA0413V-PO
	CA0414-PO		X			CA0414V-PO
	CA5259-PO		X			CA5259V-PO
	CA5265-PO		X			CA5265V-PO
	CA5533-PO		X			CA5533V-PO
3.7.4.2.13	CA5804-PO		X			CA5804V-PO
3.7.4.2.14						
3.7.4.2.15	CA5355-PO	X	X			CA5355V-PO
	CA5558-PO	X	X			CA5558V-PO
	CA5563-PO	X	X			CA5563V-PO
3.7.4.3						
3.7.4.4	CA0905-PO		X		X	CA0905V-PO
	CA0906-PO		X		X	CA0906V-PO
	CA0907-PO		X		X	CA0907V-PO
	CA0908-PO		X		X	CA0908V-PO
	CA0909-PO		X		X	CA0909V-PO
3.7.4.5						
3.7.5						
3.7.5.1						
3.7.5.2	CA0140-PO		X		X	CA0140V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	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
3.7.5.2.1	CA0860-PO		X			CA0860V-PO
	CA3028-PO		X			CA3028V-PO
	CA3029-PO		X			CA3029V-PO
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
	CA3031-PO		X			CA3031V-PO
	CA3033-PO		X			CA3033V-PO
	CA5146-PO		X	X	X	CA5146V-PO
	CA5408-PO		X			CA5408V-PO
	CA5438-PO		X		X	CA5438V-PO
3.7.5.2.3						
3.7.5.2.4						
3.7.5.2.5	CA4121-PO		X			CA4121V-PO
	CA5690-PO	X				CA5690V-PO
	CA5702-PO		X			CA5702V-PO
3.7.5.2.6	CA0148-PO	X	X			CA0148V-PO
	CA0444-PO		X			CA0444V-PO
	CA0853-PO		X	X		CA0853V-PO
	CA0855-PO		X			CA0855V-PO
	CA0856-PO		X			CA0856V-PO
	CA5712-PO		X			CA5712V-PO
3.7.5.2.7	CA5406-PO		X			CA5406V-PO
3.7.5.2.8	CA3274-PO				X	CA3274V-PO
3.7.5.2.9	CA3130-PO				X	CA3130V-PO

Section Number	Requirement Number	Method I	A	D	T	Verification Requirement
	CA5478-PO				X	CA5478V-PO
	CA5479-PO				X	CA5479V-PO
	CA5480-PO				X	CA5480V-PO
3.7.5.2.10	CA5051-PO			X		CA5051V-PO
	CA5907-PO			X		CA5907V-PO
	CA5908-PO		X		X	CA5908V-PO
3.7.5.2.11						
3.7.5.2.12	CA3064-PO		X			CA3064V-PO
3.7.5.2.13	CA5803-PO		X			CA5803V-PO
	CA5934-PO		X			CA5934V-PO
3.7.5.2.14						
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
3.7.5.3						
3.7.5.4	CA0910-PO		X		X	CA0910V-PO
	CA0911-PO		X		X	CA0911V-PO
	CA0912-PO		X		X	CA0912V-PO
	CA0913-PO		X		X	CA0913V-PO
	CA0914-PO		X		X	CA0914V-PO
	CA0915-PO		X		X	CA0915V-PO
	CA0916-PO		X		X	CA0916V-PO
3.7.5.5						
3.7.6						
3.7.6.1						
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
3.7.6.2.1	CA3024-PO		X			CA3024V-PO
	CA3025-PO		X			CA3025V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA3026-PO		X			CA3026V-PO
	CA3027-PO		X			CA3027V-PO
	CA3030-PO		X			CA3030V-PO
3.7.6.2.2	CA0163-PO		X		X	CA0163V-PO
	CA3032-PO		X			CA3032V-PO
	CA3034-PO		X			CA3034V-PO
	CA3035-PO		X			CA3035V-PO
	CA5437-PO		X		X	CA5437V-PO
3.7.6.2.3	CA5128-PO		X			CA5128V-PO
	CA5129-PO		X			CA5129V-PO
3.7.6.2.4						
3.7.6.2.5	CA5524-PO	X	X			CA5524V-PO
3.7.6.2.6	CA0883-PO		X			CA0883V-PO
	CA5125-PO	X				CA5125V-PO
	CA5900-PO			X		CA5900V-PO
3.7.6.2.7	CA5405-PO		X			CA5405V-PO
	CA5407-PO		X			CA5407V-PO
3.7.6.2.8	CA3273-PO				X	CA3273V-PO
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
3.7.6.2.10	CA3128-PO				X	CA3128V-PO
	CA3285-PO		X		X	CA3285V-PO
	CA5058-PO			X		CA5058V-PO
	CA5071-PO			X		CA5071V-PO
	CA5903-PO			X		CA5903V-PO
3.7.6.2.11	CA0158-PO		X		X	CA0158V-PO
	CA0270-PO		X		X	CA0270V-PO
3.7.6.2.12	CA3065-PO		X			CA3065V-PO
	CA5135-PO		X			CA5135V-PO
3.7.6.2.13	CA5130-PO		X			CA5130V-PO
	CA5131-PO		X			CA5131V-PO

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA5132-PO		X			CA5132V-PO
	CA5133-PO		X			CA5133V-PO
3.7.6.2.14						
3.7.6.2.15						
3.7.6.3						
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
3.7.6.5						
3.7.7						
3.7.7.1						
3.7.7.2						
3.7.7.2.1						
3.7.7.2.2						
3.7.7.2.3						
3.7.7.2.4						
3.7.7.2.5						
3.7.7.2.6	CA0862-PO					CA0862V-PO
3.7.7.2.7						
3.7.7.2.8						
3.7.7.2.9						
3.7.7.2.10						
3.7.7.2.11						
3.7.7.2.12						
3.7.7.2.13						
3.7.7.2.14						
3.7.7.2.15						
3.7.7.3						
3.7.7.4						
3.7.7.5						

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
3.7.8						
3.7.8.1						
3.7.8.2						
3.7.8.2.1						
3.7.8.2.2						
3.7.8.2.3						
3.7.8.2.4						
3.7.8.2.5						
3.7.8.2.6	CA0863-PO					CA0863V-PO
3.7.8.2.7						
3.7.8.2.8						
3.7.8.2.9						
3.7.8.2.10	CA3282-PO		X	X		CA3282V-PO
	CA3290-PO		X		X	CA3290V-PO
3.7.8.2.11						
3.7.8.2.12						
3.7.8.2.13						
3.7.8.2.14						
3.7.8.2.15						
3.7.8.3						
3.7.8.4						
3.7.8.5						
3.7.9						
3.7.9.1						
3.7.9.2	CA4127-PO		X	X	X	CA4127V-PO
3.7.9.2.1	CA5946-PO		X			CA5946V-PO
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
3.7.9.2.2.1	CA5945-PO		X			CA5945V-PO
3.7.9.2.3						
3.7.9.2.4						

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
3.7.9.2.5						
3.7.9.2.6						
3.7.9.2.7	CA5400-PO		X			CA5400V-PO
	CA5409-PO		X			CA5409V-PO
	CA5410-PO		X			CA5410V-PO
3.7.9.2.8						
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
3.7.9.2.10	CA3283-PO		X	X		CA3283V-PO
	CA5046-PO	X		X		CA5046V-PO
	CA5047-PO			X		CA5047V-PO
	CA5909-PO		X		X	CA5909V-PO
	CA5910-PO		X		X	CA5910V-PO
3.7.9.2.11						
3.7.9.2.12	CA3063-PO		X			CA3063V-PO
3.7.9.2.13	CA5182-PO		X			CA5182V-PO
	CA5184-PO		X			CA5184V-PO
3.7.9.2.14	CA3058-PO		X	X		CA3058V-PO
	CA5168-PO			X		CA5168V-PO
	CA5659-PO		X		X	CA5659V-PO
3.7.9.2.15	CA5188-PO	X	X			CA5188V-PO
	CA5559-PO	X	X			CA5559V-PO
	CA5564-PO	X	X			CA5564V-PO
3.7.9.3						
3.7.9.4	CA0923-PO		X		X	CA0923V-PO
	CA0924-PO		X		X	CA0924V-PO
	CA0925-PO		X		X	CA0925V-PO
3.7.9.5						
3.8						
3.8.1	CA3083-PO					

Section Number	Requirement Number	Method				Verification Requirement
		I	A	D	T	
	CA3284-PO		X	X		CA3284V-PO
3.8.2	CA0157-HQ		X		X	CA0157V-HQ
	CA0927-PO		X			CA0927V-PO
	CA0928-PO		X			CA0928V-PO
	CA0929-PO		X			CA0929V-PO
	CA0930-PO		X			CA0930V-PO
	CA0931-PO		X			CA0931V-PO
	CA0932-PO		X			CA0932V-PO
	CA3044-PO		X			CA3044V-PO
	CA3045-PO		X			CA3045V-PO
	CA3046-PO		X			CA3046V-PO
	CA3087-PO					
	CA3179-PO		X		X	CA3179V-PO
	CA3180-PO		X		X	CA3180V-PO
	CA4129-PO				X	CA4129V-PO
	CA4130-PO		X		X	CA4130V-PO
	CA4131-PO		X		X	CA4131V-PO
	CA5033-PO				X	CA5033V-PO
	CA5038-PO		X		X	CA5038V-PO
	CA5636-PO				X	CA5636V-PO
	CA5656-PO		X	X		CA5656V-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.

CARD REQ No	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA
CA0001-HQ	X	X	X	X	X	X		X	X
CA0002-HQ			X	X	X				
CA0003-HQ	X		X		X	X			X
CA0004-HQ	X		X		X	X			
CA0005-HQ	X	X	X	X	X	X			X
CA0006-HQ									
CA0010-HQ									
CA0011-HQ									
CA0013-HQ	X	X	X	X		X			X
CA0014-HQ	X	X	X	X		X			X
CA0020-HQ	X	X	X			X			X
CA0021-PO			X						X
CA0022-HQ			X						X
CA0023-PO	X	X	X	X					
CA0027-PO	X	X	X	X	X	X			
CA0028-PO	X		X						
CA0029-HQ	X	X	X	X		X			
CA0032-HQ	X	X	X	X	X	X			X
CA0033-HQ	X	X	X	X	X	X			X
CA0036-HQ	X	X	X	X	X	X			X
CA0037-PO	X	X	X	X	X				
CA0038-HQ		X			X	X			
CA0039-HQ	X	X	X	X	X				X
CA0040-PO	X	X	X	X	X				

CARD REQ No	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA
CA0042-PO	X	X	X	X	X	X	X	X	X
CA0044-PO	X				X				
CA0046-PO			X						
CA0047-HQ									
CA0048-PO	X	X	X	X	X				X
CA0069-HQ	X	X	X	X	X	X	X	X	X
CA0071-PO	X	X	X	X	X	X			X
CA0073-HQ									
CA0074-PO									
CA0077-HQ	X								
CA0095-HQ	X	X			X	X			
CA0096-HQ	X	X							
CA0097-HQ	X	X			X	X			
CA0099-HQ	X	X	X	X	X	X			X
CA0100-HQ	X	X	X	X	X	X			X
CA0107-HQ	X	X	X	X	X	X		X	X
CA0121-HQ	X	X	X	X	X	X			
CA0123-PO	X	X			X	X			X
CA0125-PO	X	X	X	X	X	X			X
CA0172-PO	X				X	X			
CA0181-HQ	X		X						X
CA0202-HQ			X			X			
CA0203-HQ	X		X			X			
CA0207-HQ	X		X						
CA0209-HQ			X		X	X			
CA0211-HQ	X		X		X	X			
CA0212-HQ									
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
CA0216-PO	X	X	X	X	X	X			X
CA0217-PO	X	X	X	X	X	X			X
CA0281-HQ	X	X	X	X	X	X			
CA0287-PO			X						X
CA0296-HQ	X	X	X	X	X	X		X	X

CARD REQ No	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA
CA0310-PO	X				X				X
CA0311-PO	X	X		X	X				X
CA0312-PO	X				X	X			X
CA0314-PO	X		X						
CA0316-PO	X		X	X					
CA0352-HQ	X		X						X
CA0353-PO									
CA0356-PO			X			X			
CA0383-PO	X	X	X	X	X	X			X
CA0388-HQ	X	X				X			
CA0404-HQ									
CA0405-HQ			X	X					
CA0407-PO			X						X
CA0449-PO	X	X	X	X	X	X			
CA0465-HQ									
CA0474-HQ	X	X	X	X	X	X			X
CA0476-HQ	X		X			X		X	
CA0529-PO			X			X			
CA0530-PO	X		X						X
CA0550-PO							X	X	
CA0554-PO	X	X	X	X	X		X	X	X
CA0555-PO	X	X	X	X	X				
CA0569-PO	X	X	X	X		X			
CA0817-PO	X	X	X	X					X
CA0822-HQ	X		X						
CA0823-HQ									
CA0826-PO			X			X			X
CA0889-HQ	X	X		X	X	X	X	X	X
CA0892-HQ	X	X		X	X	X			X
CA0990-PO	X	X	X	X	X		X	X	X
CA0991-PO	X	X	X	X	X		X		X
CA0993-PO	X		X	X	X	X			X
CA3004-PO	X	X	X	X	X				
CA3005-PO	X	X	X	X	X				
CA3007-PO	X	X	X	X	X	X			

CARD REQ No	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA
CA3021-PO	X	X	X	X	X	X			X
CA3037-HQ									
CA3038-HQ			X	X	X	X			
CA3039-HQ									
CA3043-PO	X	X	X	X	X	X			X
CA3051-PO	X		X	X	X	X			X
CA3141-PO			X			X		X	
CA3167-PO	X		X						
CA3175-PO	X		X			X			X
CA3184-PO	X	X			X	X			
CA3187-PO	X	X	X	X					
CA3193-PO	X	X	X	X					
CA3211-PO			X	X					
CA3214-HQ									
CA3222-PO	X		X						X
CA3226-PO	X				X	X			
CA3237-PO	X	X	X	X	X				
CA3252-PO	X	X	X	X		X			X
CA3293-PO	X	X	X	X		X			
CA4111-PO	X	X	X	X	X				X
CA5065-PO	X	X	X	X	X	X			X
CA5247-PO									
CA5289-PO	X		X			X			
CA5552-PO	X	X	X	X					X
CA5600-PO		X		X	X	X			
CA5601-PO	X		X						
CA5602-PO	X		X						
CA5604-PO	X		X			X			X
CA5618-PO	X	X	X	X	X	X	X	X	X
CA5680-PO	X	X	X	X	X	X	X	X	X
CA5710-PO	X		X		X				
CA5800-PO	X	X	X	X	X	X	X	X	X
CA5811-PO	X	X	X	X	X		X	X	X
CA5812-HQ	X	X		X	X	X			
CA5814-PO	X	X	X	X	X				

CARD REQ No	CEV	CLV	LSAM	CaLV	GS	MS	MTV	DAV	EVA
CA5815-PO	X	X	X	X	X				
CA5817-PO	X		X			X			
CA5818-HQ	X	X			X				
CA5820-PO	X	X	X	X	X	X			X
CA5821-PO					X	X			
CA5915-PO	X	X	X	X	X	X			X
CA5935-PO	X		X						X
CA5936-PO					X	X			
CA5937-PO					X	X			
CA5938-PO					X	X			
CA5939-PO						X			
CA5940-PO						X			X
CA5941-PO		X		X	X	X			
CA5942-PO						X			
CA5943-PO						X			
CA5944-PO					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
		CA0036-HQ	CARD_3.2.5
		CA0038-HQ	CARD_3.2.12
		CA0039-HQ	CARD_3.2.6
		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
		CA0121-HQ	CARD_3.2.6
		CA0123-PO	CARD_3.2.12
		CA0125-PO	CARD_3.2.12
		CA0139-PO	CARD_3.7.6.2
		CA0140-PO	CARD_3.7.5.2
		CA0142-PO	CARD_3.7.5.2
		CA0145-PO	CARD_3.7.5.2
		CA0152-PO	CARD_3.7.6.2
		CA0207-HQ	CARD_3.2.5

