National Aeronautics and Space Administration

Commercial Crew Program
John F. Kennedy Space Center

CCT-STD-1140
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Crew Transportation
Technical Standards and Design Evaluation Criteria

Date

Date

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1.0 Introduction

Under the guidance of processes provided by *Crew Transportation Plan* (CCT-PLN-1100), implementation of this document with its sister documents, *Crew Transportation Technical Management Processes* (CCT-PLN-1120), *ISS Crew Transportation and Services Requirements Document* (CCT-STD-1130)*, Crew Transportation Operations Standards* (CCT STD-1150), and *ISS to Commercial Orbital Transportation Services Interface Requirements Document* (SSP 50808), may achieve a National Aeronautics and Space Administration (NASA) certification for services to the International Space Station (ISS) for the Commercial Partner. When NASA Crew Transportation System (CTS) certification is achieved for ISS, the Commercial Partner will be eligible to provide transportation services to and from the ISS during the Services phase of the NASA Commercial Crew Program (CCP).

1.1 Purpose

In the course of over forty years of human space flight, NASA has developed a working knowledge and body of standards that seek to guide both the design and the evaluation of safe designs for space systems. The purpose of this document is to inform potential Commercial Partners of the specifications, standards, and products/artifacts that NASA considers crucial to a successful development effort, and to provide the Commercial Partner with NASA expectations, essentially the technical criteria, used in assessing these items to ensure they meet the intent of Sections 3.9 through 3.12 of CCT-REQ-1130.

The verification of technical standard requirements that utilize the "meet the intent of" language are addressed in this volume and may be satisfied through the use of alternative standards instead of the NASA, military, or industry standard listed. For these alternative standards, CCT-STD-1140 will be utilized to define the evaluation criteria that the NASA CCP will use to determine whether the proposed standard is acceptable.

Discipline specific technical work products/artifacts (e.g., plans, analyses, reports, etc.) are also called out in this volume, along with the criteria that will be used to evaluate them. The intent is to identify products that NASA deems critical to the ultimate successful certification of a CTS. It is NASA's expectation that any successful Commercial Partner's development activities would already involve these products. By listing these items in the technical products section of this document it is not NASA's intent to convey a request for formal deliverables.

CCT-STD-1140 is organized by discipline with each section containing the key products and technical assessments that will be used as a benchmark to determine acceptability of the Commercial Partner's technical standards and products.

Once the Commercial Partner and NASA have reached an agreement on an alternative technical standard, it will be added to the partnered set of standards for the CTS. Once this partnered set of standards is in place, it will be used in design evaluations in lieu of the standard called by CCT-REQ-1130. The content of CCT-STD-1140 will continue to be utilized as a reference for the types of products and analysis that are typically evaluated to establish technical adequacy for each discipline.

1.2 Scope

This document includes the criteria, expectations, and insight criteria that will be used in the evaluation of technical standards for launch vehicle, spacecraft, and ground system requirements identified by the International Space Station (ISS) Program and the CCP for the CTS. The CTS refers to all assets and services necessary to meet the requirements of CCT-REQ-1130, including pre-flight planning, trajectory and abort analysis, ground processing and manufacturing, ground operations, mission control, training, launch control, launch, on-orbit operations, post-landing recovery operations, safety and mission assurance, and all other functions required for safe and successful human space flight missions. When elements of the CTS are technical or specific to a requirement, they will be called out. For example, the term ***CTS spacecraft*** will be used when the launch vehicle and ground elements are not specific to that portion of the design.

1.3 Precedence

In the event of a conflict between the text of this document (CCT-STD-1140) and references cited herein (listed in Section 2.0), the text of this document takes precedence. The exception to this statement is for SSP 50808, which takes precedence during the arrival, docked, and departure operations. Nothing in this document supersedes applicable laws and regulations, unless a specific exemption has been obtained.

1.4 Delegation of Authority

This document was jointly prepared and will be jointly managed by the CCP and NASA ISS Program Office. CCT-STD-1140 will be maintained in accordance with standards for the CCP documentation. The responsibility for assuring the definition, control, implementation, and verification of the requirements identified in this document is the CCP. Coordination with the NASA ISS Program for verification and eventual certification of the requirements will be performed through the CCP Office.

2.0 Documents

2.1 Requirements Applicability Matrix

The table below indicates where, in CCT-STD-1140, a discipline has documented the evaluation that will be performed of the Commercial Partner's technical standard to determine if it meets the intent of the listed NASA or industry standard. This table also includes references to the appropriate section of CCT-REQ-1130 where that standard is specified.

Document Number	Title and CCT-REQ-1130 Requirement	CCT-STD-1140 Reference	CCT-STD-1140 Description
20M0540	*Assessment of Flexible Lines for Flow-Induced Vibration* (3.9.9.4)	7.6.2	Fluid Systems
AIAA S-080-1998	*Space Systems-Metallic Pressure Vessels, Pressurized Structures, and Pressure Components* (3.9.9.2)	7.6.2	Fluid Systems
AIAA S-081A-2006	*Space Systems Composite Overwrapped Pressure Vessels* (3.9.9.1)	7.6.2	Fluid Systems
ANSI/ESD S20.20	*Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)* (3.9.3.13.2)	7.1.8.2 7.2.2	Avionics and Electrical Systems EEE Parts Management
ANSI Z136.2	*Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources* (3.9.3.5.1)	4.24.2	Safety and Mission Assurance
FAA AC 20-136A	*Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning* (3.9.3.17)	7.1.7.2	Avionics and Electrical Systems
GEIA-STD-005-1	*Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-Free Solder* (3.9.3.7.3)	TBD-033	
GEIA-STD-005-2	*Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronics* (3.9.3.7.4)	7.2.2	EEE Parts Management
IPC J-STD-001D	*J-STD 001D, Requirements for Soldered Electrical and Electronic Assemblies* (3.9.3.7.1, 3.9.3.7.2)	7.1.5.2	Avionics and Electrical Systems
IPC J-STD-001D Amendment 1	*Space Applications Electronic Hardware Addendum to J-STD 001D, Requirements for Soldered Electrical and Electronic Assemblies* (3.9.3.7.1, 3.9.3.2)	7.1.5.2	Avionics and Electrical Systems
IPC-2152	*Standard for Determining Current Carrying Capacity in Printed Circuit Board Design* (3.9.3.3.3)	7.1.5.2	Avionics and Electrical Systems
IPC-2220 Series	*Family of Printed Board Design Documents* (3.9.3.3.3)	7.1.5.2	Avionics and Electrical Systems
IPC-6010 Series	*Family of Printed Board Performance Documents* (3.9.3.3.2)	7.1.5.2	Avionics and Electrical Systems

Document Number	Title and CCT-REQ-1130 Requirement	CCT-STD-1140 Reference	CCT-STD-1140 Description
IPC-CM-770	*Component Mounting Guidelines for Printed Boards* (3.9.3.12.2)	7.1.5.2	Avionics and Electrical Systems
JSC 20793	*Crewed Space Vehicle Battery Safety Requirements* (3.9.3.11.1)	7.1.4.2	Avionics and Electrical Systems
JSC 62550	*Strength Design and Verification Criteria for Glass, Ceramics, and Windows in Human Space Flight Applications* (3.9.8.1.2)	7.5.1	Structures
JSC 62809 Rev D	*Human-Rated Spacecraft Pyrotechnic Specification* (3.9.7)	7.8.2	Pyrotechnics
JSC 65827	*Thermal Protection System Design Standard for Spacecraft* (3.9.6)	7.4.1	Thermal Protection Systems
JSC 65828 Baseline	*Structural Design Requirements and Factors of Safety for Space Flight Hardware* (3.9.8.1.1)	7.5.1 7.7.2	Structures Propulsion Systems
JSC 65829	*Loads and Structural Dynamics Requirements for Space Flight Hardware* (3.9.8.2)	5.1.2 5.2.2 7.6.2 7.7.2	Structural Dynamics Integrated Vehicle Dynamics Fluid Systems Propulsion Systems
JSC 65985	*Requirements for Human Space Flight for the Trailing Deployable Aerodynamic Decelerator (TDAD)* (3.9.4.1.1)	7.9.2	Trailing Deployable Aerodynamic Decelerator
MIL-STD-461	*Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment* (3.9.3.14.1)	7.1.6.2	Avionics and Electrical Systems
MIL-STD-464	*Electromagnetic Environmental Effects Requirements for Systems* (3.9.3.15.1)	7.1.6.2	Avionics and Electrical Systems
MIL-STD-981	*Design, Manufacturing and Quality Standards for Custom Electromagnetic Devices for Space Applications* (3.9.3.16.1)	7.1.6.2	Avionics and Electrical Systems
NASA-STD-4003	*Electrical Bonding For NASA Launch Vehicles, Spacecraft, Payloads, And Flight Equipment* (3.9.3.10.1)	7.1.9.1	Avionics and Electrical Systems
NASA-STD-4005	*Low Earth Orbit Spacecraft Charging Design Standard* (3.9.3.13.1)	TBD-035	
NASA-STD-5005	*Standard for the Design and Fabrication of Ground Support Equipment* (3.10)	6.2	Ground Systems Design
NASA-STD-5009	*Nondestructive Evaluation Requirements for Fracture Critical Metallic Elements* (3.9.10.34)	TBD-036	
NASA-STD-5012	*Strength and Life Assessment Requirements for Liquid Fueled Space Propulsion System Engines* (3.9.10.1)	7.5 7.7.2	Structures Propulsion Systems
NASA-STD-5017	*Design and Development Requirements for*	7.3	Mechanisms

Document Number	Title and CCT-REQ-1130 Requirement	CCT-STD-1140 Reference	CCT-STD-1140 Description
	Mechanisms (3.9.5)	7.2.6	Fluid Systems
NASA-STD-5019	*Fracture Control Requirements for Spacecraft* (3.9.11.1)	8.1 7.6.2 7.7.2	Fracture Control Fluid Systems Propulsion Systems
NASA-STD-5020	*Requirements and Standard Practices for Mechanical Joints with Threaded Fasteners in Space Flight Hardware* (3.9.8.3)	7.5	Structures
NASA-STD-6016	*Standard Manned Spacecraft Requirements for Materials and Processes* (3.9.1.1)	8.2 7.6.2 7.7.2	Materials and Processes Fluid Systems Propulsion Systems
NASA-STD-8719.12	*Safety Standard for Explosives, Propellants, and Pyrotechnics* (3.9.9.34)	4.1.2	Safety and Mission Assurance
NASA-STD-8739.1	*Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies* (3.9.3.6.1, 3.9.3.12.1)	7.1.5.2	Avionics and Electrical Systems
NASA-STD-8739.4	*Crimping, Interconnecting Cables, Harnesses, and Wiring* (3.9.3.2.1, 3.9.3.8.1)	7.1.3.2	Avionics and Electrical Systems
NASA-STD-8739.5	*Fiber Optic Terminations, Cable Assemblies, and Installation* (3.9.3.5.2)	7.1.3.2	Avionics and Electrical Systems
NPR 7150.2A	*NASA Software Engineering Requirements* (3.9.2.1)	9.1.2	Flight and Ground Software
SAE ARP 5412A	*Aircraft Lightning Environment and Related Test Waveforms* (3.9.3.17)	7.1.7.2	Avionics and Electrical Systems
SAE ARP 5414A	*Aircraft Lightning Zoning* (3.9.3.17)	7.1.7.2	Avionics and Electrical Systems
SAE ARP 5577	*Aircraft Lightning Direct Effects Certification* (3.9.3.17)	7.1.7.2	Avionics and Electrical Systems
SMC Standard SMC-S-016 (2008) **MIL-STD-1540 C MIL-STD-1540 E (Draft) Aerospace Report No. TR-2004**	*Test Requirements for Launch, Upper-Stage, and Space Vehicles* (3.12)	7.2.2 7.6.2 7.7.2	EEE Parts Management Fluid Systems Propulsion Systems
SMC Standard SMC-S-010	*Space and Missile Systems Center Standard, Parts, Materials, and Processes Technical Requirements for Space and Launch Vehicles* (3.9.12.1)	7.2.1	EEE Parts Management
NASA-STD-8739.3	*Soldered Electrical Connections* (3.9.3.7.1)	7.1.5.2	Avionics and Electrical Systems

2.2 Reference Documents

This section provides a list of technical and manufacturing standards that can be used as references during the launch vehicle, spacecraft, and ground system design activities. These references are not part of the formal requirements levied via CCT-REQ-1130.

Document	*Title*
15 CFR Part 287	*Guidance on Federal Conformity Assessment*
ADS-TR-61-579	*Performance of and Design Criteria for Deployable Aero Decelerators*
AFFDL-TR-72-3	*Ringsail Parachute Design (Ewing)*
AFSCMAN 91-710	*Range Safety User Req'ts Manual 91-710*
AGARDograph No. 319	*Design and Testing of High-Performance Parachutes*
AGARDograph No. 6295	*The Aerodynamics of Parachutes*
AIAA S-111-2005	*Qualification and Quality Requirements for Space Solar Cells*
AIAA S-112-2005	*Qualification and Quality Requirements for Space Solar Panels*
ANSI/AIAA S-102.2.4-2009	*Performance Based Product Failure Mode, Effects, and Criticality (FMECA) Requirements*
ARM-10	*Apollo Technical Manual - Reliability*
AS9003	*Inspection and Test Quality System*
ASME Boiler and Pressure Vessel Code, Sections VIII Divisions 1, 2, and 3	
ASTM D6193	*Standard Practice for Stitches and Seams*
ASTM E1066-95	*Standard Test Method for Ammonia Colorimetric Leak Testing*
ASTM Manual 36	*Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation*
AWS D1.2/D1.2M	*Structural Welding Code-Aluminum*
AWS D1/D1.1M	*Structural Welding Code-Steel*
CxP 70038	*Constellation Program Hazard Analyses Methodology*
CxP 70043	*Constellation Program Hardware Failure Modes and Effects Analysis and Critical Items List (FMEA/CIL) Methodology*
DNA-TR-84-140	*Satellite Hardness and Survivability; Testing Rationale for Electronic Upset and Burnout Effects*
DOD-STD-2167A	*Defense Systems Software Development*
DOT/FAA/AR-MMPDS-01	*Metallic Materials Properties Development and Standardization*
EIA/IEEE J-STD-016-1995	*Standard for Information Technology Software Life-Cycle Processes Software Development Acquirer-Supplier Agreement*
FED-STD-209E	*Clean Room and Work Station Requirements, Controlled Environments*
GER-12616	*State-of-the-Art Study for High-speed Deceleration and Stabilization Devices*
GIDEP S0300-BT-PRO-010	*GIDEP Operations Manual*
GIDEP S0300-BU-GYD-010	*Government-Industry Data Exchange (GIDEP) Requirements Guide*
GSFC-STD-1000	*Goddard Space Flight Center Rules for the Design, Development, Verification, and*

