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SYSTEM REQUIREMENTS FOR THE CREW EXPLORATION VEHICLE SYSTEM

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SYSTEM REQUIREMENTS FOR THE CREW EXPLORATION VEHICLE SYSTEM

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1 INTRODUCTION

1.1 SCOPE

This requirements document establishes the technical requirements allocated to the Crew Exploration Vehicle (CEV) in support of the Lunar Sortie and International Space Station (ISS) Design Reference Missions (DRMs). They represent a first-level allocation and functional decomposition of the requirements expressed in the CxP-70000 Constellation Architecture Requirements Document (CARD). Requirements for the CEV in support of the Mars missions will either be included in a later version of this document, or in a separate document.

1.2 CONSTELLATION GOALS AND OBJECTIVES

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

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

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

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

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

The requirements in this document can be traced back to CxP 70000 Constellation Architecture Requirements Document (CARD) which is traced from CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), the Vision for Space Exploration, the NASA Authorization Act of 2005 and the NASA Strategic Plan.

1.3 DESIGN GOALS

The following discussion provides design, guidance and objectives for CEV commensurate with the overall Constellation Program objectives.

1.3.1 General

The goal of NASA's Constellation Program is to conduct a series of human space expeditions of increasing scope. These expeditions will follow an evolutionary pathway, starting in Low Earth Orbit (LEO) with missions supporting the ISS and expanding to encompass the Moon, Mars and other destinations. It is intended that the knowledge, technology, operational experience, and systems developed during each stage of this Program will provide the foundation for more extensive exploration activities as the Constellation Program matures. As part of this evolutionary philosophy, the initial steps along this path will leverage flight-proven technologies and techniques of earlier human exploration efforts including the ISS, Space Shuttle and Apollo programs.

1.3.2 CEV Design Goals

1.3.2.1 Risk Management

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

1.3.2.2 Crew Survival

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

1.3.2.3 Common Cause Failure Mode Elimination

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

1.3.2.4 In Flight Maintenance

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

1.3.2.5 Risk Management

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

1.3.2.6 Design Guidance

The design of all flight equipment and associated ground/mission equipment and procedures should be such as to accommodate the various flight tests and vehicle configurations that are planned with minimum variation of the equipment from flight to flight. For the CEV, the feedback loop and linkages between operational performance and system design are particularly important if we are to maximize learning during the long-term development process that will be required. Achieving our ambitious space exploration goals will require optimal learning from each mission and the ability to apply lessons learned to future missions and system development cycles. The CEV will be principally designed to accommodate the end-state (generally considered as the Lunar Outpost mission), with deviations into a block-upgrade or incremental/phased approach as necessary and appropriate. The CEV design approach will also be one of flexibility, in that where possible, the design will attempt to accommodate future CEV use for or efficient upgrade for other potential agency needs.

1.3.2.6.1 Control Of Hazards

1.3.2.6.1.1 Design Simplicity

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

1.3.2.6.1.2 Design Robustness

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

1.3.2.6.1.3 Redundancy

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

1.3.2.6.2 Design For Human Operability

Systems should be designed around maximizing human performance capabilities. Ground processing efficiency, mission success and crew safety will be significantly enhanced by a design of the Human-to-System environment that maximizes the effectiveness of the operations personnel. All sensing components associated with enabling operations personnel to recognize, isolate, and correct critical system malfunctions for a given vehicle should be located onboard that vehicle and be functionally independent of ground support and external interfaces. Two independent instrumented cues are required for any major change in the nominal mission plan. The source of these cues can be from space vehicle mechanical or data displays and alerts and downlink telemetry. Cues are not independent if space vehicle and ground indications are from the same sensor. Redundant sensors are required if two independent cues of a failure cannot be obtained. The vehicle will provide the flight crew with insight, intervention capability, control over vehicle automation, authority to enable irreversible actions, and critical autonomy from the ground. Display and control interfaces will be simple and intuitive. Presentation of onboard systems status information to the crew needs to be done in a consistent manner across all flight systems, and based on common well-documented practices of measure, iconography, and graphical standards. System design must preclude any failure mode requiring unreasonably swift human action to prevent a catastrophe. Unattended systems should not have catastrophic failure modes requiring immediate human intervention. Operations personnel should have the ability to intervene and override any on-board decision regardless of sensor indications, except where doing so is clearly not within human response capabilities thus imposing additional risk. A central objective of the sensor systems is to facilitate the situational awareness of both the crew and of remote operators (be they on the Earth or another vehicle). The design should allow the operator to make a rapid assessment of the current situation, including the exposure and investigation of off-nominal states. The design of the vehicle should allow for the crew to provide functional redundancy to the automated and Earth-in-the-loop systems where practical. Examples would include orbit determination, maneuver design and execution, and rendezvous and docking operations without the aid of ground control. The vehicle should require crew consent for irreversible actions where practical with respect to human reaction and decision times. Examples include commit to injection, de-orbit, and trajectory correction maneuvers. The ground should be able to control all crewed vehicle critical functionality in the event the need for un-crewed operation arises due to crew incapacitation, or maximizing effective use of crew time. The design of the vehicle should allow for the crew to provide functional redundancy to the automated and Earth-in-the-loop systems where practical. Having a human in the loop can be a parallel redundancy but not a serial redundancy which introduces single point failure.

1.3.2.6.3 Commonality / Interchangeability

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

1.3.2.6.4 Maintainability

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

1.3.2.6.5 Reliability

The design of all flight equipment and associated ground/mission equipment should focus on reliability engineering such that the critical hardware/software subsystems receive high reliability consideration. The heritage hardware items should be reviewed to address areas that need improvement as indicated by problem history with either hardware/software or processing issues. The new designs should consider high reliability standards for mission critical/safety items particularly those that will experience long mission operating life requirements and may contain some measure of difficulty for replacement/servicing.

1.3.2.6.6 Interoperability

Where practical, systems (or components of systems) should be interoperable with similar elements or components in other systems of the architecture. This approach will minimize training requirements, enhance the usability of portable or transferable equipment, and reduce logistics requirements.

1.3.2.6.7 Supportability

The logistics footprint required to support exploration missions must be minimized. Strategies to achieve this objective include implementation of commonality and standardization and across systems, and repair of failed hardware at the lowest practical hardware level.

1.3.2.6.8 Environmental Considerations

The vehicle design should minimize environmentally induced constraints on ground and flight operations. Hardware should be able to survive periods with no power and be able to return to operation from such a state.

1.3.2.6.9 Habitability

Habitability must be a prime consideration in the design of all vehicles/habitats/hardware used by a crew. Habitable volumes will provide a pressurized, shirt sleeved, temperature and humidity controlled atmosphere for the crew for all nominal extended duration phases of flight (operationally the ascent/entry phases of flight will be flown suited).

1.3.2.6.10 Open Architecture Approach

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

1.3.2.6.11 Software

A high degree of emphasis should be placed on controls over software development. New hazards and concerns will be identified throughout the development process and into operations. Software standards (such as the C3I commonality standards) are required to avoid cost of supporting dissimilar systems and architectures. Computer advancements, the emergence of highly reliable decision-making algorithms, and the emphasis on efficiency make an increased use of automated systems possible. However, full automation is often not practical and automation must be prioritized as practical. Software design and architecture should support capability for rapid changes according to changing program and operational needs. Additionally, software design should offer flexibility to allow the incorporation of upgraded and/or new LRUs with minimal impact such as use of industry standard interfaces and preserving performance margin.

1.4 MEASUREMENT UNITS

The Constellation Program has determined that the preferred primary system of measurement for the overall Constellation Program is SI. In all Level 1, 2 and 3 requirements documents SI will be shown as primary with the English unit equivalent in parenthesis. However, Constellation realizes the issues and practical need associated with use of heritage hardware components and designs (as well as associated tooling and infrastructure) and will allow at Level 4 and below the option to use English units as primary for that Project. Appropriate dimensional control plans must be in place to reduce technical risk, based on Project Manager approval. Where an interface between English and SI units exists, CEV specifications, drawings, and similar documentation will be written to include both units and depict the native design units as the primary units with the converted units in parenthesis. In addition, operational data should be presented in the same units as the development data except where information from multiple systems or elements must be operationally related. For the CEV Project, the primary system of units for development will be English, owing largely to:

- the number of heritage internal components planned to be used -the infrastructure and expertise of the suppliers planned to be used - the cost and practicality challenges associated with a project such as CEV attempting to “re-tool” the aerospace industry, who typically supply English parts and processes to the broad commercial and military aerospace/aerospace sectors - the principal near-term interface (CLV) being largely a heritage English system

The Constellation Program and CEV Project will utilize NIST SP811 for standardization and conversion of the units of measure.

2 DOCUMENTS

The documents listed in this section represent the documents that have been referenced either in part or in whole within this document. The applicable documents represent documents that have been explicitly identified within requirements statements (i.e. "shall" statements) and invoked as technical requirements for implementation. Each requirement statement identifies the applicable subsections of a document unless it has been deemed appropriate to invoke the entire document. Documents that are identified in this document but are not invoked within requirements statements are listed in the Reference Documents section.

2.1 APPLICABLE GOVERNMENT DOCUMENTS

The following requirement's documents, specifications, standards and handbooks form a part of this document to the extent specified herein.

Document Number	Title	Revision
CxP 70023	Constellation Program Design Specification for Natural Environments (DSNE)	
CxP 70026	Constellation Program Crew Exploration Vehicle (CEV) to Crew Launch Vehicle (CLV) Interface Requirements Document (IRD)	
CxP 70022-01	"Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1: Interoperability Specification"	CLV-GOE
CxP 70024	Constellation Program Human-Systems Integration Requirements (HSIR)	
CxP 70028	Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD)	
CxP 70029	Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD)	
CxP 70031	Constellation Program International Space Station (ISS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD)	
CxP 70032	Constellation Program Low Impact Docking System (LIDS) Interface Definition Document (IDD)	
CxP 70033	Constellation Program Crew Exploration Vehicle (CEV) to Extravehicular Activity (EVA) Systems Interface Requirements Document (IRD)	
CxP 70034	Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM)	

Document Number	**Title**	**Revision**
	Interface Requirements Document (IRD)	
CxP 70035	Constellation Program Portable Equipment, Payloads, and Cargo (PEPC) Interface Requirements Document (IRD)	
CxP 70036	Constellation Environmental Qualification and Acceptance Testing Requirements (CEQATR) Document	
CxP 70050-01	Constellation Program Electrical Power System Specification, Volume 1: Electrical Power Quality Performance for 28 VDC	CLV-GOE
CxP 70059	Constellation Program Safety, Reliability, and Quality Assurance (SR&QA) Requirements	
CxP 70080	Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document	
CxP 70050-02	Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28 VDC	
CxP 70118-01	"Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV) "	
CxP 70119	Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD)	
CxP 70130	Constellation Program Extravehicular Activity (EVA) Design and Construction Specification	
CxP 70135	Constellation Program Structural Design and Verification Requirements	
CxP 72085	Crew Exploration Vehicle (CEV) Outer Mold Line	
CxP 70070- ANX05, Book 1	Constellation Program Functional Security Requirements for Program Systems and Elements	
CxP 70143	Constellation Program Induced Environment Design Specification	
NASA-STD-5005	NASA Standard for Ground Support Equipment	B
JPR 8080.5	JSC Design and Procedural Standards	
NASA-STD-5017	Design and Development Requirements for Mechanisms	B/L

Document Number	**Title**	**Revision**
NPR 8715.5	Range Safety Program	
JSC 62550	Structural Design and Verification Criteria for Glass, Ceramics and Windows in Human Space Flight Applications	Draft
NASA-STD-5019	Fracture Control Requirements for Spaceflight Hardware	
NASA-STD-6001	Flammability, Odor, Off-Gassing and Compatibility Requirements & Test Procedures for Materials in Environments that Support Combustion (Superseding NHB-8060.1C)	
NPD 8710.3B	Subject: NASA Policy for Limiting Orbital Debris Generation (Revalidated 4/28/04)	
JSC 62809	Constellation Spacecraft Pyrotechnic Specification	C
NASA-STD-6016	Standard Materials and Process Requirements for Spacecraft	

2.2 APPLICABLE NON-GOVERNMENT PUBLICATIONS

The following specifications, standards and handbooks form a part of this document to the extent specified herein.

Document Number	**Title**	**Revision**
SAE-AS-5643	IEEE-1394b Interface Requirements for Military and Aerospace Vehicle Applications	
SAE-AS-5643/1	S400 Copper Media Interface Characteristics Over Extended Distances	
ANSI/AIAA S-80	Standard, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components	1998
ANSI/AIAA S-081	Standard, Space Systems – Composite Overwrapped Pressure Vessels (COPVs)	2000

2.3 REFERENCE DOCUMENTS

The following specifications, standards and handbooks were referenced in this document but not included within the technical requirements set.

2.3.1 Referenced Government Documents

The following specifications, standards, and handbooks were referenced in this document but not included within the technical requirements set.

Document Number	Title	Revision
CxP 70000	Constellation Architecture Requirements Document (CARD)	
CxP 70072-ANX01	Constellation Program Management Systems Plan, Annex 1: Constellation Glossary, Acronyms and Nomenclature (CGAN)	
CxP 70007	Constellation Design Reference Missions and Operational Concepts Document	
CxP 70051	Constellation Program Androgynous Peripheral Assembly System (APAS) Interface Definition Document (IDD)	
CxP 70003-ANX03	Constellation Program Plan, Annex 3: Acquisition Strategy Plan	
CxP 70073-02	Constellation Program Management Systems Requirements, Volume 2: Data Management Requirements	
NASA-STD-5001	Structural Design and Test Factors of Safety for Spaceflight Hardware	
AFSPCMAN-91-710	Easter and Western Range Safety User Requirements, Volumes 2,3 and 4	
NPR 2810.1	Security of Information Technology	A
NPR 8705.2	Human Rating Requirements for Space Systems	
NASA-TM-2005-214062		B/L
SSP 30426	Space Station External Contamination Control Requirements	D
FIPS-PUB-200	Minimum Security Requirements for Federal Information and Information Systems	
ED-112	Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems	
MIL-STD-1474D	Noise Limits	

2.3.2 Referenced Non-Government publications

Document Number	**Title**	**Revision**
None	**None**	**None**

2.4 ORDER OF PRECEDENCE

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence, except for the CARD, which takes precedence over this document. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3 SYSTEM REQUIREMENTS

The CEV is a system within the Constellation Program of the Exploration Systems Mission Directorate. Figure 1 illustrates the specification tree adopted for the Exploration System Mission Directorate (ESMD) and indicates the hierarchical relationship between this document and its parent document, the CARD. This section contains the essential technical requirements that apply to the performance, function, and design of the CEV. This section is intended to indicate, the minimum requirements that the CEV must meet to fulfill its intended purpose. In general, the intended purpose of the CEV is to safely deliver a crew of 4 to the Moon and return. A secondary objective is to safely deliver crew and pressurized cargo to the International Space Station (ISS) and return.

This section only contains technical requirements that the CEV must meet or a quality that the CEV must have. The section does not contain programmatic (or project) requirements which define tasks, procedures, or what the provider will deliver (such as design processes, deliverables, hazard reduction protocol techniques, or project documentation). This section only contains requirements that can be clearly verified. The requirements of this section will be verified for flight qualification.

The convention used in this document, which indicates requirements, goals, and statements of facts is as follows:

Shall - Used to indicate a binding requirement Should - Used to indicate a desired goal; Will - Used to indicate a statement of fact.