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0209-HQ	CARD_3.2.4
		CA0293-PO	CARD_3.7.6.2
		CA0353-PO	CARD_3.2.6
		CA0356-PO	CARD_3.2.11
		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
		CA0405-HQ	CARD_3.2.6
		CA0407-PO	CARD_3.2.6
		CA0432-PO	CARD_3.7.3.4
		CA0444-PO	CARD_3.7.5.2.6
		CA0529-PO	CARD_3.2.11
		CA0800-PO	CARD_3.7.1.4
		CA0822-HQ	CARD_3.2.4
		CA0826-PO	CARD_3.2.11
		CA0850-PO	CARD_3.7.4.2.5
		CA0855-PO	CARD_3.7.5.2.6
		CA0856-PO	CARD_3.7.5.2.6
		CA3200-PO	CARD_3.7.3.2.6
		CA3226-PO	CARD_3.2.2.2
		CA3251-PO	CARD_3.7.3.2.11
		CA3252-PO	CARD_3.3.7
		CA3286-PO	CARD_3.7.3.2.6
		CA4150-PO	CARD_3.7.3.2.5
		CA5552-PO	CARD_3.2.15
		CA5712-PO	CARD_3.7.5.2.6
		CA5713-PO	CARD_3.7.2.2.6

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5714-PO	CARD_3.7.4.2.6
		CA5803-PO	CARD_3.7.5.2.13
		CA5804-PO	CARD_3.7.4.2.13
		CA5814-PO	CARD_3.2.13
		CA5815-PO	CARD_3.2.13
		CA5817-PO	CARD_3.2.10
		CA5818-HQ	CARD_3.2.2.1
		CA5915-PO	CARD_3.3.8
		CA5936-PO	CARD_3.4
		CA5937-PO	CARD_3.4
		CA5938-PO	CARD_3.4
		CA5940-PO	CARD_3.4
		CA5942-PO	CARD_3.4
		CA5943-PO	CARD_3.4
		CA5944-PO	CARD_3.4
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
		CA0036-HQ	CARD_3.2.5
		CA0038-HQ	CARD_3.2.12
		CA0039-HQ	CARD_3.2.6
		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

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0121-HQ	CARD_3.2.6
		CA0123-PO	CARD_3.2.12
		CA0125-PO	CARD_3.2.12
		CA0139-PO	CARD_3.7.6.2
		CA0140-PO	CARD_3.7.5.2
		CA0142-PO	CARD_3.7.5.2
		CA0145-PO	CARD_3.7.5.2
		CA0152-PO	CARD_3.7.6.2
		CA0207-HQ	CARD_3.2.5
		CA0209-HQ	CARD_3.2.4
		CA0293-PO	CARD_3.7.6.2
		CA0353-PO	CARD_3.2.6
		CA0356-PO	CARD_3.2.11
		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
		CA0405-HQ	CARD_3.2.6
		CA0407-PO	CARD_3.2.6
		CA0432-PO	CARD_3.7.3.4
		CA0444-PO	CARD_3.7.5.2.6
		CA0529-PO	CARD_3.2.11
		CA0800-PO	CARD_3.7.1.4
		CA0822-HQ	CARD_3.2.4
		CA0826-PO	CARD_3.2.11
		CA0850-PO	CARD_3.7.4.2.5
		CA0855-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**
		CA3200-PO	CARD_3.7.3.2.6
		CA3226-PO	CARD_3.2.2.2
		CA3251-PO	CARD_3.7.3.2.11
		CA3252-PO	CARD_3.3.7
		CA3286-PO	CARD_3.7.3.2.6
		CA4150-PO	CARD_3.7.3.2.5
		CA5552-PO	CARD_3.2.15
		CA5712-PO	CARD_3.7.5.2.6
		CA5713-PO	CARD_3.7.2.2.6
		CA5714-PO	CARD_3.7.4.2.6
		CA5803-PO	CARD_3.7.5.2.13
		CA5804-PO	CARD_3.7.4.2.13
		CA5814-PO	CARD_3.2.13
		CA5815-PO	CARD_3.2.13
		CA5817-PO	CARD_3.2.10
		CA5818-HQ	CARD_3.2.2.1
		CA5915-PO	CARD_3.3.8
		CA5936-PO	CARD_3.4
		CA5937-PO	CARD_3.4
		CA5938-PO	CARD_3.4
		CA5940-PO	CARD_3.4
		CA5942-PO	CARD_3.4
		CA5943-PO	CARD_3.4
		CA5944-PO	CARD_3.4
CA0002-HQ	CARD_3.2.4	CA0137-PO	CARD_3.7.3.2.4
		CA5701-PO	CARD_3.7.5.2
CA0002-HQ	CARD_3.2.4	CA0137-PO	CARD_3.7.3.2.4
		CA5701-PO	CARD_3.7.5.2

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
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
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
CA0005-HQ	CARD_3.2	CA0002-HQ	CARD_3.2.4
		CA0014-HQ	CARD_3.2
		CA0020-HQ	CARD_3.2.3
		CA0099-HQ	CARD_3.2.1
		CA0405-HQ	CARD_3.2.6
		CA0474-HQ	CARD_3.2.2.1
		CA3038-HQ	CARD_3.2.1
		CA3141-PO	CARD_3.2.11
		CA3211-PO	CARD_3.2.6
		CA3213-PO	CARD_3.7.3.2
		CA5247-PO	CARD_3.2.6
		CA5289-PO	CARD_3.2.5
		CA5821-PO	CARD_3.2.10
CA0005-HQ	CARD_3.2	CA0002-HQ	CARD_3.2.4
		CA0014-HQ	CARD_3.2
		CA0020-HQ	CARD_3.2.3
		CA0099-HQ	CARD_3.2.1
		CA0405-HQ	CARD_3.2.6

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0474-HQ	CARD_3.2.2.1
		CA3038-HQ	CARD_3.2.1
		CA3141-PO	CARD_3.2.11
		CA3211-PO	CARD_3.2.6
		CA3213-PO	CARD_3.7.3.2
		CA5247-PO	CARD_3.2.6
		CA5289-PO	CARD_3.2.5
		CA5821-PO	CARD_3.2.10
CA0006-HQ	CARD_3.2	CA5821-PO	CARD_3.2.10
CA0006-HQ	CARD_3.2	CA5821-PO	CARD_3.2.10
CA0010-HQ	CARD_3.2.3	CA0426-PO	CARD_3.7.1.2.14
CA0010-HQ	CARD_3.2.3	CA0426-PO	CARD_3.7.1.2.14
CA0011-HQ	CARD_3.2		
CA0011-HQ	CARD_3.2		
CA0013-HQ	CARD_3.2	CA0032-HQ	CARD_3.2.2.1
		CA0033-HQ	CARD_3.2.1
		CA0207-HQ	CARD_3.2.5
		CA0287-PO	CARD_3.2.6
		CA3141-PO	CARD_3.2.11
		CA3286-PO	CARD_3.7.3.2.6
		CA4150-PO	CARD_3.7.3.2.5
		CA5303-PO	CARD_3.7.3.2.6
CA0013-HQ	CARD_3.2	CA0032-HQ	CARD_3.2.2.1
		CA0033-HQ	CARD_3.2.1
		CA0207-HQ	CARD_3.2.5
		CA0287-PO	CARD_3.2.6
		CA3141-PO	CARD_3.2.11
		CA3286-PO	CARD_3.7.3.2.6

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA4150-PO	CARD_3.7.3.2.5
		CA5303-PO	CARD_3.7.3.2.6
CA0014-HQ	CARD_3.2	CA5303-PO	CARD_3.7.3.2.6
CA0014-HQ	CARD_3.2	CA5303-PO	CARD_3.7.3.2.6
CA0020-HQ	CARD_3.2.3		
CA0020-HQ	CARD_3.2.3		
CA0021-PO	CARD_3.2.6		
CA0021-PO	CARD_3.2.6		
CA0022-HQ	CARD_3.2.6	CA0394-HQ	CARD_3.7.3.2.6
CA0022-HQ	CARD_3.2.6	CA0394-HQ	CARD_3.7.3.2.6
CA0023-PO	CARD_3.5	CA0827-PO	CARD_3.7.1.2.6.1
		CA0836-PO	CARD_3.7.3.2.6.1
		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
		CA5231-PO	CARD_3.7.3.2.6.1
CA0023-PO	CARD_3.5	CA0827-PO	CARD_3.7.1.2.6.1
		CA0836-PO	CARD_3.7.3.2.6.1
		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

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		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
		CA5231-PO	CARD_3.7.3.2.6.1
CA0027-PO	CARD_3.2.2.2	CA0170-PO	CARD_3.7.1.2.2.2
		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
		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
		CA5436-PO	CARD_3.7.4.2.2
		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
		CA5440-PO	CARD_3.7.3.2.8
CA0027-PO	CARD_3.2.2.2	CA0170-PO	CARD_3.7.1.2.2.2
		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
		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
		CA5436-PO	CARD_3.7.4.2.2
		CA5437-PO	CARD_3.7.6.2.2
		CA5438-PO	CARD_3.7.5.2.2

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5439-PO	CARD_3.7.1.2.2.2
		CA5440-PO	CARD_3.7.3.2.8
CA0028-PO	CARD_3.2.2	CA0416-PO	CARD_3.7.1.2.2.2
		CA5316-PO	CARD_3.7.3.2.2.2
CA0028-PO	CARD_3.2.2	CA0416-PO	CARD_3.7.1.2.2.2
		CA5316-PO	CARD_3.7.3.2.2.2
CA0029-HQ	CARD_3.2.6	CA0148-PO	CARD_3.7.5.2.6
		CA0569-PO	CARD_3.2.7
CA0032-HQ	CARD_3.2.2.1	CA0485-PO	CARD_3.7.4.2.2.1
		CA0501-PO	CARD_3.7.1.2.2.1
		CA0503-PO	CARD_3.7.3.2.2.1
		CA3033-PO	CARD_3.7.5.2.2
		CA3034-PO	CARD_3.7.6.2.2
		CA3163-PO	CARD_3.7.2.2.2.1
		CA5945-PO	CARD_3.7.9.2.2.1
CA0032-HQ	CARD_3.2.2.1	CA0485-PO	CARD_3.7.4.2.2.1
		CA0501-PO	CARD_3.7.1.2.2.1
		CA0503-PO	CARD_3.7.3.2.2.1
		CA3033-PO	CARD_3.7.5.2.2
		CA3034-PO	CARD_3.7.6.2.2
		CA3163-PO	CARD_3.7.2.2.2.1
		CA5945-PO	CARD_3.7.9.2.2.1
CA0033-HQ	CARD_3.2.1	CA0088-PO	CARD_3.7.1.2.1
		CA0486-PO	CARD_3.7.4.2.1
		CA0487-PO	CARD_3.7.4.2.1
		CA0504-PO	CARD_3.7.3.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA3026-PO	CARD_3.7.6.2.1

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3029-PO	CARD_3.7.5.2.1
		CA5946-PO	CARD_3.7.9.2.1
CA0033-HQ	CARD_3.2.1	CA0088-PO	CARD_3.7.1.2.1
		CA0486-PO	CARD_3.7.4.2.1
		CA0487-PO	CARD_3.7.4.2.1
		CA0504-PO	CARD_3.7.3.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA3026-PO	CARD_3.7.6.2.1
		CA3029-PO	CARD_3.7.5.2.1
		CA5946-PO	CARD_3.7.9.2.1
CA0036-HQ	CARD_3.2.5	CA5512-PO	CARD_3.7.2.2.5
		CA5524-PO	CARD_3.7.6.2.5
		CA5701-PO	CARD_3.7.5.2
CA0036-HQ	CARD_3.2.5	CA5512-PO	CARD_3.7.2.2.5
		CA5524-PO	CARD_3.7.6.2.5
		CA5701-PO	CARD_3.7.5.2
CA0037-PO	CARD_3.2.12	CA5532-PO	CARD_3.7.3.2.12
		CA5533-PO	CARD_3.7.4.2.12
CA0037-PO	CARD_3.2.12	CA5532-PO	CARD_3.7.3.2.12
		CA5533-PO	CARD_3.7.4.2.12
CA0038-HQ	CARD_3.2.12	CA5135-PO	CARD_3.7.6.2.12
CA0038-HQ	CARD_3.2.12	CA5135-PO	CARD_3.7.6.2.12
CA0039-HQ	CARD_3.2.6	CA0040-PO	CARD_3.2.12
		CA0071-PO	CARD_3.2.12
		CA0351-PO	CARD_3.7.1.2.6
		CA5112-PO	CARD_3.7.5.2.15
		CA5677-PO	CARD_3.7.2.2.6
		CA5678-PO	CARD_3.7.4.2.6

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5941-PO	CARD_3.4
CA0039-HQ	CARD_3.2.6	CA0040-PO	CARD_3.2.12
		CA0071-PO	CARD_3.2.12
		CA0351-PO	CARD_3.7.1.2.6
		CA5112-PO	CARD_3.7.5.2.15
		CA5677-PO	CARD_3.7.2.2.6
		CA5678-PO	CARD_3.7.4.2.6
		CA5941-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
		CA5677-PO	CARD_3.7.2.2.6
		CA5678-PO	CARD_3.7.4.2.6
CA0040-PO	CARD_3.2.12	CA0351-PO	CARD_3.7.1.2.6
		CA5112-PO	CARD_3.7.5.2.15
		CA5677-PO	CARD_3.7.2.2.6
		CA5678-PO	CARD_3.7.4.2.6
CA0042-PO	CARD_3.3.4		
CA0042-PO	CARD_3.3.4		
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
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
CA0047-HQ	CARD_3.2.5		
CA0047-HQ	CARD_3.2.5		

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0048-PO	CARD_3.2.15	CA0374-PO	CARD_3.7.1.2.15
		CA0815-PO	CARD_3.7.3.2.15
		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
		CA5355-PO	CARD_3.7.4.2.15
		CA5360-PO	CARD_3.7.5.2.15
CA0048-PO	CARD_3.2.15	CA0374-PO	CARD_3.7.1.2.15
		CA0815-PO	CARD_3.7.3.2.15
		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
		CA5355-PO	CARD_3.7.4.2.15
		CA5360-PO	CARD_3.7.5.2.15
CA0069-HQ	CARD_3.4		
CA0071-PO	CARD_3.2.12	CA3065-PO	CARD_3.7.6.2.12
CA0071-PO	CARD_3.2.12	CA3065-PO	CARD_3.7.6.2.12
CA0073-HQ	CARD_3.2.5		
CA0073-HQ	CARD_3.2.5		
CA0074-PO	CARD_3.2		
CA0074-PO	CARD_3.2		
CA0077-HQ	CARD_3.4		
CA0077-HQ	CARD_3.4		
CA0095-HQ	CARD_3.2.1	CA0399-PO	CARD_3.7.1.2.1

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0860-PO	CARD_3.7.5.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA3025-PO	CARD_3.7.6.2.1
CA0095-HQ	CARD_3.2.1	CA0399-PO	CARD_3.7.1.2.1
		CA0860-PO	CARD_3.7.5.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA3025-PO	CARD_3.7.6.2.1
CA0096-HQ	CARD_3.2.2.1	CA0398-PO	CARD_3.7.1.2.2.1
		CA3031-PO	CARD_3.7.5.2.2
		CA3032-PO	CARD_3.7.6.2.2
		CA3163-PO	CARD_3.7.2.2.2.1
CA0096-HQ	CARD_3.2.2.1	CA0398-PO	CARD_3.7.1.2.2.1
		CA3031-PO	CARD_3.7.5.2.2
		CA3032-PO	CARD_3.7.6.2.2
		CA3163-PO	CARD_3.7.2.2.2.1
CA0097-HQ	CARD_3.2.1	CA0860-PO	CARD_3.7.5.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA3022-PO	CARD_3.7.1.2.1
		CA3024-PO	CARD_3.7.6.2.1
CA0097-HQ	CARD_3.2.1	CA0860-PO	CARD_3.7.5.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA3022-PO	CARD_3.7.1.2.1
		CA3024-PO	CARD_3.7.6.2.1
CA0099-HQ	CARD_3.2.1	CA0486-PO	CARD_3.7.4.2.1
		CA0487-PO	CARD_3.7.4.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA3023-PO	CARD_3.7.1.2.1
		CA3029-PO	CARD_3.7.5.2.1