Document	*Title*
	Operation of Flight Systems
IEEE 730-2002	*IEEE Standard for Software Quality Assurance Plans*
IEST-STD-CC1246D	*Product Cleanliness Levels and Contamination Control*
ISO 14644	*Cleanroom Standards*
ISO 9001	*Quality Management Systems Requirements*
JPR 8080.5	*JSC Design and Procedural Standards*
JSC 25863B	*Program Requirements Document for Johnson Space Center Non-Critical Government Furnished Equipment*
JSC EA3-10-015	*Deployable Aerodynamic Decelerator Requirements for Human Space Flight (3.9.9)*
JSC-49774	*Standard Manned Spacecraft Criteria for Materials and Processes*
JSSG-2010-12	*Crew Systems Deployable Aerodynamic Decelerator (DAD) Systems Handbook*
KSC-DE-512	*Facility, System, and Equipment General Design Requirements*
KSC-NE-9439	*KSC Design Engineering Handbook for Design and Development of Ground Systems*
KSC-STD-Z-0006	*Standard for Design of Hypergolic Propellants Ground Support Equipment*
MFSC-STD-3012	*EEE Parts Management and Control for MSFC Space Flight Hardware*
MIL-A-83577B	*Assemblies, Moving Mechanical, For Space and Launch Vehicles, General Specification for*
MIL-C-5541	*Chemical Conversion Coatings on Aluminum and Aluminum Alloys*
MIL-H-7195	*General Specification for Parachute Hardware*
MIL-HDBK-17/1	*Composite Materials Handbook*
MIL-HDBK-340A	*Volume II Test Requirements for Launch, Upper Stage and Space Vehicles: Application Guidelines*
MIL-HDBK-5H	*Metallic Materials and Elements for Aerospace Vehicle Structures*
MSFC-HNDBK-505	*Structural Strength Program Requirements*
MIL-HDBK-83578	*Criteria for Explosive Systems and Devices Used on Space Vehicles*
MIL-P-27401C	*Propellant Pressurizing Agent, Nitrogen*
MIL-P-5160	*Parachute Assemblies and Major Sub-Assemblies, Packaging and Packing of*
MIL-STD-1246C	*Product Cleanliness Levels and Contamination Control Program*
MIL-STD-129	*Marking for Shipment and Storage*
MIL-STD-1522A	*Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems*
MIL-STD-1541	*Electromagnetic Compatibility Requirements for Space Systems*
MIL-STD-1546	*Parts, Materials, and Process Program Requirements*
MIL-STD-1576	*Electroexplosive Device Test Methods*
MIL-STD-1833	*Test Requirements for Ground Equipment and Associated Computer Software Supporting Space Vehicles*
MIL-STD-810G	*Environmental Test Methods and Engineering Guidelines*
MIL-STD-882	*Standard Practice for System Safety*
MIL-STD-1553	*Military Standard: Aircraft Internal Time Division Command/Response Multiplex Data Bus*
MSFC-SPEC-164	*Cleanliness of Components for Use in Oxygen, Fuel and Pneumatic Systems Spec*
MSFC-STD-156	*Riveting, Fabrication, and Inspection, Standard For*
MSFC-STD-3535	*Standard for Propellants and Pressurants Used for Test and Test Support Activities at SSC and MSFC*
MSFC-STD-486	*Standard Radiographic Inspection and Acceptance Standards for Fusion-Welded Joints*

Document	***Title***
	in Stainless and Heat-resistant Steel
NASA SP-8057 (revised 1972)	*Structural Design Criteria Applicable to a Space Shuttle*
NASA TN D-5968	*An investigation of the initial century series ringsail parachute*
NASA-CR-131200	*Apollo Parachute Landing System (Knacke)*
NASA-HDBK-1001	*Launch Site Climatic Data*
NASA-HDBK-7005	*Dynamic Environmental Criteria*
NASA-HNBK-5010 Volume 1	*Fracture Control Implementation Handbook for Space Flight Hardware other than Composite or Bonded Parts*
NASA-HNBK-5010 Volume 2	*Fracture Control Implementation Handbook for Space Flight Hardware Composite or Bonded Parts*
NASA-STD-2202-93	*Software Formal Inspections Standard*
NASA-STD-3000	*Space Flight Human System Standards*
NASA-STD-5002	*Load Analyses of Spacecraft and Payloads*
NASA-STD-7009	*Standard for Models and Simulations*
NASA-STD-8719.9	*Standard for Lifting Devices and Equipment*
NASA-TM-X-74335	*U.S. Standard Atmosphere, 1976*
NASA/SP-2010-3407	*Human Integration Design Handbook*
NESC-RP-06-108/05-173-E	*Design, Development Test and Evaluation (DDT&E) Considerations for Safe and Reliable Human-Rated Spacecraft Systems*
No Number	*NASA Fault Tree Handbook with Aerospace Applications,* *Version 1.1, dated August 2002* *http://www.hq.nasa.gov/office/codeq/doctree/texttree.htm*
NPD 8700.1	*NASA Policy for Safety and Mission Success*
NPD 8700.3	*SMA Policy for NASA Spacecraft, Instruments, and Launch Services*
NPD 8720.1	*NASA Reliability and Maintainability (R&M) Program Policy*
NPD 8730.1	*Metrology and Calibration*
NPR 2810.10	*Security of Information Technology*
NPR 6000.1	*Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment and Associated Components*
NPR 7120.5	*NASA Space Flight Program and Project Management Requirements*
NPR 7123.1	*NASA Systems Engineering Processes and Requirements*
NPR 8705.2	*NASA Human-Rating Requirements for Space Systems*
NPR 8715.3	*NASA General Safety Program Requirements*
NPR 8735.1	*Procedures for Exchanging Parts, Materials, and Safety Problem Data Utilizing the Government-Industry Data Exchange Program (GIDEP) and NASA Advisories*
NPR 8735.2	*Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts*
NWC TP 6575	*Parachute Recovery Systems Design Manual*
RTCA DO-160E	*Environmental Conditions and Test Procedures for Airborne Equipment (Sections 22 and 23)*
SAE ARP 4761	*Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*
SAE ARP 5416	*Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of*

Document	*Title*
	Lightning
SSP 30558	*Fracture Control Requirements for Space Station*
STO0407	*Cleanliness Requirements, Space Vehicles*
TBD	*JANNAF Test and Evaluation Guideline for Liquid Rocket Engines*

3.0 Background

This document has been divided into several disciplines that are traditionally part of every human-rated space flight program. Each discipline section outlines the products and processes that are typically part of, and critical to, the success of a highly complex space transportation system. The products and processes generally focus on ensuring that a comprehensive approach is taken that is consistent with the safety requirements of a human-rated system.

Each section starts with a general narrative and has three subsections as defined below:

Technical Products
A description of discipline specific artifacts that typically support the development effort and are used to substantiate the adequacy of required Commercial Partner standards called out in Section 3.9 of CCT-REQ-1130 and/or are considered a crucial product in the review of the Commercial Partner's development effort. Acceptable governing standards and processes should call for the creation of these products in some form by the Commercial Partner. The Commercial Partner may use internal processes, formats, standards, and specifications for the development of these products.

There are several technical products that will be reviewed by most of the disciplines, systems, and subsystems for substantiating the standards and processes used for designing, developing, and certifying the CTS. Examples of such artifacts are listed below. This list is not meant to be a formal list of deliverables, but is meant to convey to the Commercial Partner the typical artifacts that should be reviewed to evaluate proposed Commercial Partner designs, standards, and processes.

- Development testing results (components, subsystem, system-level)
- Design certification/qualification test results (components, subsystem, system-level)
- Design certification/qualification review data package (components, subsystem, system-level)
- Acceptance criteria and procedure (system, subsystem, and component)
- Critical design review data packages
- Failure modes and effects analysis results
- Reliability predictions and basis for predictions documentation
- Hardware specifications (components, subsystem, system-level)
- Interface control documentation
- Drawings or equivalent solid models
- System connectivity and functional schematics
- Structural and fatigue analysis reports
- Material properties
- Materials acceptance/process control plan
- Avionics functional decomposition (components, subsystem, system-level)
- Sensors/instrumentation specification and function
- Software testing and verification results
- Engineering change proposals process, material discrepancy report system, and non-conformance reporting (components, subsystem, system-level)
- Hardware acceptance test criteria (components, subsystem, system-level)

Technical Assessment

This section has a description of the technical criteria that will be used in assessing the adequacy of the Commercial Partner's standards and reflects NASA's areas of emphasis in reviewing the Commercial Partner's design. This section will describe areas of emphasis from relevant NASA and industry standards for determining if the Commercial Partner's proposed design standards meet the intent of the design standards required by Section 3.9 of CCT-REQ-1130.

This section may also describe the insight criteria that will be used to evaluate the adequacy of the Commercial Partner's design, beginning with the evaluation of the Commercial Partner's standards and processes.

References (optional)

Discipline specific list of relevant NASA and industry specifications, standards, and processes that NASA currently uses to design, develop, and certify human space flight programs. Discipline sections may include this information in order to provide the Commercial Partner a complete listing of all available technical standards that may be used for design, development, test, and evaluation of a CTS. The Commercial Partner does not need to meet the intent of these standards unless they are specified as such in CCT-REQ-1130 and Table 2.1 of CCT-STD-1140.

4.0 Safety and Mission Assurance

Safety and Mission Assurance (S&MA) encompasses the traditional disciplines of Safety, Reliability, Maintainability, and Quality Assurance. This section provides guidance on the S&MA processes outlined in CCT-PLN-1100 and the requirements contained in CCT-REQ-1130. Human Certification relies heavily on the technical activities and products described in the following S&MA sections and in CCT-PLN-1120. Other sections of this document, such as design, test, production, and workmanship standards are also of interest by S&MA, but are handled by other technical management. The following sections describe the CCP approach to the evaluation of the technical standards called in CCT-REQ-1130 for S&MA.

4.1 Safety Standard for Explosives, Propellants, and Pyrotechnics

4.1.1 Safety Standard for Explosives, Propellants, and Pyrotechnics Technical Products

An Explosive Safety Plan would summarize the approach and additional definition can be found in Section 7.8 of this document.

4.1.2 Safety Standard for Explosives, Propellants, and Pyrotechnics Technical Assessment

Review and analysis of the explosives, propellants, and pyrotechnics documentation and procedures will determine if the Commercial Partner's standards meet the intent of NASA-STD-8719.12 *Safety Standard for Explosives, Propellants, and Pyrotechnics*.

For vehicle, launch site, and any other locations where NASA personnel are operating, the Explosive Safety Plan should address:

- Operational Explosives Limits.
- Personnel Limits.
- Limit Control.
- Identification of live and inert hardware.
- Security and training.
- Operating procedures.
- Explosion hazards and exposure risk management.

4.2 Safe Use of Laser Diode and LED Sources

4.2.1 Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources Technical Products

An Optical Fiber and laser diode utilization plan would guide the design and use of these devices and should include as a minimum:

- A listing of all laser devices used during planned ground and flight operations where NASA personnel will be potentially exposed to laser sources.
- The laser specification (e.g., wavelength, power output for nominal and worst case failure scenario, etc.).
- Operational procedures, including hazard controls.

4.2.2 Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources Technical Assessment

Review and analysis of the Commercial Partner documentation and procedures will determine if the Commercial Partner's standards meet the intent of ANSI Z136.2 *Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources*.

5.0 Integrated Analysis

All integrated analyses should include the following important attributes. Documentation should demonstrate that these elements have been captured.

- All vehicle and environmental models use, address, and sufficiently account for uncertainties inherent in modeling and environment characterization.
- Interactions and relationships between subsystems are identified and defined.
- The operations team for the vehicle/mission is involved with the design teams from the earliest design phases to provide input to the design teams and to understand design decisions made.
- The coordinate frames and the system of units (and associated conversion factors) that are to be employed are documented and compliance is rigorously enforced.
- An integrated vehicle analysis that accounts for subsystem interactions and overall mission design.

5.1 Structural Dynamics Analysis, Loads, and Models

The purpose of analyses performed to predict loads and structural dynamic responses is to evaluate events which occur over the course of a vehicle's mission profile and ensure that bounding design conditions are defined. Design-to loading conditions must be identified with sufficient accuracy and statistical likelihood to preclude structural failure over the vehicle design and operational life-cycle. Key to this effort are the fidelity of the characterizations of the environments and loading sources to which a structure will be exposed and of models used for prediction of dynamic responses over the entire spectrum of excitation frequencies.

5.1.1 Structural Dynamics Analysis, Loads, and Models Technical Products

Products to substantiate adequacy of loads and dynamic response predictions typically include both models and analysis reports. These reports should document analyses (e.g., loads, vibration, vibroacoustic, etc.) conducted on the vehicle, its systems, subsystems, and components to generate data used to calculate stresses and/or to identify operational limits and restrictions. Analysis documentation/reports should include assumptions, boundary conditions, applied environments (natural and induced), and forcing functions for response analyses, rationale, models, and appropriate results. Appropriate results include all significant loads encountered during vehicle service life, from manufacturing to the end of service, and vibroacoustic environments to be used for range safety, transportation, hardware qualification, and workmanship screening. Additional products, including failsafe flight data (i.e., black box or telemetry) and system models, will be required for reconstruction following major anomalies, failures, or aborts.

Analysis reports should also include documentation of all math models used for loads and dynamic response analyses. Verification and correlation of models should be well documented with the model validation data accessible and traceable to the appropriate model. Model descriptions should indicate pertinent modeling parameters, model display, material properties used, and type of model.

5.1.2 Structural Dynamics Analyses, Loads, and Models Technical Assessment

NASA has a strong expectation that any Commercial Partner-developed standard for structural dynamics analysis, loads development, and models would include, at minimum:

- Performance of a minimum of two load cycles, including a preliminary design cycle and a verification analysis cycle.
- Use of validated models in the verification analysis cycle.

- Use of validated environments and forcing functions in the verification analysis cycle.
- Documentation of all models, environments, and forcing functions developed for assessment of all mission phases and all associated output requests, load indicators, load indicator redlines, and output transformation matrices.
- Review of the structural dynamic analyses, loads, and models will determine if a Commercial Partner's standards meet the intent of JSC-65829 *Loads and Structural Dynamics Requirements for Space Flight Hardware*. Review will place specific emphasis on:
  - Model validation.
  - Dynamic event selection and associated forcing function development.
  - Treatment of combination of effects of simultaneous or event-consistent load sources.
  - Treatment of combination of effects of quasi-static, low-frequency transient, and random loading environments.
  - Vehicle natural and induced environments used in dynamic response prediction.
  - Validation of induced environments used in dynamic response prediction.
  - Expected sources of data for anomaly/failure investigation and resolution.
  - Engine margin validation.

Specific goals of this review are to:
- Verify that the process/approach used to model the dynamics – including frequencies, modes, and damping - is complete, accurate, and incorporates appropriate uncertainty factors.
- Verify predicted responses for critical mission events via NASA Independent Verification and Validation (IV&V) coupled loads analysis using contractor models and forcing functions.
- Validate that frequencies and modes of the dynamic models are traceable to ground testing.
- Validate the induced crew cabin internal environments (acceleration, vibration, acoustic, shock) to which the flight crew will be exposed.
- Validate flight environments and flight loads.
- Validate the self-induced environments and loads to which the engine(s) will be exposed.
- Validate the engine environments and loads to which the vehicle components will be exposed during all phases of main propulsion system (MPS) development, green run, and flight, in which the engine and vehicle are hot-fire tested as a system, such as during stage green-run or MPS development tests.

Final determination that the vehicle, element (stage), system, and/or components are qualified with respect to dynamic loads and environments will be based on review of:
- Qualification/acceptance documentation, including associated test documents and data.
- Vibroacoustic and shock environment derivation analyses, including validating test data and analyses.
- Forcing functions for all significant flight events, including derivation methodologies and supporting flight/ground test data and analyses used.
- Mapping of environments to elements, system, or component locations.
- Performance requirements and substantiating ground and flight test data.

5.1.3 Structural Dynamics Analyses, Loads, and Models References

Document Number	***Title***
NASA-STD-5002	*Load Analyses of Spacecraft and Payloads*
NASA-HDBK-7005	*Dynamic Environmental Criteria*

5.2 Integrated Vehicle Dynamics Analysis

5.2.1 Integrated Vehicle Dynamics Technical Products

During atmospheric and exoatmospheric flight, space flight vehicles are subject to numerous sets of circumstances where the possibility exists for coupling between the vehicle dynamic response and either external or self-induced excitation and/or operation of vehicle subsystems. Among these are static and dynamic aeroelastic instabilities, pogo, control/structure interaction, etc. Generally, flight vehicles cannot be designed to withstand these phenomena. Rather, analyses are performed to demonstrate margins with respect to onset of these effects (divergence, flutter, panel flutter, control reversal, control/structure interaction, pogo stability, etc.).

Section 6 in JSC-65829 defines requirements covering coupling phenomena or other interaction between structural dynamics and aerodynamic environments, vehicle control systems, or propulsion system elements. Such requirements encompass multiple technical disciplines including structures, propulsion, aerodynamic, and control system architecture. It is expected that Commercial Partners may have existing standards and design practices to address and mitigate these dynamic coupling phenomena. In this event, the adequacy of such standards/practices is subject to review with respect to the requirements in JSC-65829.

Products to substantiate adequacy of integrated vehicle dynamics consideration should consist of analysis models and reports documenting analyses conducted on the vehicle, its systems, subsystems, and components to generate data used to establish margins with respect to the various coupling phenomena. Analysis documentation/reports should include assumptions, boundary conditions, applied environments (natural and induced) and forcing functions for response analyses, rationale, models, and appropriate results.

Analysis reports should also include documentation of all math models used for the analyses. Verification and correlation of models should be well documented with the model validation data accessible and traceable to the appropriate model. Model descriptions should indicate pertinent modeling parameters, model display, material properties used, and type of model.