Every requirement containing a "shall" is binding and must be verified. Goals and statement of facts are nonbinding. Also, rationales are included for each of the requirements. They are located below the binding requirements and are identified by italics. The rationales are intended to provide clarification, justification, purpose, and/or source of the requirement. It is important to note that the rationales are not binding and only provide supporting information. In the event there is an inconsistency between the requirement and the rationale, only the requirements shall be binding and take precedence.

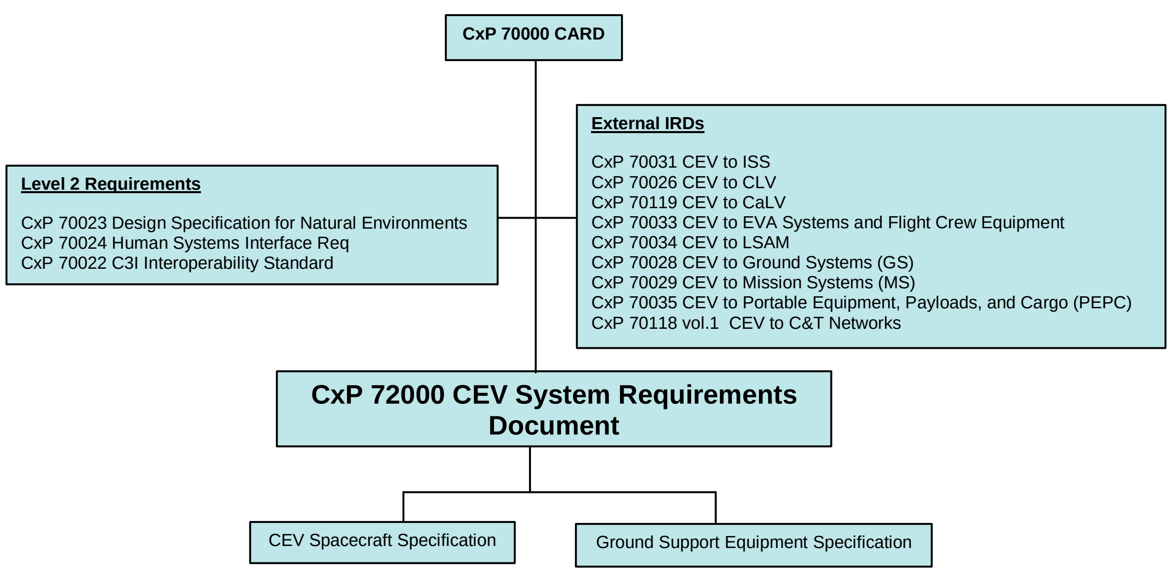

Figure 1 Hierarchical Specification Relationships

3.1 DEFINITION

Requirements in this document are written for the CEV System, which includes the Crew Module (CM), Service Module (SM) with spacecraft adapter(SA), the Launch Abort System (LAS) and associated Ground Support Equipment (GSE). When the requirements apply to only one module, they shall be stated as such. The CEV system does not include the crew. If the crew can be used for the CEV to meet the requirement then this shall be stated in the requirement.

3.1.1 Constellation Architecture

The CEV is a system of the Constellation Architecture, depicted in Figure 1. The Constellation Architecture is comprised of Spacecraft, Launch Vehicles, Support Systems, and Destination systems as reflected in Figure 1: Constellation Architecture System Hierarchy. Systems that are external to the Constellation Architecture include the Communications and Tracking Network (formerly Exploration Communication and Navigation Systems (ECANS)) and the International Space Station (ISS).

The Constellation spacecraft include the Crew Exploration Vehicle (CEV), and the Lunar Surface Access Module (LSAM). The CEV consists of a Crew Module (CM), a Service Module (SM), Spacecraft Adapter (SA) and a Launch Abort System (LAS). Several configurations of the CEV are envisioned to meet the needs of the Constellation Architecture DRMs.

The Lunar Surface Access Module (LSAM), or lunar lander, provides the capability to insert the crew into Low Lunar Orbit (LLO), carry the crew to the lunar surface, and then return them to LLO. The LSAM also has the capability to deliver significant cargo to the surface along with the crew. While on the surface, the LSAM can serve as the crew's home for up to 7 (seven) days. In an uncrewed mode, the LSAM can be used to deliver large, monolithic cargo to the lunar surface. In addition to the spacecraft, the Constellation Architecture also provides the Extravehicular Activity (EVA) Systems and Flight Crew Equipment. The EVA System includes the pressure suits, EVA life support systems, umbilicals, EVA tools and mobility aids, EVA-specific vehicle interfaces, EVA servicing equipment, suit avionics, individual crew survival equipment (i.e., integral to the pressure suit), and ground support systems. Flight Crew Equipment includes the items that are interior to the spacecraft for use by the crewmembers (i.e. restraint and mobility aids, tools, stowage items).

The Constellation launch vehicles deliver crew and cargo to Earth orbit as well as translunar trajectories. The CEV is launched atop a human-rated Crew Launch Vehicle (CLV), which provides safe, reliable transportation of the CEV to Low Earth Orbit (LEO).

The Cargo Launch Vehicle (CaLV) is the heavy-lift companion to the CLV, and will provide over 250,000 lb cargo to LEO. Integral to the CaLV is an Earth Departure Stage (EDS), a restartable stage that performs a portion of the Earth ascent and provides the propulsion to accelerate large cargo from LEO to trans-lunar trajectories.

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

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

Standard coordinate systems have been established for the Constellation Program and are documented in document (TBD-001-990).

3.1.2 CEV Description

The CEV will be used to safely transport crew and cargo from earth to space and return. In particular, it will be used to carry a crew of up to four members to and from a lunar orbit, to carry a crew of up to six members to and from the ISS, and to carry pressurized cargo to and from the ISS without the crew.

The vehicle required for the crewed lunar missions is the basic vehicle. Other uses of the vehicle may enable omission or postponement of some features needed for the lunar mission. For example, the software for the lunar mission is much more complex than that for the ISS mission. The ISS mission is needed before the lunar missions, so the lunar software development may take place after the development and use of the ISS software, as long as the design can incorporate the lunar update.

Cargo versions of the vehicle may allow omissions of features needed for crewed missions, such as crew displays, seats, crew equipment and other items. This approach is desirable if it allows transport of the needed cargo and provides a more economical life-cycle program cost.

The CEV will be designed with separate modules, the Crew Module (CM) and Service Module (SM), to minimize re-entry mass while providing adequate resources for crew operations during Constellations missions. The CM will provide the pressurized volume for the crew during launch and re-entry as well as during transit to the Moon and ISS. The CM will provide life support, thermal control, attitude control for orientation during re-entry, and a docking system to permit crew and cargo transfer between the CM and other vehicles including the LSAM and ISS. The LAS provides the CM capability for pad and launch aborts. The SM will be attached to the CM to provide additional resources and to perform propulsive maneuvers. SM functions include: propulsion for ascent orbit circularization, trans-Earth-injection and mid-course correction maneuvers, thermal control, and electrical power generation and storage. During launch, the CEV will be mated via a Spacecraft Adapter (SA) to the CLV. The CEV will separate at the SA to SM interface following a successful launch or in the event of a launch abort.

3.1.3 CEV External Interface Description

The CEV interfaces with the following NASA and Constellation Program systems to complete its DRMs:

- Lunar Surface Access Module (LSAM)
- Extravehicular Activity (EVA) Systems and Flight Crew Equipment
- Crew Launch Vehicle (CLV)
- Cargo Launch Vehicle (CaLV)
- Ground Systems (GS)
- Mission Systems (MS)

Systems that are external to the Constellation Architecture include:

- The Communications and Tracking Network (formerly Exploration Communication and Navigation Systems (ECANS))
- The International Space Station (ISS)

Specific interface requirements between the CEV and each system will be captured in separate Interface Requirements Documents (IRDs) or Interface Definition Documents (IDDs), which are listed as CEV applicable documents in section

2.1. Figure 2 below identifies a top-level of CEV external interfaces to other elements.

The CEV has interfaces with the listed Systems in the following categories:	
Loads, Structures, And Mechanisms	
Loads	CLV, CaLV, LSAM, EVA, GS, ISS
Structures	CLV, LSAM, EVA, GS, ISS
Mechanisms	LSAM, GS, ISS
Umbilicals	EVA, GS
Power	
Power Characteristics	LSAM, EVA, GS, ISS
Isolation	LSAM, EVA, GS, ISS
Circuit Protection	EVA, GS
Electromagnetic Environmental Effects	CLV, LSAM, EVA, GS, ISS
Bonding and Grounding	CLV, LSAM, EVA, GS, ISS
Environmental Control and Life Support	
Atmosphere	LSAM, EVA, ISS, GS
Thermal	LSAM, ISS, EVA, GS
Potable Water	EVA, GS
Gasses and Fluids	
Propellant Fluids	GS
Thermal Gasses and Fluids	CLV, EVA, GS
Communications	
RF Communications	CaLV, LSAM, GS, ISS, CTN
Hardline Communications	CLV, LSAM, EVA, GS, ISS
Networks (Internet Protocol)	CLV, CaLV, LSAM, EVA, GS, MS, CTN
Security	CaLV, LSAM, GS, MS, CTN, EVA
Data and Information	
Information (terminology, messages structures, field formats and types)	CLV, LSAM, EVA, GS, MS, ISS, CTN
Data (Voice, Motion Imagery, Command, Telemetry, Files)	CLV, CaLV, LSAM, EVA, GS, MS, ISS, CTN
Flight Performance	
Guidance, Navigation, and Control	LSAM, ISS
Mass Properties	CLV, LSAM, ISS
Proximity Operations and Docking Performance	CaLV, LSAM, ISS
Human Factors	
Human Factors	LSAM, EVA, GS
Additional interfaces not captured by standard categories above	
Various	CLV, LSAM,GS, ISS

Figure 2 External Interfaces to Other Elements

3.2 CEV REQUIREMENTS

CA0056-PO **CEV Return of Crew and Cargo from Lunar Rendezvous Orbit**

The CEV shall return the crew and cargo from Lunar Rendezvous Orbit (LRO) to the Earth surface.

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

CA0091-PO **Transport to LDO**

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

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

CV0001 **Lunar Mission Transport Capacity**

The CEV shall transport crews of 2, 3, and 4 crew members from Earth to Lunar Destination Orbit and from Lunar Destination Orbit to Earth in accordance with the capabilities listed in Table 1, Total Lunar DRM Crew, Destination Cargo, and Equipment Definition.

*Rationale: Lunar "Crew" mass numbers in the table represent a 43rd percentile total crew mass selected from the all-male population in the 1988 Anthropometric Survey of US Army Personnel (or ANSUR) (ref. Natick/TR-89/044), projected forward by NASA to 2015. The mass numbers here represent the 95th percentile total crew mass. Total crew mass is assumed to be normally distributed with mean = n*m, and standard deviation = sqrt(n)*s, where n = crew size, m = mean of individual crew mass, and s = standard deviation of individual crew mass. Total crew mass is to be used for performance planning. Items that interface with individual crewmembers (such as seats and harnesses) must handle individual crewmembers per the Human Systems Integration Requirements (HSIR). For missions with a reduced crew complement, the lunar CEV must operate within the mass, pressurized volume, and center of gravity limits of the four-crew configuration, including any conversion of crew and equipment mass and volume into destination cargo. "Destination Cargo" masses are gross values. The cargo container volume and mass are included in the total destination cargo values. Destination cargo is specified as Outbound/Return and includes only the cargo to be transported to and from the lunar surface. See the Glossary for the definition of cargo. "Crew Equipment" and "EVA Equipment" values are provided for an example 18-day nominal lunar mission and include the following: Food System, EVA & Crew Survival, Exercise Countermeasure, Medical, Personal Hygiene, Sleeping, Photography, Housekeeping, Clothing & Crew Preferences, Maintenance, Operational Supplies, and Trash Stowage. Specific consumables have not been provided for contingencies and instead it is expected that consumable margins for the 18-day nominal mission will be used for these situations. Equipment does not include vehicle specific spares or other GFE portable equipment.*

Table 1 Total Lunar DRM Crew, Destination Cargo, and Equipment Definition

	Crew Size	Total Mass(lbm)	Total Volume (ft^3)
Crew	**2**	**376**	**n/a**
	3	**550**	**n/a**
	4	**721**	**n/a**
Destination Cargo (Outbound/Return)	**2**	**0/220**	**0/2.65**
	3	**0/220**	**0/2.65**
	4	**0/220**	**0/2.65**
Crew Equipment	**2**	**448**	**26**
	3	**593**	**35**
	4	**738**	**44**
EVA Equipment	**2**	**250**	**21**
	3	**353**	**30**
	4	**456**	**40**

CA5312-PO **CEV Deliver Crew/Cargo - ISS**

The CEV shall deliver the crew and pressurized cargo from the Earth surface to the ISS.

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

CV0011 **ISS Crew and Cargo Mission Transport Capacity**

The CEV shall be configurable to deliver crewmembers and pressurized cargo from Earth to ISS and from ISS to Earth in accordance with the capabilities listed in Table 2, Total ISS DRM Crew, Destination Cargo, and Equipment Definition.

*Rationale: "Crew" mass values in the table represent an approximately 43rd percentile total crew mass selected from the all-male population in the 1988 Anthropometric Survey of US Army Personnel (or ANSUR) (ref. Natick/TR-89/044), projected forward by NASA to 2015. The mass numbers here represent the 95th percentile total crew mass. Total crew mass is assumed to be normally distributed with mean = n*m, and standard deviation = sqrt(n)*s, where n = crew size, m = mean of individual crew mass, and s = standard deviation of individual crew mass. The ISS "Destination Cargo" mass is a gross value and includes the cargo container and packaging mass. For missions with a reduced crew complement, the ISS CEV must operate within the mass, pressurized volume and* *center of gravity limits of the six-crew configuration, including any conversion of crew and equipment mass and volume into destination cargo.*

Table 2 Total ISS DRM Crew, Destination Cargo, and Equipment Definition

	Crew Size	Total Mass (lbm)	Total Volume (ft ^3)
Crew	1	199	n/a
	2	376	n/a
	3	550	n/a
	4	721	n/a
	5	892	n/a
	6	1062	n/a
Destination Cargo	1	2065	121
	2	1615	95
	3	1210	71
	4	805	47
	5	395	23
	6	0	0
Crew Equipment	1	264	13
	2	343	17
	3	422	21
	4	500	25
	5	579	29
	6	658	33
EVA Equipment	1	103	9
	2	206	18
	3	309	28
	4	412	37
	5	515	46
	6	618	53

CV0622 **CEV Lunar Orbit Operations for Lunar Sortie Missions**

The CEV shall operate in lunar orbit to support Lunar Sortie missions to any designated location on the lunar surface.

Rationale: Designated lunar landing locations, which may be anywhere on the lunar surface, will allow Lunar Sortie missions to maximize the potential science return and provide the flexibility in selecting a lunar outpost location. This requirement does not imply the ability to go anywhere on the Moon at any time. For example, thermal conditions at lunar noon on the equator may cause excessive system requirements, which would be mitigated by a morning/evening mission. (CA0013)

CV0623 **CEV Lunar Orbit Operations for Lunar Outpost Missions**

The CEV shall operate in Lunar orbit to support a Lunar Outpost located within 1.0 degrees latitude of the lunar South Pole (TBR-001-009).

Rationale: Polar Regions of the moon present unique opportunities for lunar resource utilization, scientific investigations, advantages for transportation system flexibility, efficiency. Specific outpost site selection criteria will be developed and documented in a separate (TBD-001-009) HQ controlled document as was done during Apollo. (CA0014)

CA3203-PO **CEV Return Crew/Cargo to Earth - ISS**

The CEV shall return the crew and pressurized cargo from the ISS to the Earth surface.