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3030-PO	CARD_3.7.6.2.1
		CA3036-PO	CARD_3.7.3.2.1
CA0099-HQ	CARD_3.2.1	CA0486-PO	CARD_3.7.4.2.1
		CA0487-PO	CARD_3.7.4.2.1
		CA1065-PO	CARD_3.7.2.2.1
		CA3023-PO	CARD_3.7.1.2.1
		CA3029-PO	CARD_3.7.5.2.1
		CA3030-PO	CARD_3.7.6.2.1
		CA3036-PO	CARD_3.7.3.2.1
CA0100-HQ	CARD_3.2.7	CA0566-PO	CARD_3.7.2.2.7
		CA0874-PO	CARD_3.7.4.2.7
		CA5812-HQ	CARD_3.2.7
CA0100-HQ	CARD_3.2.7	CA0566-PO	CARD_3.7.2.2.7
		CA0874-PO	CARD_3.7.4.2.7
		CA5812-HQ	CARD_3.2.7
CA0107-HQ	CARD_3.2.2	CA0027-PO	CARD_3.2.2.2
		CA0028-PO	CARD_3.2.2
		CA0146-PO	CARD_3.7.5.2.2
		CA0172-PO	CARD_3.2.2
		CA0274-PO	CARD_3.7.1.2.2
		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

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0352-HQ	CARD_3.2.2.2
		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
		CA3062-PO	CARD_3.7.3.2.14
		CA3138-PO	CARD_3.7.1.2.2
		CA3139-PO	CARD_3.7.3.2.2
		CA3226-PO	CARD_3.2.2.2
		CA3259-PO	CARD_3.7.1.2.2
		CA3280-PO	CARD_3.7.1.2.10
		CA3281-PO	CARD_3.7.3.2.10
		CA3282-PO	CARD_3.7.8.2.10
		CA3283-PO	CARD_3.7.9.2.10
		CA3284-PO	CARD_3.8.1
		CA4123-PO	CARD_3.7.5.2
		CA4132-PO	
		CA5125-PO	CARD_3.7.6.2.6
		CA5146-PO	CARD_3.7.5.2.2
		CA5160-PO	CARD_3.7.4.2.2
		CA5168-PO	CARD_3.7.9.2.14
		CA5170-PO	CARD_3.7.9.2.2
		CA5191-PO	CARD_3.7.3.2.2
		CA5194-PO	CARD_3.7.3.2.2
		CA5236-PO	CARD_3.7.3.2.2.2
		CA5669-PO	CARD_3.7.6.2
		CA5711-PO	CARD_3.7.1.2.14

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5801-PO	CARD_3.7.3.2.8
CA0121-HQ	CARD_3.2.6	CA0028-PO	CARD_3.2.2
		CA0049-PO	CARD_3.7.4.2.6
		CA0059-PO	CARD_3.7.1.2.11
		CA0062-PO	CARD_3.7.3.2.4
		CA0082-PO	CARD_3.7.1.2.5
		CA0091-PO	CARD_3.7.1.2
		CA0128-PO	CARD_3.7.4.2.11
		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
		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
		CA0461-PO	CARD_3.7.3.2.11
		CA0829-PO	CARD_3.7.1.2.6.2
		CA0837-PO	CARD_3.7.3.2.6.2
		CA0839-PO	CARD_3.7.3.2.5
		CA0847-PO	CARD_3.7.4.2.6.1
		CA0850-PO	CARD_3.7.4.2.5
		CA0886-PO	CARD_3.7.1.2.14
		CA3137-PO	CARD_3.7.3.2.14
		CA3164-PO	CARD_3.7.1.2.5
		CA3186-PO	CARD_3.7.4.2.11
		CA3204-PO	CARD_3.7.1.2.6

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3205-PO	CARD_3.7.3.2.11
		CA3206-PO	CARD_3.7.3.2.6
		CA3208-PO	CARD_3.7.3.2.6
		CA3209-PO	CARD_3.7.1.2.6
		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
		CA5819-PO	CARD_3.7.1.2.11
CA0121-HQ	CARD_3.2.6	CA0028-PO	CARD_3.2.2
		CA0049-PO	CARD_3.7.4.2.6
		CA0059-PO	CARD_3.7.1.2.11
		CA0062-PO	CARD_3.7.3.2.4
		CA0082-PO	CARD_3.7.1.2.5
		CA0091-PO	CARD_3.7.1.2
		CA0128-PO	CARD_3.7.4.2.11
		CA0129-PO	CARD_3.7.4.2.11
		CA0131-PO	CARD_3.7.1.2.11
		CA0133-PO	CARD_3.7.1.2.11

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0135-PO	CARD_3.7.3.2.11
		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
		CA0461-PO	CARD_3.7.3.2.11
		CA0829-PO	CARD_3.7.1.2.6.2
		CA0837-PO	CARD_3.7.3.2.6.2
		CA0839-PO	CARD_3.7.3.2.5
		CA0847-PO	CARD_3.7.4.2.6.1
		CA0850-PO	CARD_3.7.4.2.5
		CA0886-PO	CARD_3.7.1.2.14
		CA3137-PO	CARD_3.7.3.2.14
		CA3164-PO	CARD_3.7.1.2.5
		CA3186-PO	CARD_3.7.4.2.11
		CA3204-PO	CARD_3.7.1.2.6
		CA3205-PO	CARD_3.7.3.2.11
		CA3206-PO	CARD_3.7.3.2.6
		CA3208-PO	CARD_3.7.3.2.6
		CA3209-PO	CARD_3.7.1.2.6
		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

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		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
		CA5819-PO	CARD_3.7.1.2.11
CA0123-PO	CARD_3.2.12	CA0072-PO	CARD_3.7.2.2.12
		CA0178-PO	CARD_3.7.1.2.12
		CA1066-PO	CARD_3.7.2.2.12
		CA3063-PO	CARD_3.7.9.2.12
		CA3065-PO	CARD_3.7.6.2.12
CA0123-PO	CARD_3.2.12	CA0072-PO	CARD_3.7.2.2.12
		CA0178-PO	CARD_3.7.1.2.12
		CA1066-PO	CARD_3.7.2.2.12
		CA3063-PO	CARD_3.7.9.2.12
		CA3065-PO	CARD_3.7.6.2.12
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
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
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
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
		CA4123-PO	CARD_3.7.5.2
		CA5146-PO	CARD_3.7.5.2.2
CA0181-HQ	CARD_3.2.6	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
CA0181-HQ	CARD_3.2.6	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	CA0022-HQ	CARD_3.2.6
		CA0826-PO	CARD_3.2.11
CA0202-HQ	CARD_3.2	CA0022-HQ	CARD_3.2.6
		CA0826-PO	CARD_3.2.11
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
		CA0813-PO	CARD_3.7.3.2.14
		CA0814-PO	CARD_3.7.3.2.14
		CA3164-PO	CARD_3.7.1.2.5
		CA3165-PO	CARD_3.7.3.2.14
		CA5128-PO	CARD_3.7.6.2.3
		CA5385-PO	CARD_3.7.3.2.14
CA0207-HQ	CARD_3.2.5	CA0813-PO	CARD_3.7.3.2.14
		CA3164-PO	CARD_3.7.1.2.5
		CA4150-PO	CARD_3.7.3.2.5
CA0207-HQ	CARD_3.2.5	CA0813-PO	CARD_3.7.3.2.14
		CA3164-PO	CARD_3.7.1.2.5
		CA4150-PO	CARD_3.7.3.2.5
CA0209-HQ	CARD_3.2.4	CA0090-PO	CARD_3.7.3.2.4
		CA5131-PO	CARD_3.7.6.2.13
		CA5701-PO	CARD_3.7.5.2
CA0209-HQ	CARD_3.2.4	CA0090-PO	CARD_3.7.3.2.4
		CA5131-PO	CARD_3.7.6.2.13
		CA5701-PO	CARD_3.7.5.2
CA0211-HQ	CARD_3.2.4	CA0062-PO	CARD_3.7.3.2.4
		CA0868-PO	CARD_3.7.1.2.4
		CA5132-PO	CARD_3.7.6.2.13
CA0211-HQ	CARD_3.2.4	CA0062-PO	CARD_3.7.3.2.4
		CA0868-PO	CARD_3.7.1.2.4
		CA5132-PO	CARD_3.7.6.2.13
CA0212-HQ	CARD_3.2.4		
CA0212-HQ	CARD_3.2.4		
CA0213-PO	CARD_3.2.7	CA0435-PO	CARD_3.7.1.2.7
		CA0890-PO	CARD_3.7.3.2.7

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		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
		CA5806-PO	CARD_3.7.4.2.7
		CA5916-PO	CARD_3.7.2.2.1
		CA5930-PO	CARD_3.7.4.2.1
CA0213-PO	CARD_3.2.7	CA0435-PO	CARD_3.7.1.2.7
		CA0890-PO	CARD_3.7.3.2.7
		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
		CA5806-PO	CARD_3.7.4.2.7
		CA5916-PO	CARD_3.7.2.2.1
		CA5930-PO	CARD_3.7.4.2.1
CA0214-PO	CARD_3.2.7	CA0436-PO	CARD_3.7.1.2.7
		CA0891-PO	CARD_3.7.3.2.7
		CA5407-PO	CARD_3.7.6.2.7
		CA5408-PO	CARD_3.7.5.2.2
		CA5410-PO	CARD_3.7.9.2.7
		CA5805-PO	CARD_3.7.2.2.1
		CA5806-PO	CARD_3.7.4.2.7
CA0214-PO	CARD_3.2.7	CA0436-PO	CARD_3.7.1.2.7
		CA0891-PO	CARD_3.7.3.2.7
		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
		CA5806-PO	CARD_3.7.4.2.7
CA0215-PO	CARD_3.2.7	CA0258-PO	CARD_3.7.2.2.2
		CA0437-PO	CARD_3.7.1.2.7
		CA5399-PO	CARD_3.7.3.2.7
		CA5400-PO	CARD_3.7.9.2.7
		CA5403-PO	CARD_3.7.4.2.7
CA0215-PO	CARD_3.2.7	CA0258-PO	CARD_3.7.2.2.2
		CA0437-PO	CARD_3.7.1.2.7
		CA5399-PO	CARD_3.7.3.2.7
		CA5400-PO	CARD_3.7.9.2.7
		CA5403-PO	CARD_3.7.4.2.7
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
		CA5469-PO	CARD_3.7.3.2.9
		CA5470-PO	CARD_3.7.3.2.9
		CA5471-PO	CARD_3.7.3.2.9
		CA5472-PO	CARD_3.7.4.2.9
		CA5473-PO	CARD_3.7.4.2.9
		CA5474-PO	CARD_3.7.4.2.9
		CA5475-PO	CARD_3.7.6.2.9

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5476-PO	CARD_3.7.6.2.9
		CA5477-PO	CARD_3.7.6.2.9
		CA5478-PO	CARD_3.7.5.2.9
		CA5479-PO	CARD_3.7.5.2.9
		CA5480-PO	CARD_3.7.5.2.9
		CA5816-PO	CARD_3.7.2.2.9
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
		CA5469-PO	CARD_3.7.3.2.9
		CA5470-PO	CARD_3.7.3.2.9
		CA5471-PO	CARD_3.7.3.2.9
		CA5472-PO	CARD_3.7.4.2.9
		CA5473-PO	CARD_3.7.4.2.9
		CA5474-PO	CARD_3.7.4.2.9
		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
		CA5479-PO	CARD_3.7.5.2.9
		CA5480-PO	CARD_3.7.5.2.9
		CA5816-PO	CARD_3.7.2.2.9

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0217-PO	CARD_3.2.9	CA0427-PO	CARD_3.7.1.2.9
		CA0428-PO	CARD_3.7.1.2.9
		CA0431-PO	CARD_3.7.3.2.9
		CA0858-PO	CARD_3.7.5.2
		CA3115-PO	CARD_3.7.3.2.9
		CA3118-PO	CARD_3.7.2.2.9
		CA3121-PO	CARD_3.7.9.2.9
		CA3122-PO	CARD_3.7.9.2.9
		CA3124-PO	CARD_3.7.4.2.9
		CA3127-PO	CARD_3.7.6.2.9
		CA3128-PO	CARD_3.7.6.2.10
		CA3130-PO	CARD_3.7.5.2.9
		CA5033-PO	CARD_3.8.2
		CA5636-PO	CARD_3.8.2
CA0281-HQ	CARD_3.2.6	CA0049-PO	CARD_3.7.4.2.6
		CA0091-PO	CARD_3.7.1.2
		CA0848-PO	CARD_3.7.4.2.6.1
		CA0827-PO	CARD_3.7.1.2.6.1
		CA0836-PO	CARD_3.7.3.2.6.1
		CA1005-PO	CARD_3.7.2.2.6.1
		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
CA0281-HQ	CARD_3.2.6	CA0049-PO	CARD_3.7.4.2.6
		CA0091-PO	CARD_3.7.1.2
		CA0848-PO	CARD_3.7.4.2.6.1
		CA0827-PO	CARD_3.7.1.2.6.1
		CA0836-PO	CARD_3.7.3.2.6.1

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA1005-PO	CARD_3.7.2.2.6.1
		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
CA0287-PO	CARD_3.2.6		
CA0287-PO	CARD_3.2.6		
CA0296-HQ	CARD_3.2.10	CA0470-PO	CARD_3.7.1.2.10
		CA0476-PO	CARD_3.2.10
		CA0887-PO	CARD_3.7.3.2.10
		CA0896-PO	CARD_3.7.1.4
		CA0899-PO	CARD_3.7.2.4
		CA0904-PO	CARD_3.7.3.4
		CA0909-PO	CARD_3.7.4.4
		CA0916-PO	CARD_3.7.5.4
		CA0922-PO	CARD_3.7.6.4
		CA0927-PO	CARD_3.8.2
		CA0928-PO	CARD_3.8.2
		CA0929-PO	CARD_3.8.2
		CA0930-PO	CARD_3.8.2
		CA0931-PO	CARD_3.8.2
		CA0932-PO	CARD_3.8.2
		CA3044-PO	CARD_3.8.2
		CA3046-PO	CARD_3.8.2
		CA3280-PO	CARD_3.7.1.2.10
		CA3281-PO	CARD_3.7.3.2.10
		CA3282-PO	CARD_3.7.8.2.10
		CA3283-PO	CARD_3.7.9.2.10
		CA3284-PO	CARD_3.8.1

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA4129-PO	CARD_3.8.2
		CA5033-PO	CARD_3.8.2
		CA5038-PO	CARD_3.8.2
		CA5071-PO	CARD_3.7.6.2.10
		CA5636-PO	CARD_3.8.2
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
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
		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
		CA5160-PO	CARD_3.7.4.2.2
CA0311-PO	CARD_3.2.2.2	CA0151-PO	CARD_3.7.5.2.2
		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
		CA5160-PO	CARD_3.7.4.2.2
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

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0984-PO	CARD_3.7.1.2.2
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	CA0368-PO	CARD_3.7.1.2.11
		CA5273-PO	CARD_3.7.3.2.11
CA0314-PO	CARD_3.2.11	CA0368-PO	CARD_3.7.1.2.11
		CA5273-PO	CARD_3.7.3.2.11
CA0316-PO	CARD_3.2.6	CA0432-PO	CARD_3.7.3.4
		CA0800-PO	CARD_3.7.1.4
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
		CA3165-PO	CARD_3.7.3.2.14
		CA4154-PO	CARD_3.7.1.2.2
		CA5237-PO	CARD_3.7.1.2.2.2
		CA5238-PO	CARD_3.7.3.2.2.2
		CA5240-PO	CARD_3.7.1.2.6
CA0352-HQ	CARD_3.2.2.2	CA0532-PO	CARD_3.7.1.2.2
		CA3003-PO	CARD_3.7.9.2.2
		CA3165-PO	CARD_3.7.3.2.14
		CA4154-PO	CARD_3.7.1.2.2
		CA5237-PO	CARD_3.7.1.2.2.2
		CA5238-PO	CARD_3.7.3.2.2.2
		CA5240-PO	CARD_3.7.1.2.6
CA0353-PO	CARD_3.2.6		

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0353-PO	CARD_3.2.6		
CA0356-PO	CARD_3.2.11	CA0158-PO	CARD_3.7.6.2.11
		CA0418-PO	CARD_3.7.3.2.11
		CA3145-PO	CARD_3.7.3.2.11
CA0356-PO	CARD_3.2.11	CA0158-PO	CARD_3.7.6.2.11
		CA0418-PO	CARD_3.7.3.2.11
		CA3145-PO	CARD_3.7.3.2.11
CA0383-PO	CARD_3.3.5	CA0384-PO	
		CA3083-PO	CARD_3.8.1
		CA3087-PO	CARD_3.8.2
CA0383-PO	CARD_3.3.5	CA0384-PO	
		CA3083-PO	CARD_3.8.1
		CA3087-PO	CARD_3.8.2
CA0388-HQ	CARD_3.2.3	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
CA0404-HQ	CARD_3.2		
CA0404-HQ	CARD_3.2		
CA0405-HQ	CARD_3.2.6		
CA0405-HQ	CARD_3.2.6		
CA0407-PO	CARD_3.2.6		
CA0407-PO	CARD_3.2.6		
CA0449-PO	CARD_3.2.8	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