5.2.2 Integrated Vehicle Dynamics Technical Assessment

Review and assessment of integrated dynamics analyses will determine if a Commercial Partner's standards meet the intent of JSC-65829, Loads and Structural Dynamics Requirements for Space Flight Hardware. Review will and assessment will emphasize:

- Validation of the process/approach used to model the dynamics – including frequencies, modes, and damping
- Validation of the models used in performing the analyses
- Validation of induced environments used in dynamic response prediction
- Demonstration of required margins for static and dynamic aeroelastic effects (divergence, flutter, panel flutter, control surface buzz, control reversal, etc.)
- Characterization of stall flutter and verification of positive structural/control margins at high angle-of-attack (where applicable to vehicle design)
- Demonstration of required control system stability margins with respect to vehicle flexible dynamics
- Results and margins from pogo stability analysis
- Evaluation of propulsion thrust oscillation, if any, on the integrated vehicle stack

- Predictions of vehicle slosh mode frequencies and damping
- Demonstration of required control system stability margins with respect to vehicle slosh modes
- Mitigation of flow-induced vibration in flex hoses and bellows
- Availability of data and models for anomaly/failure investigation and resolution

5.2.3 Integrated Vehicle Dynamics References

Document Number	*Title*
NASA SP-8057 (revised 1972)	*Structural Design Criteria Applicable to a Space Shuttle*
NASA-HDBK-7005	*Dynamic Environmental Criteria*

5.3 Flight Mechanics and GN&C

The purpose of analyses and tests performed in this area is to demonstrate that vehicle flight will be safe and successful with respect to these discipline areas through analysis. Key to this effort is correct modeling of the various vehicle systems along with their uncertainties, and rigorous verification.

5.3.1 Flight Mechanics and GN&C Technical Products

Products to substantiate adequacy of flight mechanics and GN&C analysis and test typically include both models and analysis and test reports. Analysis reports should include sufficient information to demonstrate that the appropriate amount of rigorous analysis has been conducted, and provide the detail necessary for the reader to reach the same conclusions. Analysis reports should also include documentation of all math models and simulations used. Verification and correlation of models and simulations should be well documented with the model validation data accessible and traceable to the appropriate model. Likewise, test reports should document the appropriate testing sufficient for the reader to verify that the tests were appropriately conducted and that the results were successful.

5.3.2 Flight Mechanics and GN&C Technical Assessment

NASA has a strong expectation that any Commercial Partner flight mechanics and GN&C analysis for human-rated systems would include, at minimum:

- High-fidelity 6 degree-of-freedom time domain simulation including dispersions and failure modes is performed.
- Flight control designs meet stability and controllability criteria when the analysis shows that all performance criteria are met with dispersed conditions without saturating the flight controls and that there is rigid body stability with 6db gain margin and 30 degrees phase margin for nominal conditions, with equivalent robustness measures for non-classical control design approaches, and stability demonstrated for flexible body modes and dispersed conditions with appropriate margins. Controllable means that there is sufficient control power available to initiate or counter a translation or rotation, in the presence of disturbances. The level of control power required must take into account the amount needed for stability augmentation, plus the amount needed for maneuvering, plus an appropriate margin
- Flight control system stability analysis determines what, if any, slosh damping characteristics are required to maintain vehicle or spacecraft stability.
- Dispersion analysis demonstrates high mission success percentages.

- The control actuation system has the sufficient control authority required for known disturbances and dispersions.
- The dynamics in ALL flight phases are analyzed (e.g., aerodynamics, flexibility, damping, gyrodynamics, plume impingement, moving mechanical assemblies, fluid motion, changes in mass properties, tail-wags-dog, etc.).

NASA has a strong expectation that testing for human-rated systems would include items, such as the following:

- All heritage hardware/software in the CTS subsystem architecture is evaluated and tested, to determine its viability for use in a system with differences in build, flight configuration, mission application, flight environment, or design/operations teams.
- The system is tested and flown in the same configuration and operational modes.
- The vehicle subsystem models used in simulations are validated by test to the maximum extent possible.
- Verification of subsystem design models and simulations should be performed prior to human flight.
- All unexpected results or anomalies during hardware testing are explained and/or incorporated into the simulation math model.
- Hardware-in-the-Loop testing (that includes sufficient hardware to capture all critical subsystem interfaces) to verify proper and expected H/W and S/W interactions in all operational modes, during mode transitions, and all mission critical events, and including all software paths.
- End-to-end integrated flight HWIL simulation should be used for validating the software simulation for timing and communications models.
- A true end-to-end sensors-to-actuators polarity and coordinate systems test is conducted for all flight hardware/software configurations, including all flight harnesses/data paths, and resolving all test anomalies.
- Test reports should include analysis results performed in support of verification and validation of performance requirements.
- Flight tests are performed to verify and validate nominal and abort design and operations with flight-like hardware and software.

5.3.3 Flight Mechanics and GN&C References

Document Number	***Title***
NASA-TM-2008-215106	*GN&C Engineering Best Practices for Human-Rated Spacecraft Systems*
TBD	*TBD*

5.4 Integrated Abort Analysis

The purpose of integrated abort analyses are to confirm that a robust abort capability exists across all mission phases, beginning with the timeframe that the crew ingresses the launch vehicle stack, all the way until the crew has successfully been recovered post-mission by the ground support team.

5.4.1 Integrated Abort Analysis Technical Products

Products to substantiate adequacy of abort design and operations typically include both models and analysis and test reports. Analysis reports should cover the full range of abort options from pre-launch through post-landing phases. Analysis reports should include sufficient information to demonstrate that the appropriate amount of rigorous analysis has been conducted, and provide the detail necessary for the reader to reach the same conclusions. Analysis reports should also include documentation of all math models and simulations used. Verification and correlation of models should be well documented with the model validation data accessible and traceable to the appropriate model. Likewise, test reports should document the appropriate testing sufficient for the reader to verify that the tests were appropriately conducted and that the results were successful. Test reports should include analysis of abort flight test missions performed in support of verification and validation of abort capabilities.

5.4.2 Integrated Abort Analysis Technical Assessment

NASA expects that the commercial provider will perform 3 DOF and 6 DOF statistical analyses using closed-loop GN&C simulation and including vehicle and environmental uncertainties, which address at least the following areas:

- Abort trigger settings, designed such that they will provide for both a low probability of false positive and a low probability of false negative.
- Identification of parameters or measurements used as abort trigger and the process and rationale for their selection
- Identification and simulation of ascent failure scenarios, conducted to ensure the ability of the crew module to depart the launch vehicle prior to reaching any vehicle and crew module limit loads or other “demise” criteria (in nearly all cases).
- Analysis of ascent abort operations and its interaction with pending flight termination commanding.
- Appropriate abort effectiveness percentages are achieved at each moment in each flight phase.

The above analyses are conducted for probabilistic dispersed flight conditions and for probabilistic failure modes. During modeling of failures and subsequent abort, loss of control dynamic effects and blast and debris environments should be considered, along with launch abort vehicle stability and control and subsequent crew module flight.

6.0 Ground Systems

6.1 Ground Systems Design

6.1.1 Ground Systems Design Technical Products

Products to convey the minimum design and construction standards and best practices when designing Ground Support Equipment (GSE) that interfaces with flight hardware (includes situations when personnel are present) and ensuring inclusion of requirements in the design, procurement, and fabrication of GSE. Documentation that substantiates that each component has been adequately analyzed and/or tested to demonstrate compliance with the intent of the tailored requirements using a documented, accepted standard (e.g., NASA-STD-5005C).

6.1.2 Ground Systems Design Technical Assessment

NASA's review of the Ground Support Equipment documentation will determine if a Commercial Partner's standards meet the intent of NASA-STD-5005C and will place emphasis on the following areas:

- Functionality, design, and integrity of primary structures
- Support of Program Critical Hardware
- Detailed stress analysis including a summary of the margins of safety
- Proof Test Demonstrations including Test Reports
- Component Material Certification
- Critical Weld Inspections

6.1.3 Ground Systems Design References

Document Number	***Title***
NASA-STD-8719.9	*Standard for Lifting Devices and Equipment*
MSFC-STD-156	*Riveting, Fabrication, and Inspection, Standard For*
MSFC-STD-486	*Standard Radiographic Inspection and Acceptance Standards for Fusion-Welded Joints in Stainless and Heat-resistant Steel*
AWS D1/D1.1M	*Structural Welding Code-Steel*
AWS D1.2/D1.2M	*Structural Welding Code-Aluminum*
ASME Boiler and Pressure Vessel Code, Sections VIII Divisions 1, 2, and 3	
KSC-DE-512	*Facility, System, and Equipment General Design Requirements*
KSC-NE-9439	*KSC Design Engineering Handbook for Design and Development of Ground Systems*
KSC-STD-Z-0006	*Standard for Design of Hypergolic Propellants Ground Support Equipment*

7.0 Launch Vehicle, Spacecraft, and Crew Systems Design

7.1 Avionics and Electrical Systems

7.1.1 Avionics Technical Products

The complexity of avionics equipment and the involvement of many independent organizations significantly add to the risk to performing a successful mission. Loss of mission due to an avionics failure proves to be very costly. Testing the avionics equipment extensively at several assembly levels (from units to the overall system) through the various program verification phases (Qualification, Acceptance, Pre-launch, On-orbit) has been a cost effective way of further assuring successful equipment and operation.

In order to substantiate that, the Commercial Partner meets the intent of standards required by CCT-REQ-1130, and to demonstrate that the system design meets applicable requirements for human-rating (which is capable of sustaining its operational role during the life-cycle), emphasis will be placed on the following as a minimum:

- Subsystem and Unit Level Specifications
- EEE Parts Selection Plan and Screening Process
- Materials Selection Plan for Chassis (if different from that used for mechanical structure)
- Fasteners Selection Plan for Chassis and Assembly (if different from that used for mechanical structure)
- Unit Interconnect Drawings and Schematics
- Printed Wiring Board Schematics and Layout Drawings
- Box Level Assembly Drawings
- As-Designed and As-Built EEE Parts List
- As-Designed and As-Built Mechanical Parts List
- Programmable Device Design and Implementation Processes
- Programmable Device Design Documentation (code and schematics)
- Programmable Device Test Plans and Data
- Qualification Plans, Procedures and As-run and Data (including EMI/EMC, ESD and Lightning transient testing)
- Worst Case Circuit Analysis for each avionics unit
- Avionics System Analysis/test for throughput, noise/ripple on power, and electrical impedance/isolation for signals
- Acceptance Test Plans, Procedures and As-run Data
- Avionics Integrated System Test Plans, Procedures and As-run Data
- Electrical Power Quality Requirements (including details on control of electrical faults)
- Electrical Power and Energy Management Plan
- Sneak Circuit Analysis

7.1.2 Avionics Technical Assessment

Review and analysis of the electrical interconnect system design and verification process will determine if a Commercial Partner's standards meet the intent of SMC-S-016 *Test Requirements for Launch, Upper-Stage, and Space Vehicles*.

For all existing avionics unit designs, qualification test reports/data will be reviewed to ensure testing was performed according to the qualification plan and to evaluate any anomalies identified during testing and the resolution of those anomalies. For all avionics unit designs, acceptance test plans and acceptance test reports/data will be reviewed prior to completion of vehicle integration, to ensure testing was performed to the acceptance test plan and all hardware passed acceptance testing. As-built design and manufacturing information will be made available for review for each avionics unit. Avionics systems level designs, interfaces, and analyses will be reviewed for evaluation of proper avionics system function and adequate margins. All systems level test plans and results, from a laboratory environment and from vehicle integration, will be made available for review to ensure testing was performed to the test plan and the avionics system passed all integrated testing. Test results will show that on-board computational capability is sufficient to execute all critical software operations at the appropriate frequency.

For new avionics unit designs, an assessment will be performed on all design documentation and component/materials selection plans to ensure specifications are met, qualification plans will be evaluated to ensure units are tested to appropriate environmental levels, including EMI/EMC in accordance with the Commercial Partner provided Environmental Electromagnetic Effects Control Plan. For new or modified Avionics system-level designs, specifications will be evaluated to make sure avionics unit interfaces are verified to meet system interface requirements, and system-level test reports will be reviewed to ensure appropriate system performance. For all new or modified avionics unit designs, and all new or modified avionics systems designs, the Commercial Partner will include avionics as part of the formal design review and certification process.

7.1.3 Interconnecting Cable and Harnesses

Considerable experience has been gained in the area of electrical wiring subsystems throughout NASA's history of human space flight. It is clear that there has to be sufficient processes and requirements for procuring components, implementing procedures for fabrication, installation, and testing, as well as associated training. Because of the large amount of wiring required and its impact on weight, volume, and the function of other subsystems, the importance of electrical wiring and connecting devices cannot be overemphasized.

7.1.3.1 Interconnecting Cable and Harness Technical Products

In order to substantiate that the Commercial Partner meets the intent of NASA-STD 8739.4 *Crimping, Interconnecting Cables, Harnesses, and Wiring*, NASA-STD-8739.5 *Fiber Optic Terminations, Cable Assemblies, and Installation*, and JSC 62809 *Human-Rated Spacecraft Pyrotechnic Specification*, and to certify the design, fabrication, and installation for human-rating, emphasis will be placed on the following as a minimum:

- Voltage Drop Analysis
- Routing and Bend Radius Documentation showing circuit EMC
- Comprehensive Cabling Bill of Materials
- Harness Manufacturing Process Specification
- Tool Calibration and Maintenance
- Cable Qualification Test Plan
- Harness Acceptance Test plan
- Personnel Training and Certification/Re-certification Plan
- Installation Plan

- Cable/Harness Test and Inspection Plan
- Cable Maintenance Plan
- Interconnectivity Schematics
- Wire Lists
- Installation Drawings
- Sneak Circuit Analysis

7.1.3.2 Interconnecting Cable and Harness Assembly Technical Assessment

Review and analysis of the electrical interconnect system design and verification process will determine if a Commercial Partner's standards meet the intent of the following:

- NASA-STD 8739.4 *Crimping, Interconnecting Cables, Harnesses, and Wiring*
- NASA-STD-8739.5 *Fiber Optic Terminations, Cable Assemblies, and Installation*
- JSC 62809 *Human-Rated Spacecraft Pyrotechnic Specification*

A review of the documented methods and procedures proposed to incorporate requirements for interconnecting cable and harness assembly design, fabrication, installation, and associated testing will place emphasis on the following areas:

- Materials (conductor, insulation, connectors, etc.)
- Conductor stripping processes
- Crimping processes and verifications
- Separation of redundant harnesses/circuits
- Electromagnetic interference/compatibility
- Routing, support, and protection of harnesses for operating environments
- Adjacent bent pin assessment
- Red plague mitigation

7.1.4 Crewed Vehicle Battery Safety

7.1.4.1 Crewed Vehicle Battery Safety Technical Products

In order to substantiate that the Commercial Partner meets the intent of JSC 20793 *Crew Vehicle Battery Safety Requirements*, and to certify the design for human-rating, emphasis will be placed on the safety data package, which should include as a minimum the following:

- Failure Modes and Effects Analysis (including toxicity, materials, and off-gassing)
- Data that allows insight into the hazards (e.g., venting, fire, thermal runaway, etc.) as well as the controls for mitigation along with the test methods used to verify the controls
- Battery specifications, qualification, certification, lot, and flight acceptance test plans
- Data from these tests

7.1.4.2 Crewed Vehicle Battery Safety Technical Assessment

Review and analysis of the electrical crewed vehicle battery system design and verification process will determine if a Commercial Partner's standards meet the intent of JSC 20793 *Crew Vehicle Battery Safety Requirements*.

Taking into account the battery's chemistry, launch environment, on-orbit usage, complexity, capacity, location, its propensity for venting, fire and thermal runaway, etc., evaluation criteria of the Crewed

Vehicle Battery Safety Report/Plan/Test documentation submitted will place emphasis on the following areas:

- Fault tolerance to catastrophic failures
- Incorporation and verification of hazard controls
- Charging system implementation (if applicable) and safety
- Mission criticality

7.1.5 Printed Wiring Boards

7.1.5.1 Printed Wiring Boards Technical Products

In order to substantiate that the Commercial Partner's alternate documents meet the intent of standards identified in CCT-REQ-1130 for printed circuit board design, fabrication, and assembly, a review of the alternate documents will be conducted.