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

3.2.1 CEV Mission Success

CA0088-PO **CEV Lunar Sortie Loss of Mission Risk**

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

Rationale: The 1 in 50 (TBR-001-058) means a .02 (or 2%) probability of LOM due to the CEV during any Lunar Sortie mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

CA3023-PO **CEV LOM for Lunar Outpost Crew**

The CEV shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Outpost Crew mission to no greater than 1 in (TBD-001-515).

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

CA0399-PO **CEV ISS Loss of Mission Risk**

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

Rationale: The 1 in 250 (TBR-001-056) means a .004 (or .4%) probability of LOM due to the CEV during any ISS Crewed mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

CA3022-PO **CEV LOM for ISS Cargo**

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

Rationale: The 1 in (TBD-001-513) means a (TBD-001-513) (or (TBD-001-513)%) probability of LOM due to the CEV during any ISS Cargo mission. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.2.2 CEV Crew Survival

CV0097 **Post Landing Safing Performance**

The CEV shall provide safing of systems that pose hazards to flight and ground recovery crews within 5 minutes upon landing.

Rationale: The CEV post landing environment must be free of hazards in a timely manner to allow safe ingress and egress of the CEV crew and recovery forces. The 5 minute safing period starts when the parachute risers are separated from the CM. (derived project requirement)

CA4154-PO **CEV Unpressurized Operations**

The CEV shall perform the functions necessary to return the crew to the surface of the Earth in at least 120 (TBR-001-980) hours with an unpressurized cabin.

Rationale: Vehicle functions to return the crew to the surface of the Earth in an unpressurized cabin pertain to the functions that are needed to get the crew back to Earth. Examples of critical vehicle functions include but are not limited to propulsion, communications, guidance, navigation, control, parachutes, etc. The 120 (TBR-001-980) hours is coupled to the CEV and EVA System requirements to sustain the crews' life for the length of time to return the crew to Earth. As the CEV may lose pressure during the lunar loiter time, the vehicle may need to function with an unpressurized cabin for longer than 120 (TBR-001-980) hours.

CA4154D-PO **PBS - CEV Unpressurized Cabin Crew Support**

The CEV shall perform the functions necessary to return the crew to the surface of the Earth in no more than 120 (TBR-001-980) hours with an unpressurized cabin.

Rationale: Vehicle functions to return the crew to the surface of the Earth in an unpressurized cabin pertain to the functions that are needed to get the crew back to Earth. Examples of critical vehicle functions include but are not limited to propulsion, communications, guidance, navigation, control, parachutes, etc. The 120 (TBR-001-980) hours is coupled to the CEV and EVA System requirements to sustain the crews' life for the length of time to return the crew to Earth. As the CEV may lose pressure during the lunar loiter time, the vehicle may need to function with an unpressurized cabin for longer than 120 (TBR-001-980) hours.

CA0274-PO **CEV Emergency Entry Modes**

The CEV shall provide an Emergency Entry mode that is available from the command of SM separation through Earth landing.

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

CA0274D-PO **PBS - CEV Emergency Entry Modes**

The CEV shall provide an Emergency Entry mode that is available from the command of SM separation through Earth landing.

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

CA0984-PO **CEV Crew Survival After Landing Environment**

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

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

CA0984D-PO **PBS - CEV Crew Survival During Landing Environment**

The CEV shall assure crew survival during and after landing touchdown in wind and sea state conditions as defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Section 3.5.18 for all water landings, and 3.6.18, for abort in-water landings.

Rationale: This requirement assures that the crew will be able to survive landing impacts in sea state 7 and Beaufort Wind 8 conditions following any landing in water.

CA0194-PO **CEV Crew Survival After Landing**

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

Rationale: This requirement is needed to provide crew survival after a water landing in a sea state where the hatch cannot be opened. The 36 (TBR-001-045) hours assumes the longest time that the ground support would take to recover the crew. This assumes that the power system will have to provide the basic ventilation and emergency systems. The requirement was developed for water landing to address the design case for the developers.

CA0194D-PO **PBS - Crew Survival After Water Landing**

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

Rationale: This requirement is needed to provide crew survival after a water landing in a sea state where the hatch cannot be opened. The 36 (TBR-001-045) hours assumes the longest time that the ground support would take to recover the crew. This assumes that the power system will have to provide the basic ventilation and emergency systems. The requirement was developed for water landing to address the design case for the developers.

CV0830 **CEV Crew Survival After Landing**

The CEV shall provide for crew survival, without permanent crew disability, for at least 36 hours with the hatch closed in sea state conditions defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Section 3.5.19, following a landing in the water.

Rationale: (CA0194-PO)

CA0983-PO **CEV Launch Abort Environment**

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

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

CA3259-PO **CEV Landing Visual Aids**

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

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

CA3259D-PO **PBS - CEV Landing Visual Aids**

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

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

CA0532-PO **CEV Unpressurized Cabin Crew Support**

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

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

CV0448 **Unpressurized Crew Survival**

The CEV shall provide hydration, breathable atmosphere, power, communication and thermal control for the suited crew in an unpressurized environment state for not less than 120 hours (TBR-002-036).

Rationale: This emergency capability is necessary to support contingency operations for cabin leaks during ascent or on orbit to enable the survival of four crewmembers. 144 hours supports maximum duration required for any point return to Earth during a lunar mission. The sizing of this capability for a lunar mission contingency return envelopes a contingency return of six crew from an ISS mission. This capability may also be used to support contingency EVA operations.

CA3108-PO **CEV Suit Stowage**

The CEV shall provide suit stowage such that a suit can be accessed within 2 (TBR-001-157) minutes per crew member for donning.

Rationale: Suits need to be stowed in CEV such that they are readily accessible to facilitate the full crew donning their suits while the ECLSS system feeds the leak. The two minutes for each crew member to retrieve their suit (in order to begin the donning process) is a subset of the 1 hour ECLSS requirement to feed the leak. The suit retrieval time is not necessarily always required at the beginning of the feed the leak 1 hour period, as it likely will be more efficient in the CEV Volume provided to have sets of crew members retrieve and don their suits serially.

CA3108D-PO **PBS - CEV Suit Stowage**

The CEV shall provide suit stowage such that each individual suit can be accessed within 2 (TBR) minutes per crewmember for donning.

Rationale: Suits need to be stowed in CEV such that they are readily accessible to facilitate the full crew donning their suits while the ECLSS system feeds the leak. The two minutes for each crew member to retrieve their suit (in order to begin the donning process) is a subset of the 1 hour ECLSS requirement to feed the leak. The suit retrieval time is not necessarily always required at the beginning of the feed the leak 1 hour period, as it likely will be more efficient in the CEV Volume provided to have sets of crew members retrieve and don their suits serially.

CA3138-PO **CEV Fire Detection and Suppression**

The CEV shall provide fire detection and suppression for the CEV pressurized volume.

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

CV0716 **Affected Volumes**

The CEV shall provide fire detection and suppression in all crew module volumes inside the crew cabin that contain both a potential ignition source and forced air flow.

Rationale: By definition, there is no risk of fire in enclosed volumes that do not contain a potential ignition source, such as stowage lockers for food, clothing, or other types of equipment lacking batteries or electrical connectivity to power sources. Such enclosed volumes lacking ignition sources do not require any provisions for fire detection and suppression. Since the open cabin area of the spacecraft must provide air circulation for crew respiration, and since various types of electrical equipment in use there could provide an ignition source, the open or habitable cabin volume must have provisions for fire detection and suppression. If airflow is provided in enclosed volumes containing a potential ignition source they must have provisions for fire detection and suppression. Static electricity discharge is not considered an ignition source for solid materials as testing has shown that static discharge will not ignite solid materials.

CV0717 **Materials Flammability â " Enclosed Bays**

For enclosed bays containing an ignition source and no forced air flow, the CEV shall provide a means of fire suppression within the bay OR all exposed components located within the bay shall be composed of materials that comply with NASA-STD-6016 materials flammability requirements at an atmospheric oxygen concentration that is 10% higher than the maximum O2 concentration expected within the bay during nominal operations.

Rationale: Note that the term "bay" refers to a larger volume that may contain one or more smaller, separate avionics boxes. "Exposed components" includes the outside surfaces of any individual electrical or electro-mechanical volumes, but not their interior components. Materials certification that all exposed components within an enclosed bay are self-extinguishing at an O2 concentration 10% higher than the maximum O2 concentration expected within the bay during nominal operations, combined with a lack of forced air flow within the volume, will provide a margin of safety to permit the deletion of provisions for fire suppression for that volume. If an enclosed volume does have forced *air flow, provisions for fire detection would be required as well as fire suppression, since fire propagation in zero-g is caused primarily by the forced air flow. Note that the 10% is an absolute value, not a percentage of the O2 concentration. For example, if the nominal atmospheric O2 concentration within the bay was 20%, all exposed materials within the bay would need to be certified as self-extinguishing at 30% O2 in order to remove provisions for fire suppression from the bay. If the nominal atmospheric O2 concentration within the bay was 30%, all exposed materials within the bay would need to be certified as self-extinguishing at 40% O2 in order to remove provisions for fire suppression from the bay.*

CV0715 **Fire Containment and Failure Reporting**

For electrical and electro-mechanical equipment volumes containing an ignition source and no forced air flow, the CEV shall provide a fire containment enclosure or detect, isolate and report all failure modes for these volumes that may cause potential fire events within these volumes.

Rationale: Relevant failure modes, such as over-temperature components and/or excessive current draw, have the potential to cause a fire event. Batteries, of all types, are also potential ignition sources that can lead to a fire event. Fire containment enclosure means an enclosure which will confine any fire or flame to the inside of the enclosure, and will prevent its propagation outside the enclosure. Detection, isolation and reporting of the failure modes alert the crew and mission systems of a hazardous onboard condition and prevent fire events or propagation. .

CA0493-PO **CEV ISS Crew Safe Haven Capability**

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

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

CV0015 **Safe Haven - Life Support Initiation**

The CEV nominal cabin pressure regulation, temperature regulation, and a breathable atmosphere source for the crew shall be operational within one (TBR-002-017) minute of initiation of CEV life support system start up command in the case of an emergency requiring ISS evacuation to CEV.

Rationale: In order to support a habitable environment for the crew, the life support system will need to be functional in a short period of time. The one minute life support requirement is modeled after the current Soyuz capability.

CA0325-PO **CEV Earth Landing**

The CEV shall provide for Earth landing throughout each mission phase.

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

CV0713 **Water Landing Mode**

The CEV shall perform water landing.

Rationale: The capability to land in water is required as a normal landing mode, and because a return to land may not be possible throughout each mission phase (CA0325) or from an Emergency Entry Mode abort soon after SM separation (CA0274).

CV0095 **Vehicle Self-righting for Water Landing**

The CEV shall be self-righting for water landing for at least 36 hours.

Rationale: Egress could be severely hampered if the spacecraft was inverted, particularly if the hatch was below the water line. Crew survival would be severely compromised if they were forced to remain inverted for any extended time while awaiting rescue. (CV0713)

3.2.2.1 CEV Crew Survival Probabilities

CA5913-PO **CEV Abort LOC Risk**

The CEV shall limit the risk of loss of crew (LOC) during a pad or ascent abort to no greater than 1 in (TBD-001-947).

Rationale: The 1 in (TBD-001-947) means a (TBD-001-947) (or (TBD-001-947)%) probability of LOC during any ascent abort. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO): Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

CA0501-PO **CEV Lunar Sortie Loss of Crew Risk**

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

Rationale: The 1 in 200 (TBR-001-057) means a .005 (or .5%) probability of LOC due to the CEV during any Lunar Sortie mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

CA3040-PO **CEV LOC for Lunar Outpost Crew**

The CEV shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Outpost Crewed Mission to no greater than 1 in (TBD-001-559).

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

CA0398-PO **CEV ISS Loss of Crew Risk**

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

Rationale: The 1 in 1700 (TBR-001-055) means a .00059 (or .059%) probability of LOC due to the CEV during any ISS Crew mission. The baseline numbers were derived from a preliminary PRA within NASA-TM-2005-214062, NASA's Exploration Systems Architecture Study. This requirement is driven by CxP 70003-ANX01, Constellation Program Plan, Annex 1: Need, Goals, and Objectives (NGO), Safety Goal CxP-G02: Provide a substantial increase in safety, crew survival and reliability of the overall system over legacy systems.

3.2.2.2 CEV Emergency Egress, Aborts & Early Return for Survivability

3.2.2.2.1 Emergency Egress

CA0334-PO **CEV Flight Crew Unassisted Emergency Egress - Pre-Launch**

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

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

CV0857 **Hatch - Emergency Operations Mode**

The CEV shall provide a primary crew ingress/egress hatch with an emergency operations mode that will open the hatch within 5 seconds of initiation of the emergency mode during all ground operations at 30 psig (TBR-002-257).

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

CV0818 **Secondary Egress Path**

The CEV shall provide a post landing alternate egress path for the un-pressurized suited crewmembers to egress from the inside of the vehicle.

Rationale: For an off-nominal landing with the CEV on its side, or in cases where there is an obstruction, the primary egress hatch may not be useable for egress.

CA0335-PO **CEV Ground and Flight Crew Unassisted Emergency Egress - Pre**

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

Rationale: For contingency situations, where no ground crew is immediately available in the white room to assist, 6 suited flight crew plus 2 ground crew will need the capability to egress the vehicle for safety reasons. This should drive design of seat restraints, internal access platforms, hand holds, launch suit and egress paths in the pre-launch orientation to allow the ground and suited flight crew to egress without external ground crew assistance. The time for the combined suited crew and ground crew to egress the vehicle may be different than the sum of the individual times for suited crew only or ground crew only.

CV0031 **Ground Operations Personnel Emergency Egress**

The CEV shall provide for unassisted pre-launch emergency egress from the CEV of up to 6 ground operations personnel in not greater than 120 seconds.

Rationale: It is expected that the suited crew egress requirement (CV????) will govern the design of the CEV from an egress perspective. However, the intent of this requirement is to prevent the placement of work platforms and/or other ground processing equipment in a manner that could adversely impact the ground crew egress time.

CA0466-PO **CEV Flight Crew Unassisted Emergency Egress - Post Landing**

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

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

CA0466D-PO **PBS - CEV Flight Crew Unassisted Emergency Egress - Post Landing**

The CEV shall provide for unassisted emergency egress for all suited crewmembers upon landing within 3 minutes of parachute release.

Rationale: For contingency or aborted landings, where no ground crew is immediately available, the crew will need the capability to egress the vehicle for safety reasons, or to assist in search and rescue operations. 3 minutes is chosen to allow time to deploy egress equipment, and for all crew to egress the CM. It does not include time to safe the vehicle.

3.2.2.2.2 Aborts

CA0333-PO **CEV Abort Coverage**

The CEV shall perform aborts from the time the CEV abort system is armed on the launch pad until the mission destination is reached.

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

CA0170-PO **CEV Automatic Abort Determination**

The CEV shall automatically determine the need for an abort.

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

3.2.2.2.2.1 Automated Abort

CV0660 **Inhibit Automatic Abort**

The CEV shall inhibit the automatic abort sequence upon receipt of the command from the crew, except for abort sequence initiated upon notification of FTS indication.

Rationale: This requirement meets the intent of NPR 8705.2 Requirement

34480. The ability of the crew to inhibit automatic abort sequences is desired to enhance crew safety especially in cases where communication with ground systems is not available. (CA3110)

CV0837 **Automated abort mode selection**

The CEV shall automatically select abort modes.