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3111-PO	CARD_3.7.3.2.8
		CA3112-PO	CARD_3.7.2.2.8
		CA3113-PO	CARD_3.7.4.2.8
		CA3249-PO	CARD_3.7.1.2.8
		CA3250-PO	CARD_3.7.3.2.8
		CA3254-PO	CARD_3.7.1.2.8
		CA3255-PO	CARD_3.7.1.2.8
		CA3256-PO	CARD_3.7.2.2.8
		CA3257-PO	CARD_3.7.4.2.8
		CA3258-PO	CARD_3.7.3.2.8
		CA3272-PO	CARD_3.7.3.2.8
		CA3273-PO	CARD_3.7.6.2.8
		CA3274-PO	CARD_3.7.5.2.8
		CA3275-PO	CARD_3.7.2.2.8
		CA3276-PO	CARD_3.7.4.2.8
		CA3277-PO	CARD_3.7.3.2.8
		CA5033-PO	CARD_3.8.2
		CA5636-PO	CARD_3.8.2
		CA5656-PO	CARD_3.8.2
CA0449-PO	CARD_3.2.8	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
		CA3111-PO	CARD_3.7.3.2.8
		CA3112-PO	CARD_3.7.2.2.8
		CA3113-PO	CARD_3.7.4.2.8
		CA3249-PO	CARD_3.7.1.2.8
		CA3250-PO	CARD_3.7.3.2.8

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3254-PO	CARD_3.7.1.2.8
		CA3255-PO	CARD_3.7.1.2.8
		CA3256-PO	CARD_3.7.2.2.8
		CA3257-PO	CARD_3.7.4.2.8
		CA3258-PO	CARD_3.7.3.2.8
		CA3272-PO	CARD_3.7.3.2.8
		CA3273-PO	CARD_3.7.6.2.8
		CA3274-PO	CARD_3.7.5.2.8
		CA3275-PO	CARD_3.7.2.2.8
		CA3276-PO	CARD_3.7.4.2.8
		CA3277-PO	CARD_3.7.3.2.8
		CA5033-PO	CARD_3.8.2
		CA5636-PO	CARD_3.8.2
		CA5656-PO	CARD_3.8.2
CA0465-HQ	CARD_3.2.6		
CA0465-HQ	CARD_3.2.6		
CA0474-HQ	CARD_3.2.2.1	CA0485-PO	CARD_3.7.4.2.2.1
		CA3033-PO	CARD_3.7.5.2.2
		CA3035-PO	CARD_3.7.6.2.2
		CA3040-PO	CARD_3.7.1.2.2.1
		CA3041-PO	CARD_3.7.3.2.2.1
		CA3163-PO	CARD_3.7.2.2.2.1
CA0474-HQ	CARD_3.2.2.1	CA0485-PO	CARD_3.7.4.2.2.1
		CA3033-PO	CARD_3.7.5.2.2
		CA3035-PO	CARD_3.7.6.2.2
		CA3040-PO	CARD_3.7.1.2.2.1
		CA3041-PO	CARD_3.7.3.2.2.1
		CA3163-PO	CARD_3.7.2.2.2.1

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0476-HQ	CARD_3.2.10	CA3285-PO	CARD_3.7.6.2.10
		CA3287-PO	CARD_3.7.1.2.10
		CA3288-PO	CARD_3.7.1.2.10
		CA3289-PO	CARD_3.7.3.2.10
		CA3290-PO	CARD_3.7.8.2.10
		CA5909-PO	CARD_3.7.9.2.10
		CA5910-PO	CARD_3.7.9.2.10
		CA5911-PO	CARD_3.7.4.2.10
		CA5912-PO	CARD_3.7.2.2.10
CA0476-PO	CARD_3.2.10	CA3285-PO	CARD_3.7.6.2.10
		CA3287-PO	CARD_3.7.1.2.10
		CA3288-PO	CARD_3.7.1.2.10
		CA3289-PO	CARD_3.7.3.2.10
		CA3290-PO	CARD_3.7.8.2.10
		CA5909-PO	CARD_3.7.9.2.10
		CA5910-PO	CARD_3.7.9.2.10
		CA5911-PO	CARD_3.7.4.2.10
		CA5912-PO	CARD_3.7.2.2.10
CA0529-PO	CARD_3.2.11	CA0158-PO	CARD_3.7.6.2.11
		CA0284-PO	CARD_3.7.3.2.11
CA0529-PO	CARD_3.2.11	CA0158-PO	CARD_3.7.6.2.11
		CA0284-PO	CARD_3.7.3.2.11
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
		CA3107-PO	CARD_3.7.3.2.14

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA3108-PO	CARD_3.7.1.2.2
		CA3140-PO	CARD_3.7.1.2.14
		CA3181-PO	CARD_3.7.3.2.14
		CA4154-PO	CARD_3.7.1.2.2
		CA5168-PO	CARD_3.7.9.2.14
		CA5193-PO	CARD_3.7.3.2.2
		CA5659-PO	CARD_3.7.9.2.14
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
		CA3107-PO	CARD_3.7.3.2.14
		CA3108-PO	CARD_3.7.1.2.2
		CA3140-PO	CARD_3.7.1.2.14
		CA3181-PO	CARD_3.7.3.2.14
		CA4154-PO	CARD_3.7.1.2.2
		CA5168-PO	CARD_3.7.9.2.14
		CA5193-PO	CARD_3.7.3.2.2
		CA5659-PO	CARD_3.7.9.2.14
CA0550-PO	CARD_3.2.13		
CA0550-PO	CARD_3.2.13		
CA0554-PO	CARD_3.3.1.1		
CA0554-PO	CARD_3.3.1.1		
CA0555-PO	CARD_3.3.1.1	CA3018-PO	CARD_3.7.5.2.15
CA0555-PO	CARD_3.3.1.1	CA3018-PO	CARD_3.7.5.2.15
CA0569-PO	CARD_3.2.7		
CA0569-PO	CARD_3.2.7		

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0817-PO	CARD_3.3.1		
CA0817-PO	CARD_3.3.1		
CA0822-HQ	CARD_3.2.4	CA5155-PO	CARD_3.7.1.2.4
		CA5156-PO	CARD_3.7.3.2.4
CA0822-HQ	CARD_3.2.4	CA5155-PO	CARD_3.7.1.2.4
		CA5156-PO	CARD_3.7.3.2.4
CA0823-HQ	CARD_3.2.4		
CA0823-HQ	CARD_3.2.4		
CA0826-PO	CARD_3.2.11	CA0158-PO	CARD_3.7.6.2.11
CA0826-PO	CARD_3.2.11	CA0158-PO	CARD_3.7.6.2.11
CA0889-HQ	CARD_3.2	CA0010-HQ	CARD_3.2.3
		CA0011-HQ	CARD_3.2
		CA0023-PO	CARD_3.5
		CA0036-HQ	CARD_3.2.5
		CA0038-HQ	CARD_3.2.12
		CA0039-HQ	CARD_3.2.6
		CA0042-PO	CARD_3.3.4
		CA0044-PO	CARD_3.2.6
		CA0047-HQ	CARD_3.2.5
		CA0048-PO	CARD_3.2.15
		CA0071-PO	CARD_3.2.12
		CA0073-HQ	CARD_3.2.5
		CA0074-PO	CARD_3.2
		CA0100-HQ	CARD_3.2.7
		CA0123-PO	CARD_3.2.12
		CA0139-PO	CARD_3.7.6.2
		CA0140-PO	CARD_3.7.5.2
		CA0142-PO	CARD_3.7.5.2

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0145-PO	CARD_3.7.5.2
		CA0152-PO	CARD_3.7.6.2
		CA0212-HQ	CARD_3.2.4
		CA0282-PO	CARD_3.7.4.2.4
		CA0293-PO	CARD_3.7.6.2
		CA0347-PO	CARD_3.7.1.2.3
		CA0353-PO	CARD_3.2.6
		CA0373-PO	CARD_3.7.1.2.6
		CA0386-HQ	CARD_3.7.1.5
		CA0389-HQ	CARD_3.7.2.2.6
		CA0391-HQ	CARD_3.7.4.2.6
		CA0404-HQ	CARD_3.2
		CA0406-PO	CARD_3.7.1.2.6.2
		CA0444-PO	CARD_3.7.5.2.6
		CA0465-HQ	CARD_3.2.6
		CA0823-HQ	CARD_3.2.4
		CA0855-PO	CARD_3.7.5.2.6
		CA0856-PO	CARD_3.7.5.2.6
		CA0862-PO	CARD_3.7.7.2.6
		CA0863-PO	CARD_3.7.8.2.6
		CA3037-HQ	CARD_3.2.2.1
		CA3039-HQ	CARD_3.2.1
		CA3214-HQ	CARD_3.2.6
		CA3215-PO	CARD_3.7.4.2
		CA3226-PO	CARD_3.2.2.2
		CA3252-PO	CARD_3.3.7
		CA5552-PO	CARD_3.2.15
		CA5712-PO	CARD_3.7.5.2.6

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5713-PO	CARD_3.7.2.2.6
		CA5714-PO	CARD_3.7.4.2.6
		CA5803-PO	CARD_3.7.5.2.13
		CA5804-PO	CARD_3.7.4.2.13
		CA5814-PO	CARD_3.2.13
		CA5815-PO	CARD_3.2.13
		CA5817-PO	CARD_3.2.10
		CA5818-HQ	CARD_3.2.2.1
		CA5915-PO	CARD_3.3.8
		CA5936-PO	CARD_3.4
		CA5937-PO	CARD_3.4
		CA5938-PO	CARD_3.4
		CA5940-PO	CARD_3.4
		CA5942-PO	CARD_3.4
		CA5943-PO	CARD_3.4
		CA5944-PO	CARD_3.4
CA0889-HQ	CARD_3.2	CA0010-HQ	CARD_3.2.3
		CA0011-HQ	CARD_3.2
		CA0023-PO	CARD_3.5
		CA0036-HQ	CARD_3.2.5
		CA0038-HQ	CARD_3.2.12
		CA0039-HQ	CARD_3.2.6
		CA0042-PO	CARD_3.3.4
		CA0044-PO	CARD_3.2.6
		CA0047-HQ	CARD_3.2.5
		CA0048-PO	CARD_3.2.15
		CA0071-PO	CARD_3.2.12
		CA0073-HQ	CARD_3.2.5

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0074-PO	CARD_3.2
		CA0100-HQ	CARD_3.2.7
		CA0123-PO	CARD_3.2.12
		CA0139-PO	CARD_3.7.6.2
		CA0140-PO	CARD_3.7.5.2
		CA0142-PO	CARD_3.7.5.2
		CA0145-PO	CARD_3.7.5.2
		CA0152-PO	CARD_3.7.6.2
		CA0212-HQ	CARD_3.2.4
		CA0282-PO	CARD_3.7.4.2.4
		CA0293-PO	CARD_3.7.6.2
		CA0347-PO	CARD_3.7.1.2.3
		CA0353-PO	CARD_3.2.6
		CA0373-PO	CARD_3.7.1.2.6
		CA0386-HQ	CARD_3.7.1.5
		CA0389-HQ	CARD_3.7.2.2.6
		CA0391-HQ	CARD_3.7.4.2.6
		CA0404-HQ	CARD_3.2
		CA0406-PO	CARD_3.7.1.2.6.2
		CA0444-PO	CARD_3.7.5.2.6
		CA0465-HQ	CARD_3.2.6
		CA0823-HQ	CARD_3.2.4
		CA0855-PO	CARD_3.7.5.2.6
		CA0856-PO	CARD_3.7.5.2.6
		CA0862-PO	CARD_3.7.7.2.6
		CA0863-PO	CARD_3.7.8.2.6
		CA3037-HQ	CARD_3.2.2.1
		CA3039-HQ	CARD_3.2.1

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA3214-HQ	CARD_3.2.6
		CA3215-PO	CARD_3.7.4.2
		CA3226-PO	CARD_3.2.2.2
		CA3252-PO	CARD_3.3.7
		CA5552-PO	CARD_3.2.15
		CA5712-PO	CARD_3.7.5.2.6
		CA5713-PO	CARD_3.7.2.2.6
		CA5714-PO	CARD_3.7.4.2.6
		CA5803-PO	CARD_3.7.5.2.13
		CA5804-PO	CARD_3.7.4.2.13
		CA5814-PO	CARD_3.2.13
		CA5815-PO	CARD_3.2.13
		CA5817-PO	CARD_3.2.10
		CA5818-HQ	CARD_3.2.2.1
		CA5915-PO	CARD_3.3.8
		CA5936-PO	CARD_3.4
		CA5937-PO	CARD_3.4
		CA5938-PO	CARD_3.4
		CA5940-PO	CARD_3.4
		CA5942-PO	CARD_3.4
		CA5943-PO	CARD_3.4
		CA5944-PO	CARD_3.4
CA0892-HQ	CARD_3.2	CA0023-PO	CARD_3.5
		CA0036-HQ	CARD_3.2.5
		CA0039-HQ	CARD_3.2.6
		CA0042-PO	CARD_3.3.4
		CA0044-PO	CARD_3.2.6
		CA0048-PO	CARD_3.2.15

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		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
		CA0123-PO	CARD_3.2.12
		CA0139-PO	CARD_3.7.6.2
		CA0140-PO	CARD_3.7.5.2
		CA0142-PO	CARD_3.7.5.2
		CA0145-PO	CARD_3.7.5.2
		CA0152-PO	CARD_3.7.6.2
		CA0293-PO	CARD_3.7.6.2
		CA0386-HQ	CARD_3.7.1.5
		CA0389-HQ	CARD_3.7.2.2.6
		CA0444-PO	CARD_3.7.5.2.6
		CA0565-HQ	CARD_3.7.1.2.4
		CA0855-PO	CARD_3.7.5.2.6
		CA0856-PO	CARD_3.7.5.2.6
		CA0864-PO	CARD_3.7.1.2.4
		CA0865-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

PARENT		CHILDREN	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA3252-PO	CARD_3.3.7
		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
		CA5130-PO	CARD_3.7.6.2.13
		CA5233-PO	CARD_3.7.1.2.4
		CA5312-PO	CARD_3.7.1.2
		CA5552-PO	CARD_3.2.15
		CA5701-PO	CARD_3.7.5.2
		CA5712-PO	CARD_3.7.5.2.6
		CA5713-PO	CARD_3.7.2.2.6
		CA5714-PO	CARD_3.7.4.2.6
		CA5803-PO	CARD_3.7.5.2.13
		CA5804-PO	CARD_3.7.4.2.13
		CA5814-PO	CARD_3.2.13
		CA5815-PO	CARD_3.2.13
		CA5817-PO	CARD_3.2.10
		CA5818-HQ	CARD_3.2.2.1
		CA5915-PO	CARD_3.3.8
		CA5936-PO	CARD_3.4
		CA5937-PO	CARD_3.4
		CA5938-PO	CARD_3.4
		CA5939-PO	CARD_3.4
		CA5942-PO	CARD_3.4
		CA5943-PO	CARD_3.4
		CA5944-PO	CARD_3.4
CA0990-PO	CARD_3.3.1		
CA0990-PO	CARD_3.3.1		