In addition, the Commercial Partner will provide or make available individual printed circuit board documentation including, but not limited to, vendor conducted test reports, as well as tested and untested coupons that substantiates that the "as-designed" and "as-built" configurations meet or exceed the intent of the baseline of requirements established by the applicable standards. In addition to meeting or exceeding the requirements outlined in the reference documents, workmanship on printed circuit assemblies will further be verified by successful completion of certification testing, including but not limited to the following:

- 100% burn-in
- Thermal cycling (vacuum, if applicable)
- Vibration

Design of the certification testing will conform to the expected operating environments.

7.1.5.2 Printed Wiring Boards Technical Assessment

Review and analysis of the electrical crewed vehicle battery system design and verification process will determine if a Commercial Partner's standards meet the intent of the following:

- IPC J-STD-001 *Requirements for Soldered Electrical and Electronic Assemblies Electrical Clearance*
- IPC J-STD-001 Amendment 1 *Space Applications Electronic Hardware Addendum to J-STD 001, Requirements for Soldered Electrical and Electronic Assemblies*
- IPC 2152 *Standard for Determining Current Carrying Capacity in Printed Circuit Board Design*
- IPC 2220 Series *Family of Printed Board Design Documents*
- IPC 6010 Series *Family of Printed Board Performance Documents*
- IPC-CM-770 *Component Mounting Guidelines for Printed Boards*
- NASA-STD-8739.1 *Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies*
- NASA-STD-8739.3 *Soldered Electrical Connections*

Assessment of the Commercial Partners alternate design/fabrication/Assembly standards will place emphasis on the following areas:

- Material selection criteria
- Plating/final finishes
- Electrical clearance

- Conductor width/thickness
- Vibration mitigation
- Tin Whisker Mitigation
- Thermal management
- Component Placement
- Holes and Interconnects
- Coupon Definition
- Testing

7.1.6 Electromagnetic Environment Compatibility

7.1.6.1 Electromagnetic Environment Compatibility Technical Products

Attention to Electromagnetic Environmental Effects and Electromagnetic Compatibility (EMC) is essential to the operational success of any vehicle design that incorporates electronic, electrical, and electromechanical subsystems operating in dynamically changing electromagnetic environments composed of both man-made and naturally occurring threats, such as the direct and indirect effects of a lightning strike.

The referenced Electromagnetic Compatibility standards documents should be implemented within the design of the commercial vehicle. EMC analysis, design, and test documentation products will be provided as follows, as a basis for successful design validation:

- EMC Control Plan
- EMC Hazard Assessment Report
  - Electromagnetic radiation hazards to personnel, ordnance, and volatile materials;
  - Hazardous effects of p-static and direct/indirect lightning activity
  - Electrostatic charge generating mechanisms, to avoid fuel ignition and ordnance hazards, to protect personnel from electrical shock, and to prevent performance degradation or damage to electronics
  - Potential personnel hazards due to high RF transmitter output powers and antenna characteristics
  - Potential fire hazards due to arcing or sparking from mented or vaporized material
- EMC Analysis and Certification Plan
- Group A & B Test Data*
- List of Material Used in Fabrication*
- Schematic and Assembly Drawings*
- EEE Derating Analysis*
- Certification Standards for Test Equipment*

  *For MIL-STD-981

7.1.6.2 Electromagnetic Environment Compatibility Technical Assessment

Review and analysis of the electromagnetic environment compatibility design and verification process will determine if a Commercial Partner's standards meet the intent of the following:

- MIL-STD-461 *Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*
- MIL-STD-464 *Electromagnetic Environmental Effects Requirements for Systems*
- MIL-STD-981 *Design, Manufacturing, and Quality Standards for Custom Electromagnetic Devices for Space Applications*

An assessment of Electromagnetic Compatibility verification products will place emphasis on the quality and completeness of the products in the following review areas:

- EMC requirements traceability report
- EMC certification test plan
- EMC certification data**

  **Includes MIL-STD-981 data, which will be reviewed to verify that the device meets the operational and environmental requirements, as well as the compatibility of the materials used.

7.1.7 Lightning Protection

7.1.7.1 Lightning Protection Technical Products

The adequacy of lighting protection designed into the vehicle should be established by the Commercial Partner with the provision of the following products during the vehicle design and development, in accordance with the referenced documents:

- Lightning zoning report (report of those vehicle surfaces or structures likely to experience lightning channel attachment and/or current flow between attachment points)
- Lightning current paths analysis
- Lightning hazards assessment report (report on evaluation of vehicle structures or components whose failure or malfunction due to lightning could contribute to hazardous conditions or events)
- Lightning protection plan
- Lightning protection verification plan
- Lightning protection verification results/data
- Lightning actual transient level analysis and equipment transient design level specification report

7.1.7.2 Lightning Protection Technical Assessment

Review and analysis of the lightning protection design and verification process will determine if a Commercial Partner's standards meet the intent of the following:

- FAA AC 20-136A *Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning*
- SAE ARP 5412A *Aircraft Lightning Environment and Related Test Waveforms*
- SAE ARP 5414A *Aircraft Lightning Zoning*
- SAE ARP 5577 *Aircraft Lightning Direct Effects Certification*

An assessment of lightning protection verification products will emphasize the quality and completeness of the products in following review areas:

- Vehicle zoning appropriate to natural environment interaction
- Assessment of direct and indirect lightning hazards to critical systems
- Requirements traceability to verification tests
- Application of adequate margins

7.1.8 Electrostatic Controls

7.1.8.1 Electrostatic Controls Technical Products

The control of electrostatic charging and dissipation effects in crewed Space System elements and integrated assemblies should be documented through development and provision of the following products to describe the vehicle design, as well as the establishment and maintenance of workmanship and manufacturing measures and practices:

- Electrostatic Discharge Control Plan
- Triboelectrification controls design assessment
- Design analysis for ESD protection
- Survey reporting on compliance with ESD Control Plan provisions

7.1.8.2 Electrostatic Controls Technical Assessment

Review and analysis of the ESD control process will determine if a Commercial Partner's standards meet the intent of ANSI/ESD S20.20 *Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)*.

An evaluation of the Commercial Partner's electrostatic controls will focus on the Commercial Partner technical standards and technical processes that control and safely dissipate the build-up of electrostatic charges caused by Precipitation Static (p-static) effects, fluid flow, air flow, exhaust gases flow, personnel charging, charging of launch vehicles (including prelaunch conditions) and space vehicles (post deployment), and other charge generating mechanisms, to (1) avoid fuel ignition and pyrotechnic hazards, (2) protect personnel from shock hazards, and (3) prevent performance degradation or damage to electronics.

An assessment of Electrostatic Controls verification products will emphasize the quality and completeness of the submitted ESD Control Plan and supporting documentation in the following review areas:

- Electrostatic charging and dissipation design requirements traceability
- Adequacy of controls to satisfy ESD design parameters
- Component parts inspection and handling
- Equipment and sub-assemblies marking and labeling processes
- Manufacturing personnel protective measures and practices
- Maintenance of adequate controls over product manufacturing life-cycle
- ESD "design to" goals

In regard to ESD testing and "design to" thresholds, a successful ESD control regime will include industry standard "design to" withstand goals and this will be an expectation of the NASA team when evaluating the Commercial Partner's proposed standards and processes. NASA typically designs an ESD withstand rating, for unpowered electronic equipment and components, such that they shall not be damaged by an Electrostatic Discharge (ESD) at a level equal to or less than 4,000 volts applied to the case of the equipment or to any pin on equipment external connectors. Equipment sensitive to ESD events at levels between 4,000 volts and 15,000 volts shall be labeled as ESD sensitive and shall be handled to prevent immediate or latent damage failures.

7.1.9 Electrical Bonding

7.1.9.1 Electrical Bonding Technical Products

The adequacy of electrical bonding features implemented for all mechanical interfaces in the crewed Space System should be documented by the following products during the vehicle design and manufacturing to meet the intent of NASA-STD-4003 *Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment*:

- Electrical Bonding Plan
- Electrical Bonding Verification Data

7.1.9.2 Electrical Bonding Technical Assessment

Review and analysis of the electrical bonding design and verification process will substantiate that a Commercial Partner's standards meet the intent of NASA-STD-4003.

An assessment of Electrical Bonding verification products will place emphasis on the quality and completeness of the products in the following review areas:
- Identification of electrical bond paths
- Proper allocation of electrical bonding classes to mechanical interfaces
- Analysis of applied electrical bonding processes
- Test measurements of installed electrical bonds

7.1.10 Avionics and Electrical Systems References

Document Number	*Title*
AIAA S-111-2005	*Qualification and Quality Requirements for Space Solar Cells*
AIAA S-112-2005	*Qualification and Quality Requirements for Space Solar Panels*
SAE ARP 5416	*Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning*
JPR 8080.5	*JSC Design and Procedural Standards*
RTCA DO-160E	*Environmental Conditions and Test Procedures for Airborne Equipment (Sections 22 and 23)*

7.2 EEE (Electrical, Electronic and Electromechanical) Parts Management

The EEE parts management plan establishes the minimum technical requirements for electronic parts used in the design, development, and fabrication of electronic hardware for the Commercial crew and launch vehicle. The plan should manage and control the selection, acquisition, traceability, testing, handling, packaging, storage, and application of the EEE parts in the CTS.

The CTS subsystems should emphasize parts selection that fit the application, the environment, reliability and assurability for a human-rated program. The best practices for the development and implementation of an Aerospace EEE Parts Control Plan can be found in several Military and/or NASA standards described below:
- SMC Standard SMC-S-010 *Space and Missile Systems Center Standard, Parts, Materials, and Processes Technical Requirements for Space and Launch Vehicles*
- MSFC-STD-3012 *Electrical, Electronic, and Electromechanical (EEE) Parts Management and Implementation Plan for MSFC Space Flight Hardware* or an equivalent document.

7.2.1 EEE Parts Management Technical Products

A comprehensive EEE Parts verification and implementation plan as described in SMC Standard SMC-S-010, Space and Missile Systems Center Standard, Parts, Materials, and Processes Technical Requirements for Space and Launch Vehicles or MSFC-STD-3012 or an equivalent document. An analysis/review of the following design documentation will determine the adequacy of the implementation of this plan:
- EEE Parts Selection Plan and Screening Process (NOTE: contained in Paragraph 7.1.1)

- As-Designed and As-Built EEE Parts List (NOTE: contained in Paragraph 7.1.1) including rationale behind the use of less than the highest reliability parts which addresses the application including performance, environment, criticality, and mission lifetime.
- Derating and application analysis (An example of NASA typical wire/cable derating criteria can be found in of SSP 30312 Appendix B)

7.2.2 EEE Parts Management Technical Assessment

In order to substantiate that the Commercial Partner's alternate documents meet the intent of standards identified in CCT-REQ-1130 for EEE Parts, a review of the EEE Parts Management Plan and support documentation will be conducted. Emphasis will be placed in the following areas for compliance:

- EEE Parts Requirements
  - EEE Parts Selection to meet mission requirements
  - Parts qualification and screening
  - Pure Tin mitigation plan should meet the intent of GEIA-STD-00005-2
  - Counterfeit Parts Control Plans (CPCP) (reference SAE/AS5553) including control of parts obsolescence.
- EEE Parts procurement Processes
- Traceability and Reporting of non-conformances should meet the intent of NPR 8735.1
- EEE parts Controlling Specifications
- Parts assurance actions including audits
- ESD implementation plan should meet the intent of ANSI/ESD S20.20
- Ionizing Radiation Control Plan that defines the test regime necessary to meet the environment. For on-orbit, this environment is specified in SSP 30512 *Space Station Ionizing Radiation Design Environment.*

7.3 Mechanisms Subsystem

Mechanisms are components and systems in which mechanical parts move relative to one another in order to provide some desired function on the spacecraft. Correct operation of the mechanism subsystem is required to ensure crew safety and mission success.

The mechanism subsystem should employ designs which can be readily submitted to engineering analyses while conforming to standard aerospace industry practices. The designs should utilize materials having mechanical properties that are well characterized for the intended service environments and design conditions. Likewise, all sub-components used in the design of mechanisms should have well understood and predictable performance in the intended service environments and design limits. These component items may include, but aren’t limited to, switches, bearings, motors, dampers, clutches, torque limiters, lubricants, springs, and so forth. For reusable and multi-mission hardware, these criteria are applicable throughout the service life of the mechanism.

The best practices for this design and verification process and its associated documentation can be found in the relevant NASA standard, described below:

- NASA-STD-5017 *Design and Development Requirements for Mechanisms*. Section 4.7, Fastener Retention and Section 4.8.9, Preload Bolt Criteria may be excluded as the best practices for structural fasteners are contained within other NASA documentation.

NASA-STD-5017 provides an excellent set of guidelines for the design and development of any aerospace mechanism. Much of the guidance specified within this standard has been derived from lessons-learned throughout the NASA agency and across multiple flight programs.

7.3.1 Mechanisms Subsystems Technical Products

The Commercial Partner should provide design documentation to substantiate that all vehicle mechanisms have been adequately designed and verified, and demonstrate that they meet the intent of NASA-STD-5017. An analysis/review of the following design documentation will determine the adequacy of mechanism design standards:

- Design drawings and specifications that fully describe the mechanism subsystem and components, as well as their proper integration into the flight vehicle.
- Detailed engineering analysis of each mechanism subsystem, including a complete summary of mechanism torque/force margins where applicable, and also the margins of safety for each mechanism sub component within the allowable mechanism rigging tolerances.
- A full description of any computational models and methods used in the analysis, a description of the assumptions used to facilitate the modeling, as well as the testing which supports the assumptions within these models.
- Test plans, results and reports, to include but not limited to: qualification testing, acceptance testing, design life and cycle testing, and environmental testing.
- An analysis of the criticality of each mechanism on the spacecraft with regards to its implication for crew safety.

7.3.2 Mechanisms Subsystems Technical Assessment

A review of the mechanism design and verification documents will place emphasis on the following areas:

- Mechanism design, performance, integrity, and operability for all mission phases, including pre-mission integrated testing, and post-mission recovery and vehicle safing.
- Validation that Commercial Partner verification tests adhere to “test like you fly” philosophy.
- Review of component, subsystem, and system requirements traceability from the vendor to the primary Commercial Partner.

7.4 Thermal Protection System

7.4.1 Thermal Protection Systems Technical Products

The fundamental purpose of the spacecraft’s Thermal Protection System (TPS) is to protect the vehicle from the ascent and reentry environments, and maintain structure temperatures within specified limits. The TPS presents catastrophic hazards and will contain elements that cannot be practically designed with any level of failure tolerance.

JSC-65827 *Thermal Protection System Design Standard for Spacecraft* provides the best practices for the design and verification of the TPS, and is the approved standard for addressing the absence of TPS failure tolerance. Thus documentation must be provided that substantiates that the TPS has been adequately tested and/or analyzed to meet the intent of JSC-65827. It is recognized that Commercial Partners may choose existing standards or maintain their own technical standards for TPS design, analysis and test, under the condition that the detailed intent of JSC-65827 is met.

To the extent specified in JSC-65827, the following documents should also be applied to the TPS:

- For structural design and verification of the TPS, use JSC-65828 *Structural Design Requirements and Factors of Safety for Space Flight Hardware*, or equivalent
- For fracture control of the TPS, use NASA-STD-5019 *Fracture Control Requirements for Spacecraft*, or equivalent
- For materials and processes associated with the TPS, use NASA-STD-6016 *Standard Materials and Processes for Spacecraft*, or equivalent.

Specific Commercial Partner provided products that should be developed in order to demonstrate flight certification of the TPS include, but are not limited to, the following: TPS certification plan; requirements and description document; risk management plan; subsystem/component specifications; materials properties plan and report, including material allowables; qualification test plans and reports; thermal and structural analysis reports, including margin policy and model validation reports; damage tolerance assessment, including MMOD; reliability assurance plan and analysis reports; quality assurance plan, data and documentation; and acceptance data package.

7.4.2 Thermal Protection Systems Technical Assessment

TPS Certification is primarily implemented through a Verification and Validation (V&V) program applied to the TPS design through the development and qualification program and applied to the TPS hardware through an acceptance program. TPS Certification requires not only that the TPS satisfy its allocated functional and interface requirements at all levels, but also that TPS operational environments are understood for all mission phases and that the TPS response to those environments is understood and predictable. An evaluation of the submitted TPS certification documentation will place emphasis on the following areas:

- Verification of functionality, design, and integrity for all mission phases
- Detailed thermal/structural analysis including a fully substantiated margin policy and analytical model validation evidence
- Test Data:
  - Aerothermal testing at coupon and element (as applicable) levels to demonstrate performance in the predicted environment and potential failure modes
  - Material property testing and results
  - Structural and thermal/structural testing at coupon, element, sub-component and component/vehicle levels
- Component, subsystem, and system requirements traceability; and knowledge and verification of environments.