Rationale: Some flight phases may have more than one valid abort mode based on current configuration and performance. The CEV must be able to select an abort mode from those valid modes available. This selected mode will not have priority over the crew or Mission Systems' selected abort mode received per CV0654 or CV0735. (CA5439-PO)

CV0838 **CEV Abort Maneuvers**

The CEV shall automatically perform abort maneuvers.

Rationale: In cases where response time is limited, the CEV should be able to perform abort maneuvers automatically. It is also likely that once an abort has been selected, the abort sequence of targeting and maneuver execution will be automated. (CA5439)

CA0522-PO **CEV Automatic Abort Initiation for FTS**

The CEV shall automatically initiate an ascent abort sequence upon notification of FTS indication.

Rationale: If flight termination is required for the launch vehicle, the CEV is likely to also be destroyed without a successful ascent abort separating the spacecraft away from the explosion hazard. The type of indication that triggers ascent abort is specified in CxP 70026, Constellation Program Crew Exploration Vehicle

- To - Crew Launch Vehicle Interface Requirements Document.

CA0522D-PO **PBS - CEV Automatic Abort Initiation for FTS**

The CEV shall automatically initiate an ascent abort sequence upon notification of FTS indication.

Rationale: Initiation of an abort with the LAS, if required, will need to occur quickly to escape CLV catastrophic failures. An acceptable length of time (measured in milliseconds) needs to be specified to ensure that the CEV can getaway from the area of imminent danger in time. Onboard abort initiation includes FTS initiated, manual, automated, and uplinked abort commands from MS.

CA5439-PO **CEV Automatic Abort Execution**

The CEV shall automatically perform abort.

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

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

CV0053 **CEV Automatically Initiated Ascent Abort**

The CEV shall automatically initiate the ascent abort sequence.

Rationale: Required by NPR 8705.2, Paragraph 3.9.15 (Requirement 34488). During certain flight phases (e.g., atmospheric flight) there may be very little time between initial malfunction onset and catastrophic failure. While keeping a human (e.g. the crew) in the decision path reduces inadvertent abort/escape initiation, human responses are relatively slow. Thus, automatic initiation is needed for failure situations where manual initiation may not be rapid enough to ensure successful abort/escape. The CEV is also monitoring the CLV flight path and attitude and may use this knowledge to determine conditions that would require an automatic CEV initiated abort.

CV0535 **CEV Automatically Initiated Pad Abort**

The CEV shall automatically initiate the pad abort sequence.

Rationale: Required by NPR 8705.2, Paragraph 3.9.15 (Requirement 34488). During final countdown operations there may be very little time between initial malfunction onset and catastrophic failure. While keeping a human (e.g. the crew) in the decision path reduces inadvertent abort/escape initiation, human responses are relatively slow. Thus, automatic initiation is needed for failure situations where manual initiation may not be rapid enough to ensure successful abort/escape.

3.2.2.2.2.2 Manual Abort

CV0045 **Ground Systems Initiated Pad Abort**

The CEV shall initiate the pad abort sequence upon receipt of the pad abort sequence command from Ground Systems.

Rationale: Required by NPR 8705.2, Paragraph 3.9.13. Ground control has insight on the status of the vehicle from ground and onboard CLV monitoring systems. Catastrophic failures during the pre-launch phase are more likely to be detected from ground observation than by the onboard crew. Additionally, ground initiation of pad abort serves to backup the crew activated abort. (CA0449)

CV0652 **Mission Systems Initiated Abort**

The CEV shall initiate the abort sequence upon receipt of the abort sequence command from Mission Systems.

Rationale: NPR 8705.2 Requirement 34486 includes both ascent and pad aborts. Pad aborts are required by NPR 8705.2 Paragraph

3.9.13. Mission systems has status into the vehicle from the CEV via C&T networks. (CA0449)

CV0653 **Crew Initiated Aborts**

The CEV shall initiate the abort sequence upon receipt of the abort sequence command from the crew.

Rationale: This requirement meets the intent of NPR 8705.2 Requirement

34478. The crew may observe a pending or actual catastrophic failure of the CLV independent of the ground. Since this type of failure is time critical, crew capability to initiate aborts is required. Crew initiated aborts allow redundant implementation when coupled with the ground initiated (Mission Systems and Ground Systems) abort capabilities. (CA0449)

CV0654 **Abort Mode Selection from Mission Systems**

The CEV shall select abort modes upon receipt of the command from Mission Systems.

Rationale: This requirement meets the intent of NPR 8705.2 Requirement34485. Some flight phases may have more than one valid abort mode based on current configuration and performance. The CEV needs to allow the selection by the Mission Systems of a preferred abort mode. (CA0333)

CV0735 **Abort Mode Selection from the Crew**

The CEV shall select abort modes upon receipt of the command from the crew.

Rationale: This requirement meets the intent of NPR 8705.2 Requirement

34477. Some flight phases may have more than one valid abort mode based on current configuration and performance, the CEV needs to allow the selection by the crew of a preferred abort mode. (CA0333)

3.2.2.2.2.3 Abort Performance

CV0058 **Abort Initiation Latency**

The CEV shall achieve 80% (TBR-002-231) of required LAS thrust within 300 milliseconds (TBR-002-013) of CEV onboard abort command initiation, where the time measurement is taken from the time the initiated command has been received by the CEV.

Rationale: Initiation of an abort with the LAS, if required, will need to occur quickly to escape CLV catastrophic failures. An acceptable length of time (measured in milliseconds) needs to be specified to ensure that the CEV can getaway from the area of imminent danger in time. Onboard abort initiation includes manual, automated, and uplinked abort commands from GS for pad abort and MS. (derived project requirement)

CV0711 **Pad Abort Performance**

The CEV shall provide sufficient range and altitude performance during pad and low altitude aborts to achieve a water landing, with full Landing and Recovery System (LRS) deployment and functionality, for 95% (TBR-002-247) of the pad abort wind cases as defined in DSNE section (TBD-002-204) and thermal radiation environments as defined in the TBD, such that CEV landing ensures no greater than low risk of crew injury as defined by HSIR section 3.2.4.2.

Rationale: The CEV will need to achieve sufficient pad abort altitude to allow for parachute deployment, staging, and deceleration. The off-shore range at parachute deployment will also need to be sufficient such that on-shore winds do not blow the CEV back on to terrain or environments which would lead to crew injury. Examples of issues could be: insufficient water depth (unless landing attenuation system is designed for such case), land (unless landing attenuation system can be activated), other obstacles which exceed design criteria such as large burms, railroad tracks, and structures, and blast or thermal effects from a catastrophic CLV failure. (CA0333)

CV0712 **Positive Separation During Abort**

For CEV ascent aborts during CLV first stage, the CEV shall exceed a minimum separation distance of 175 ft, relative to a CLV that is assumed to continue to accelerate along its planned trajectory, for all times greater than 3 seconds after abort motor initiation.

Rationale: During the high drag abort, the LAS must provide sufficient thrust to overcome a thrusting CLV and all aerodynamic drag including: free stream, proximity effects, and jet plume interaction. (CA0333)

CV0841 **Flight Separations**

The CEV shall provide flight separations without re-contact with any flight hardware.

Rationale: Re-contact with flight hardware could be a risk to the crew and vehicle thus impacting crew safety and mission success. Flight separation events include LAS jettison, launch abort, SM separation, docking mechanism jettison, etc.

CV0052 **CEV Ascent Abort Targeting**

The CEV shall automatically calculate ascent abort targets.

Rationale: For launch vehicle failures that do not allow orbit insertion, the CEV spacecraft propulsion may be effective in shifting the landing footprint up or downrange. These propulsive maneuvers may be posigrade, retrograde or even radial in nature. Aerodynamic maneuvering of the spacecraft through lift vector modulation may also shift the landing point. This would allow landing closer to land or prepositioned rescue forces. (CA5439)

CV0061 **CEV Abort To Orbit Targeting**

The CEV shall automatically calculate abort to orbit targets.

Rationale: For a launch vehicle upper stage failure occurring late in powered flight, the CEV may achieve a stable orbit by executing a posigrade maneuver with spacecraft propulsion systems. (CA5439)

CA0579-PO **CEV Ascent Abort Landing Outside DAEZ**

The CEV shall provide ascent aborts for ISS missions that result in landing outside the Down-range Abort Exclusion Zone (DAEZ).

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

CA0498-PO **CEV Abort Without CLV Thrusts**

The CEV shall abort without relying on thrust from the CLV.

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

CA5234-PO **CEV Landing Zone Capability**

The CEV shall provide the capability for vehicle landing in zones for earth ascent aborts defined by Figure (TBD-001-076) for all lunar missions.

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

3.2.2.2.3 Early Return

CV0008 **Early Return After Achieving Mission Destination**

The CEV shall provide for early return to Earth after achieving mission destination.

Rationale: Anytime crew return is part of the Human Rating Requirements, as well as the program policy on crew safety. Mission destination identifies the point at which the outbound portion of a crewed mission is considered to be completed (e.g., lunar orbit for cases of crewed lunar missions without a lunar landing phase, lunar surface landing, ISS hard dock). (CA0325)

CA0416-PO **CEV Return to Earth Independent of Communications with MS**

The CEV shall return the crew to the Earth surface independent of communications with the Mission Systems during all mission phases.

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

CA5237-PO **CEV Time Allotted for Return Crew to Earth**

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

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

CA5237D-PO **PBS - CEV Time Allotted for Return Crew to Earth**

The CEV shall return the crew from Lunar Rendezvous Orbit (LRO) to the surface of the Earth within 142 (TBR) hours from docking with LSAM.

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

3.2.3 CEV Crew Size

CA0447-PO **CEV LEO Crew Capability**

The CEV shall have the capability to transport crews of 0, 1, 2, 3, 4, 5 and 6 into LEO with a single launch.

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

3.2.4 CEV Cargo Delivery and Return

3.2.4.1 Pressurized Cargo Delivery & Return

CA0868-PO **CEV Pressurized Cargo Return Mass**

The CEV shall return at least 100 kg (220 lbm) of pressurized cargo from LRO to Earth for crewed lunar missions.

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

CA5155-PO **CEV Cargo Volume**

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

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

CA3182-PO **CEV Cargo Delivery to ISS**

The CEV shall deliver cargo from the Earth to the ISS for uncrewed ISS missions.

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

CA0864-PO **CEV Pressurized Cargo Mass**

The CEV shall deliver a crew of four with at least 365 kg (805 lbm) of pressurized cargo from Earth to ISS.

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

CA0865-PO **CEV Pressurized Cargo Return Mass**

The CEV shall return a crew of four along with at least 365 kg (805 lbm) of pressurized cargo from ISS to Earth.

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

CA0866-PO **CEV Pressurized Cargo Delivery Mass**

The CEV shall deliver at least 2850 kg (6,283 lbm) (gross) of pressurized cargo from the Earth to the ISS for an ISS Cargo mission.

Rationale: The Mass Delivered requirement is based on the analysis documented in TDS18B. Analysis in TDS18B determined that a 5 m (16.5 ft) diameter CEV would have a

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

CA0866D-PO **PBS - CEV Pressurized Cargo Delivery Mass**

The CEV shall deliver at least 2858 kg (6,300 lbm) (gross) of pressurized cargo from the Earth to the ISS for an ISS Cargo mission.

Rationale: "The Mass Delivered requirement is based on the analysis documented in TDS18B. Analysis in TDS18B determined that a 5 m (16.5 ft) diameter CEV would have a

10.76 m3 (380 ft3) available volume limit for cargo and this volume limit would limit the mass storage of the CEV to 2,858 kg (6,300 lbm). TDS18B assumed that secondary structure mass would be accounted for in the vehicle weight. CEV Mass Delivered supports ISS upmass requirements for payloads, crew supplies and other consumables."

CA5233-PO **CEV Pressurized Cargo Return Mass**

The CEV shall return at least 2,858 kg (6,283 lbm) of pressurized cargo from the ISS to the Earth for an uncrewed mission.

Rationale: The Mass Returned requirement is based on the analysis documented in TDS18B and (TBD-001-851) analysis. Analysis in TDS18B determined that a 5 m (16.5 ft) diameter CEV would have a 8.58 m3 (303 ft3) available volume limit for Cargo and this volume limit would limit the mass storage of the CEV to 2.858 kg (6,283 lbm). TDS18B assumed that secondary structure mass would be accounted for in the vehicle weight. (TBD-001-851) analysis validated this maximum CEV Return Mass based upon center of gravity location and the related vehicle passive stability. CEV Mass Delivered supports ISS up-mass requirements for payloads, crew supplies and other consumables.

CA5233D-PO **PBS - CEV Pressurized Cargo Return Mass**

The CEV shall return at least 2,858 kg (6,300 lbm) of pressurized cargo from the ISS to the Earth for an uncrewed mission.

Rationale: The Mass Returned requirement is based on the analysis documented in TDS18B and (TBD-001-851) analysis. Analysis in TDS18B determined that a 5 m (16.5 ft) diameter CEV would have a 10.76 m3 (380 ft3) available volume limit for Cargo and this volume limit would limit the mass storage of the CEV to 2,858 kg (6,300 lbm). TDS18B assumed that secondary structure mass would be accounted for in the vehicle weight. (TBD-001-851) analysis validated this maximum CEV Return Mass based upon center of gravity location and the related vehicle passive stability. CEV Mass Delivered supports ISS up-mass requirements for payloads, crew supplies and other consumables.

CA0565-HQ **CEV ISS Cargo Volume Capability**

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

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

3.2.4.2 Unpressurized Cargo Delivery

CAxxxAD-PO **PBS - Unpressurized Cargo Data, Command, and Control Interface**

The CEV shall provide a data interface for unpressurized cargo.

Rationale: The capability to communicate with and command cargo will be provided. Cargo may need to transmit health and status data to CEV or transmit scientific data to CEV for storage and/or for transmission to the ground. Data rate and other capabilities will be defined on a per mission basis.

CV0763 **Unpressurized Cargo Data, Command, and Control Interface**

The CEV shall provide a standard, redundant, non-flight critical data bus interface for unpressurized cargo

Rationale: The capability to communicate with cargo will be provided. Data rate and other capabilities will be defined on a per mission basis. This requirement provides a "data port" in the unpressurized cargo area for use by the cargo if needed. A mission kit could be used to implement this requirement for missions requiring communications for unpressurized cargo. This requirement provides a "data port" in the unpressurized cargo area for use by the cargo if needed, i.e. a mission kit could be used to implement this requirement. The intent of this requirement is to be allocated to the Service Module.(derived project requirement)

CAxxxBD-PO **PBS - ISS Unpressurized Cargo**

The CEV shall deliver unpressurized cargo to the ISS.

Rationale: The ISS CMG should be used as a benchmark for mass, volume, dimensions, and payload delivery. However, this capability will also encompass the delivery of other ISS related payloads as required

CV0764 **ISS Unpressurized Cargo Mass**

The CEV shall deliver an unpressurized cargo mass of at least 590 <TBR-002-205> kg (1,300 lbs) (gross) to the ISS.

Rationale: The CMG was used as a benchmark for payload delivery. However, this capability will also allow the delivery of other ISS related payloads as required. (derived project requirement)

CAxxxCD-PO **PBS - Lunar Unpressurized Cargo**

The CEV shall deliver unpressurized cargo for lunar missions.