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0991-PO	CARD_3.2.15	CA3018-PO	CARD_3.7.5.2.15
CA0991-PO	CARD_3.2.15	CA3018-PO	CARD_3.7.5.2.15
CA0993-PO	CARD_3.2.10	CA0511-PO	CARD_3.7.1.2.10
		CA0517-PO	CARD_3.7.3.2.10
		CA5039-PO	CARD_3.7.1.2.8
		CA5040-PO	CARD_3.7.1.2.8
		CA5044-PO	CARD_3.7.4.2.10
		CA5046-PO	CARD_3.7.9.2.10
		CA5047-PO	CARD_3.7.9.2.10
		CA5051-PO	CARD_3.7.5.2.10
		CA5054-PO	CARD_3.7.3.2.10
		CA5058-PO	CARD_3.7.6.2.10
CA0993-PO	CARD_3.2.10	CA0511-PO	CARD_3.7.1.2.10
		CA0517-PO	CARD_3.7.3.2.10
		CA5039-PO	CARD_3.7.1.2.8
		CA5040-PO	CARD_3.7.1.2.8
		CA5044-PO	CARD_3.7.4.2.10
		CA5046-PO	CARD_3.7.9.2.10
		CA5047-PO	CARD_3.7.9.2.10
		CA5051-PO	CARD_3.7.5.2.10
		CA5054-PO	CARD_3.7.3.2.10
		CA5058-PO	CARD_3.7.6.2.10
CA3004-PO	CARD_3.3.2		
CA3004-PO	CARD_3.3.2		
CA3005-PO	CARD_3.3.2		
CA3005-PO	CARD_3.3.2		
CA3007-PO	CARD_3.2.10	CA5900-PO	CARD_3.7.6.2.6
		CA5901-PO	CARD_3.7.1.2.10

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		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
CA3021-PO	CARD_3.2.10	CA0993-PO	CARD_3.2.10
CA3037-HQ	CARD_3.2.2.1		
CA3037-HQ	CARD_3.2.2.1		
CA3038-HQ	CARD_3.2.1	CA0486-PO	CARD_3.7.4.2.1
		CA0487-PO	CARD_3.7.4.2.1
		CA3027-PO	CARD_3.7.6.2.1
		CA3028-PO	CARD_3.7.5.2.1
		CA3042-PO	CARD_3.7.3.2.1
CA3038-HQ	CARD_3.2.1	CA0486-PO	CARD_3.7.4.2.1
		CA0487-PO	CARD_3.7.4.2.1
		CA3027-PO	CARD_3.7.6.2.1
		CA3028-PO	CARD_3.7.5.2.1
		CA3042-PO	CARD_3.7.3.2.1
CA3039-HQ	CARD_3.2.1		
CA3039-HQ	CARD_3.2.1		
CA3043-PO	CARD_3.2.10		
CA3051-PO	CARD_3.2.10		
CA3141-PO	CARD_3.2.11	CA0160-PO	
CA3141-PO	CARD_3.2.11	CA0160-PO	
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	CA3140-PO	CARD_3.7.1.2.14
		CA3166-PO	CARD_3.7.1.2.6
		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
CA3175-PO	CARD_3.2.6	CA3140-PO	CARD_3.7.1.2.14
		CA3166-PO	CARD_3.7.1.2.6
		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
		CA3202-PO	CARD_3.7.2.2.6
		CA4135-PO	CARD_3.7.1.2.6.1
CA3184-PO	CARD_3.2.6	CA0191-PO	CARD_3.7.1.2.6
		CA3202-PO	CARD_3.7.2.2.6
		CA4135-PO	CARD_3.7.1.2.6.1
CA3187-PO	CARD_3.3.2		
CA3187-PO	CARD_3.3.2		
CA3193-PO	CARD_3.3.2		
CA3193-PO	CARD_3.3.2		
CA3211-PO	CARD_3.2.6	CA3212-PO	CARD_3.7.4.2
		CA3216-PO	CARD_3.7.4.2.11
		CA3224-PO	CARD_3.7.4.2.11
		CA5231-PO	CARD_3.7.3.2.6.1
CA3211-PO	CARD_3.2.6	CA3212-PO	CARD_3.7.4.2
		CA3216-PO	CARD_3.7.4.2.11

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA3224-PO	CARD_3.7.4.2.11
		CA5231-PO	CARD_3.7.3.2.6.1
CA3214-HQ	CARD_3.2.6		
CA3214-HQ	CARD_3.2.6		
CA3222-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
		CA0172-PO	CARD_3.2.2
		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
		CA5146-PO	CARD_3.7.5.2.2
		CA5669-PO	CARD_3.7.6.2
CA3226-PO	CARD_3.2.2.2	CA0145-PO	CARD_3.7.5.2
		CA0146-PO	CARD_3.7.5.2.2
		CA0172-PO	CARD_3.2.2
		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
		CA5146-PO	CARD_3.7.5.2.2
		CA5669-PO	CARD_3.7.6.2
CA3237-PO	CARD_3.3.2		
CA3237-PO	CARD_3.3.2		

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA3252-PO	CARD_3.3.7	CA0157-HQ	CARD_3.8.2
		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
		CA3144-PO	CARD_3.7.3.2.11
		CA3145-PO	CARD_3.7.3.2.11
		CA3146-PO	CARD_3.7.4.2.11
		CA3248-PO	CARD_3.7.1.2.11
		CA3251-PO	CARD_3.7.3.2.11
CA3252-PO	CARD_3.3.7	CA0157-HQ	CARD_3.8.2
		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
		CA3144-PO	CARD_3.7.3.2.11
		CA3145-PO	CARD_3.7.3.2.11
		CA3146-PO	CARD_3.7.4.2.11
		CA3248-PO	CARD_3.7.1.2.11
		CA3251-PO	CARD_3.7.3.2.11
CA3293-PO	CARD_3.2.13		
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

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA5820-PO	CARD_3.2.10
CA5247-PO	CARD_3.2.6		
CA5247-PO	CARD_3.2.6		
CA5289-PO	CARD_3.2.5	CA0082-PO	CARD_3.7.1.2.5
		CA0842-PO	CARD_3.7.3.2.5
CA5289-PO	CARD_3.2.5	CA0082-PO	CARD_3.7.1.2.5
		CA0842-PO	CARD_3.7.3.2.5
CA5552-PO	CARD_3.2.15	CA5555-PO	CARD_3.7.1.2.15
		CA5556-PO	CARD_3.7.3.2.15
		CA5557-PO	CARD_3.7.2.2.15
		CA5558-PO	CARD_3.7.4.2.15
		CA5559-PO	CARD_3.7.9.2.15
		CA5560-PO	CARD_3.7.1.2.15
		CA5561-PO	CARD_3.7.3.2.15
		CA5562-PO	CARD_3.7.2.2.15
		CA5563-PO	CARD_3.7.4.2.15
		CA5564-PO	CARD_3.7.9.2.15
CA5552-PO	CARD_3.2.15	CA5555-PO	CARD_3.7.1.2.15
		CA5556-PO	CARD_3.7.3.2.15
		CA5557-PO	CARD_3.7.2.2.15
		CA5558-PO	CARD_3.7.4.2.15
		CA5559-PO	CARD_3.7.9.2.15
		CA5560-PO	CARD_3.7.1.2.15
		CA5561-PO	CARD_3.7.3.2.15
		CA5562-PO	CARD_3.7.2.2.15
		CA5563-PO	CARD_3.7.4.2.15
		CA5564-PO	CARD_3.7.9.2.15
CA5600-PO	CARD_3.2.12	CA0413-PO	CARD_3.7.4.2.12

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0414-PO	CARD_3.7.4.2.12
		CA1068-PO	CARD_3.7.2.2.12
		CA3064-PO	CARD_3.7.5.2.12
		CA5605-PO	CARD_3.7.3.2.12
CA5600-PO	CARD_3.2.12	CA0413-PO	CARD_3.7.4.2.12
		CA0414-PO	CARD_3.7.4.2.12
		CA1068-PO	CARD_3.7.2.2.12
		CA3064-PO	CARD_3.7.5.2.12
		CA5605-PO	CARD_3.7.3.2.12
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
		CA3251-PO	CARD_3.7.3.2.11
CA5604-PO	CARD_3.2.5	CA3285-PO	CARD_3.7.6.2.10
		CA5148-PO	CARD_3.7.1.2.6
		CA5149-PO	CARD_3.7.3.2.6
CA5604-PO	CARD_3.2.5	CA3285-PO	CARD_3.7.6.2.10
		CA5148-PO	CARD_3.7.1.2.6
		CA5149-PO	CARD_3.7.3.2.6
CA5618-PO	CARD_3.3.7		
CA5680-PO	CARD_3.3.8		
CA5680-PO	CARD_3.3.8		
CA5710-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
		CA5505-PO	CARD_3.7.3.2.13
		CA5934-PO	CARD_3.7.5.2.13
		CA5935-PO	CARD_3.2.13

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5710-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
		CA5505-PO	CARD_3.7.3.2.13
		CA5934-PO	CARD_3.7.5.2.13
		CA5935-PO	CARD_3.2.13
CA5800-PO	CARD_3.3.5		
CA5811-PO	CARD_3.3.1.1		
CA5811-PO	CARD_3.3.1.1		
CA5812-HQ	CARD_3.2.7		
CA5814-PO	CARD_3.2.13		
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
		CA5915-PO	CARD_3.3.8
CA5820-PO	CARD_3.2.10		
CA5821-PO	CARD_3.2.10		
CA5915-PO	CARD_3.3.8		
CA5935-PO	CARD_3.2.13		
CA5936-PO	CARD_3.4		
CA5937-PO	CARD_3.4		
CA5938-PO	CARD_3.4		
CA5939-PO	CARD_3.4		
CA5940-PO	CARD_3.4		
CA5941-PO	CARD_3.4		
CA5942-PO	CARD_3.4		
CA5943-PO	CARD_3.4		

PARENT		CHILDREN	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5944-PO	CARD_3.4		

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**
CA0002-HQ	CARD_3.2.4	CA0005-HQ	CARD_3.2
CA0002-HQ	CARD_3.2.4	CA0005-HQ	CARD_3.2
CA0005-HQ	CARD_3.2	CA0001-HQ	CARD_3.2
CA0005-HQ	CARD_3.2	CA0001-HQ	CARD_3.2
CA0006-HQ	CARD_3.2	CA0001-HQ	CARD_3.2
CA0006-HQ	CARD_3.2	CA0001-HQ	CARD_3.2
CA0010-HQ	CARD_3.2.3	CA0889-HQ	CARD_3.2
CA0010-HQ	CARD_3.2.3	CA0889-HQ	CARD_3.2
CA0011-HQ	CARD_3.2	CA0889-HQ	CARD_3.2
CA0011-HQ	CARD_3.2	CA0889-HQ	CARD_3.2
CA0013-HQ	CARD_3.2	CA0001-HQ	CARD_3.2
CA0013-HQ	CARD_3.2	CA0001-HQ	CARD_3.2
CA0014-HQ	CARD_3.2	CA0005-HQ	CARD_3.2
CA0014-HQ	CARD_3.2	CA0005-HQ	CARD_3.2
CA0020-HQ	CARD_3.2.3	CA0005-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
CA0021-PO	CARD_3.2.6	CA0001-HQ	CARD_3.2
CA0022-HQ	CARD_3.2.6	CA0202-HQ	CARD_3.2
CA0022-HQ	CARD_3.2.6	CA0202-HQ	CARD_3.2
CA0032-HQ	CARD_3.2.2.1	CA0013-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

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0033-HQ	CARD_3.2.1	CA0013-HQ	CARD_3.2
CA0038-HQ	CARD_3.2.12	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
CA0038-HQ	CARD_3.2.12	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
CA0040-PO	CARD_3.2.12	CA0039-HQ	CARD_3.2.6
CA0040-PO	CARD_3.2.12	CA0039-HQ	CARD_3.2.6
CA0047-HQ	CARD_3.2.5	CA0889-HQ	CARD_3.2
CA0047-HQ	CARD_3.2.5	CA0889-HQ	CARD_3.2
CA0049-PO	CARD_3.7.4.2.6	CA0121-HQ	CARD_3.2.6
		CA0129-PO	CARD_3.7.4.2.11
		CA0281-HQ	CARD_3.2.6
CA0049-PO	CARD_3.7.4.2.6	CA0121-HQ	CARD_3.2.6
		CA0129-PO	CARD_3.7.4.2.11
		CA0281-HQ	CARD_3.2.6
CA0051-PO	CARD_3.7.4.2.6.2	CA0129-PO	CARD_3.7.4.2.11
CA0051-PO	CARD_3.7.4.2.6.2	CA0129-PO	CARD_3.7.4.2.11
CA0059-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA0059-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA0062-PO	CARD_3.7.3.2.4	CA0121-HQ	CARD_3.2.6
		CA0211-HQ	CARD_3.2.4
CA0062-PO	CARD_3.7.3.2.4	CA0121-HQ	CARD_3.2.6
		CA0211-HQ	CARD_3.2.4
CA0072-PO	CARD_3.7.2.2.12		
		CA0123-PO	CARD_3.2.12
CA0072-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
CA0073-HQ	CARD_3.2.5	CA0889-HQ	CARD_3.2
CA0073-HQ	CARD_3.2.5	CA0889-HQ	CARD_3.2
CA0074-PO	CARD_3.2	CA0889-HQ	CARD_3.2
CA0074-PO	CARD_3.2	CA0889-HQ	CARD_3.2
CA0082-PO	CARD_3.7.1.2.5		
		CA0121-HQ	CARD_3.2.6
		CA5289-PO	CARD_3.2.5
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
CA0088-PO	CARD_3.7.1.2.1		
		CA0033-HQ	CARD_3.2.1
CA0090-PO	CARD_3.7.3.2.4	CA0209-HQ	CARD_3.2.4
CA0090-PO	CARD_3.7.3.2.4	CA0209-HQ	CARD_3.2.4
CA0091-PO	CARD_3.7.1.2		
		CA0121-HQ	CARD_3.2.6
		CA0281-HQ	CARD_3.2.6
CA0091-PO	CARD_3.7.1.2		
		CA0121-HQ	CARD_3.2.6
		CA0281-HQ	CARD_3.2.6
CA0099-HQ	CARD_3.2.1	CA0005-HQ	CARD_3.2
CA0099-HQ	CARD_3.2.1	CA0005-HQ	CARD_3.2
CA0121-HQ	CARD_3.2.6	CA0001-HQ	CARD_3.2
CA0121-HQ	CARD_3.2.6	CA0001-HQ	CARD_3.2
CA0125-PO	CARD_3.2.12	CA0001-HQ	CARD_3.2

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0125-PO	CARD_3.2.12	CA0001-HQ	CARD_3.2
CA0128-PO	CARD_3.7.4.2.11	CA0121-HQ	CARD_3.2.6
CA0128-PO	CARD_3.7.4.2.11	CA0121-HQ	CARD_3.2.6
CA0129-PO	CARD_3.7.4.2.11	CA0121-HQ	CARD_3.2.6
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
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
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
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
CA0135-PO	CARD_3.7.3.2.11	CA0121-HQ	CARD_3.2.6
CA0137-PO	CARD_3.7.3.2.4	CA0002-HQ	CARD_3.2.4
CA0137-PO	CARD_3.7.3.2.4	CA0002-HQ	CARD_3.2.4
CA0151-PO	CARD_3.7.5.2.2		
		CA0310-PO	CARD_3.2.2.2
		CA0311-PO	CARD_3.2.2.2
CA0151-PO	CARD_3.7.5.2.2		
		CA0310-PO	CARD_3.2.2.2
		CA0311-PO	CARD_3.2.2.2
CA0158-PO	CARD_3.7.6.2.11		

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		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
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
CA0160-PO		CA0152-PO	CARD_3.7.6.2
		CA3141-PO	CARD_3.2.11
CA0160-PO		CA0152-PO	CARD_3.7.6.2
		CA3141-PO	CARD_3.2.11
CA0163-PO	CARD_3.7.6.2.2		
		CA0152-PO	CARD_3.7.6.2
		CA0172-PO	CARD_3.2.2
		CA3252-PO	CARD_3.3.7
CA0163-PO	CARD_3.7.6.2.2		
		CA0152-PO	CARD_3.7.6.2
		CA0172-PO	CARD_3.2.2
		CA3252-PO	CARD_3.3.7
CA0178-PO	CARD_3.7.1.2.12		
		CA0123-PO	CARD_3.2.12
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

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
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
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
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
CA0194-PO	CARD_3.7.1.2.2		
		CA0312-PO	CARD_3.2.2
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
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
CA0209-HQ	CARD_3.2.4	CA0001-HQ	CARD_3.2
CA0212-HQ	CARD_3.2.4	CA0889-HQ	CARD_3.2
CA0212-HQ	CARD_3.2.4	CA0889-HQ	CARD_3.2
CA0258-PO	CARD_3.7.2.2.2		
		CA0215-PO	CARD_3.2.7
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