7.5 Structures

Structures are components and assemblies designed to sustain loads or pressures, provide stiffness and stability, or provide support or containment. Internal components are not considered primary structures if their failure would not result in a critical or catastrophic hazard.
Flight hardware structure shall maintain structural integrity during the service life of the spacecraft and launch vehicle, including damage tolerance capability and resistance to effects of aging on the hardware, as applicable. The design loads are determined by the integrated system loads analysis or analysis of subsystem flight or ground events, and are defined in the Loads Control Plan.

The launch vehicle and spacecraft structural subsystems should employ designs that are amenable to engineering analyses by current state-of-the-art methods and conforming to standard aerospace industry practices. More specifically, the designs are assumed to use materials having mechanical properties that are well characterized for the intended service environments and all design conditions. For reusable and multi-mission hardware, these criteria are applicable throughout the service life and all of the missions. Repaired or refurbished structures must meet the design and verification standards for new hardware. The best practices for this design and verification process and its associated documentation can be found in the relevant NASA standards, described below:

- Use JSC-65828 *Structural Design Requirements and Factors of Safety for Space Flight Hardware* for primary structure other than windows and propulsion systems with more than 6000 lb thrust.
- To mitigate the risk of catastrophic structural failure due to the presence and growth of flaws or damage throughout the service life, use NASA-STD-5019 for fracture control.
- For design and verification of propulsion systems with thrust exceeding 6000 lbs, use NASA-STD-5012.
- For design and verification of glass or ceramic structural components, including windows, use JSC-62550 *Strength Design and Verification Criteria for Glass, Ceramics, and Windows in Human Space Flight Applications.*
- Design and verification best practices for structural fasteners are addressed in NASA-STD-5020 *Requirements for Threaded Fastening Systems in Space Flight Hardware*.

A Commercial Partner may choose existing standards or maintain their own technical standards for structural design and verification, and may propose this substitution subject to NASA CCP approval. Technical standards are not intended to address every contingency. Therefore, design factors may be tailored to reflect the rigor applied to understanding typical uncertainties in the design or performance of the structural subsystem: predicted loads and environments, predicted structural response, load path simplicity, material properties, manufacturing or maintenance variability, and damage tolerance capabilities.

7.5.1 Structures Subsystem Technical Products

A comprehensive Structural Verification Plan (SVP) (as described in JSC-65828) documenting the full structural analysis, test, and assessment program, provides the basis for successful design validation.

NASA expects to review the SVP at all design and engineering milestones. The initial delivery of the SVP should occur early in the design phase, before more than 40% of the drawings are released. The fidelity at this first review should be detailed enough to define the structural verification approach including planned development testing.

The SVP must be maintained and updated because the hardware design and the design data will evolve as the loads, mass properties, temperatures and other environments are verified. The SVP should be updated prior to the final design review to support these evolutions and to update the structural verification approach, as needed.

In support of design validation, the Commercial Partner should prepare documentation that substantiates that the structure has been adequately designed and verified to meet the intent of standards described herein.

The documentation should include:

- A Structural Verification Plan (SVP) as described in JSC-65828.
- Glass and Ceramics Verification Plan (GCVP) as described in JSC-62550 that outlines how structural glass and ceramics will be verified.
- Design drawings that fully describe the subsystem and components and their assembly into the flight vehicle.
- Detailed stress analysis including a complete summary of the minimum margin of safety for each structural part.
- A full description of the numerical models and methods used in the analysis, and the tests that validate those models.
- Test plans, results and reports including structural and damage tolerant certifications of composite/bonded structures by building block testing.
- Test plans, results and reports describing the verification results for glass and ceramics.
- A Fracture Control Plan (FCP) and Fracture Control Summary Report as outlined in the Fracture Control section of this document.

7.5.2 Structures Subsystem Technical Assessment

NASA's review of the structural design and verification documents will place emphasis on the following areas:

- Primary structure design functionality and integrity for all mission phases
- Validation that Commercial Partner verification tests adhere to "test as you fly" philosophy
- Review of component, subsystem, and system requirements traceability from the vendor to the primary Commercial Partner.

7.5.3 Structures Subsystem References

Reference documents are listed in the documents and standards described above. Not all of the following documents are in every standard discussed in this section of CCT-STD-1140.

Document Number	***Title***
ANSI/AIAA S-080-1998	*Space Systems - Metallic Pressure Vessels, Pressurized Structures, and Pressure Components*, September 13, 1999
ANSI/AIAA S-081A-2006	*Space Systems - Composite Overwrapped Pressure Vessels (COPVs),* July 24, 2006
ASTM C1368	*Standard Test Method for Determination of Slow Crack Growth Parameters of Advanced Ceramics by constant Stress-Rate Flexural Testing at Ambient Temperature*
ASTM C1421-01b	*Standard Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperature*
ASTM C1576	*Standard Test Method for Determination of Slow Crack Growth Parameters of Advanced Ceramics by Constant Stress Flexural Testing (Stress Rupture) at Ambient Temperature*
JSC-28918	*EVA Design Requirements and Considerations*

JSC-49774A	*Standard Manned Spacecraft Requirements for Materials and Processes*
JSC-65828	*Structural Design Requirements and Factors of Safety for Space Flight Hardware*
JSC 65829	*Loads and Structural Dynamics Requirements for Space Flight Hardware*
JSC 65831	*Fracture Control Standard for Spacecraft*
MIL-HDBK-60	*Threaded Fasteners-Tightening to Proper Tension*
NASA-STD-5012	*Strength and Life Assessment Requirements for Liquid Fueled Space Propulsion System Engines, Baseline, June 13, 2006*
NASA-STD-5001	*Structural Design and Test Factors of Safety for Spacecraft Hardware*
NASA-STD-5017	*Design and Development Requirements for Mechanisms*
NASA-STD-5019	*Fracture Control Requirements for Space Flight Hardware*
NASA-STD 5020	*Requirements and Standard Practices for Mechanical Joints with Threaded Fasteners in Space Flight Hardware*
NASA-STD-6008	*NASA Fastener Procurement, Receiving Inspection, and Storage Practices for Space Flight Hardware*
NASA-STD-6016	*Standard Materials and Processes Requirements for Spacecraft*
NASA-STD-7001	*Payload Vibroacoustic Test Criteria*
NASA-TM-X-73305	*Astronautic Structures Manual*
NPR 8705.4	*Risk Classification for NASA Payloads*
SSP 50808	*ISS IRD*

7.6 Fluid Systems

The launch vehicle, spacecraft, and crew systems design may include liquid and gaseous fluid systems that utilize, control, or supply fluids. Fluids systems may include, but are not limited to, water, oxygen, cryogenic systems, storables, hydraulic fluids, pressurization fluids (including helium and nitrogen), thermal conditioning, and environmental control fluids. Any and all associated fluid storage, lines, fittings, valves, and other fluid components are considered part of the fluid systems. The design, assembly, test, and certification of all fluid systems must be adequately documented and must be available for review throughout all stages of the fluids system development life-cycle. Proper design and integration of fluid systems is essential to ensure crew safety and mission success.

Many sections of this document and the CTS requirements document reference technical products that compliment fluids system design. These products not only apply at the integrated vehicle level, but are also applicable at the subsystem-level. These products are not repeated here, but will be evaluated as critical to fluid systems and this section must be augmented with those other technical products to be considered complete, e.g., Hazard Analysis.

7.6.1 Fluids Subsystem Technical Products

In support of Design validation, the following products will be used to substantiate that the fluid systems have been adequately designed, assembled, tested, serviced, and verified:

- Systems design analysis for each subsystem, including but not limited to:
  - Design drawings and specifications that fully describe the subsystem and components, as well as their integration into the flight vehicle.
  - Fluid subsystems mission operation plans, including emergency/contingency operations.
  - For fluids whose leakage is hazardous, also include a summary of verification test, analyses, and controls.
  - Engineering analysis of each subsystem showing margins, including but not limited to:
    - Pressure budget analysis.
    - COPV and pressure vessel design.
    - Flow induced vibration analysis.
    - Fluid line design: combined pressure/thermal/mechanical load analysis.
    - Fatigue analysis, Non-Hazardous Leak Before Burst (NHLBB), and /or safe life analysis.
    - Transient pressure analysis for design and operational impacts.
    - Consumables management analysis.
      - Mission assumptions
      - Usage plans
    - Allowable leakage.
    - Relief Mechanisms.
  - Material analysis and fluid compatibility.
    - Oxygen compatibility assessment
      - Material uses
      - Processes
    - Materials exposed to hazardous fluids shall be evaluated or tested for compatibility (as referenced in NASA-STD-6016)
- Acceptance and qualification test plans and methods.
  - Analysis/inspection reports
  - Demonstration test results
  - Test procedures results and pass/fail criteria
- Integrated fluid system testing results, including but not limited to:
  - Integrated software / avionics and fluid system testing.
- Requirements verification report.
- Fabrication process control plan.
- Inspection plan (including NDE) and inspector certification program.
- Fluid servicing and ground operating procedures.
- Contamination control plan (as referenced in NASA-STD-6016).
- Fluid use and procurement specification.

7.6.2 Fluid Subsystem Technical Assessment

Evaluation of the fluids systems documentation products will focus on establishing confidence in the products, hardware design, and processes. Confidence will be established by assessing the provided documentation products against government and industry standards, lessons learned and best practices where they exist and are relevant to the fluid systems under assessment.

Assessments of Fluid Systems will place emphasis on the following:

- Evaluation of fluid system related design and hazard analysis, reliability analysis, separation of critical redundant systems assessments, plans and operations to determine that integrated components and systems will operate as designed and will not cause injury to the crew or damage to the system.
- Evaluation of models, simulation data, and reports to assess whether models and simulations used in the design and certification of fluid systems have been properly validated, utilized, and are configuration controlled. Review and analysis of the modeling and analysis methodology will determine if a Commercial Partner's standards meet the intent of JSC-65829 *Loads and Structural Dynamics Requirements for Space Flight Hardware* and 20M02540 *Assessment of Flexible Lines for Flow-Induced Vibration.*
- Evaluation of inspection plan and inspection certification program to ensure appropriate inspection milestones are planned.
- Review of fluid component design products to verify the design requirements are met. Review and analysis of the component design will determine if a Commercial Partner's standards meet the intent of NASA-STD-5017 *Design and Development Requirements for Mechanisms.*
- Evaluation of pressure vessel and COPV analysis to verify design requirements are met. Review and analysis of the design and verification process will determine if a Commercial Partner's standards meet the intent of AIAA S-080 *Space Systems-Metallic Pressure Vessels, Pressurized Structures, and Pressure Components* and AIAA S-081A *Space Systems Composite Overwrapped Pressure Vessels.*
- Evaluation of NHLBB pressure component design to verify design requirements are met. Review and analysis of the component design will determine if a Commercial Partner's standards meet the intent of NASA-STD-5019 *Fracture Control Requirements for Space Flight Hardware.*
- Review of acceptance and qualification products to verify CTS products (including refurbished or re-flown products) meet performance specifications, demonstrate error-free workmanship, and are ready to be committed to flight. Review and analysis of the propulsion systems and component qualification methodology will determine if a Commercial Partner's standards meet the intent of SMC-S-016 *Test Requirements for Launch, Upper-Stage, and Space Vehicles*
- Review of the integrated fluid system test results to verify expected operation and system requirements are met. Review and analysis of the propulsion systems and component qualification methodology will determine if a Commercial Partner's standards meet the intent of SMC-S-016.
- Review of fluid servicing and ground operating procedures to verify fluid system integrity is maintained. Review and analysis of the system ground & flight design will determine if a Commercial Partner's standards meet the intent of NASA-STD-6016.
- Evaluation of systems consumables analysis and loading procedures to ensure adequate margin in accordance with nominal mission plan analysis documents including contingency and emergency scenarios as developed by the CCP.

7.6.3 Fluid Systems References

Document Number	***Title***
SAE-AS5440	*Design and Installation Requirements for Hydraulic Systems, Aircraft*

7.7 Propulsion Systems

Launch vehicle propulsion systems (liquid, solid, or hybrid propellants) include boost stage, upper stage, in-space, and auxiliary propulsion systems. These systems may contain propellant tanks, propellant feed, pressurization, thrust vectoring, avionics, and data collection and monitoring systems. Propulsion systems require rigorous design, development, test, and evaluation (DDT&E) programs due to the inherent complexity and tight controls levied by extreme functional and performance targets necessary for ensuring crew safety and mission success. It should also be understood that due to the various types of propulsion systems, the various degrees of complexity of propulsion systems and the heritage of the specific propulsion system technology, there is no succinct method or set of predefined standards for propulsion system certification.

Human-rating a given propulsion system cannot be completely addressed independently from the integrated vehicle architecture. Integration of systems across interfaces is key to understanding how a system could fail. Understanding these hazards and their potential propagation paths allows mitigations, such as fault avoidance (design out), design margins, redundancy, caution and warning devices, and/or special procedures to minimize flight risk.

7.7.1 Propulsion Subsystem Technical Products

Due to the variations in design implementation paths and risk management, it is necessary to invoke a comprehensive strategy that encompasses a wide range of engineering disciplines and practices to ensure the flight worthiness of propulsion systems for manned space vehicles. The propulsion system DDT&E process must be adequately documented and must be available for review throughout all stages of the propulsion system life-cycle.

In this document many of the transportation certification requirements sections reference technical products that compliment propulsion system design. These products not only apply at the integrated vehicle level, but are also applicable at the propulsion subsystem and critical components. Correspondingly, these products, listed in Sections 4.0 through 9.0, do not need to be repeated here, but will be evaluated as critical to propulsion systems and this section must be augmented with those other technical products to be considered complete.

In further support of design validation, the following products are typically used to substantiate the propulsion system has been adequately designed and verified:

- Functional and Performance Analysis Reports with Supporting Verification Reports/Data (e.g., results from Water Hammer Analysis Model(s), system power balance model, motor ballistics analysis, propulsion system dynamics models, induced environments, component level tests, qualification testing, etc.).
- Propulsion system concept of operations (i.e., integrated system test and checkout, loading operations, timings and hardware operational sequence pre-launch, ignition, mainstage operation, shutdown, abort, and recovery).

7.7.2 Propulsion Subsystem Technical Assessment

Evaluation criteria will establish confidence in the propulsion systems products and processes by assessing the provided documentation products against government and industry standards, lessons learned, and best practices where they exist and are relevant to the propulsion systems under assessment.

The intent is to provide confidence that the design processes and operating procedures are commensurate with accepted standards and meet initial quality expectations for human space flight.

Assessment of propulsion systems will place emphasis on the following:

- Tank slosh damping characteristics are understood through well-anchored slosh analysis, typically through flight or ground test, and are consistent with control system stability analysis.
- Evaluation of models, simulation data, and reports to assess whether models and simulations used in the design and certification of propulsion systems have been properly validated, utilized, and are configuration controlled. Examples include engine performance, ballistics, structural margins, thermal balance, plume impingement, water hammer, propellant slosh, and pogo. Analytical methodology and approach is significant in providing confidence since it is not typical to have statistically relevant samples of test or flight data. Review and analysis of the modeling and analysis methodology will determine if a Commercial Partner's standards meet the intent of JSC-65829 *Loads and Structural Dynamics Requirements for Space Flight Hardware.*
- Evaluation of the propulsion system structural design, verification process, and associated documentation will determine if the Commercial Partner's standards meet the intent of NASA-STD-5012 *Strength and Life Assessment Requirements for Liquid Fueled Space Propulsion System Engines*, JSC 65828 *Structural Design Requirements and Factors of Safety for Space Flight Hardware*, and NASA-STD-5019 *Fracture Control Requirements for Spacecraft*.
- Evaluation of propulsion system and component design, and hazard analysis, reliability analysis, separation of critical redundant systems assessments, plans, and operations to determine that integrated components and systems will operate as designed and will not cause injury to the crew or damage to the system.
- Review of development and qualification data, processes, and procedures to ensure that test limits encompass worst case environments during all mission phases and have accounted for build-to-build and run-to-run variations. Review and analysis of the propulsion systems and component qualification methodology will determine if a Commercial Partner's standards meet the intent of SMC-S-016 *Test Requirements for Launch, Upper-Stage, and Space Vehicles.*
- Review of acceptance test procedures (ATP) to determine adequacy of Commercial Partner's processes for exposing manufacturing and assembly flaws, while ensuring consistent performance and proper functionality of propulsion system and its components. Review and analysis of the propulsion systems acceptance test procedures will determine if a Commercial Partner's standards meet the intent of SMC-S-016.
- Review of Materials and Process Control Systems to ensure consistent performance and proper functionality of the propulsion system and its components, special emphasis will be focused on solid rocket motors. Review of Material and Process Control System to determine if the Commercial Partner's standards meet the intent of NASA-STD-6016.