Rationale: Allocation of CA0003-HQ and CA0004-HQ. This capability would be similar to the capability provided by the Apollo Service Module Scientific Instrument Module (SIM) Bay. The goal would be to provide a flexible capability to support a myriad of scientific and engineering activities that may vary from mission to mission. Fields of study that may leverage this capability include: lunar surface mapping, lunar gravity field mapping, space environment measurements, evaluation of environmental exposure of materials and/or components planned for future missions, and infrastructure systems such as navigation or communication satellites that could be deployed from the CEV. Specific objectives for each lunar sortie and outpost mission will be defined in a separate ESMD document. A mass of at least 413kg (900 lbm (gross)) (TBR-002-252) and volume of at least (TBR-002-253) 0.57 m3 (20 ft3) with (TBR-002-254) 2.7m per side allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure

CV0766 **Lunar Unpressurized Cargo Mass Capability**

The CEV shall deliver an unpressurized cargo mass of at least 413kg (909 lbm (gross) (TBR-002-206) to support the Lunar DRM.

Rationale: This is not an allocation or set aside of mass for lunar cargo. This mass should be used to size the cargo interface. The actual mass allocated to cargo will be traded against other cargo mass specified in CV0001, table

1. The 413kg (909 lbs) was arrived at by subtracting the mass requirements for a crew of 2 from the mass requirements for a crew of 4 in table 1. This will allow the program to trade unpressurized cargo mass against other mission specific driven masses.

CAxxxDD-PO **PBS - Electrical Power**

The Constellation Architecture shall provide electrical power for unpressurized cargo.

CV0762 **Unpressurized Cargo Power**

The CEV shall provide two independent, non-mission specific, electrical power interfaces designated for unpressurized cargo each capable of providing power up to 1.0 kW maximum.

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

CV0765 **ISS Unpressurized Cargo Volume**

The CEV shall provide a cubic volume of at least 1.54 m (5.1 ft) on a side (total of 3.68 m3 (130 ft3)) for delivery of un-pressurized cargo to ISS.

Rationale: The CMG was used as a benchmark for payload delivery. However, this capability will also allow the delivery of other ISS related payloads as required. (derived project requirement)

CV0768 **Lunar Unpressurized Cargo Volume**

The CEV shall provide a contiguous volume of at least (TBR-002-207)

0.57 m3 (20 ft3) with (TBD-002-234)m per side for delivery of un-pressurized cargo to support the Lunar DRM.

Rationale: This volume is above the volume specified in CV0001, table 1.

CA0547-PO **CEV Science/Engineering Volume Allocation - Unpressurized**

The CEV shall provide 0.57 (TBR-001-750) m3 (20 ft3) of volume allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure elements during the cruise and lunar orbit phases of lunar missions.

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

3.2.5 CEV Mission rates and Durations

CV0010 **ISS Mission Duration - Active**

The CEV shall provide no less than 6 days of active vehicle transit operations during an ISS Crew Mission.

Rationale: Active operations are defined as when the crew is inside and supported by the CEV resources. Active vehicle duration includes three days for launch, rendezvous, and docking; one day for contingency docking, and two days for return, which includes contingency post-undock dwell time for resolving systems problems. The safe haven requirement uses the contingency time within this requirement. On landing there is an additional 36 hours for crew recovery that is addressed in a different requirement. (CA0892)

CV0769 **CEV Flight Rates**

The CEV shall provide the capacity to perform missions according to the mission rates and opportunities specified in the CEV Flight Rate Table 3.

Rationale: The CEV must be designed to support a minimum mission frequency in order to provide a sustainable human exploration program and to maintain acceptable flight crew and ground personnel proficiency. Mission frequencies drive infrastructure design, allocation of production capabilities, storage capacities and replenishment supplies of ground and mission support systems. In addition, flight rate drives turnaround and maintenance activities for the CEV. The rates in the table reflect the expected nominal flight rate plus a surge capacity accounted for by the maximum flight rate in conjunction with the minimum interval. All intervals are expressed in calendar days. Budgets will determine opportunities for flight rate surges. The nominal rate is intended to be applied to variable resources; however, in order to preserve the ability to add a flight when budgets permit, long lead or fixed resources should apply the maximum rate. The following assumptions are incorporated into the flight rate plan:1) Intervals are measured from launch to launch of each system.2) Concurrent ops scenarios are limited to the ISS Crew rotation/Lunar Sortie missions 3) During lunar sortie mission, planned CEV operations for ISS will be limited to docked (quiescent) operations.4) There will not be more than one vehicle of the same type launching or landing per day.6) Missions are based upon the Design Reference Missions described in CxP 70007, Constellation Design Reference Missions and Operational Concepts Document. (3.2 allocated CA0036)

Table 3 Flight Rate Table

Mission	Nominal Annual Rate	Maximum Annual Rate	Minimum Interval
ISS	2 crew	3 crew	4 months (TBR-001-240)
	3 cargo	3 cargo	4 months (TBR-001-240)
Lunar Sortie	2	3	180 days (TBR-001-240)
The flight rates in the table reflect the expected nominal flight rate plus a surge capacity accounted for by the maximum flight rate in conjunction with the minimum interval. Budgets will determine opportunities for flight rate surges. The nominal rate is intended to be applied to variable resources; however, in order to preserve the ability to add a flight when budgets permit, long lead for fixed resources should apply the maximum flight rate. The following assumptions are incorporated into the flight rate plan: 1. Intervals are measured from launch to launch of each system. 2. ISS crew rotations and lunar missions may be conducted concurrently. 3. There will not be more than one vehicle launching or landing per day.			

CA3164-PO **CEV Lunar Orbit Habitable Environment**

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

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

CA3164D-PO **PBS - CEV Lunar Orbit Habitable Environment**

The CEV shall provide a habitable environment for a crew of four for a minimum of 21.1 (TBR) days during each lunar mission.

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

CA0082-PO **CEV LLO Loiter Duration**

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

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

CA0060-HQ **CEV/ISS Docked Mission Duration**

The CEV shall remain docked to the ISS for at least 210 days.

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

CV0012 **ISS Mission Duration - Quiescent**

The CEV shall provide at least 210 days of uncrewed operations while docked at the ISS.

Rationale: ISS Crew rotations are 6 months. The CEV will remain at the station during the duration of the crew rotation. A one month contingency was added for Margin for on-orbit life. The contingency days are available to address crew rotation mission overlaps. The ISS-CEV IRD (CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document) contains definition of power that ISS will provide to CEV.

3.2.6 CEV Architecture Definition

CV0077 **CEV Hatch - EVA Crew Ingress**

The CEV shall provide a hatch sized for egress and ingress by pressurized suited EVA crew per the CEV to EVA IRD, CxP 70033 Constellation Program Crew Exploration Vehicle (CEV) to Extravehicular Activity (EVA) Systems Interface Requirements Document (IRD).

Rationale: This capability is required for the contingency EVAs. Crew may be in surface suits or launch/entry/abort/contingency EVA suits. The suit architecture is still being defined. (CA3166)

CV0303 **Maximum Design Pressure**

The CEV crew module maximum design pressure (MDP) shall be

15.8 (TBR-002-245) psid.

Rationale: This provides a test and design-to number for the CEV crew module pressure vessel. The CEV will maintain the internal-to-external pressure less than the MDP, including transient pressure excursions. (derived project requirement)

CV0315 **LIDS Interface**

The CEV shall dock using the Low Impact Docking System (LIDS).

Rationale: The LIDS mechanism was selected by the ESAS team as mating mechanism for Constellation elements for the lunar mission. This decision was based on many considerations including levels of size, fault tolerance, and ability to dock or berth. The LIDS mechanism will be provided as Government Furnished Equipment. (CV0011, CV0001)

CV0811 **Launch Site**

The CEV shall launch from the KSC/Eastern Range.

Rationale: The KSC/Eastern Range is NASA's primary launch site for human space missions and is the lowest latitude contiguous US (CONUS) launch site available to NASA. Additionally, the Eastern Range has substantial legacy support infrastructure in place that may be leveraged in support of Constellation missions. (3.2 allocation CARD CA0346)

CV0812 **Protection of Internal Devices**

The CEV shall protect devices internal to the pressurized volume that are intended to be connected and disconnected during a lunar mission from lunar dust contamination.

Rationale: If carried inside the habitable volume, the CEV project recognizes that dust from the lunar surface could be harmful to equipment. The CEV must protect against the harmful effects lunar dust may have on seals and quick disconnect devices. (CA0021)

CA0351-PO **CEV Launch Lighting Conditions**

The CEV shall launch independent of ambient lighting conditions.

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

CA0448-PO **CEV Single Crewmember Control**

The CEV, when operated by the crew, shall be controllable by a single crewmember.

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

CA0448D-PO **PBS - CEV Return To Earth Capability**

The CEV shall allow a single crewmember to perform safety and mission critical functions where crew actions are necessary.

Rationale: Vehicle systems must be designed so that more than one crew member is not required to operate the vehicle. There may be circumstances where crewmembers are unconscious or incapacitated leaving only a single crew member capable of vehicle control.

CA5240-PO **CEV Transfer from LLO to LSAM in LRO**

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

Rationale: This requirement allocates a portion of the 130 (TBR-001-005) hours that the Constellation Architecture needs to return the crew to the earth surface. The number of hours allocated allows for the orbit transfer of the CEV to LRO.

CA5319-PO **CEV Ascent Target Transfer**

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

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

CA0324-PO **CEV Landing at CONUS Sites**

The CEV shall return to Earth on land at designated CONUS landing sites.

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

CA3166-PO **CEV EVAs on Lunar Missions**

The CEV shall provide for at least 2 (TBR-001-206) EVA operations of at least 4 (TBR-001-207) hours duration each on lunar missions independent of other flight vehicles.

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

CV0659 **EVA Translation Paths**

The CEV shall provide EVA translation paths as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Requirements Doc (IRD).

Rationale: An EVA translation path allows the EVA crewmember to translate to an EVA worksite or from one vehicle to another in support of unscheduled or contingency EVAs.

As an example, In the event of a contingency EVA transfer of the crew from the LSAM to the CEV, a translation path between the LSAM hatch to the CEV hatch needs to be provided. Detailed requirements for translation paths on CEV that are necessary for specific EVA tasks are covered in the appropriate system IRDs/ICDs.

CV0672 **EVA Egress**

The CEV shall provide the infrastructure for the EVA crewmember to egress the vehicle as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Requirements Doc (IRD).

Rationale: The CEV shall provide the infrastructure for the EVA crewmember to egress the vehicle as defined in the CEV to EVA IRD CxP 70033.

CV0673 **EVA Ingress**

The CEV shall provide the infrastructure for the EVA crewmember to ingress the vehicle as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Requirements Doc (IRD).

Rationale: At the completion of the EVA, the EVA crewmember(s) will need an unobstructed path to ingress the spacecraft and close the side hatch. This path needs to be compatible with EVA from a safety and human factors standpoint.

CV0674 **Stabilization of EVA Crewmembers**

The CEV shall provide infrastructure for EVA crewmembers to stabilize themselves while performing EVA tasks as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Requirements Doc (IRD).

Rationale: The ability for the EVA crewmember to stabilize themselves on the exterior of the spacecraft is critical to safety and success of EVA tasks. Without proper stabilization, the task may be impossible to perform and the EVA crewmember is at higher risk to of unsafe uncontrolled movement and spatial disorientation.

CA3168-PO **CEV External Control for Cabin Depressurization**

The CEV shall provide an external control to depressurize the cabin that is operable by an EVA crewmember.

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

CV0075 **Non-Propulsive CEV Cabin Depressurization**

The CEV shall provide non-propulsive CEV internal depressurization.

Rationale: This capability is required for a contingency scenario where the crew cannot ingress the CEV through the pressurized docking vestibule. The crew must then be able to depressurize the CEV cabin from outside the spacecraft.

CA5148-PO **Three Concurrent CEV On-Orbit Missions**

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

Rationale: Multiple CEV vehicles will be operated in-space concurrently for ISS and for lunar missions. CEV infrastructure must allow for managing multiple vehicles and for ground control to uniquely identify and control individual vehicles (e.g., unique transponder signals identifiers and command and telemetry format headers).

CA4152-PO **ISS Based EVAs on CEV**

The CEV shall provide the infrastructure to perform ISS-based EVAs on ISS missions.

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

3.2.6.1 CEV Control Mass

CA0827-PO **Control Mass - CEV**

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

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

CA0827D-PO **PBS - Control Mass - CEV**

The CEV shall have a Control Mass of 21,918 kg (48,320 lbm) at the Lunar Ascent Target.

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

CA4134-PO **CEV Control Mass Lunar Lift Off**

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

Rationale: The Control Mass for the CEV at Lift-Off is based on the CEV DAC-2 analysis. Mass control is required for the concurrent design of multiple Systems which have an overall performance or mission goal. This Control Mass can be determined by summing the CEV Crew Module, Service Module, Spacecraft Adapter and Launch Abort System masses. This Control Mass is needed with the Program Reserve to size CLV Mass Delivered requirements.

CA4134D-PO **PBS - CEV Control Mass Lunar Lift Off**

The CEV shall have a Control Mass of 29,220 kg (64420 lbm) at Lift-Off for the Lunar Mission.

Rationale: The Control Mass for the CEV at Lift-Off is based on the CEV DAC-2 analysis. Mass control is required for the concurrent design of multiple Systems which have an overall performance or mission goal. This Control Mass can be determined by summing the CEV Crew Module, Service Module, Spacecraft Adapter and Launch Abort System masses. This Control Mass is needed with the Program Reserve to size CLV Mass Delivered requirements.

CA4135-PO **CEV LAS Jettison**

The CEV shall jettison the LAS not later than 30 seconds after Upper Stage Engine ignition command.

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

CA4135D-PO **PBS - CEV LAS Jettison**

The CEV shall jettison the LAS between 6 (TBR) seconds and 30 seconds after Upper Stage Engine ignition command during nominal ascent.

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

CA4139-PO **CEV Control Mass CaLV Rendevous**

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

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

CA4139D-PO **PBS - CEV Control Mass CaLV Rendezvous**

The CEV shall have a Control Mass of 20,639 (TBR-001-159) kg (45,500 lbm) at the time of CaLV rendezvous.

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

CA4163-PO **CEV Control Mass ISS Lift Off**

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

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

CA4164-PO **CEV Control Mass ISS Lift Off**

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

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

3.2.6.2 CEV Delta-V

CA0829-PO **CEV Delta-V for Lunar Missions**

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

Rationale: The minimum translational delta-V requirement is based on analysis. This number is based on the Lunar Outpost mission and includes the delta-V necessary for orbit circularization from the ascent target, RPOD with the CaLV/LSAM in ERO, altitude maintenance during the lunar *surface stay, aligning the CEV parking orbit with the LSAM ascent orbit at worst case orientation, performing a TEI sequence with a 90 degree plane change, and executing TCMs during the Earth return for lunar polar outpost missions. It also accounts for GN&C performance dispersions. This excludes the attitude control delta-V.*

CA0829D-PO **PBS - CEV Delta-V for Lunar Missions**

The CEV shall provide a minimum translational delta-V of xxxx (TBR-001-148) m/s (4960 ft/s) for lunar missions.

Rationale: The minimum translational delta-V requirement is based on analysis. This number is based on the Lunar Outpost mission and includes the delta-V necessary for orbit circularization from the ascent target, RPOD with the CaLV/LSAM in ERO, altitude maintenance during the lunar surface stay, aligning the CEV parking orbit with the LSAM ascent orbit at worst case orientation, performing a TEI sequence with a 90 degree plane change, and executing TCMs during the Earth return for lunar polar outpost missions. It also accounts for GN&C performance dispersions.Â This excludes the attitude control delta-V.

CV0853 **Translational Delta-V Tank Size**

The CEV shall provide a minimum translational delta-V tank size of 5293 (TBR-002-256) ft/s.