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0293-PO	CARD_3.7.6.2
		CA3252-PO	CARD_3.3.7
		CA5669-PO	CARD_3.7.6.2
CA0270-PO	CARD_3.7.6.2.11		
		CA0152-PO	CARD_3.7.6.2
		CA0293-PO	CARD_3.7.6.2
		CA3252-PO	CARD_3.3.7
		CA5669-PO	CARD_3.7.6.2
CA0281-HQ	CARD_3.2.6	CA0121-HQ	CARD_3.2.6
CA0281-HQ	CARD_3.2.6	CA0121-HQ	CARD_3.2.6
CA0282-PO	CARD_3.7.4.2.4	CA0889-HQ	CARD_3.2
CA0282-PO	CARD_3.7.4.2.4	CA0889-HQ	CARD_3.2
CA0284-PO	CARD_3.7.3.2.11	CA0529-PO	CARD_3.2.11
CA0284-PO	CARD_3.7.3.2.11	CA0529-PO	CARD_3.2.11
CA0287-PO	CARD_3.2.6	CA0013-HQ	CARD_3.2
CA0287-PO	CARD_3.2.6	CA0013-HQ	CARD_3.2
CA0314-PO	CARD_3.2.11	CA0121-HQ	CARD_3.2.6
CA0314-PO	CARD_3.2.11	CA0121-HQ	CARD_3.2.6
CA0316-PO	CARD_3.2.6	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
CA0324-PO	CARD_3.7.1.2.6		
		CA0044-PO	CARD_3.2.6
CA0325-PO	CARD_3.7.1.2.2		
		CA3226-PO	CARD_3.2.2.2
CA0325-PO	CARD_3.7.1.2.2		
		CA3226-PO	CARD_3.2.2.2

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0329-PO	CARD_3.7.1.2.11		
		CA0044-PO	CARD_3.2.6
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
CA0333-PO	CARD_3.7.1.2.2.2		
		CA0027-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
CA0344-PO	CARD_3.7.1.2.10		
		CA0172-PO	CARD_3.2.2
		CA0312-PO	CARD_3.2.2
CA0347-PO	CARD_3.7.1.2.3		
		CA0889-HQ	CARD_3.2
CA0347-PO	CARD_3.7.1.2.3		
		CA0889-HQ	CARD_3.2
CA0351-PO	CARD_3.7.1.2.6		
		CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
CA0351-PO	CARD_3.7.1.2.6		
		CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
CA0353-PO	CARD_3.2.6	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
CA0353-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
CA0356-PO	CARD_3.2.11	CA0001-HQ	CARD_3.2
CA0356-PO	CARD_3.2.11	CA0001-HQ	CARD_3.2
CA0368-PO	CARD_3.7.1.2.11		
		CA0314-PO	CARD_3.2.11
CA0373-PO	CARD_3.7.1.2.6		
		CA0889-HQ	CARD_3.2
CA0373-PO	CARD_3.7.1.2.6		
		CA0889-HQ	CARD_3.2
CA0374-PO	CARD_3.7.1.2.15		
		CA0048-PO	CARD_3.2.15
CA0374-PO	CARD_3.7.1.2.15		
		CA0048-PO	CARD_3.2.15
CA0384-PO		CA0383-PO	CARD_3.3.5
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
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
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
CA0399-PO	CARD_3.7.1.2.1		

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0095-HQ	CARD_3.2.1
CA0404-HQ	CARD_3.2	CA0889-HQ	CARD_3.2
CA0404-HQ	CARD_3.2	CA0889-HQ	CARD_3.2
CA0405-HQ	CARD_3.2.6	CA0001-HQ	CARD_3.2
		CA0005-HQ	CARD_3.2
CA0405-HQ	CARD_3.2.6	CA0001-HQ	CARD_3.2
		CA0005-HQ	CARD_3.2
CA0406-PO	CARD_3.7.1.2.6.2		
		CA0889-HQ	CARD_3.2
CA0406-PO	CARD_3.7.1.2.6.2		
		CA0889-HQ	CARD_3.2
CA0407-PO	CARD_3.2.6	CA0001-HQ	CARD_3.2
CA0407-PO	CARD_3.2.6	CA0001-HQ	CARD_3.2
CA0413-PO	CARD_3.7.4.2.12	CA5600-PO	CARD_3.2.12
CA0413-PO	CARD_3.7.4.2.12	CA5600-PO	CARD_3.2.12
CA0414-PO	CARD_3.7.4.2.12	CA5600-PO	CARD_3.2.12
CA0414-PO	CARD_3.7.4.2.12	CA5600-PO	CARD_3.2.12
CA0416-PO	CARD_3.7.1.2.2.2		
		CA0028-PO	CARD_3.2.2
CA0416-PO	CARD_3.7.1.2.2.2		
		CA0028-PO	CARD_3.2.2
CA0418-PO	CARD_3.7.3.2.11	CA0356-PO	CARD_3.2.11
CA0418-PO	CARD_3.7.3.2.11	CA0356-PO	CARD_3.2.11
CA0430-PO	CARD_3.7.2.4		
		CA0449-PO	CARD_3.2.8
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

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		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
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
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
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
CA0448-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
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
CA0461-PO	CARD_3.7.3.2.11	CA0121-HQ	CARD_3.2.6
CA0465-HQ	CARD_3.2.6	CA0889-HQ	CARD_3.2
CA0465-HQ	CARD_3.2.6	CA0889-HQ	CARD_3.2
CA0474-HQ	CARD_3.2.2.1	CA0005-HQ	CARD_3.2

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA0474-HQ	CARD_3.2.2.1	CA0005-HQ	CARD_3.2
CA0485-PO	CARD_3.7.4.2.2.1	CA0032-HQ	CARD_3.2.2.1
		CA0474-HQ	CARD_3.2.2.1
CA0485-PO	CARD_3.7.4.2.2.1	CA0032-HQ	CARD_3.2.2.1
		CA0474-HQ	CARD_3.2.2.1
CA0486-PO	CARD_3.7.4.2.1	CA0033-HQ	CARD_3.2.1
		CA0099-HQ	CARD_3.2.1
		CA3038-HQ	CARD_3.2.1
CA0486-PO	CARD_3.7.4.2.1	CA0033-HQ	CARD_3.2.1
		CA0099-HQ	CARD_3.2.1
		CA3038-HQ	CARD_3.2.1
CA0487-PO	CARD_3.7.4.2.1	CA0033-HQ	CARD_3.2.1
		CA0099-HQ	CARD_3.2.1
		CA3038-HQ	CARD_3.2.1
CA0487-PO	CARD_3.7.4.2.1	CA0033-HQ	CARD_3.2.1
		CA0099-HQ	CARD_3.2.1
		CA3038-HQ	CARD_3.2.1
CA0494-PO	CARD_3.7.1.2.6		
		CA0044-PO	CARD_3.2.6
		CA3226-PO	CARD_3.2.2.2
CA0494-PO	CARD_3.7.1.2.6		
		CA0044-PO	CARD_3.2.6
		CA3226-PO	CARD_3.2.2.2
CA0498-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
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		

CHILD		PARENT(s)	
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		
		CA0032-HQ	CARD_3.2.2.1
CA0503-PO	CARD_3.7.3.2.2.1	CA0032-HQ	CARD_3.2.2.1
CA0503-PO	CARD_3.7.3.2.2.1	CA0032-HQ	CARD_3.2.2.1
CA0504-PO	CARD_3.7.3.2.1	CA0033-HQ	CARD_3.2.1
CA0504-PO	CARD_3.7.3.2.1	CA0033-HQ	CARD_3.2.1
CA0511-PO	CARD_3.7.1.2.10		
		CA0993-PO	CARD_3.2.10
CA0511-PO	CARD_3.7.1.2.10		
		CA0993-PO	CARD_3.2.10
CA0517-PO	CARD_3.7.3.2.10	CA0993-PO	CARD_3.2.10
CA0517-PO	CARD_3.7.3.2.10	CA0993-PO	CARD_3.2.10
CA0529-PO	CARD_3.2.11	CA0001-HQ	CARD_3.2
CA0529-PO	CARD_3.2.11	CA0001-HQ	CARD_3.2
CA0532-PO	CARD_3.7.1.2.2		
		CA0352-HQ	CARD_3.2.2.2
		CA0530-PO	CARD_3.2.2.2
CA0532-PO	CARD_3.7.1.2.2		
		CA0352-HQ	CARD_3.2.2.2
		CA0530-PO	CARD_3.2.2.2
CA0566-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA0566-PO	CARD_3.7.2.2.7		
		CA0100-HQ	CARD_3.2.7
CA0579-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA0579-PO	CARD_3.7.1.2.2.2		

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		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
CA0815-PO	CARD_3.7.3.2.15	CA0048-PO	CARD_3.2.15
CA0815-PO	CARD_3.7.3.2.15	CA0048-PO	CARD_3.2.15
CA0823-HQ	CARD_3.2.4	CA0889-HQ	CARD_3.2
CA0823-HQ	CARD_3.2.4	CA0889-HQ	CARD_3.2
CA0826-PO	CARD_3.2.11	CA0001-HQ	CARD_3.2
		CA0202-HQ	CARD_3.2
CA0826-PO	CARD_3.2.11	CA0001-HQ	CARD_3.2
		CA0202-HQ	CARD_3.2
CA0827-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0281-HQ	CARD_3.2.6
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
CA0829-PO	CARD_3.7.1.2.6.2		
		CA0121-HQ	CARD_3.2.6
CA0836-PO	CARD_3.7.3.2.6.1	CA0023-PO	CARD_3.5
		CA0281-HQ	CARD_3.2.6
CA0836-PO	CARD_3.7.3.2.6.1	CA0023-PO	CARD_3.5

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0281-HQ	CARD_3.2.6
CA0837-PO	CARD_3.7.3.2.6.2	CA0121-HQ	CARD_3.2.6
CA0837-PO	CARD_3.7.3.2.6.2	CA0121-HQ	CARD_3.2.6
CA0839-PO	CARD_3.7.3.2.5	CA0121-HQ	CARD_3.2.6
CA0839-PO	CARD_3.7.3.2.5	CA0121-HQ	CARD_3.2.6
CA0842-PO	CARD_3.7.3.2.5	CA5289-PO	CARD_3.2.5
CA0842-PO	CARD_3.7.3.2.5	CA5289-PO	CARD_3.2.5
CA0847-PO	CARD_3.7.4.2.6.1	CA0121-HQ	CARD_3.2.6
CA0847-PO	CARD_3.7.4.2.6.1	CA0121-HQ	CARD_3.2.6
CA0848-PO	CARD_3.7.4.2.6.1	CA0281-HQ	CARD_3.2.6
		CA3212-PO	CARD_3.7.4.2
CA0848-PO	CARD_3.7.4.2.6.1	CA0281-HQ	CARD_3.2.6
		CA3212-PO	CARD_3.7.4.2
CA0850-PO	CARD_3.7.4.2.5	CA0001-HQ	CARD_3.2
		CA0121-HQ	CARD_3.2.6
CA0850-PO	CARD_3.7.4.2.5	CA0001-HQ	CARD_3.2
		CA0121-HQ	CARD_3.2.6
CA0853-PO	CARD_3.7.5.2.6		
		CA0140-PO	CARD_3.7.5.2
CA0853-PO	CARD_3.7.5.2.6		
		CA0140-PO	CARD_3.7.5.2
CA0860-PO	CARD_3.7.5.2.1		
		CA0095-HQ	CARD_3.2.1
		CA0097-HQ	CARD_3.2.1
CA0860-PO	CARD_3.7.5.2.1		
		CA0095-HQ	CARD_3.2.1
		CA0097-HQ	CARD_3.2.1
CA0862-PO	CARD_3.7.7.2.6	CA0889-HQ	CARD_3.2

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA0862-PO	CARD_3.7.7.2.6	CA0889-HQ	CARD_3.2
CA0863-PO	CARD_3.7.8.2.6	CA0889-HQ	CARD_3.2
CA0863-PO	CARD_3.7.8.2.6	CA0889-HQ	CARD_3.2
CA0868-PO	CARD_3.7.1.2.4		
		CA0211-HQ	CARD_3.2.4
CA0868-PO	CARD_3.7.1.2.4		
		CA0211-HQ	CARD_3.2.4
CA0874-PO	CARD_3.7.4.2.7	CA0100-HQ	CARD_3.2.7
		CA0566-PO	CARD_3.7.2.2.7
CA0874-PO	CARD_3.7.4.2.7	CA0100-HQ	CARD_3.2.7
		CA0566-PO	CARD_3.7.2.2.7
CA0886-PO	CARD_3.7.1.2.14		
		CA0121-HQ	CARD_3.2.6
CA0886-PO	CARD_3.7.1.2.14		
		CA0121-HQ	CARD_3.2.6
CA0890-PO	CARD_3.7.3.2.7	CA0213-PO	CARD_3.2.7
CA0890-PO	CARD_3.7.3.2.7	CA0213-PO	CARD_3.2.7
CA0891-PO	CARD_3.7.3.2.7	CA0214-PO	CARD_3.2.7
CA0891-PO	CARD_3.7.3.2.7	CA0214-PO	CARD_3.2.7
CA0983-PO	CARD_3.7.1.2.2		
		CA0048-PO	CARD_3.2.15
		CA0312-PO	CARD_3.2.2
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

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
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
CA0993-PO	CARD_3.2.10	CA3021-PO	CARD_3.2.10
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
CA1008-PO	CARD_3.7.2.2.12		
		CA0125-PO	CARD_3.2.12
CA1017-PO	CARD_3.7.2.2.11		
		CA3202-PO	CARD_3.7.2.2.6
CA1017-PO	CARD_3.7.2.2.11		
		CA3202-PO	CARD_3.7.2.2.6
CA1023-PO	CARD_3.7.2.2.6		
		CA3202-PO	CARD_3.7.2.2.6
CA1023-PO	CARD_3.7.2.2.6		
		CA3202-PO	CARD_3.7.2.2.6
CA1029-PO	CARD_3.7.2.2.8		
		CA3202-PO	CARD_3.7.2.2.6
CA1029-PO	CARD_3.7.2.2.8		
		CA3202-PO	CARD_3.7.2.2.6
CA1053-PO	CARD_3.7.2.2.7		
		CA0566-PO	CARD_3.7.2.2.7
CA1053-PO	CARD_3.7.2.2.7		

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0566-PO	CARD_3.7.2.2.7
CA1054-PO	CARD_3.7.2.2.7		
		CA0566-PO	CARD_3.7.2.2.7
CA1054-PO	CARD_3.7.2.2.7		
		CA0566-PO	CARD_3.7.2.2.7
CA1056-PO	CARD_3.7.2.2.7		
		CA0566-PO	CARD_3.7.2.2.7
CA1056-PO	CARD_3.7.2.2.7		
		CA0566-PO	CARD_3.7.2.2.7
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
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		
		CA0123-PO	CARD_3.2.12
CA1066-PO	CARD_3.7.2.2.12		
		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		

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0048-PO	CARD_3.2.15
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
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
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
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
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		

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		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
CA3023-PO	CARD_3.7.1.2.1		
		CA0099-HQ	CARD_3.2.1
CA3024-PO	CARD_3.7.6.2.1		
		CA0097-HQ	CARD_3.2.1
CA3024-PO	CARD_3.7.6.2.1		
		CA0097-HQ	CARD_3.2.1
CA3025-PO	CARD_3.7.6.2.1		
		CA0095-HQ	CARD_3.2.1
CA3025-PO	CARD_3.7.6.2.1		
		CA0095-HQ	CARD_3.2.1
CA3026-PO	CARD_3.7.6.2.1		
		CA0033-HQ	CARD_3.2.1
CA3026-PO	CARD_3.7.6.2.1		
		CA0033-HQ	CARD_3.2.1
CA3027-PO	CARD_3.7.6.2.1		
		CA3038-HQ	CARD_3.2.1
CA3027-PO	CARD_3.7.6.2.1		
		CA3038-HQ	CARD_3.2.1
CA3028-PO	CARD_3.7.5.2.1		
		CA3038-HQ	CARD_3.2.1
CA3028-PO	CARD_3.7.5.2.1		
		CA3038-HQ	CARD_3.2.1
CA3029-PO	CARD_3.7.5.2.1		