7.7.3 Propulsion Subsystem References

The following list is intended to provide additional references that NASA has traditionally used and that may help to communicate the standards against which the Commercial Partner's processes will be assessed.

Document Number	***Title***
MSFC-SPEC-164	*Cleanliness of Components for Use in Oxygen, Fuel, and Pneumatic Systems Spec*

MSFC-STD-3535	*Standard for Propellants and Pressurants Used for Test and Test Support Activities at SSC and MSFC*
TBD	*JANNAF Test and Evaluation Guideline for Liquid Rocket Engines*
NASA-STD-5006	*General Fusion Welding Requirements for Aerospace Materials Used in Flight Hardware*
MIL-DTL-38999	*Connectors, Electrical Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded and Breech Coupling), Environment Resistant, Removable for Crimp and Hermetic Solder Contacts, General Specification for*
ASME Y14.5M-1994	*Dimensioning and Tolerancing*
SAE-AS-1098	*Fitting End, Flared Tube, for Seal Ring, Standard Dimensions for, Design Standard*
NASA-STD-5001	*Structural Design and Test Factors of Safety for Spacecraft Hardware*
NPR 8705.2	*NASA Human-Rating Requirements for Space Systems*
MSFC-HNDBK-505	*Structural Strength Program Requirements*
CPIA Publication 655, Jan 1997	*Guidelines for Combustion Stability Specifications and Verification Procedures for Liquid Propellant Rocket Engines*

7.8 Pyrotechnics Subsystem

7.8.1 Pyrotechnics Subsystem Technical Products

The "one time, every time" single use nature of pyrotechnic devices and the criticality of their associated functions require that a confidence be instilled through thorough documentation, review, and test of the component lot build parts and processes.

Typically, documentation that substantiates that the individual pyrotechnic components and the pyrotechnic systems have been adequately designed, manufactured, and tested to demonstrate compliance with the intent of this requirement using a documented, accepted standard (e.g., JSC 62809D) will be generated. Documentation provided should include:

- Concept of operation and design detail of each pyrotechnic system, including layouts, identification of components, interfaces/interconnect detail, and identification of fault tolerance within each system.
- Worst-case predicted natural and induced environments for each device/system.
- Design Specification and Source Control or Vendor Control Drawing for each device.
- Baseline Review and Production Review documentation for each device (i.e., Phase I and Phase II Review data in accordance with JSC 62809D).
- Development Test Reports with accompanying technical data.
- Margin Test Reports with accompanying technical data.
- Qualification Test Plans and Reports with accompanying technical data.
- Analyses supporting qualification of each device and system.
- Lot Acceptance Data Information and Data Package (i.e., Phase III Review data in accordance with JSC 62809D).
- Age Life Test Plans and Reports with accompanying technical data.

7.8.2 Pyrotechnics Subsystem Technical Assessment

Review and analysis of the pyrotechnic subsystem design and verification process will determine if a Commercial Partner's pyrotechnic standards address the requirements in and meet the intent of JSC-62809D *Human-Rated Spacecraft Pyrotechnic Specification*.

A review of the submitted documentation will place emphasis on the following areas:

- Mission criticality
- Applicability of the component to its intended system function
- Component and piece parts traceability up to and including powders
- Testing to demonstrate margin
- Detailed analysis and testing to verify the component's ability to properly function after exposure to natural and induced environments
- Component phase reviews of critical systems, as defined within JSC 62809

If a commercial provider proposes an equivalent standard and/or process to meet the intent of JSC 62809, it is NASA's expectation that the minimum items for inclusion with respect to pyrotechnics are as follows:

- Evaluation of the failure tolerance of each pyro subsystem design to verify single fault tolerance for fails to operate failure modes. If not completely fault tolerant, an evaluation of data that demonstrates that design sensitivities are understood and failure modes mitigated.
- Review of Lot Acceptance Data, which will occur on a recurring basis for every production lot, to verify:
    - Each lot is of the same design and construction, fabricated in one unchanging and essentially continuous manufacturing process, with traceability maintained on each device and piece part/material.
    - Only one lot of each explosive or pyrotechnic material is used in a lot of explosively loaded components or devices.
    - Successful performance of non-destructive Lot Acceptance Tests on 100% of each production lot of devices.
    - Successful performance of destructive lot acceptance testing conducted after completion of non-destructive tests on a randomly selected sample of the production. The destructive lot acceptance testing includes subjection of the components to specified thermal and dynamic environments prior to performance test.
- Review of qualification reports and data for each pyrotechnic device and system. The review will verify that testing has utilized test hardware of the same configuration and manufactured under the same production process as the flight hardware, and that hardware properly functions after exposure to the worst case natural and induced environments anticipated during its operational life.
- Evaluation of auto ignition temperature testing & analysis for the explosive materials selected to verify that they will not auto ignite when subjected to 50°F above the maximum predicted thermal exposure for which the device is designed.
- Evaluation of pyrotechnic and explosive materials seal designs to verify that loaded components are sealed to a leak rate not greater than 1 x 10-6 cc/second of helium when measured at one atmosphere differential pressure.
- Evaluation of threaded parts to ensure appropriate engagement and captive features with an expectation that all parts are positively locked.

- Evaluation of the design of pressure actuated devices to verify that components exposed to operating pressure are capable of withstanding an internal static proof pressure of 1.2 times the maximum operating pressure without permanent deformation or leakage, and an internal pressure of 1.5 times the maximum operating pressure without structural failure (burst).
- Evaluation of the design of pressure actuated devices to ensure they are capable of withstanding internal pressures generated in operation with the movable part restrained in its initial position and without rupture or the release of shrapnel, debris, or hot gases that could compromise crew safety or mission success.
- Evaluation of the compatibility of materials used in devices to verify that all materials are compatible with each other to the extent that no reaction occurs that might adversely affect the component or system performance or safety.
- Evaluation of each pyrotechnic system design to verify that the designs preclude incorrect installation and assembly.
- Evaluation of margin test results on pyrotechnic component interfaces, component performance and, as applicable, subsystem performance.
- Evaluation of commercial provider proposed age life evaluation methodology to verify that testing will be conducted at specific intervals to demonstrate that performance characteristics continue to meet lot acceptance criteria without significant degradation.
- Evaluation of the commercial provider's pyro device configuration control which should be unique for its pyrotechnic devices and should be established and maintained for the design, manufacturing processes, materials, inspection, acceptance, and qualification of all pyrotechnic devices.

7.9 Trailing Deployable Aerodynamic Decelerator

7.9.1 Trailing Deployable Aerodynamic Decelerator (TDAD) Technical Products

A primary requirement for manned spacecraft is to provide safe entry, landing, and recovery on Earth for crew returning from LEO destinations.

Documentation must substantiate that the deceleration system has been adequately designed, manufactured, and verified to demonstrate compliance with the intent of this requirement using documented, accepted standards, and design guides, such as NWC TP 6575 *Parachute Recovery System Design Manual (Knacke)*, and JSSG-2010-12 *Crew Systems Deployable Aerodynamic Decelerator (DAD) Systems Handbook*.

Various documented technical standards exist in the TDAD design industry, the adequacy of which are subject to review. As such, the Commercial Partner should provide the following products during the flight certification process to ensure the TDAD has been sufficiently designed and verified:

- Assembly and Detailed Drawings, Drawing Tree, and CAD Models
- Concept of Operations Document, including timing sequences, system geometry, operational uses, and capabilities, as well as its integration with other components and/or subsystems, for the entire life-cycle and each mission phase of the system
- Interface Control Documents
- Design Analysis Reports: stress analysis reports, and design models, simulations, and analysis
- Mass Properties Report comprised of mass values, as well as growth allowance allocations, for all system components

- Safety documents to include Fault Tree Analysis, Probabilistic Risk Assessment Results, Hazard Analysis, Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL), and Reliability & Maintainability (R&M) Report
- Verification and Validation Document, defining the plan for (including type), and documenting the results of, verification and validation activities
- Qualification & Acceptance Procedures, including incoming materials lot acceptance
- Certification Plan
- Critical Manufacturing Processes
- Ground Safety Analysis Report
- Sustaining Engineering Plan
- Materials Identification and Usage List (MIUL)
- Test Configuration Documents
- Post-Flight Test (Closure) Reports

7.9.2 TDAD Technical Assessment

Evaluation criteria for submitted documentation, standards, and processes, will emphasize the following areas in order to determine whether the Commercial Partner's standards meet the intent of JSC 65985 *Requirements for Human Space Flight for the Trailing Deployable Aerodynamic Decelerator*:

- Overall system function and integrity, to include rate of descent
- Seam and Joint Testing Reports
- Test descriptions for any static or dynamic testing (i.e., 'test like you fly')
- Component, subsystem, and system requirements traceability
- Knowledge and verification of environments
- Design Factors of Safety and Derating Factors as directed in NWC TP 6575 *Parachute Recovery System Design Manual*
- Modeling derivations and assumptions and trajectory and stress analyses to include wake effects on parachute performance and summary of margins of safety
- Load dispersions for nominal and off-nominal mission cases
- Safety and reliability approaches and mitigation plans for failure tolerance and failure propagation of each DAD subsystem design to verify single-fault tolerance (loss of crew) and satisfactory propagation methods
- Testing configuration and number of runs for full-scale system tests (nominal and off-nominal, documenting how close the configuration is to flight), material lots testing, and margin testing

7.9.3 TDAD References

Document Number	*Title*
ADS-TR-61-579	*Performance of and Design Criteria for Deployable Aero Decelerators*
ARM-10	*Apollo Technical Manual - Reliability*
ASTM D6193	*Standard Practice for Stitches and Seams*
JPR 8080.5	*JSC Design and Procedural Standards*
JSC-49774	*Standard Manned Spacecraft Criteria for Materials and Processes*
JSSG-2010-12	*Crew Systems Deployable Aerodynamic Decelerator (DAD) Systems Handbook*

MIL-H-7195	*General Specification for Parachute Hardware*
MIL-P-5160	*Parachute Assemblies and Major Sub-Assemblies, Packaging and Packing of*
MIL-STD-129	*Marking for Shipment and Storage*
NASA-STD-3000	*Space Flight Human System Standards*
NASA-STD-5005	*Standard for the Design and Fabrication of Ground Support Equipment*
NASA-STD-5019	*Fracture Control Requirements for Space Flight Hardware*
NASA-STD-6016	*Standard Materials and Processes Requirements for Spacecraft*
NPR 6000.1	*Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components*
NPR 8705.2	*NASA Human-Rating Requirements for Space Systems*

8.0 Specialty Engineering

8.1 Fracture Control

8.1.1 Fracture Control Technical Products

It is NASA policy that fracture control be imposed on all human-rated space flight hardware to ensure safety by mitigating the risk of catastrophic failure due to the presence of flaws.

It is expected that a Fracture Control Plan (FCP) and a Fracture Control Summary Report (FCSR) consistent with the intent of NASA-STD-5019 will be generated.

8.1.2 Fracture Control Technical Assessment

In order to substantiate that the Commercial Partner has met the intent of NASA-STD-5019, the FCP will be evaluated to assure that specific fracture control methodology and procedures are in place for the prevention of catastrophic failure associated with propagation of cracks, flaws, or damage during fabrication, testing, handling, transportation, and operational life. The plan should also include a description of how the prime contractor or vehicle owner imposes any applicable fracture control requirements onto subcontractors and suppliers.

It is expected that the FCSR will provide the following information as described in NASA-STD-5019, Section 6.3:

- Sufficient information to ensure certification that fracture control requirements have been met. Sufficient hardware descriptions including sketches and figures to convey a clear understanding of the hardware elements and their functions.
- Supporting detailed documentation.
- An accounting of all parts and their disposition for fracture control.
- For fail safe parts, identification of NDE and inspection plans, Material Usage Agreements (MUAs), discrepancies, or deviations from design that affect fracture control and flaw detections and their resolutions.
- Identification of any flaws that may be accepted on risk by the program authority.

8.1.3 Fracture Control References

Document Number	***Title***
SSP 30558	*Fracture Control Requirements for Space Station*
NASA-HNBK-5010 Volume 1	*Fracture Control Implementation Handbook for Space Flight Hardware other than Composite or Bonded Parts*
NASA-HNBK-5010 Volume 2	*Fracture Control Implementation Handbook for Space Flight Hardware Composite or Bonded Parts*
JSC 25863B	*Program Requirements Document for Johnson Space Center Non-Critical Government Furnished Equipment*

8.2 Materials and Processes

8.2.1 Materials and Processes Technical Products

In order to validate the flight readiness of any hardware or system, there are minimum requirements for materials and processes (M&P) that must be met. Included are materials and processes requirements used in design, fabrication, and testing of flight components for both manned and unmanned spacecraft systems.

All hardware is covered by M&P requirements, including vendor-designed, off-the-shelf, and vendor-furnished items. The prime contractor is responsible to flow down these requirements to their subcontractors and lowest component-level suppliers. To prevent damage or contamination of flight hardware, also covered is interfacing ground support equipment, hardware processing equipment, hardware packaging, and hardware shipment.

The Commercial Partner will be responsible for meeting the intent of NASA-STD-6016 requirements. This may be accomplished through the development of an M&P Selection, Control, and Implementation Plan, or by constructing a matrix of applicable and non-applicable paragraphs.

It is recommended that within the construct of the implementation plan or applicability matrix, that the following subject matter be specifically addressed:

- Nondestructive Evaluation Plan
- Contamination Control Plan
- Finishes Plan
- Design Allowables
- MUAs
- Materials and Processes Identification and Usage List (MIUL)

8.2.2 Materials and Processes Technical Assessment

A review of the submitted M&P documentation and plans will focus on the following elements to substantiate that the Commercial Partner's standards for M&P meet the intent of NASA-STD-6016:

- Assurance that the M&P used are selected by considering the worst-case operational requirements for the particular application and the design engineering properties of the candidate materials.
- Identification of applicable standards and specifications, including government, industry, and company generated.
- Documentation of the methods used to control compliance of requirements by subcontractors and vendors.
- Methodology for coordinating, approving, and tracking all engineering drawings, engineering orders, and other documents that establish or modify materials and/or processes usage.

9.0 Software

9.1 Flight and Ground Software

9.1.1 Flight and Ground Software Technical Products

A review of Commercial Partner documentation covering the requirements, design, implementation, test and verification, operation, and management of safety critical software products will be performed to ensure that they address the intent of appropriate NASA standards and specifications. Of interest are those items classified as 'Class A' according to the definition contained in Appendix E of NPR 7150.2A, specifically ground and flight software 'developed and/or operated by or for NASA that is needed to perform a primary mission objective of human space flight and directly interacts with human space flight systems,' and that has direct impacts on the health and safety of the crew. NASA will negotiate with each Commercial Partner to jointly identify the specific software products that fall into this category.

Documentation related to any software models or simulations whose results are used to make critical decisions regarding design, development, manufacturing, and ground or flight operations that may impact human safety or program defined mission success criteria will also be reviewed. Of particular interest are the methods and procedures used for verification, validation, and quantification of uncertainty that is used to assess and certify the credibility of the model.

Of particular interest to NASA is how the Commercial Partner will address the intent of appropriate requirements contained in the NASA Security of Information Technology standard designed to adequately ensure that the confidentiality, integrity, and availability of critical software components. A thorough review of appropriate software security plans, policies, and procedures concerning the management of safety critical software components will be conducted to determine that sufficient security controls and protection are implemented.