Rationale: Defines the minimum propellant tank size that provides mission flexibility with the intent to nominally load the tanks to 4960 ft/s. This capability allows global access lunar sorties with full duration stay times. (CA0829)

3.2.7 CEV Safety (Systems, Public and Planetary)

CA0436-PO **CEV Two Fault Tolerance for Catastrophic Hazards**

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

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

CV0772 **Range Safety**

The CEV shall comply with NPR 8715.5, Range Safety Program, Preface and sections 1.1-1.2, 1.3.7, 1.4, 2.1, 2.3-2.4, 3.1-3.2, 3.3-3.4, and Appendix A.

Rationale: Safety of the public, ground personnel and property is imperative. NPR 8715.5, Range Safety Program, provides risk guidelines, a process and methodology of calculating Expectation of Casualty (Ec), Probability of Casualty (Pc), and Probability of Impact (Pi), and a process for accepting risk levels above the guidelines. The process the CEV Project will use to determine the probabilities flight to flight and to review each risk number for acceptance is provided in TBD CEV document. The selected (tailored) sections of the NPR also address tailoring of the host ranges? range safety requirements (such as AFSPCMAN 91-710, Range Safety User Requirements Manual) for CxP, and (TBD-001-263). (3.2 allocation CA0100)

CV0775 **CEV Module Disposal**

The CEV shall dispose of expendable modules and other orbital debris in accordance with NPD 8710.3B, NASA Policy for Limiting Orbital Debris Generation.

Rationale: During ascent the CEV must jettison the launch abort system (as applicable) which should land in the open ocean. On entry the CEV must dispose the service module and docking mechanism (for ISS missions) in the open ocean prior to landing downrange. Ocean disposal requires a 370.4 km (200 nmi) buffer for foreign land and 46.3 km (25 nmi) buffer for U.S. territories. The heat shield, drogue chutes, and other items jettisoned below 50,000 ft should impact within the controlled landing zone. (3.2 allocation CA0569).

CV0782 **Safety Requirements**

The CEV shall comply with the requirements from CxP-70059, SR&QA Technical Requirements document.

Rationale: Safety requirements to design based on lessons learned are mandated for NASA programs and projects. (3.3 allocation CA5915)

CV0821 **Physical inhibits for ground testing**

The CEV shall provide for control of ground safety hazards in accordance with document (TBD-002-236).

CV0850

The CEV shall dispose of expendable modules or debris without contacting the CLV during nominal liftoff and ascent operation

CV0851

The CEV shall dispose of expendable modules or debris without contacting the launch pad during nominal liftoff operation.

CA0435-PO **CEV Single Fault Tolerant for Critical Hazards**

The CEV shall be single fault tolerant for critical hazards and loss of mission, except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance must be achieved without the use of EVA, emergency operations or emergency systems.

Rationale: Single Fault Tolerance provides for mission critical failures and is dictated by programmatic decision to ensure mission success. The Constellation Program will define levels of fault tolerance that are satisfied by multiple systems and the allocations to those systems. This does not preclude more than the minimum level of fault tolerance.

CA0437-PO **CEV Redundancy Separation**

The CEV shall comply with the requirement in JPR 8080.5, JSC Design and Procedural Standards, Section G-2.

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

CV0575 **Prevention of CEV Fault Propagation**

The CEV shall prevent propagation of the effects for identified subsystem faults and component failures that, if propagated, could result in a catastrophic or critical hazard.

Rationale: Faults must be prevented from propagating to minimize harm and prevent loss of critical resources, and to ensure reconfiguration capability for vehicle recovery. Methods of preventing fault propagation include firewalls and vehicle moding. Fault and failures can be identified via the FMEA/CIL, among other techniques. This is one of the sets of requirements fulfills the intent of NPR 8705.2 section 3.5.1 (requirement 34460)

CV0736 **Computer Based Control Common Cause Failure Protection**

The CEV shall provide protection from the effects of software common cause failures when a failure of a system function results in loss of life.

Rationale: NPR 8705.2, Section 3.10.1 calls for a "design that prevents or mitigates the effects of common cause failures in time-critical software". Historically, software common cause failures have had their root cause associated with errors introduced during the software development process, primarily in the requirements and design phases. These errors are not uniformly considered mitigated by adoption of fault tolerance requirements. Examples of historical requirements phase incidents include loss of the 1999 Mars Polar Lander. Landing dynamics were not fully captured in requirements and the software was written without the ability to make a distinction between landing gear deployment and touchdown. The Boeing 757 crash in 1995 was attributed to errors introduced during the software design phase when assigning airport abbreviations to autopilot landing sites. The loss of the Mars Climate Orbiter was caused by guidance calculations using English vs. metric not caught during the implementation phase. Many additional historical examples exist. (NPR 8705.2A, Section 3.10.1)

3.2.8 CEV Command and Data

3.2.8.1 Command Generation

CA3254-PO **Command Generation**

The CEV shall generate commands.

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

CA3254D-PO **PBS - Command Generation**

The CEV shall generate commands.

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

CA3249-PO **CEV Command Generation Interface**

The CEV shall provide an interface for the crew to generate commands

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

3.2.8.2 Command and Data Reception

CV0552 **Reception of Commands and Data**

The CEV shall receive commands and data during all mission phases exclusive of interruptions caused by operational constraints.

Rationale: This requirement necessitates the reception of commands, as well as data, during all mission phases, integrated ground testing and post landing operations, except when operationally constrained. Examples of operational constraints can include communication blockages and operational constraints associated with mission phases, nominal unpowered operations during integrated ground processing, and nominal unpowered operations post-landing. This requirement is consistent with Constellation concept of operations for communications and tracking during mission phases. The communications and tracking is constrained by network limitations (Zone of Exclusion (ZOE), network handover), physical blockages, RFI, software masking, restriction due to EVA or external vehicle exposure limits, re-entry plasma or other operational constraints. (Derived project requirement)

CV0143 **Reception of Crew Commands**

The CEV shall receive commands from the crew.

Rationale: In order to control the vehicle the crew must have a method to send commands to the CEV systems. These commands can include hand controller, manual *inputs, switches, display interaction, keyboard inputs, and electronically generated commands. (NPR 8705.2 Paragraph 3.10.2)*

CV0145 **Reception of Commands and Data from Constellation**

The CEV shall receive commands and data from other Constellation Systems.

Rationale: It will be necessary to receive commands from other Constellation Systems (e.g. MCC, LSAM, etc.) during nominal crewed and uncrewed operations, and as a redundancy to failures. The IRDs will define performance parameters, such as latency, as well as command format. (Derived project requirement)

CV0737 **Reception of Commands and Data from ISS**

The CEV shall receive commands and data from the ISS.

Rationale: It will be necessary to receive commands from the ISS during nominal crewed and uncrewed operations, and as a redundancy to failures. The IRDs will define performance parameters, such as latency, as well as command format. (Derived project requirement)

CV0844 **Safe configuration**

The CEV shall maintain a safe configuration without ground and crew interaction for a period of no less than 12 hours during all mission phases following a failure of safety and mission critical functions.

Rationale: For Lunar Missions, using a 2 C&T network ground station configuration, the longest outage for the high gain antenna is 9 hours and 38 minutes. The comm outage, allowing for ~20% margin, is 12 hours. During these periods, the uncrewed CEV will have to meet CA0213-PO and CA0214-PO for single- and dual-fault tolerance to critical and catastrophic hazards, respectively. Crew interaction cannot be used to satisfy this requirement since the crew will be on the lunar surface during the outages. For cases where a failure cannot be isolated or cannot be recovered using redundancy, the system may be reconfigured to a predefined safe mode to prevent further degradation toward a catastrophic or critical hazard. (CA5466-PO)

CV0846 **Command And Data Reception**

The CEV shall receive commands and data during all ground operations and mission phases exclusive of interruptions caused by operational constraints.

3.2.8.3 Command Validation

CA0134-PO **Command Validation**

The CEV shall execute commands valid in the current state.

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

CV0556 **ISS Command Validation**

The CEV shall validate commands received from the ISS.

Rationale: Commands received from the crew or external systems must be validated prior to execution to ensure safety. Validation can be a staged process including verifying the originator has authorization, validating against the current mode or state, ensuring proper formatting, ensuring data is within limits or ensuring against other subsystem constraints.

CV0560 **Crew Command Validation**

The CEV shall validate commands received from the crew.

Rationale: Commands received from the crew or external systems must be validated prior to execution to ensure safety. Validation can be a staged process including verifying the originator has authorization, validating against the current mode or state, ensuring proper formatting, ensuring data is within limits or ensuring against other subsystem constraints.

CV0571 **Constellation System Command Validation**

The CEV shall validate commands received from the other Constellation Systems.

Rationale: Commands received from the crew or external systems must be validated prior to execution to ensure safety. Validation can be a staged process including verifying the originator has authorization, validating against the current mode or state, ensuring proper formatting, ensuring data is within limits or ensuring against other subsystem constraints.

CV0615 **Command Notification**

The CEV shall provide a notification for validity of commands.

Rationale: Command notification includes a response for both valid and invalid commands. Command originators need a response or acknowledgement to understand status of a command. CEV command failures, particularly crew initiated commands, warrant near real-time indication of failure to the crew, ground, and/or command initiator. (Derived project requirement)

3.2.8.4 Command Execution

CV0570 **Command Execution Status**

The CEV shall provide execution status of commands.

Rationale: Command initiators should know the status of commands for monitoring and awareness of vehicle state. The status along with command history can be provided at various stages of the command execution process, including receipt, cueing, validation, effector initiation, etc., and will be provided to the crew, ground, or command initiator as determined. (Derived project requirement)

CA3255-PO **Command Execution**

The CEV shall execute commands which are addressed to the CEV.

Rationale: The system will execute commands generated internally or from other systems in order to perform the specified function or operation. The ability for Constellation Systems to command execution on remote Constellation systems is required per the operations concept where the system with crew present may need to command systems without the crew onboard (e.g. LSAM commanding the CEV). In addition, the verification that the command is intended to be executed on the system will support the multi-hop routing capability.

CA3255D-PO **PBS - Command Execution**

The CEV shall execute valid commands which are addressed to the CEV.

Rationale: The system will execute commands generated internally or from other systems in order to perform the specified function or operation. The ability for Constellation Systems to command execution on remote Constellation systems is required per the operations concept where the system with crew present may need to command systems without the crew onboard (e.g. LSAM commanding the CEV). In addition, the verification that the command is intended to be executed on the system will support the multi-hop routing capability.

CV0569 **Crew Command Execution**

The CEV shall execute valid commands received from the crew.

Rationale: In order to control the vehicle, the crew must have a method to execute commands to the CEV systems. These commands can include hand controller, manual inputs, switches, display interaction, keyboard inputs, electronically generated commands. (NPR 8705.2 Paragraph 3.10.2)

CV0572 **Constellation System Command Execution**

The CEV shall execute valid commands received from Constellation Systems.

Rationale: In order to control the vehicle during nominal or unmanned operations, external systems including ground or other constellation architecture elements must have a method to execute commands to the CEV systems (NPR 8705.2 Paragraph 3.10.2).

CV0738 **ISS Command Execution**

The CEV shall execute valid commands received from ISS.

Rationale: For ISS missions, the operation concept includes control of the CEV from the ISS.

3.2.8.5 Command and Data Latency

CV0612 **Command Latency**

The CEV shall have crew, Constellation Systems, and ISS initiated command latency no greater than 200ms (TBR-002-232) while processing commands, where the performance measurement is taken from the time the initiated command has been received by the CEV, to the time the command has been received by the target sub-system.

Rationale: In order to command and manage the vehicle, commands must be provided to their destinations in a timely manner and the command must not be stale. An upper bound on command latency must be established to drive and manage overall avionics and software system design and end-to-end avionics and software performance. Many commands provide flight control or could affect critical flight related safety functions, including abort command execution. Command latency requirements for this or shorter time frames have been established in prior programs (STS/CAU). As an example, the command latency boundaries for a crew initiated command (to redirect antennae) begins when the command is entered by the crew to time of receipt by the subsystem to initiate antennae redirection. Note this requirement is related to the abort initiation SRD requirement CV0058. (Derived project requirement)

CV0739 **Telemetry Data Latency**

The CEV shall have a latency no greater than 1 <TBR-002-233> second while processing data destined for telemetry, where the performance measurement is taken from the time of subsystem data read to the time of data transmission from the CEV.

Rationale: In order to manage the vehicle from external systems, current status of the vehicle must be maintained in a timely manner and data should not be stale. An upper bound on telemetry latency must be established to drive and manage overall avionics and software system design and end-to-end avionics and software performance. This does not mean that all telemetry is at the highest speed (i.e. there can be data points sampled and telemetered very infrequently), but for the fastest telemetry and once the data is expected for downlink, system processing should not impose a latency of greater than the time determined. An example of the telemetry latency boundaries could be for a parameter that has been established at a once-per-second rate, from the time that sensor is read to the time when that piece of data leaves the antennae, it should not be more than 1 second old. (Derived project requirement)

CV0740 **Crew Status Data Latency**

The CEV shall have a latency no greater than 1 <TBR-002-234> second while processing data destined for crew display, where the performance measurement is taken from the time of subsystem data read to the time data is presented to the crew.

Rationale: In order to manage the vehicle, current status of the vehicle must be presented to the crew in a timely manner and data should not be stale. An upper bound on data display latency must be established to drive and manage overall avionics and software system design and end-to-end avionics and software performance. This does not mean that all data will be displayed at the highest speed (i.e. there can be data points updated very infrequently) but for data that is chosen to be displayed, CEV avionics and software system processing should not impose a latency of greater than the time determined. An example of the display latency boundaries could be for a parameter that has been established to be viewed at once-every-two-second rate, the time from when that sensor/parameter is generated to the time when that piece of data is displayed on the screen should not be more than three seconds. (Derived project requirement)

3.2.8.6 Data Generation and Display

CA0428-PO **CEV Generate Health and Status**

The CEV shall generate Health and Status information.

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

CV0153 **CEV Generate Health and Status for Safety and Mission Critic**

The CEV shall generate the health and status information on active and standby equipment for safety and mission critical functions.

Rationale: In order to alert the crew or ground of potential problems, the CEV must be capable of generating the health and status of vehicle functions. The availability of this information provides the insight into the vehicle systems necessary to assess the performance of the systems, identify anomalies, confirm isolation of faults, recover lost functionality (if redundancy exists), and support troubleshooting efforts to understand the failure or possibly recover failed systems. (NPR 8705.2, Paragraph 3.2.1 and Paragraph 3.3.1.)

CV0172 **Maintenance Data Collection and Storage**

The CEV shall provide equipment maintenance data for safety and mission critical systems.

Rationale: Maintenance data is the data provided by spacecraft components that aids in determining the future reliability, remaining useful life, and performance degradation of components onboard the spacecraft. Maintenance data is typically not used for onboard or ground processing during a mission but is collected by the vehicle to support ground operations and logistics. Types of maintenance data include total hours of operation, number of times powered on, and build in test (BIT) history. The recording of maintenance data is typically done on each device and is often done in nonvolatile memory. It is necessary for the maintenance personnel to have the capability to acquire this data from the onboard devices. (NPR 8705.2 Paragraph 3.6.1)

CV0539 **Health and Status information to External Operators**

The CEV shall provide health and status information to Constellation Systems and ISS.

Rationale: In order to alert the crew in other vehicles or ground of potential problems, the CEV must be capable of providing the health and status of critical functions. In addition, checkpoint data and flight computer memory dumps would be provided to Mission Systems. This data is used, for example, to duplicate actual in-flight scenarios in order to validate operations products, conduct specific training sessions, or initialize test scenarios for troubleshooting flight computer failures and flight software errors. (NPR 8705.2, Paragraph

3.2.1 and Paragraph 3.3.1.) (CA0428)

CV0576 **Data Quality Indication**

The CEV shall provide data quality indicators (e.g. current or stale).