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0033-HQ	CARD_3.2.1
		CA0099-HQ	CARD_3.2.1
CA3029-PO	CARD_3.7.5.2.1		
		CA0033-HQ	CARD_3.2.1
		CA0099-HQ	CARD_3.2.1
CA3030-PO	CARD_3.7.6.2.1		
		CA0099-HQ	CARD_3.2.1
CA3030-PO	CARD_3.7.6.2.1		
		CA0099-HQ	CARD_3.2.1
CA3031-PO	CARD_3.7.5.2.2		
		CA0096-HQ	CARD_3.2.2.1
CA3031-PO	CARD_3.7.5.2.2		
		CA0096-HQ	CARD_3.2.2.1
CA3032-PO	CARD_3.7.6.2.2		
		CA0096-HQ	CARD_3.2.2.1
CA3032-PO	CARD_3.7.6.2.2		
		CA0096-HQ	CARD_3.2.2.1
CA3033-PO	CARD_3.7.5.2.2		
		CA0032-HQ	CARD_3.2.2.1
		CA0474-HQ	CARD_3.2.2.1
CA3033-PO	CARD_3.7.5.2.2		
		CA0032-HQ	CARD_3.2.2.1
		CA0474-HQ	CARD_3.2.2.1
CA3034-PO	CARD_3.7.6.2.2		
		CA0032-HQ	CARD_3.2.2.1
CA3034-PO	CARD_3.7.6.2.2		
		CA0032-HQ	CARD_3.2.2.1
CA3035-PO	CARD_3.7.6.2.2		

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		CA0474-HQ	CARD_3.2.2.1
CA3035-PO	CARD_3.7.6.2.2		
		CA0474-HQ	CARD_3.2.2.1
CA3036-PO	CARD_3.7.3.2.1	CA0099-HQ	CARD_3.2.1
CA3036-PO	CARD_3.7.3.2.1	CA0099-HQ	CARD_3.2.1
CA3037-HQ	CARD_3.2.2.1	CA0889-HQ	CARD_3.2
CA3037-HQ	CARD_3.2.2.1	CA0889-HQ	CARD_3.2
CA3038-HQ	CARD_3.2.1	CA0005-HQ	CARD_3.2
CA3038-HQ	CARD_3.2.1	CA0005-HQ	CARD_3.2
CA3039-HQ	CARD_3.2.1	CA0889-HQ	CARD_3.2
CA3039-HQ	CARD_3.2.1	CA0889-HQ	CARD_3.2
CA3040-PO	CARD_3.7.1.2.2.1		
		CA0474-HQ	CARD_3.2.2.1
CA3040-PO	CARD_3.7.1.2.2.1		
		CA0474-HQ	CARD_3.2.2.1
CA3041-PO	CARD_3.7.3.2.2.1	CA0474-HQ	CARD_3.2.2.1
CA3041-PO	CARD_3.7.3.2.2.1	CA0474-HQ	CARD_3.2.2.1
CA3042-PO	CARD_3.7.3.2.1	CA3038-HQ	CARD_3.2.1
CA3042-PO	CARD_3.7.3.2.1	CA3038-HQ	CARD_3.2.1
CA3058-PO	CARD_3.7.9.2.14	CA0530-PO	CARD_3.2.2.2
CA3058-PO	CARD_3.7.9.2.14	CA0530-PO	CARD_3.2.2.2
CA3063-PO	CARD_3.7.9.2.12	CA0123-PO	CARD_3.2.12
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
CA3064-PO	CARD_3.7.5.2.12		
		CA5600-PO	CARD_3.2.12
CA3065-PO	CARD_3.7.6.2.12		

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
		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
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
CA3069-PO		CA0383-PO	CARD_3.3.5
CA3072-PO	CARD_3.7.3.2.10	CA0383-PO	CARD_3.3.5
CA3074-PO	CARD_3.7.4.2.10	CA0383-PO	CARD_3.3.5
CA3105-PO	CARD_3.7.1.2.14		
		CA0530-PO	CARD_3.2.2.2
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
CA3106-PO	CARD_3.7.1.2.14		
		CA0530-PO	CARD_3.2.2.2
CA3107-PO	CARD_3.7.3.2.14	CA0530-PO	CARD_3.2.2.2
CA3107-PO	CARD_3.7.3.2.14	CA0530-PO	CARD_3.2.2.2
CA3108-PO	CARD_3.7.1.2.2		
		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

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA3110-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA3111-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3111-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3112-PO	CARD_3.7.2.2.8		
		CA0449-PO	CARD_3.2.8
CA3112-PO	CARD_3.7.2.2.8		
		CA0449-PO	CARD_3.2.8
CA3113-PO	CARD_3.7.4.2.8	CA0449-PO	CARD_3.2.8
CA3113-PO	CARD_3.7.4.2.8	CA0449-PO	CARD_3.2.8
CA3135-PO	CARD_3.7.3.2.14	CA0814-PO	CARD_3.7.3.2.14
CA3135-PO	CARD_3.7.3.2.14	CA0814-PO	CARD_3.7.3.2.14
CA3137-PO	CARD_3.7.3.2.14	CA0121-HQ	CARD_3.2.6
CA3137-PO	CARD_3.7.3.2.14	CA0121-HQ	CARD_3.2.6
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
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
CA3141-PO	CARD_3.2.11	CA0005-HQ	CARD_3.2
		CA0013-HQ	CARD_3.2
CA3141-PO	CARD_3.2.11	CA0005-HQ	CARD_3.2
		CA0013-HQ	CARD_3.2
CA3142-PO	CARD_3.7.1.2.11		
		CA3252-PO	CARD_3.3.7

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
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
CA3143-PO	CARD_3.7.2.2.11		
		CA3252-PO	CARD_3.3.7
CA3144-PO	CARD_3.7.3.2.11	CA3252-PO	CARD_3.3.7
CA3144-PO	CARD_3.7.3.2.11	CA3252-PO	CARD_3.3.7
CA3145-PO	CARD_3.7.3.2.11	CA0356-PO	CARD_3.2.11
		CA3252-PO	CARD_3.3.7
CA3145-PO	CARD_3.7.3.2.11	CA0356-PO	CARD_3.2.11
		CA3252-PO	CARD_3.3.7
CA3146-PO	CARD_3.7.4.2.11	CA3252-PO	CARD_3.3.7
CA3146-PO	CARD_3.7.4.2.11	CA3252-PO	CARD_3.3.7
CA3163-PO	CARD_3.7.2.2.2.1		
		CA0032-HQ	CARD_3.2.2.1
		CA0096-HQ	CARD_3.2.2.1
		CA0474-HQ	CARD_3.2.2.1
CA3163-PO	CARD_3.7.2.2.2.1		
		CA0032-HQ	CARD_3.2.2.1
		CA0096-HQ	CARD_3.2.2.1
		CA0474-HQ	CARD_3.2.2.1
CA3166-PO	CARD_3.7.1.2.6		
		CA3175-PO	CARD_3.2.6
CA3166-PO	CARD_3.7.1.2.6		
		CA3175-PO	CARD_3.2.6
CA3167-PO	CARD_3.3.6	CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
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
CA3168-PO	CARD_3.7.1.2.6		
		CA0181-HQ	CARD_3.2.6
CA3181-PO	CARD_3.7.3.2.14	CA0530-PO	CARD_3.2.2.2
CA3181-PO	CARD_3.7.3.2.14	CA0530-PO	CARD_3.2.2.2
CA3186-PO	CARD_3.7.4.2.11	CA0121-HQ	CARD_3.2.6
CA3186-PO	CARD_3.7.4.2.11	CA0121-HQ	CARD_3.2.6
CA3200-PO	CARD_3.7.3.2.6	CA0001-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
CA3202-PO	CARD_3.7.2.2.6		
		CA0281-HQ	CARD_3.2.6
		CA3184-PO	CARD_3.2.6
CA3204-PO	CARD_3.7.1.2.6		
		CA0121-HQ	CARD_3.2.6
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
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
CA3206-PO	CARD_3.7.3.2.6	CA0121-HQ	CARD_3.2.6
CA3207-PO	CARD_3.7.1.2.6		
		CA0121-HQ	CARD_3.2.6

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA3208-PO	CARD_3.7.3.2.6	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
CA3209-PO	CARD_3.7.1.2.6		
		CA0121-HQ	CARD_3.2.6
CA3211-PO	CARD_3.2.6	CA0005-HQ	CARD_3.2
CA3211-PO	CARD_3.2.6	CA0005-HQ	CARD_3.2
CA3212-PO	CARD_3.7.4.2	CA3211-PO	CARD_3.2.6
CA3212-PO	CARD_3.7.4.2	CA3211-PO	CARD_3.2.6
CA3213-PO	CARD_3.7.3.2	CA0005-HQ	CARD_3.2
CA3213-PO	CARD_3.7.3.2	CA0005-HQ	CARD_3.2
CA3214-HQ	CARD_3.2.6	CA0889-HQ	CARD_3.2
CA3214-HQ	CARD_3.2.6	CA0889-HQ	CARD_3.2
CA3215-PO	CARD_3.7.4.2	CA0889-HQ	CARD_3.2
CA3215-PO	CARD_3.7.4.2	CA0889-HQ	CARD_3.2
CA3216-PO	CARD_3.7.4.2.11	CA0049-PO	CARD_3.7.4.2.6
		CA3211-PO	CARD_3.2.6
		CA3212-PO	CARD_3.7.4.2
CA3216-PO	CARD_3.7.4.2.11	CA0049-PO	CARD_3.7.4.2.6
		CA3211-PO	CARD_3.2.6
		CA3212-PO	CARD_3.7.4.2
CA3217-PO	CARD_3.7.4.2.6	CA0049-PO	CARD_3.7.4.2.6
		CA3212-PO	CARD_3.7.4.2
CA3217-PO	CARD_3.7.4.2.6	CA0049-PO	CARD_3.7.4.2.6
		CA3212-PO	CARD_3.7.4.2
CA3224-PO	CARD_3.7.4.2.11	CA0049-PO	CARD_3.7.4.2.6
		CA3211-PO	CARD_3.2.6

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA3212-PO	CARD_3.7.4.2
CA3224-PO	CARD_3.7.4.2.11	CA0049-PO	CARD_3.7.4.2.6
		CA3211-PO	CARD_3.2.6
		CA3212-PO	CARD_3.7.4.2
CA3225-PO	CARD_3.7.4.2.11	CA0049-PO	CARD_3.7.4.2.6
		CA3212-PO	CARD_3.7.4.2
CA3225-PO	CARD_3.7.4.2.11	CA0049-PO	CARD_3.7.4.2.6
		CA3212-PO	CARD_3.7.4.2
CA3249-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA3249-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA3250-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3250-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3254-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA3254-PO	CARD_3.7.1.2.8		
		CA0449-PO	CARD_3.2.8
CA3255-PO	CARD_3.7.1.2.8		
		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
CA3256-PO	CARD_3.7.2.2.8		
		CA0449-PO	CARD_3.2.8
CA3257-PO	CARD_3.7.4.2.8	CA0449-PO	CARD_3.2.8
CA3257-PO	CARD_3.7.4.2.8	CA0449-PO	CARD_3.2.8

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA3258-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3258-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3272-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3272-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3273-PO	CARD_3.7.6.2.8		
		CA0152-PO	CARD_3.7.6.2
		CA0449-PO	CARD_3.2.8
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
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
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
		CA3276-PO	CARD_3.7.4.2.8
CA3276-PO	CARD_3.7.4.2.8	CA0449-PO	CARD_3.2.8
		CA3276-PO	CARD_3.7.4.2.8
CA3277-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3277-PO	CARD_3.7.3.2.8	CA0449-PO	CARD_3.2.8
CA3285-PO	CARD_3.7.6.2.10		
		CA0152-PO	CARD_3.7.6.2
		CA0476-PO	CARD_3.2.10
		CA5604-PO	CARD_3.2.5

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA3285-PO	CARD_3.7.6.2.10		
		CA0152-PO	CARD_3.7.6.2
		CA0476-PO	CARD_3.2.10
		CA5604-PO	CARD_3.2.5
CA3286-PO	CARD_3.7.3.2.6	CA0001-HQ	CARD_3.2
		CA0013-HQ	CARD_3.2
CA3286-PO	CARD_3.7.3.2.6	CA0001-HQ	CARD_3.2
		CA0013-HQ	CARD_3.2
CA3287-PO	CARD_3.7.1.2.10		
		CA0476-PO	CARD_3.2.10
CA3287-PO	CARD_3.7.1.2.10		
		CA0476-PO	CARD_3.2.10
CA3288-PO	CARD_3.7.1.2.10		
		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
CA3290-PO	CARD_3.7.8.2.10	CA0476-PO	CARD_3.2.10
CA3290-PO	CARD_3.7.8.2.10	CA0476-PO	CARD_3.2.10
CA3292-PO	CARD_3.7.4.2.8	CA3212-PO	CARD_3.7.4.2
		CA3215-PO	CARD_3.7.4.2
CA3292-PO	CARD_3.7.4.2.8	CA3212-PO	CARD_3.7.4.2
		CA3215-PO	CARD_3.7.4.2
CA3302-PO	CARD_3.7.4.2.8	CA3212-PO	CARD_3.7.4.2
		CA3215-PO	CARD_3.7.4.2
CA3302-PO	CARD_3.7.4.2.8	CA3212-PO	CARD_3.7.4.2
		CA3215-PO	CARD_3.7.4.2

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA4121-PO	CARD_3.7.5.2.5		
		CA0281-HQ	CARD_3.2.6
CA4121-PO	CARD_3.7.5.2.5		
		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
CA4122-PO	CARD_3.7.5.2		
		CA0044-PO	CARD_3.2.6
		CA0145-PO	CARD_3.7.5.2
CA4125-PO	CARD_3.7.9.2.9	CA0216-PO	CARD_3.2.9
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
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
CA4128-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA4134-PO	CARD_3.7.1.2.6.1		
		CA0023-PO	CARD_3.5
		CA0281-HQ	CARD_3.2.6
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

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA0121-HQ	CARD_3.2.6
		CA3184-PO	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
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
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
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
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
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
CA4145-PO	CARD_3.7.3.2.6.2	CA3213-PO	CARD_3.7.3.2

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA4150-PO	CARD_3.7.3.2.5	CA0001-HQ	CARD_3.2
		CA0013-HQ	CARD_3.2
		CA0207-HQ	CARD_3.2.5
CA4150-PO	CARD_3.7.3.2.5	CA0001-HQ	CARD_3.2
		CA0013-HQ	CARD_3.2
		CA0207-HQ	CARD_3.2.5
CA4152-PO	CARD_3.7.1.2.6		
		CA0181-HQ	CARD_3.2.6
		CA3167-PO	CARD_3.3.6
		CA3175-PO	CARD_3.2.6
CA4152-PO	CARD_3.7.1.2.6		
		CA0181-HQ	CARD_3.2.6
		CA3167-PO	CARD_3.3.6
		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
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
CA5040-PO	CARD_3.7.1.2.8		
		CA0993-PO	CARD_3.2.10

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5044-PO	CARD_3.7.4.2.10	CA0993-PO	CARD_3.2.10
CA5044-PO	CARD_3.7.4.2.10	CA0993-PO	CARD_3.2.10
CA5046-PO	CARD_3.7.9.2.10	CA0993-PO	CARD_3.2.10
CA5046-PO	CARD_3.7.9.2.10	CA0993-PO	CARD_3.2.10
CA5047-PO	CARD_3.7.9.2.10	CA0993-PO	CARD_3.2.10
CA5047-PO	CARD_3.7.9.2.10	CA0993-PO	CARD_3.2.10
CA5051-PO	CARD_3.7.5.2.10		
		CA0993-PO	CARD_3.2.10
CA5051-PO	CARD_3.7.5.2.10		
		CA0993-PO	CARD_3.2.10
CA5054-PO	CARD_3.7.3.2.10	CA0993-PO	CARD_3.2.10
CA5054-PO	CARD_3.7.3.2.10	CA0993-PO	CARD_3.2.10
CA5058-PO	CARD_3.7.6.2.10		
		CA0152-PO	CARD_3.7.6.2
		CA0993-PO	CARD_3.2.10
CA5058-PO	CARD_3.7.6.2.10		
		CA0152-PO	CARD_3.7.6.2
		CA0993-PO	CARD_3.2.10
CA5112-PO	CARD_3.7.5.2.15		
		CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
CA5112-PO	CARD_3.7.5.2.15		
		CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
CA5131-PO	CARD_3.7.6.2.13		
		CA0209-HQ	CARD_3.2.4
		CA0293-PO	CARD_3.7.6.2
CA5131-PO	CARD_3.7.6.2.13		