Specific documents to be examined include the full set of artifacts produced during the software life-cycle process as conducted in accordance with commonly accepted industry standards (e.g., DOD-STD-2167A, MIL-STD-498, IEEE J-STD-016, ISO 12207, etc.) and will normally include, but not be limited to, some or all of the following:

- Software Management Plans
- Software Security Plans for Development Environment of Class A Products
- Software Development Plans
- Software Requirements Specifications
- Software Operations Concept Documents
- Software Design Documents
- Software Product Specifications
- Software Interface Design Documents
- Software Test Plans
- Software Test Procedures
- Software Test Reports
- Software User's Manuals

9.1.2 Flight and Ground Software Technical Assessment

A review of the software technical products will substantiate that the Commercial Partner software design processes meet the intent of NPR 7150.2A *NASA Software Engineering Requirements*, for Class A software.

Specific areas to be focused on during this review include how critical software components will be designed, developed, tested, managed, and used in the overall design and operation of the vehicle, and how those components will ensure a safe and habitable environment for the crew and support the detection and mitigation of any risks to their well being. These factors are the result of acquired knowledge and lessons learned from over forty years of NASA human space flight experience and generally involve topics, such as:

- Fault tolerance.
- Failure detection, identification, and isolation or recovery.
- Similar or dissimilar redundancy.
- Autonomous operation of safety critical functions.
- Manual override of automatic functions.
- Extent of ground and crew visibility into system operation and performance.
- Amount of crew involvement and interaction required.
- Accurate and timely notifications of faults and anomalies.
- Command authentication and validation (including response to inadvertent commanding).
- Ground monitor and control of vehicle systems without crew involvement.
- Maintaining vehicle control and crew environment during abort scenarios.

9.1.3 Flight and Ground Software References

Document Number	*Title*
NASA NPR 2810.1	*Security of Information Technology*
NASA NPR 7150.2	*NASA Software Engineering Requirements*
NASA-STD-7009	*Standard for Models and Simulations*

Appendix A: Acronyms

Acronyms	Phrase
AC	Alternating Current
ACGIH	American Conference of Governmental Industrial Hygienists
AED	Automatic External Defibrillator
AI	Approach Initiation
ALARA	As Low As Reasonably Achievable
AMP	Ambulatory Medical Pack
ATV	Automated Transfer Vehicle
BDC	Baseline Data Collection
CCP	Commercial Crew Program
CCT	Commercial Crew Transportation
CFM	Cubic Feet/Minute
CHSIP	Commercial Human System Integration Process
CIL	Critical Items List
CM	Configuration Management
CO2	Carbon Dioxide
COPV	Composite Overwrapped Pressure Vessel
COTS	Commercial Orbital Transportation System
CG	Center of Gravity
CP	Commercial Partner
CRS	Cargo Resupply Contract
CTS	Crew Transportation System
CVCC	Commercial Vehicle Control Center
DAEZ	Down-range Abort Exclusion Zone
DC	Direct Current
DDT&E	Design, Development, Test and Evaluation
EARD	Exploration Architecture Requirements Document
ECLSS	Environmental Control and Life Support Systems
EER	Estimated Energy Requirements
EMT	Emergency Medical Technician
EOM	End of Mission
EPA	Environmental Protection Agency
ESD	Electrostatic Discharge
ESMD	NASA Exploration Systems Mission Directorate
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
FEU	Flight Equivalent Unit

Acronyms	Phrase
FIV	Flow-Induced Vibration
FMEA	Failure Mode and Effects Analysis
FTS	Flight Termination System
GCR	Galactic Cosmic Radiation
GFE	Government Furnished Equipment
GIDEP	Government-Industry Data Exchange Program
GLACIER	General Laboratory Active Cryogenic ISS Experiment Refrigerator
GNC	Guidance, Navigation, Control
GSE	Ground Support Equipment
HCN	Hydrogen Cyanide
HCL	Hydrogen Chloride
HEA	Human Error Analysis
HEPA	High Efficiency Particulate Air
HIDH	Human Integration Design Handbook
HQR	Handling Qualities Rating
HTV	H-II Transfer Vehicle
HUD	Heads Up Display
HZ	Hertz
IEEE	Institute of Electrical and Electronic Engineers
IDD	Interface Definition Document
IP	International Partner
IR	Infrared
IRD	Interface Requirements Document
ISO	International Standards Organization
ISS	International Space Station
IT	Information Technology
IVA	Intravehiclar Activity
JSC	Johnson Space Center
KSC	Kennedy Space Center
LOC	Loss Of Crew
LOM	Loss Of Mission
MA	Milli Ampere
MCC-H	International Space Station Mission Control Center – Houston
MCL	Mean Crew Load
MCL	Maximum Contaminant Levels
MDL	Mid Deck Locker
MFCO	Mission Flight Control Offices
MMOD	Micro Meteoroid Orbital Debris
MORD	Medical Operations Requirements Document
MSDV	Motion Sickness Dose Value
MTBF	Mean Time Between Failures

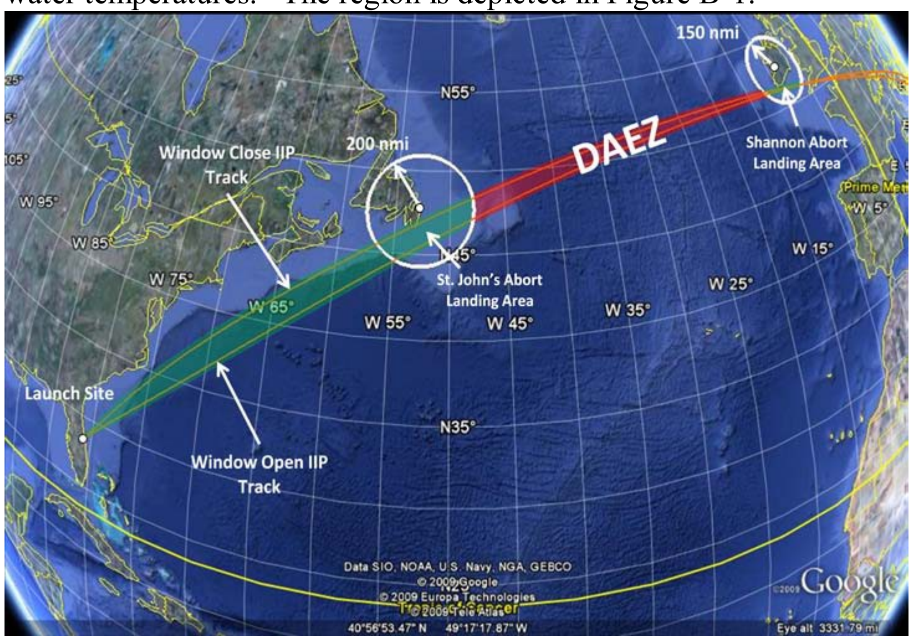
Acronyms	Phrase
MUA	Materials Usage Agreement
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NC	Noise Criterion
NCL	Nominal Crew Load
NDE	Nondestructive Evaluation
NIOSH	National Institute for Occupational Safety and Health
NIR	Non-Ionizing Radiation
NPD	NASA Policy Document
NPR	NASA Procedural Requirement
ODAR	Obsolescence Driven Avionics Redesign
ORU	Orbital Replaceable Units
OSHA	Occupational Safety and Health Administration
PNP	Probability of No Penetration
PPE	Personal Protective Equipment
PPCO2	Carbon Dioxide Partial Pressure
PPO2	Oxygen Partial Pressure
PRA	Probabilistic Risk Assessment
R&M	Reliability and Maintainability
RER	Respiratory Exchange Ratio
RF	Radio Frequency
RMS	Root Mean Squared
RPCM	Remote Power Control Module
RSO	Range Safety Officer
SAR	Search and Rescue
SAS	Space Adaptation Syndrome
SIL	Speech Interference Level
SMA	Safety and Mission Assurance
SMAC	Spacecraft Maximum Allowable Concentrations
SME	Subject Matter Expert
SPE	Solar Particle Events
SPL	Sound Pressure Level
SRD	System Requirements Document
SRP	Safety Review Panel
SSP	Space Station Program
SUS	System Usability Scale
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Specified
TDAD	Trailing Deployable Aerodynamic Decelerator

Acronyms	Phrase
TEE	Total Energy Expenditure
TICB	Transportation Integration Control Board
TPS	Thermal Protection System
TWA	Time Weighted Average
USOS	United States Operations Segment
UV	Ultra Violet

Appendix B: Definitions

Term	Definition
Abort	The forced early return of the crew to a nominal or contingency landing site when failures or the existence of uncontrolled catastrophic hazards prevent continuation of the mission profile and a return is required for crew survival. The crew is safely returned to a landing site in the space system nominally used for entry and landing/touchdown.
Ambient Light	Any surrounding light source (existing lighting conditions). This could be a combination of natural lighting (sunlight, moonlight) and any artificial light source provided. For example, in an office there would be ambient light sources of both the natural sunlight and the fluorescent lights above (general office lighting).
Analysis	A verification method utilizing techniques and tools such as math models, prior test data, simulations, analytical assessments, etc. Analysis may be used in lieu of, or in addition to, other methods to ensure compliance to specification requirements. The selected techniques may include, but not be limited to, engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and analog modeling. Analysis may be used when it can be determined that rigorous and accurate analysis is possible, test is not cost effective, and verification by inspection is not adequate.
Annunciate	To provide a visual, tactile or audible indication.
Approach Ellipsoid	A 4 x 2 x 2 km ellipsoid, centered at the ISS center of mass, with the long axis aligned with the V-Bar.
Approach Initiation	The approach Initiation is the first rendezvous maneuver during a nominal approach that is targeted to bring the vehicle inside the ISS approach ellipsoid.
Ascent	The period of time from initial motion away from the launch pad until physical separation from the launch vehicle during nominal flight or during an abort.
Ascent Abort	An abort performed during ascent, where the crewed spacecraft is separated from the launch vehicle without the capability to achieve a safe stable orbit. The crew is safely returned to a landing site in a portion of the spacecraft nominally used for entry and landing/touchdown.
Automated	Automatic (as opposed to human) control of a system or operation.
Autonomous	Ability of a space system to perform operations independent from any ground-based systems. This includes no communication with, or real-time support from, mission control or other ground systems.
Catastrophic Event	An event resulting in the death or permanent disability of a ground closeout or flight crewmember or an event resulting in the unplanned loss/destruction of a major element of the CTS or ISS during the mission that could potentially result in the death or permanent disability of a flight crewmember.
Catastrophic Hazard	A condition that could result in the death or permanent disability of a

	ground closeout or flight crewmember or in the unplanned loss/destruction of a major element of the CTS during the mission that could potentially result in the death or permanent disability of a flight crewmember.
Cargo	An item (or items) required to maintain the operability of the ISS and/or the health of its crew, and that must be launched as soon as possible.
Contingency	Provisioning for an event or circumstance that is possible but cannot be predicted with certainty.
Crew	Any human onboard the spacecraft after the hatch is closed for flight or onboard the spacecraft during flight.
Crewmember	Persons onboard the vehicle that are certified to assist in its operation during any phase of flight, and/or certified to perform particular tasks during the mission (such as a robotic operation or an extravehicular activity).
Command	Directive to a processor or system to perform a particular action or function.
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.
Crew Awake period	The time between the scheduled crew sleep periods.
Crew Transportation System (CTS)	The collection of all space-based and ground-based systems (encompassing hardware and software) used to conduct space missions or support activity in space, including, but not limited to, the integrated space vehicle, space-based communication and navigation systems, launch systems, and mission/launch control. This definition is the same as the definition of Space System found in NPR 8705.2B.
CTS Element	One component part of the overall Crew Transportation System. For example, the spacecraft is an element of the CTS.
Critical Software	Any software component whose behavior or performance could lead to a catastrophic event or abort. This includes the flight software as well as ground-control software.
Critical Software/Firmware	Software/Firmware that resides in a safety-critical system that is a potential hazard cause or contributor, supports a hazard control or mitigation, controls safety-critical functions, or detects and reports 1) fault trends that indicate a potential hazard and/or 2) failures which lead to a hazardous condition.
Critical (sub)System	A (sub) system is assessed as critical if loss of overall (sub)system function, or improper performance of a (sub)system function, could result in a catastrophic event or abort.
Critical Hazard	A condition that may cause a severe injury or occupational illness, loss of mission, or major property damage to facilities, systems, or flight hardware.
De-conditioned	"De-conditioned" defines a space flight crewmember or passenger whose physiological capabilities, including musculoskeletal, cardiopulmonary, and neurovestibular, have deteriorated as a result of long duration exposure to the micro-gravity and space environment and may result in degraded crewmember performance for nominal and off-nominal mission tasks. The space environment may include adverse effects of confinement, isolation,

	noise, deprivation of sensory and motor stimulation, and high workloads.
Definitive Medical Care	A capability equivalent to a tertiary care/Level I hospital (trauma and neurosurgery capabilities).
Demonstration	A method of verification that consists of a qualitative determination of the properties of a test article. This qualitative determination is made through observation, with or without special test equipment or instrumentation, which verifies characteristics such as human engineering features, services, access features, and transportability. Demonstration requirements are normally implemented within a test plan, operations plan, or test procedure.
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.
Downrange Abort Exclusion Zone	A geographical region of the North Atlantic Ocean to be avoided for water landings during ascent aborts for ISS missions due to rough seas and cold water temperatures. The region is depicted in Figure B-1.  **Figure B-1 Ascent Downrange Abort Exclusion Zone**
Emergency	An unexpected event or events during a mission that requires immediate action to keep the crew alive or serious injury from occurring.
Emergency Egress	Capability for a crew to exit the vehicle and leave the hazardous situation or catastrophic event within the specified time. Flight crew emergency egress can be unassisted or assisted by ground personnel.
Emergency Equipment and	Systems (Ground or Flight) that exist solely to prevent loss of life in the presence of imminent catastrophic conditions. Examples include fire

Systems	suppression systems and extinguishers, emergency breathing devices, and crew escape systems. Emergency systems are not considered a leg of failure tolerance for the nominal, operational equipment and systems, and do not serve as a design control to prevent the occurrence of a catastrophic condition. Emergency equipment and systems are not required to be designed and tested to the full range of functional, performance and certification requirements defined for the nominal, operational equipment and systems
Emergency Medical	The capability to respond to crew illness or injury in order to prevent, or mitigate, crew demise or permanent disability. This includes either an inherent capability on a vehicle, timely transfer to a place or vehicle that can provide higher level medical care, or both.
End of Mission	The planned landing time for the entire mission including the nominal pre-flight agreed to docked mission duration.
Entry	The period of time that begins with the final commitment to enter the atmosphere from orbit or from an ascent abort, and ending when the velocity of the spacecraft is zero relative to the landing surface.
Entry Interface	The point in the entry phase where the spacecraft contacts the atmosphere (typically at a geodetic altitude of 400,000 feet), resulting in increased heating to the thermal protection system and remainder of the spacecraft exterior surfaces.
Failure	Inability of a system, subsystem, component, or part to perform its required function within specified limits (Source - NPR 8715.3).
Failure Tolerance	The ability to sustain a certain number of failures and still retain capability. A component, subsystem, or system that cannot sustain at least one failure is not considered to be fault tolerant.
Fault	An undesired system state and/or the immediate cause of failure (e.g., maladjustment, misalignment, defect, or other). The definition of the term "fault" envelopes the word "failure," since faults include other undesired events such as software anomalies and operational anomalies (Source - MIL-STD-721C). Faults at a lower level could lead to failures at the higher subsystem or system level.
Flight Operations	All operations of the flight vehicle and the crew and ground teams supporting the flight vehicle from liftoff until landing.
Flight Crew	Any human on board the space system during the mission that has been trained to monitor, operate, and control the space system; same as crew.
Flight Phase	A particular phase or timeframe during a mission is referred to as a flight phase. The term “all flight phases” is defined as the following flight phases: pre-launch, ascent, on-orbit free-flight, docked operations, deorbit/entry, landing, post-landing.