Rationale: For data cyclically produced by the CEV, the data should have a data quality indicator describing whether the data as current or stale. This includes cyclically updated data sent by the CEV to crew displays, to other Constellation Systems, and to the ISS.

CV0831 **Health and status information processing**

The CEV shall process health and status information.

Rationale: Provides for automated ""decision support"" functions using health and status information residing within the CEV. (CA0217)

CV0820 **Developmental Flight Instrumentation**

The CEV shall generate engineering and developmental flight instrumentation data.

Rationale: A data acquisition system which can be configured on a per mission basis as needed for different sensor types, sensor locations, data storage and telemetry would provide the capability to acquire critical engineering data over the life of the program for design enhancement, performance improvements, verification of flight environments and accident investigation.

CA0427-PO **CEV Health and Status Information to the Crew**

The CEV shall provide Health and Status information to the crew.

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

CV0156 **Display of Health and Status Information to Crew**

The CEV shall provide health and status information of the CEV, ISS, and other Constellation Systems to the crew.

Rationale: In order for the crew to be aware of the health of the CEV, EVA, other vehicles, or integrated stack, the CEV will monitor the performance, health, configuration, status, failures, and hazards for display to the crew. (NPR 8705.2 Paragraph 3.2.1)

CV0555 **Shared Resources Crew Display**

The CEV shall provide the real-time utilization of shared resources (e.g. Power, Thermal, Data) to the crew.

Rationale: The CEV needs the ability to display the real-time utilization of shared resources to the crew to enhance crew situation awareness.

CV0813 **Power and Data Ports**

The CEV shall provide 6 quality of power and data ports in accordance with CxP 70035, Portable Equipment, Payloads, Cargo (PEPC) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).

Rationale: Government furnished portable equipment that will fly on the vehicle will need access to CEV power and data resources.

3.2.8.7 Data Recording

CV0536 **Health and Status Recording**

The CEV shall record at least 8 Gigabytes of health and status information on CEV active and standby equipment for safety and mission critical functions.

Rationale: This requirement meets the intent of NPR8705.2 paragraph

3.6.1 to record health and status information. (CA0993 location CARD 3.2)

CV0170 **Onboard Telemetry Data Recording**

The CEV shall provide capacity to record at least 12 hours telemetry data at 192 kbps at baseband onboard.

Rationale: For Lunar Missions, using a 2 C&T network ground station configuration, the longest outage for the high gain antenna is 9 hours and 38 minutes. (CA0993 location CARD 3.2)

CV0171 **Auxiliary Data Recording**

The CEV shall provide capacity to record at least 12 Gigabytes of auxiliary data.

Rationale: Auxiliary data may include developmental flight instrumentation data, mission engineering analysis data and life cycle data that could affect vehicle turnaround operations. Auxiliary data is not downlinked real-time and may either be downlinked when possible or only reviewed post-mission. Continuous improvement and failure analysis capabilities have often been inhibited on past programs due to the lack of adequate engineering data (e.g. thermal, mechanical, and aero loads), even after multiple missions. Collection of engineering performance data is critical to efficient design improvement. An auxiliary data acquisition system will support in-flight and post-flight engineering evaluation for safety and performance improvements and reductions of over-conservatism (such as weight reduction) for future missions. As an example, the orbiter cable tray assessment for PAL ramp removal required over $20M in wind tunnel testing when the data could have been collected on the 100+ previous missions. (CA0993 location CARD 3.2)

CV0843 **Onboard Operational Parameter Loading**

The CEV shall provide the capability to load operational parameters that have been written to non-volatile memory upon receipt of a command from the crew, ISS, or other Constellation Systems.

Rationale: In support of computer recovery operations, It will be necessary to load into computer memory the operational parameters that have been written to permanent storage. This is necessary to allow the crew and mission systems to return the avionics system to a nominal operational configuration following computer failures. For example, data of operational interest such as Fault Detection and Annunciation table limit changes, TDRS state vectors updates, etc will be written to non-volatile memory periodically so that these operational parameters can be read back into computer memory if the need arises. For example, if a sensor malfunctions on the CEV, Mission Systems may uplink a limit change to the fault detection limit tables based on the new sensor's performance to prevent it from inadvertently ringing an alarm. In the event of total CEV computer failure and subsequent recovery operations, it is desirable to be able to reload these limit changes and other operational parameters from non-volatile memory thereby returning the CEV flight computers to the same operational state they were in prior to the computer failure.

CV0550 **Equipment Maintenance Data**

The CEV shall record equipment maintenance data for safety and mission critical systems.

Rationale: NPR 8705.2 Paragraph 3.6.1. Maintenance data is the data provided by spacecraft components that aids in determining the future reliability, remaining useful life, and performance degradation of components onboard the spacecraft. The collection of maintenance data is typically not used for onboard or ground processing during a mission but is collected by the vehicle to support ground operations and logistics. Types of maintenance data include total hours of operation, number of times powered on, and build in test (BIT) history. (CA0993 location CARD3.2)

CA5039-PO **CEV Storage for Recording Digital Data**

The CEV shall provide (TBD-001-220) bytes of digital storage for recording digital data received from other Constellation Systems.

Rationale: Having storage space for other system's recorded data provides the Constellation Architecture the capability to transfer stored data to ensure that data is available when needed. The recording function is separate from the archival function and is sized on a per-mission basis. The archival function is assumed to be addressed at the Constellation level in CxP 70073-02, Constellation Program Management Systems Requirements, Volume 2: Data Management Requirements. The amount of space required for each system will change with mission type. CEV is encouraged to provide larger than necessary storage space for early missions in preparation for the larger space requirements in later phases of the program. Additional performance details (duration, etc.) will be defined in CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element.

CV0741 **CLV Data Recording**

The CEV shall record up to 20 Gigabytes of ascent data from CLV.

Rationale: CLV upper stage will not be recovered, therefore the only way to capture CLV video and data is to record it on CEV.

CA0511-PO **CEV Flight Data Recorder**

The CEV shall record critical data for reconstruction of catastrophic events.

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

CV0173 **Data Recording For Accident Investigation**

The CEV shall record flight data essential for accident investigation during ascent and entry onto non-volatile memory that meets (TBD-002-232) hardening.

Rationale: Imposing only Chapter 2.4 of EUROCAE ED-112 assures the survivability requirements referenced by FAA TSO-124a are met, but does not impose all operational requirements for a FAA Crash Recorder which may not apply to the CEV program.

CA5040-PO **CEV Recording of Digital Data**

The CEV shall record System-generated digital data received from other Constellation Systems.

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

3.2.8.8 Data Time Stamping

CV0833 **Time Stamping of Audio and Motion Imagery**

The CEV shall time stamp audio and motion imagery.

Rationale: According to the International Telecommunications Union Recommendation, ITU-R BT.1359-1 (1998), Relative Timing of Sound and Vision for Broadcasting, Tests conducted have shown that the thresholds of detectability are about +45 ms to -125 ms and thresholds of acceptability are about +90 ms to -185 ms on the average. As an additional need, time correlation of vehicle and equipment parameters with associated motion imagery is crucial in analysis, documentation, or troubleshooting of events.

CV0688 **Time Stamp Precision**

The CEV shall time stamp vehicle data to a precision that uniquely identifies every collected data set.

Rationale: The precision of a time-stamp is extremely important in order to control the vehicle and analyze the data after a mission. Precision reflects the number of significant digits used to measure time. For example, if 100 Hz is the fastest collection cycle, then the precision must be fine enough for a 10 ms resolution. The precision needed must be high enough to time stamp data collected from within one dataset. The term data set assumes a cyclic execution environment and is a grouping of data by processor collection cycle such that the group must be distinguished from other groups of similar data taken at a previous or future time. Operational needs will dictate the granularity of data set time stamping. This requirement does not dictate that data sets from different processors be distinguished by time stamp alone. (Derived project requirement)

CV0689 **Time Stamp Accuracy**

The CEV shall time stamp vehicle data to an accuracy of +- (TBD-002-208) of maximum collection cycle rate for each collected data set.

Rationale: The accuracy of a time-stamp is extremely important in order to control the vehicle and analyze the data after a mission. This includes data destined for telemetry or recording. Accuracy reflects how close the measured time value is to the ``correct'' or ``truthful'' time value. For example, if 100 Hz is the fastest collection cycle, then the worst case time accuracy must be +/- 5 ms. The term data set assumes a cyclic execution environment and is a grouping of data by processor collection cycle such that the group must be distinguished from other groups of similar data taken at a previous or future time. Operational needs will dictate the granularity of data set time stamping. This requirement does not dictate that data sets from different processors be distinguished by time stamp alone. (Derived project requirement)

CV0848 **Time Synchronization**

The CEV shall synchronize vehicle time sources.

Rationale: Multiple vehicle time sources must be synchronized to provide the capability to determine the chronological sequence of data stamped by different time sources. (Derived project requirement)

3.2.8.9 Onboard Data and Software Reconfiguration

CA5901-PO **Data Reconfiguration of Stored Commands, Sequences, and Data**

The CEV shall accept reconfiguration of stored commands, sequences and data.

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

CV0152 **Software Update**

The CEV shall update onboard software with uplinked software.

Rationale: Mission success and crew survival are enhanced by the ability of the Ground Systems, Mission Systems, and/or crew to update the onboard software to adapt to contingency situations or to correct for unexpected software anomalous behavior.

CV0616 **Data Update**

The CEV shall update onboard data parameters with uplinked values.

Rationale: Mission success and crew survival are enhanced by the ability of the ground and/or crew to update the onboard data. Ground control and the crew need the ability to easily change parameters, limits, stored automation sequences, automation sequence *triggers, and configuration data to control system behavior. Turn around time of data and parameters will be determined operationally.*

CV0627 **Data Reconfiguration**

The CEV shall provide data reconfiguration.

Rationale: Different phases of flight development and execution will require different configurations of the software and data associated with constellation systems in order to achieve mission objectives. Data to be reconfigured includes changes to software constants and variables, telemetry downlink configuration details, changes to any parameters associated with individual instances of system hardware or hardware health and changes to any parameters associated with operational philosophy. System data must be configurable in real-time in order to respond to changes brought on by failures, changes in the space environment or changes to mission objectives. Historical experience shows that when a system's software configuration is not modifiable by other systems, there is a significant increase in lifecycle costs [CxP-O11] and an increase in the burden on ground and mission operation support of system operation through the need to develop operational 'work-arounds' due to software configuration deficiencies [CxP-O34]. Software variable changes in previous vehicle architectures have required re-delivery of flight software driving overall programmatic cost throughout the lifecycle. (CA3007 location CARD 3.2)

3.2.9 CEV Systems Management

3.2.9.1 Management of Health and Status

CV0549 **Resource Monitoring**

The CEV shall monitor the real-time utilization of shared resources.

Rationale: To ensure onboard resources are utilized according to nominal operation, the CEV requires the ability to monitor the use of shared resources, including power, thermal, and data, to ensure sufficient resources are available. The ground and the flight crew will need the ability to determine whether adjustments to the resource allocation may be needed, based on vehicle mode, resource availability, and fault recovery processes. (CA0428)

CV0553 **Vehicle Mode Transition**

The CEV shall perform vehicle mode transitions.

Rationale: The CEV must have the ability to direct and coordinate across systems, the transition from one vehicle mode to another. A vehicle mode is a predetermined operational configuration with a specified functionality or flight condition, such as being attached to the ISS (ISS quiescent), or uncrewed while in lunar orbit (LLO quiescent). These mode transitions should have the capability to be initiated by flight crew, Constellation Systems, or ISS. For example ISS quiescent mode is the low power, keep-alive state which maintains the health of the CEV systems required for the next phase of operation when docked to the ISS. LLO quiescent mode is the uncrewed state which maintains the health of the CEV systems while in LLO and ensures sufficient functionality in the CEV to allow for the LSAM to dock and the crew to return. (CA0428)

CV0554 **Mode Transition Monitoring**

The CEV shall provide transition status for any mode transition.

Rationale: A mode transition must be monitored to ensure the proper configuration defined by the mode has been achieved. If the mode transition was successful, the CEV should ensure that functions which are not allowed in the new mode are inhibited and functions which are allowed in the new mode are enabled. (CA0428)

CV0617 **Functional Inhibits for the Current Operating Mode**

The CEV shall inhibit functions that are invalid for the current operating mode.

Rationale: In order to ensure that no restrictions to the current operational vehicle configuration are violated, the CEV needs to inhibit functions that are incompatible with the operating mode. For example, if the spacecraft is in ascent, the firing of the drogue chute must be inhibited. However, the CEV will allow commands from the crew, ISS, or other Constellation Systems to inhibit and enable functions as desired. (CA3110)

CV0154 **Operational Status Determination**

The CEV shall determine the operational status of standby (powered on) redundant components prior to placing them into active status.

Rationale: Prior to changing over to a redundant string, when the redundant component is not currently the prime, the ability to perform the required functions needs to be verified prior to performing the switch over. It is implied that the component is not in the active computation string, but is powered on. (CA0428)

CV0204 **Subsystem Checkout**

The CEV shall provide a subsystem checkout capability initiated by the crew, ISS, or other Constellation Systems.

Rationale: A means to verify that the subsystem is properly functioning will be needed. Examples of subsystem checkouts include the flight control system tests done by Shuttle prior to entry or the atmospheric revitalization tests performed prior to docking the LSAM upon returning from the lunar surface. (CA0428)

3.2.9.2 FDIR

CV0819 **Autonomous Mission Return**

The CEV shall autonomously plan and execute safety critical resource usage to return to earth at any time during the mission.

Rationale: Crew survival upon a condition that leads to mission abort with no communication with mission systems, depends on their ability to manage potentially degraded CEV systems and critical resources necessary to facilitate their safe return to Earth at any point in their mission. Mission operations experience shows that real-time resource reallocation, can be very complex without analysis capabilities that can evaluate the current state of resources and propagate against available mission scenarios. Such capabilities can provide the crew with the necessary information to select a course of action that maximizes the options for a safe return to Earth (CA0416)

CA0438-PO **CEV Fault Detection**

The CEV shall detect system faults which result in loss of vehicle, loss of life and loss of mission.

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

CA0438D-PO **PBS - CEV Fault Detection**

The CEV shall detect system faults which could result in loss of vehicle, loss of life and loss of mission.

Rationale: Fault detection is required for crew safety and mission success by enabling recovery of such critical functions. In addition, fault detection enables crew abort or flight termination (in case of non-recoverable failures). Faults subject to detection are further specified by CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element. FDIR is a redundancy *management function necessary to manage fault tolerance. This level II requirement addresses the loss of vehicle, loss of life, and loss of mission.*

CV0158 **Fault Detection**

The CEV shall detect faults to the subsystem or component active and standby (powered on) redundancy level that could result in Emergency, Warning, or Caution (Class 1, 2 or 3) events.

Rationale: In order for the operators to adequately assess the health of the CEV, and identify conditions indicating the need to abort, faults must be detected. The operators require this information in order to make a determination if the mission should progress, be shortened or terminated. Class 1 covers any event that threatens the vehicle or the life of the crew and requires immediate action. Class 2 covers any event that requires immediate correction to avoid loss of or major impact to the vehicle or potential loss of crew. Class 3 covers any event that is not time critical in nature but further degradation has the potential to threaten the loss of crew, or the loss of redundant equipment. This set of requirements fulfills the intent of NPR 8705.2 section 3.5.1; requirement 34460.