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		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
CA5132-PO	CARD_3.7.6.2.13		
		CA0211-HQ	CARD_3.2.4
		CA0293-PO	CARD_3.7.6.2
CA5133-PO	CARD_3.7.6.2.13		
		CA0293-PO	CARD_3.7.6.2
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
CA5135-PO	CARD_3.7.6.2.12		
		CA0038-HQ	CARD_3.2.12
		CA0152-PO	CARD_3.7.6.2
CA5148-PO	CARD_3.7.1.2.6		
		CA5604-PO	CARD_3.2.5
CA5148-PO	CARD_3.7.1.2.6		
		CA5604-PO	CARD_3.2.5
CA5149-PO	CARD_3.7.3.2.6	CA5604-PO	CARD_3.2.5
CA5149-PO	CARD_3.7.3.2.6	CA5604-PO	CARD_3.2.5
CA5155-PO	CARD_3.7.1.2.4		
		CA0822-HQ	CARD_3.2.4
CA5155-PO	CARD_3.7.1.2.4		
		CA0822-HQ	CARD_3.2.4

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5156-PO	CARD_3.7.3.2.4	CA0822-HQ	CARD_3.2.4
CA5156-PO	CARD_3.7.3.2.4	CA0822-HQ	CARD_3.2.4
CA5159-PO	CARD_3.7.2.2.2.2		
		CA0311-PO	CARD_3.2.2.2
CA5159-PO	CARD_3.7.2.2.2.2		
		CA0311-PO	CARD_3.2.2.2
CA5169-PO	CARD_3.7.9.2.2	CA0310-PO	CARD_3.2.2.2
CA5169-PO	CARD_3.7.9.2.2	CA0310-PO	CARD_3.2.2.2
CA5182-PO	CARD_3.7.9.2.13	CA5710-PO	CARD_3.2.13
CA5182-PO	CARD_3.7.9.2.13	CA5710-PO	CARD_3.2.13
CA5184-PO	CARD_3.7.9.2.13	CA5710-PO	CARD_3.2.13
CA5184-PO	CARD_3.7.9.2.13	CA5710-PO	CARD_3.2.13
CA5188-PO	CARD_3.7.9.2.15	CA0048-PO	CARD_3.2.15
CA5188-PO	CARD_3.7.9.2.15	CA0048-PO	CARD_3.2.15
CA5193-PO	CARD_3.7.3.2.2	CA0530-PO	CARD_3.2.2.2
CA5193-PO	CARD_3.7.3.2.2	CA0530-PO	CARD_3.2.2.2
CA5195-PO	CARD_3.7.3.2.6	CA0181-HQ	CARD_3.2.6
		CA3175-PO	CARD_3.2.6
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
CA5203-PO	CARD_3.7.9.2.2	CA0310-PO	CARD_3.2.2.2
CA5231-PO	CARD_3.7.3.2.6.1	CA0023-PO	CARD_3.5
		CA3211-PO	CARD_3.2.6
		CA3213-PO	CARD_3.7.3.2
CA5231-PO	CARD_3.7.3.2.6.1	CA0023-PO	CARD_3.5
		CA3211-PO	CARD_3.2.6
		CA3213-PO	CARD_3.7.3.2

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5237-PO	CARD_3.7.1.2.2.2		
		CA0352-HQ	CARD_3.2.2.2
CA5237-PO	CARD_3.7.1.2.2.2		
		CA0352-HQ	CARD_3.2.2.2
CA5238-PO	CARD_3.7.3.2.2.2	CA0352-HQ	CARD_3.2.2.2
CA5238-PO	CARD_3.7.3.2.2.2	CA0352-HQ	CARD_3.2.2.2
CA5240-PO	CARD_3.7.1.2.6		
		CA0352-HQ	CARD_3.2.2.2
CA5240-PO	CARD_3.7.1.2.6		
		CA0352-HQ	CARD_3.2.2.2
CA5247-PO	CARD_3.2.6	CA0005-HQ	CARD_3.2
CA5247-PO	CARD_3.2.6	CA0005-HQ	CARD_3.2
CA5259-PO	CARD_3.7.4.2.12	CA0413-PO	CARD_3.7.4.2.12
CA5259-PO	CARD_3.7.4.2.12	CA0413-PO	CARD_3.7.4.2.12
CA5265-PO	CARD_3.7.4.2.12	CA0413-PO	CARD_3.7.4.2.12
CA5265-PO	CARD_3.7.4.2.12	CA0413-PO	CARD_3.7.4.2.12
CA5273-PO	CARD_3.7.3.2.11	CA0314-PO	CARD_3.2.11
CA5273-PO	CARD_3.7.3.2.11	CA0314-PO	CARD_3.2.11
CA5275-PO	CARD_3.7.3.2.11	CA0121-HQ	CARD_3.2.6
CA5275-PO	CARD_3.7.3.2.11	CA0121-HQ	CARD_3.2.6
CA5284-PO	CARD_3.7.3.2.11	CA0121-HQ	CARD_3.2.6
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
CA5285-PO	CARD_3.7.3.2.11	CA0121-HQ	CARD_3.2.6
CA5286-PO	CARD_3.7.1.2.11		
		CA0121-HQ	CARD_3.2.6
CA5286-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**
CA5289-PO	CARD_3.2.5	CA0005-HQ	CARD_3.2
CA5289-PO	CARD_3.2.5	CA0005-HQ	CARD_3.2
CA5290-PO	CARD_3.7.3.2.11	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
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
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
		CA0014-HQ	CARD_3.2
CA5303-PO	CARD_3.7.3.2.6	CA0013-HQ	CARD_3.2
		CA0014-HQ	CARD_3.2
CA5316-PO	CARD_3.7.3.2.2.2	CA0028-PO	CARD_3.2.2
CA5316-PO	CARD_3.7.3.2.2.2	CA0028-PO	CARD_3.2.2
CA5323-PO	CARD_3.7.2.2.12		
		CA1066-PO	CARD_3.7.2.2.12
CA5323-PO	CARD_3.7.2.2.12		
		CA1066-PO	CARD_3.7.2.2.12
CA5355-PO	CARD_3.7.4.2.15	CA0048-PO	CARD_3.2.15
CA5355-PO	CARD_3.7.4.2.15	CA0048-PO	CARD_3.2.15
CA5360-PO	CARD_3.7.5.2.15		
		CA0048-PO	CARD_3.2.15
CA5360-PO	CARD_3.7.5.2.15		
		CA0048-PO	CARD_3.2.15
CA5399-PO	CARD_3.7.3.2.7	CA0215-PO	CARD_3.2.7
CA5399-PO	CARD_3.7.3.2.7	CA0215-PO	CARD_3.2.7
CA5400-PO	CARD_3.7.9.2.7	CA0215-PO	CARD_3.2.7
CA5400-PO	CARD_3.7.9.2.7	CA0215-PO	CARD_3.2.7

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5403-PO	CARD_3.7.4.2.7	CA0215-PO	CARD_3.2.7
CA5403-PO	CARD_3.7.4.2.7	CA0215-PO	CARD_3.2.7
CA5405-PO	CARD_3.7.6.2.7		
		CA0213-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
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
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
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
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
CA5410-PO	CARD_3.7.9.2.7	CA0214-PO	CARD_3.2.7
CA5431-PO	CARD_3.7.4.2.8	CA0874-PO	CARD_3.7.4.2.7
CA5431-PO	CARD_3.7.4.2.8	CA0874-PO	CARD_3.7.4.2.7
CA5432-PO	CARD_3.7.4.2.7	CA0874-PO	CARD_3.7.4.2.7
CA5432-PO	CARD_3.7.4.2.7	CA0874-PO	CARD_3.7.4.2.7
CA5433-PO	CARD_3.7.4.2.7	CA0874-PO	CARD_3.7.4.2.7
CA5433-PO	CARD_3.7.4.2.7	CA0874-PO	CARD_3.7.4.2.7

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
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
CA5435-PO	CARD_3.7.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA5436-PO	CARD_3.7.4.2.2	CA0027-PO	CARD_3.2.2.2
CA5436-PO	CARD_3.7.4.2.2	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
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
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
CA5439-PO	CARD_3.7.1.2.2.2		
		CA0027-PO	CARD_3.2.2.2
CA5440-PO	CARD_3.7.3.2.8	CA0027-PO	CARD_3.2.2.2
CA5440-PO	CARD_3.7.3.2.8	CA0027-PO	CARD_3.2.2.2
CA5465-PO	CARD_3.7.1.2.9		
		CA0216-PO	CARD_3.2.9
CA5465-PO	CARD_3.7.1.2.9		
		CA0216-PO	CARD_3.2.9

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5466-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
CA5469-PO	CARD_3.7.3.2.9	CA0216-PO	CARD_3.2.9
CA5469-PO	CARD_3.7.3.2.9	CA0216-PO	CARD_3.2.9
CA5470-PO	CARD_3.7.3.2.9	CA0216-PO	CARD_3.2.9
CA5470-PO	CARD_3.7.3.2.9	CA0216-PO	CARD_3.2.9
CA5471-PO	CARD_3.7.3.2.9	CA0216-PO	CARD_3.2.9
CA5471-PO	CARD_3.7.3.2.9	CA0216-PO	CARD_3.2.9
CA5472-PO	CARD_3.7.4.2.9	CA0216-PO	CARD_3.2.9
CA5472-PO	CARD_3.7.4.2.9	CA0216-PO	CARD_3.2.9
CA5473-PO	CARD_3.7.4.2.9	CA0216-PO	CARD_3.2.9
CA5473-PO	CARD_3.7.4.2.9	CA0216-PO	CARD_3.2.9
CA5474-PO	CARD_3.7.4.2.9	CA0216-PO	CARD_3.2.9
CA5474-PO	CARD_3.7.4.2.9	CA0216-PO	CARD_3.2.9
CA5475-PO	CARD_3.7.6.2.9		
		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
CA5476-PO	CARD_3.7.6.2.9		
		CA0216-PO	CARD_3.2.9

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5477-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
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
CA5479-PO	CARD_3.7.5.2.9		
		CA0216-PO	CARD_3.2.9
CA5480-PO	CARD_3.7.5.2.9		
		CA0216-PO	CARD_3.2.9
CA5480-PO	CARD_3.7.5.2.9		
		CA0216-PO	CARD_3.2.9
CA5495-PO	CARD_3.7.1.2.13		
		CA5710-PO	CARD_3.2.13
CA5495-PO	CARD_3.7.1.2.13		
		CA5710-PO	CARD_3.2.13
CA5505-PO	CARD_3.7.3.2.13	CA5710-PO	CARD_3.2.13
CA5505-PO	CARD_3.7.3.2.13	CA5710-PO	CARD_3.2.13
CA5509-PO		CA0123-PO	CARD_3.2.12
CA5512-PO	CARD_3.7.2.2.5	CA0036-HQ	CARD_3.2.5
CA5524-PO	CARD_3.7.6.2.5		
		CA0036-HQ	CARD_3.2.5
		CA0139-PO	CARD_3.7.6.2
		CA0152-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
CA5524-PO	CARD_3.7.6.2.5		
		CA0036-HQ	CARD_3.2.5
		CA0139-PO	CARD_3.7.6.2
		CA0152-PO	CARD_3.7.6.2
		CA0293-PO	CARD_3.7.6.2
CA5526-PO		CA0038-HQ	CARD_3.2.12
CA5532-PO	CARD_3.7.3.2.12	CA0037-PO	CARD_3.2.12
CA5532-PO	CARD_3.7.3.2.12	CA0037-PO	CARD_3.2.12
CA5533-PO	CARD_3.7.4.2.12	CA0037-PO	CARD_3.2.12
CA5533-PO	CARD_3.7.4.2.12	CA0037-PO	CARD_3.2.12
CA5555-PO	CARD_3.7.1.2.15		
		CA5552-PO	CARD_3.2.15
CA5555-PO	CARD_3.7.1.2.15		
		CA5552-PO	CARD_3.2.15
CA5556-PO	CARD_3.7.3.2.15	CA5552-PO	CARD_3.2.15
CA5556-PO	CARD_3.7.3.2.15	CA5552-PO	CARD_3.2.15
CA5557-PO	CARD_3.7.2.2.15		
		CA5552-PO	CARD_3.2.15
CA5557-PO	CARD_3.7.2.2.15		
		CA5552-PO	CARD_3.2.15
CA5558-PO	CARD_3.7.4.2.15	CA5552-PO	CARD_3.2.15
CA5558-PO	CARD_3.7.4.2.15	CA5552-PO	CARD_3.2.15
CA5559-PO	CARD_3.7.9.2.15	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
CA5560-PO	CARD_3.7.1.2.15		

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
		CA5552-PO	CARD_3.2.15
CA5561-PO	CARD_3.7.3.2.15	CA5552-PO	CARD_3.2.15
CA5561-PO	CARD_3.7.3.2.15	CA5552-PO	CARD_3.2.15
CA5562-PO	CARD_3.7.2.2.15		
		CA5552-PO	CARD_3.2.15
CA5562-PO	CARD_3.7.2.2.15		
		CA5552-PO	CARD_3.2.15
CA5563-PO	CARD_3.7.4.2.15	CA5552-PO	CARD_3.2.15
CA5563-PO	CARD_3.7.4.2.15	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
CA5605-PO	CARD_3.7.3.2.12	CA5600-PO	CARD_3.2.12
CA5659-PO	CARD_3.7.9.2.14	CA0530-PO	CARD_3.2.2.2
CA5659-PO	CARD_3.7.9.2.14	CA0530-PO	CARD_3.2.2.2
CA5677-PO	CARD_3.7.2.2.6	CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
CA5678-PO	CARD_3.7.4.2.6	CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
CA5678-PO	CARD_3.7.4.2.6	CA0039-HQ	CARD_3.2.6
		CA0040-PO	CARD_3.2.12
CA5690-PO	CARD_3.7.5.2.5		
		CA0125-PO	CARD_3.2.12
CA5690-PO	CARD_3.7.5.2.5		
		CA0125-PO	CARD_3.2.12
CA5702-PO	CARD_3.7.5.2.5		
		CA0125-PO	CARD_3.2.12
CA5702-PO	CARD_3.7.5.2.5		
		CA0125-PO	CARD_3.2.12

CHILD		PARENT(s)	
CARD Req No.	Doc Section	CARD Req No.	Doc Section
CA5805-PO	CARD_3.7.2.2.1		
		CA0213-PO	CARD_3.2.7
		CA0214-PO	CARD_3.2.7
CA5805-PO	CARD_3.7.2.2.1		
		CA0213-PO	CARD_3.2.7
		CA0214-PO	CARD_3.2.7
CA5806-PO	CARD_3.7.4.2.7	CA0213-PO	CARD_3.2.7
		CA0214-PO	CARD_3.2.7
CA5806-PO	CARD_3.7.4.2.7	CA0213-PO	CARD_3.2.7
		CA0214-PO	CARD_3.2.7
CA5812-HQ	CARD_3.2.7	CA0100-HQ	CARD_3.2.7
CA5816-PO	CARD_3.7.2.2.9	CA0216-PO	CARD_3.2.9
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
CA5825-PO	CARD_3.7.2.2.7	CA3163-PO	CARD_3.7.2.2.2.1
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
CA5911-PO	CARD_3.7.4.2.10	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	CA0566-PO	CARD_3.7.2.2.7
CA5918-PO	CARD_3.7.4.2.7	CA0874-PO	CARD_3.7.4.2.7
CA5919-PO	CARD_3.7.2.2.7	CA0566-PO	CARD_3.7.2.2.7
CA5920-PO	CARD_3.7.4.2.7	CA0874-PO	CARD_3.7.4.2.7

CHILD		PARENT(s)	
CARD Req No.	**Doc Section**	**CARD Req No.**	**Doc Section**
CA5930-PO	CARD_3.7.4.2.1	CA0213-PO	CARD_3.2.7
CA5934-PO	CARD_3.7.5.2.13	CA5710-PO	CARD_3.2.13
CA5935-PO	CARD_3.2.13	CA5710-PO	CARD_3.2.13
CA5940-PO	CARD_3.4	CA0001-HQ	CARD_3.2
		CA0889-HQ	CARD_3.2
CA5941-PO	CARD_3.4	CA0039-HQ	CARD_3.2.6
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