Flight Systems	Any equipment, system, subsystem or component that is part of the integrated space system.
Flight Hardware	All components and systems that comprise the internal and external portions of the spacecraft, launch vehicle, launch abort system, and crew worn equipment.
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
Free-Flight Operations	Vehicle on-orbit operations that occur when the spacecraft is not in contact with any part of the ISS.
Ground Crew	Ground personnel that assists the flight crew in entering the spacecraft, closing the hatch, and performing leak checks.
Ground Hardware	All components and systems that reside on the ground in support of the mission including the Commercial Vehicle Control Center (CVCC), launch pad, ground support equipment, recovery equipment, facilities, and communications, network, and tracking equipment.
Ground Processing	The work required to prepare the spacecraft for its mission from post-landing to launch. This work includes launch vehicle*/spacecraft*/crew recovery, spacecraft return to the processing facility*, launch vehicle and spacecraft preparation at the processing facility, transport to the launch site, support during integration and checkout with the launch vehicle, and launch countdown activities. [*Applies only to reusable spacecraft.]
Habitable	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 NASA-STD-3000.
Hazard	A state or a set of conditions, internal or external to a system, that has the potential to cause harm (Source - NPR 8715.3).
Hazard Analysis	The process of identifying hazards and their potential causal factors.
Health & Status Data	Data, including Emergency, Caution and Warning data, that can be analyzed or monitored describing the ability of the system or system components to meet their performance requirements.
Human Error	Either an action that is not intended or desired by the human or a failure on the part of the human to perform a prescribed action within specified limits of accuracy, sequence, or time that fails to produce the expected result and has led or has the potential to lead to an unwanted consequence.
Human Error Analysis (HEA)	A systematic approach used to evaluate human actions, identify potential human error, model human performance, and qualitatively characterize how human error affects a system. HEA provides an evaluation of human actions and error in an effort to generate system improvements that reduce the frequency of error and minimize the negative effects on the system.

	HEA is the first step in Human Risk Assessment and is often referred to as qualitative Human Risk Assessment.
Ill or Injured	Refers to a crewmember whose physiological and/or psychological well-being and health has deteriorated as a result of an illness (e.g., appendicitis) or injury (e.g., trauma, toxic exposure) and requires medical capabilities exceeding those available on ISS and transportation to ground-based definitive medical care. Ill or injured crewmember performance for nominal and off-nominal mission tasks will be degraded.
Inspection	A method of verification that determines conformance to requirements by the use of standard quality control methods to ensure compliance by review of drawings and data. This method is used wherever documents or data can be visually used to verify the physical characteristics of the product instead of the performance of the product.
Integrated Space Vehicle	The integrated space vehicle consists of all the system elements that are occupied by the crew during the space mission and provide life support functions for the crew (i.e., the crewed elements). The integrated space vehicle also includes all elements physically attached to the crewed element during the mission. The integrated space vehicle is part of the larger space system used to conduct the mission. This definition is the same as the definition for crewed space system found in NPR 8705.2B. The following examples are provided for clarification: Example 1: A launch vehicle for a crewed spacecraft is part of the integrated space vehicle for ascent. Example 2: When the crew ingresses a vehicle for launch, the vehicle is physically connected to the launch pad. The specific launch pad systems that interface with the launch vehicle and spacecraft are considered part of the integrated space vehicle but not the entire launch pad.
ISS Integrated Operations	All operations starting at 90 minutes prior to the ISS Approach Initiation and last until the vehicle leaves the ISS Approach Ellipsoid on a non-return trajectory.
Landing	The final phase or region of flight consisting of transition from descent, to an approach, touchdown, and coming to rest.
Launch Opportunity	The period of time during which the relative position of the launch site and the ISS orbital plane permit the launch vehicle to insert the spacecraft into a target plane for a rendezvous with ISS within 72 hours (northerly launches only to avoid overflight of Cuba). This re-occurs approximately every 23 hours and 36 minutes. A launch opportunity may consist of multiple launch windows of a few minutes each to account for different phasing requirements based on the time of rendezvous (Flight Day 1, 2, or 3).
Launch Vehicle	The vehicle that contains the propulsion system necessary to deliver the energy required to insert the spacecraft into orbit or provide the propulsion

	capability necessary to execute an ascent abort.
Launch Probability	The probability that the System will successfully complete a scheduled launch event. The launch opportunity will be considered scheduled at 24 hours prior to the opening of the launch window.
Loss of Crew	Death or permanently debilitating injury to one or more crewmembers.
Loss of Mission	Loss of or the inability to complete enough of the primary mission objectives such that a repeat mission must be flown.
Maintenance	The function of keeping items or equipment in, or restoring them to, a specified operational condition. It includes servicing, test, inspection, adjustment/alignment, removal, replacement, access, assembly/disassembly, lubrication, operation, decontamination, installation, fault location, calibration, condition determination, repair, modification, overhaul, rebuilding, and reclamation.
Manual Control	The crew's ability to bypass automation in order to exert direct control over a space system or operation. For control of a spacecraft's flight path, manual control is the ability for the crew to affect any flight path within the capability of the flight control system. Similarly, for control of a spacecraft's attitude, manual control is the ability for the crew to affect any attitude within the capability of the flight/attitude control system.
Mission	The mission begins with entry of the crew into the spacecraft, includes delivery of the crew to/from ISS, and ends with successful delivery of the crew to NASA after landing.
NASA Crew	The NASA crewmembers or the NASA sponsored crewmembers being transferred to and from the ISS. These include international partner crewmembers.
Operator	Any human interacting with the integrated space vehicle during the mission.
Orbit	This flight phase starts just after final orbit insertion and ends at the completion of the first deorbit burn.
Override	To take precedence over system control functions.
Passenger	Any human on board the space system while in flight that has no responsibility to perform any mission task for that system. Often referred to as "Space Flight Participant."
Permanent Disability	A non-fatal occupational injury or illness resulting in permanent impairment through loss of, or compromised use of, a critical part of the body, to include major limbs (e.g., arm, leg), critical sensory organs (e.g., eye), critical life-supporting organs (e.g., heart, lungs, brain), and/or body parts controlling major motor functions (e.g., spine, neck). Therefore, permanent disability includes a non-fatal injury or occupational illness that permanently incapacitates a person to the extent that he or she cannot be rehabilitated to achieve gainful employment in their trained occupation and

	results in a medical discharge from duties or civilian equivalent.
Post-Landing	The flight phase beginning with the actual landing event when the vehicle has no horizontal or vertical motion and ending with the last crew member egress from the spacecraft
Proximity Operations	This flight phase starts just prior to the Approach Initiation and ends with the intentional contact of the vehicles' docking mechanisms or when the vehicle leaves the ISS Approach Ellipsoid.
Recovery	This phase of the mission occurs after the spacecraft comes to rest from landing.
Reliability	The probability that a system of hardware, software, and human elements will function as intended over a specified period of time under specified environmental conditions.
Rendezvous	The flight phase of executing a series of on-orbit maneuvers to move the spacecraft into the proximity of its target. This phase starts with orbit insertion and ends just prior to the approach initiation.
Rescue	The process of locating the crew, proceeding to their position, providing assistance, and transporting them to a location free from danger.
Risk	The combination of (1) the probability (qualitative or quantitative) including associated uncertainty that the space system will experience an undesired event (or sequences of events) such as internal system or component failure or an external event and (2) the magnitude of the consequences (personnel, public, and mission impacts) and associated uncertainties given that the undesired event(s) occur(s).
Risk Assessment	An evaluation of a risk item that determines (1) what can go wrong, (2) how likely is it to occur, and (3) what the consequences are.
Safe Haven	A functional association of capabilities and environments that is initiated and activated in the event of a potentially life-threatening anomaly and allows human survival until rescue, the event ends, or repair can be affected. It is a location at a safe distance from or closed off from the life-threatening anomaly.
Safety	The absence from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment.
Safety Critical	A procedure, operation, limit, event, personnel role, hardware, or software which has the potential to constitute a significant risk to human life, ground facilities, flight hardware, or mission success. Often, items that are safety critical are subject to highly time-sensitive events, where prior rehearsal is necessary for success.
Software	Computer instructions or data, stored electronically. Systems software includes the operating system and all the utilities that enable the computer

	to function. Applications software includes programs that do real work for users, such as word processors, spreadsheets, data management systems, and analysis tools. Software can be Commercial Off-The-Shelf (COTS), Contractor developed, Government Furnished, or combinations thereof.
Spacecraft	All system elements that are occupied by the crew/passengers during the space mission and provide life support functions for the crew/passengers. The crewed element includes all the subsystems that provide life support functions for the crew/passengers. Defined as "crewed space element" in NPR 8705.2B.
Stowage	The accommodation of physical items in a safe and secure manner in the spacecraft. This does not imply that resources other than physical accommodations (e.g., power, thermal, etc.) are supplied.
Subsystem	A secondary or subordinate system within a system (such as the spacecraft) that performs a specific function or functions. Examples include electrical power, guidance and navigation, attitude control, telemetry, thermal control, propulsion, structures subsystems. A subsystem may consist of several components (hardware and software) and may include interconnection items such as cables or tubing and the support structure to which they are mounted.
System	The aggregate of the ground segment, flight segment, and workforce required for crew rescue and crew transport
Technical Authority	The NASA individual who specifically maintains technical responsibility for establishment of, changes to, and waivers of requirements in a designated area. There are three Technical Authorities: Engineering, Safety and Mission Assurance, Health and Medical.
Test	A method of verification in which technical means, such as the use of special equipment, instrumentation, simulation techniques, and the application of established principles and procedures are used for the evaluation of components, subsystems, and systems to determine compliance with requirements. Test will be selected as the primary method when analytical techniques do not produce adequate results; failure modes exist which could compromise personnel safety, adversely affect flight systems or payload operation, or result in a loss of mission objectives; or for any components directly associated with Space Station and orbiter interfaces. The analysis of data derived from tests is an integral part of the test program, and should not be confused with analysis as defined above. Tests will be used to determine quantitative compliance to requirements and produce quantitative results.
Validation	Proof that the product accomplishes the intended purpose. May be determined by a combination of test, analysis, and demonstration.
Verification	Proof of compliance with a requirement or specifications based on a combination of test, analysis, demonstration, and inspection.

Appendix C: Record of To Be Determined (TBD), To Be Resolved (TBR), and To Be Supplied Items

C.1: Open Items

TBD Reference	TBD Description	Status	Comments
TBD-009	Missing content for Integrated Thermal Analysis.	Open	Evaluate need for Thermal Analysis.
TBD-018	Determine need for and content of aerodynamics section and thermal sections. Action from 1st checkpoint.	Open	
TBD-026	Evaluate need for insight and evaluation section for launch vehicle and spacecraft pressure equalization and venting.	Open	Preliminary review of GSE design standards complete and no additional content or standards were identified for CCT-REQ-1130 or CCT-STD-1140. Team is still evaluating flight side.
TBD-029	Chief engineer to determine best method of properly documenting ESD requirements in CCT-STD-1140. Depending on whether JPR 8080.5/E-20 is added as a "meet the intent" requirement of CCT-REQ-1130 or specific requirements are pulled from JPR 8080.5 and made a part of CCT-REQ-1130, Table 2.1 and Table 2.2 of CCT-STD-1140 must be updated to show that the ESD requirements of JPR 8080.5 are not just references.	Open	
TBD-034	JSC 65830 was added to CCT-REQ-1130 to replace MSFC-HNDBK-505, however the Structures discipline did not add the technical assessment for this standard in CCT-STD-1140	Open	JSC 65830 formally accepted by TRB on 3/29.
TBD-035	Provide update to the avionics discipline that includes evaluation criteria for proposed alternates to NASA-STD-4005.	Open	NASA-STD-4005 is called out in CCT-REQ-1130, 3.9.3.13.1, but CCT-STD-1140 has no corresponding technical assessment.
TBD-036	Provide update to the 1140 that includes evaluation criteria for proposed alternates to NASA-STD-5009.	Open	NASA-STD-5009 is called out in CCT-REQ-1130, 3.9.10.3, but CCT-STD-1140 has no corresponding technical assessment.

C.2: Closed Items

TBD Reference	TBD Description	Status	Comments
TBD-001	Missing content for Avionics.	Closed	Removed Avionics section. Standards for avionics and communications are covered by Electrical systems.
TBD-002	Missing content for Comm and Tracking.	Closed	Removed Comm and Tracking section. Standards for avionics and communications are covered by

TBD Reference	TBD Description	Status	Comments
			Electrical systems.
TBD-003	Need to determine applicability of Space Solar Cells to the Electrical Systems section.	Closed	Removed TBD-003. No content for this section. Only part of References.
TBD-004	Need to determine applicability of to the Electrical Systems section. This may be redundant to Section 10.6 EEC.	Closed	Removed TBD-004 as this is redundant to EEC section.
TBD-005	Need to determine applicability of Space Solar Cells to the Electrical Systems section.	Closed	Removed TBD-005. No content for this section. Only part of references.
TBD-006	Need to determine if ECLSS section is still required since Fluids section has now been added to the document.	Closed	ECLSS Combined with Fluids.
TBD-007	Missing content for GN&C section.	Closed	Removed GN&C section. No standards or processes identified for GN&C at present.
TBD-008	Need to determine if wiring integration Section 9.12 is still necessary.	Closed	Electrical systems addresses wire.
TBD-010	Missing content for Commercial Partner products for environments.	Closed	
TBD-011	Missing content for NASA assessment of Commercial Partner environments products.	Closed	
TBD-012	Missing content for MMOD environments, Section 10.2.	Closed	Removed all sections for environments. No standards or processes identified.
TBD-013	Missing content for Radiation Environments, Section 10.3.	Closed	Removed all sections for environments. No standards or processes identified.
TBD-014	Determine where to place SMC Standard SMC-S-016 (2008) MIL-STD-1540E Aerospace Report No. TR-2004, Test Requirements for Launch, Upper-Stage, and Space Vehicles. It was originally in the Environment sections but does not really apply. This standard discusses testing and does not discuss environments except as it is related to qualification testing.	Closed	
TBD-016	Determine which section of 1140 should provide evaluation of ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation.	Closed	Tied this standard to fluids systems.
TBD-017	Determine need for and content of EEE parts selection section.	Closed	Draft EEE parts selection section added. This is only a first cut and will be refined.
TBD-019	Update Appendix A – General References after receipt of updates from SMA.	Closed	Removed Appendix A. Incorporated all references into Section 2.2.
TBD-020	Develop language to address	Closed	NASA-STD-5005 was added as a meet the intent

TBD Reference	TBD Description	Status	Comments
	GSE/Facilities on Non-NASA facilities (if any appropriate) in addition to language here for NASA facilities.		standard in CCT-REQ-1130. GSE section in CCT-STD-1140 has been updated to reflect this.
TBD-021	Incorporate changes to Reference table (Section 2.2) based on review of the document by the Launch Services Program (LSP).	Closed	LSP review complete and updates to 2.2 are included in this revision.
TBD-022	Update Section 8.1 to include technical assessment for Avionics.	Closed	Completed per Avionics update 1/19/2011.
TBD-023	Coordinate Engineering and SMA TA inputs for Sections 5.7 and 10.0.	Closed	This is overcome by events as SMA is completely rewriting their section. Will readdress, if required, following new SMA submittal.
TBD-024	Chief Engineer will form a Flight Mechanics team with members from JSC, MSFC, and NESC. Team will evaluate whether there are standards or processes that need to be included in CCT-STD-1140.	Closed	GNC and Flight Mechanics section added to CCT-STD-1140.
TBD-025	Evaluate need for insight and evaluation section for systems integration.	Closed	SE&I information will be put into CCT-PLN-1100 or CCT-PLN-1120.
TBD-027	HMTA evaluate need for additional 1140 content based on removal of some requirements in CCT-REQ-1130.	Closed	HMTA information will not reside in CCT-STD-1140
TBD-028	Review processes in CCT-PLN-1100 to determine which require additional content in CCT-STD-1140.	Closed	All programmatic processes were removed from CCT-STD-1140 as a result of program direction following Draft 3.0 release.
TBD-030	Allocate MIL-STD-1540E properly. Currently Table 2.1 lists Avionics, Fluids, and Propulsion disciplines as the principle evaluators of this standard. However, this standard applies across the board. Need to determine how to handle this for the entire book.	Closed	MIL-STD-1540E has been referenced in the EEE Parts Management, Fluids, and Propulsion sections of CCT-STD-1140. Further document updates will refine this as necessary.
TBD-031	SMA to refine sections on PRA and Human Error Analysis and provide updated content.	Closed	SMA section has been completely rewritten to remove any program or project type processes. Those will now be part of CCT-PLN-1120.
TBD-032	Allocate ANSI/NCSL Z540.3-2006, to the proper discipline and provide supporting technical assessment if required.	Closed	This standard is not part of any evaluations in CCT-STD-1140. If this standard is anywhere, it would be part of CCT-PLN-1120.
TBD-033	Provide technical assessment criteria for GEIA-STD-0005-2.	Closed	Avionics and Electrical Systems updated as part of Draft 4.0.