CV0580 **Loss of Communication Detection**

The CEV shall detect loss of communications with Mission Systems in the absence of a communication signal for more than 12 hours.

Rationale: CEV needs to be able to determine when there is a failure of the on-board C&T system as opposed to natural RF link interruptions. This is especially true for cases of un-crewed operations when the crew is on the lunar surface. If the spacecraft has not heard from the ground for some period of time, the assumption is that maybe the currently active communication hardware has failed, and FDIR functions should be initiated. For Lunar Missions, using a 2 C&T network ground station configuration, the longest outage for the high gain antenna is 9 hours and 38 minutes. The communications outage, allowing for ~20% margin, is 12 hours. The 12 hours is a reconfigurable parameter that can be adjusted based on ISS or Lunar Missions.

CV0541 **Independent Detection of Faults**

The CEV shall provide independent means for detection of a failure that could result in a catastrophic or critical hazard.

Rationale: The vehicle must detect failures unambiguously without relying upon a single measurement in order to clearly isolate and identify the failure. The number of independent means required will depend on the function. Independent means may be provided by distinct duplicate sensors communicating via different hardware buses or by a single instrumented value and a corresponding calculated value based on other unrelated data items. For example, an abort condition needs to have independent confirmation before declaring the abort to ensure it is not just a sensor failure. Examples would be distinct duplicate sensors communicating to different hardware busses, or, a trajectory derived measurement compared to a propellant fuel gage.

CA5465-PO **CEV Failure Isolation**

The CEV shall isolate detected faults to the level required for recovery of function.

Rationale: Fault isolation is required for crew safety and mission success by identifying the root cause of a system fault, which allows for the safing and recovery of affected systems. In addition, fault isolation enables appropriate recovery steps, or crew abort or flight termination in the case of non-recoverable failures. Faults subject to isolation are further specified by the CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element.

CV0159 **Fault Identification**

The CEV shall identify the source of detected subsystem faults and component failures.

Rationale: Faults associated with Class 1, Class 2, and Class 3 events must be isolated (identify the source of the fault and prevent propagation of the fault). This requirement is the component of fault isolation that deals with identification of the fault source, which includes identifying the root (or primary) cause of multiple faults. The source will be identified to the lowest level of isolation available when a fault causes multiple Class 1, Class 2, and Class 3 events to enhance crew situational awareness and the ability to timely execute recovery actions. Identification is associated with faults that are detected as defined by requirement CV0158 (fault detection). The requirement that is a component of fault isolation that deals with preventing propagation of the fault is CV0575, located

3.2.7 CEV Safety (Systems, Public, and Planetary). (NPR 8705.2 section 3.5.1)

CA5466-PO **CEV Recovery from Failure**

The CEV shall provide recovery from isolated faults.

Rationale: Fault recovery is required for vehicle faults and failures which could lead to loss of vehicle, loss of life, loss of mission, or loss of system redundancy. Faults subject to recovery are further specified in the CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element. This requirement does not preclude procedural recovery from other faults or failures.

CV0160 **Fault Recovery Using Available Redundancy**

The CEV shall recover from isolated subsystem faults and component failures, where redundancy exists, to prevent a catastrophic or critical hazard.

Rationale: Fault recovery uses the available redundancy built into the design to restore the vehicle functionality. The redundancy requirements for 1 & 2 FT drive this implementation. Fault Recovery does not preclude In-Flight Maintenance (IFM), however IFM will be used only as a contingency based on Flight Ops decisions. IFM is not to be used as nominal fault recovery. The fault recovery time will be dependant on the function lost. For example, a crew safety function (such as a toxic leak) will require faster recovery time than a function for mission success (such as loss of a redundant cabin fan). Note that dissimilar redundancy is acceptable when identical functional redundancy is not available. (NPR 8705.2 section 3.5.1)

CV0557 **Reallocation of Shared Resources for Fault Recovery**

The CEV shall reallocate the real-time utilization of shared resources (e.g. Power, Thermal, Data) in support of fault recovery.

Rationale: The CEV requires the ability to automatically adjust the allocation of shared resources in support of fault recovery. Implementation could be similar to the load-shed tables used in the ISS, or could be more dynamic, depending upon the vehicle operational constraints. For example, the task may involve balancing the requirements of the active thermal, antenna pointing and solar array pointing, if applicable, with the vehicle thermal pointing constraints. This assumes that the crew or ground would inhibit the function if it was not compatible with the current operations, and that they will have the ability to change the reallocation using reconfigurable data parameters.

3.2.9.3 Control of Automation

CA5904-PO **Execute Reconfigurable Sequences**

The CEV shall execute reconfigurable automation sequences valid in the current state.

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

CV0824 **Onboard Automation Sequence Scheduling**

The CEV shall provide reconfigurable time and event scheduling for the execution of automation sequences.

Rationale: This requirement establishes the capability to schedule and trigger the execution of automation sequences based on pre-determined mission time or events. This capability enhances safety and mission success by reducing crew and ground operator workload, allows uncrewed CEV mission execution independent of the ground, and provides an aid to the crew to safely return to the Earth in the event of loss of communications with the ground. This will allow the coordinated execution of vehicle configuration changes including flight phase and vehicle mode transitions, and related subsystem reconfiguration. For example, this would include the sequencing associated with vehicle reconfiguration and execution of such events as the TEI burn and de-orbit preparation activities. (CA5904)

CA3110-PO **CEV Control of Automation**

The CEV shall accept Control of Automation.

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

CA3110D-PO **PBS - CEV Control of Automation**

The CEV shall accept Control of Automation.

Rationale: Control of Automation is defined as the commanded ability to select, initiate, inhibit, override, and terminate automation. The crew, ISS, or other Constellation Systems will need commands to select, initiate, inhibit, override, and terminate automated functions on the CEV during various operational phases. Reference NPR 8705.2, Human-Rating Requirements for Space Systems, Sections 3.2.7 (34445), 3.3.5 (34451).

CV0743 **Initiate Selected Automated Functions**

The CEV shall initiate the execution of selected automated CEV functions upon receipt of crew, ISS, or other Constellation System commands.

Rationale: CEV operators will need to select and initiate automated CEV functions during various operational phases. This ability is required for the CEV crew, ISS crew, or other Constellation System operators to control automated functions onboard the CEV. Reference HRR NPR 8705.2 section 3.2.7 (34445), section 3.3.5 (34451)

CV0150 **Inhibit of Automated Operations**

The CEV shall inhibit the execution of an automated CEV function upon receipt of the inhibit command for that function from the crew, ISS, or other Constellation Systems.

Rationale: There are times when automated functions must be prevented from executing. Inhibits prevent the execution of an automated function prior to initiation. This ability is required for the CEV crew, ISS crew, or other Constellation System operators to control automated functions onboard the CEV.

CV0544 **Re-enable Inhibited Automated Functions**

The CEV shall enable the execution of an automated CEV function that was previously inhibited, upon receipt of the enable command for that function from the crew, ISS, or other Constellation Systems.

Rationale: Previously inhibited automated functions need the ability to be re-enabled. This ability is required for the CEV crew, ISS crew, or other Constellation System operators to control automated functions onboard the CEV.

CV0148 **Override of Automated Functions**

The CEV shall provide the crew, ISS, or other Constellation Systems with override of automated CEV functions that are physically and safely interruptible.

Rationale: For safety purposes, automated functions should be designed with an override capability which allows the human operators to stop, safe, or assume manual control of the automated function after it was initiated. The point at which the override occurs will differ depending on the function. Some activities may only be taken to a safe state and no manual control is available. This ability is required for the CEV crew, ISS crew, or other Constellation System operators to control automated functions onboard the CEV. (NPR 8705.2 Crew Interaction requirement for override section 3.2.4 and Human-System Interactions (Ground Control) override section 3.3.5)

CV0747 **Terminate Automated Functions**

The CEV shall terminate the execution of an automated CEV function upon receipt of the terminate command for that function from the crew, ISS, or other Constellation Systems.

Rationale: Automated functions must have the ability to be terminated after the automated function was initiated. The point at which the termination occurs will differ depending on the function. This ability is required for the CEV crew, ISS crew, or other Constellation System operators to control automated functions onboard the CEV.

3.2.9.4 Vehicle Re-initialization

CV0558 **Crew Commanded Flight Processor Vehicle Re-initialization**

The CEV shall re-initialize the flight processor(s) into a predefined operating configuration upon receipt of an action from the crew.

Rationale: It is necessary for the crew to have the ability to re-initialize the flight computers in response to an anomalous condition. This includes the ability to re-initialize flight processors either individually or all together (even in the case that no flight processor is active). The use of the word "action" implies that this operation is accomplished using switches or buttons, not merely through the use of electronic commanding. Note that re-initializing into a predefined operating configuration includes automatically reloading, and interrogating the environment to determine either if the re-initialization should wait for a command to synchronize and start executing. A predefined operating configuration includes the software/firmware configuration data that contains the necessary initial conditions for all processor computational functions to start execution. Configuration data also includes reconfigurable data of operational interest such as Fault Detection and Annunciation table limit changes, TDRS state vectors updates, and telemetry formats. This capability would provide options for recovery and continuation of the mission, or at a minimum a safe return of the crew. (Derived project requirement)

CV0561 **Externally Commanded Flight Processor Vehicle Re-initialization**

The CEV shall re-initialize a single flight processor into a predefined operating configuration upon receipt of a command from the ISS and other Constellation Systems.

Rationale: It is necessary for external operators, to have the ability to re-initialize a flight processor in response to an anomalous condition. Since this command can be sent by external operators, it should be restricted to a single processor for each single command in order to avoid bringing down all of the processors and relying upon the re-initialization process for resynchronization. Note that re-initializing into a predefined operating configuration includes automatically reloading, and interrogating the environment to determine either if the re-initialization should wait for a command to synchronize the processors and start executing, or to *automatically begin synchronizing and start executing. A predefined operating configuration includes the software/firmware configuration data that contains the necessary initial conditions for all processor computational functions to start execution. Configuration data also includes reconfigurable data of operational interest such as Fault Detection and Annunciation table limit changes, TDRS state vectors updates, and telemetry formats. For example, if a sensor malfunctions on the CEV, Mission Systems may uplink a limit change to the fault detection limit tables based on the new sensor's performance to prevent it from inadvertently ringing an alarm. In the event of total CEV computer failure and subsequent recovery operations, it is desirable to be able to reload these limit changes and other operational parameters from non-volatile memory thereby returning the CEV flight computers to the same operational state they were in prior to the computer failure. Loading of this configuration data aids the crew and mission systems to return the avionics system to a nominal operational configuration following computer failures. The commanded re-initialization capability would provide options for recovery and continuation of the mission, or at a minimum a safe return of the crew. (Derived project requirement)*

CV0562 **Automated Vehicle Re-initialization During Uncrewed Operation**

The CEV shall re-initialize the flight processors upon recovery from vehicle electrical power loss, to restore vehicle control and communication during uncrewed operations.

Rationale: During uncrewed operations in Low Lunar Orbit, it is necessary for the CEV to re-initialize the flight processors following the restoration of electrical power after a power interruption (a transient fault interrupting the entire vehicle). Following power loss, the CEV should restore electrical power, and re-initialize the flight processors into a predefined operating configuration (loading, synchronizing, and beginning execution in a “safe mode”). Configuration data also includes reconfigurable data of operational interest such as Fault Detection and Annunciation table limit changes, TDRS state vectors updates, and telemetry formats. The safe mode configuration must be sufficient to initialize GN&C functions to control the trajectory and attitude, and to configure the communications system to attempt to re-establish communication with the ground. This requirement assumes that the software/firmware initialization logic would allow the flight processors to interrogate the outside operating environment sufficiently to determine the proper actions. (Derived project requirement)

CV0842 **Save Configuration Data**

The CEV shall save configuration data upon receipt of the command from the crew or other Constellation Systems.

Rationale: Data of operational interest such as Fault Detection and Annunciation table limit changes, TDRS state vectors updates, etc should be written to non-volatile memory periodically so that these operational parameters can be read back into computer memory if the need arises. For example, if a sensor malfunctions on the CEV, Mission Systems may uplink a limit change to the fault detection limit tables based on the new sensor's performance to prevent it from inadvertently ringing an alarm. In the event of total CEV computer failure and subsequent recovery operations, it is desirable to be able to reload these limit changes and other operational parameters from non-volatile memory thereby returning the CEV flight computers to the same operational state they were in prior to the computer failure.

CV0563 **Checkpoint Generation**

The CEV shall, upon receipt of a commanded, scheduled or triggered event, save the computational execution state information (checkpoint).

Rationale: The capture and saving of a checkpoint, based upon a triggered, scheduled, or manual event, is critical to providing repeatability for verification, validation and training for the vehicle systems. A checkpoint is a snapshot of software/firmware computational state data and possibly related configuration data that is necessary to restart a processor from a previously saved state. A training or test run restarted from a checkpoint must have identical results with the original run.

In addition it will be useful for ground-based software maintenance and analysis. (Derived project requirement)

CV0619 **Checkpoint Exporting**

The CEV shall export to external systems the saved computational execution state (checkpoint) data.

Rationale: This is envisioned to be used as a ground only capability, but is a function of the flight processors in support of testing and training. The checkpoint data needs to be exported to external systems (ground test or training systems) and uniquely saved. Saving the checkpoint data is critical to support verification & validation (such as in the CEV Avionics Integration Lab (CAIL)), and training for the vehicle systems, and it is useful for ground-based software maintenance and analysis. (Derived project requirement)

CV0618 **Checkpoint Loading**

The CEV shall load a computational execution state (checkpoint) specified by a ground facility operator in support of ground testing and training.

Rationale: This is envisioned to be used as a ground only capability, but is a function of the flight processors in support of testing and training. Loading checkpoint data is critical to support verification & validation (such as in the CEV Avionics Integration Lab (CAIL)), and training for the vehicle systems, and it may prove to be useful for ground-based software maintenance and analysis. It is critical that this function does not get accidentally activated during a flight or else the processors could wait for a checkpoint response from an external device to export/load the checkpoint when there may be no external device to provide the checkpoint response. (Derived project requirement).

CV0564 **CEV Restart from a Checkpoint**

The CEV shall restart from a specified computational execution state (checkpoint) while assuring time synchronization between flight processors, subsystem hardware, and test equipment in support of ground testing and training.

Rationale: This is envisioned to be used as a ground only capability, but is a function of the flight processors in support of testing and training. The ability to restart from a loaded checkpoint is critical to support verification, validation and training for the vehicle systems. Restarting initializes the vehicle to the identical state captured in a previously saved vehicle checkpoint and begins execution. This execution requires time synchronization among flight processors and the ability for systems to synchronize computational dependencies. (Derived project requirement)

CV0565 **Restart Synchronization with Ground Facility Processors**

The CEV shall provide the capability for the flight processors to be synchronized with ground facility processors upon flight processor restart from a checkpoint.

Rationale: This is a ground only capability of the flight system to support testability and training. The CEV flight software/firmware must synchronize execution with external systems (training/test systems – simulators, hardware emulators) upon restart from a previously saved state (checkpoint). (Derived project requirement)

3.2.10 CEV Communications

3.2.10.1 General Requirements Applicable to All Communication

CV0750 **CEV Communication Between Systems**

The CEV shall communicate between Constellation Systems and ISS using the standards and protocols per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1; Interoperability Specification, Table Appendix E-1, C3I Interoperability Requirements Applicability to CEV.

Rationale: Communication is essential to successful mission execution. Communication between systems is necessary for accomplishment of all mission objectives and includes data, voice, and motion imagery. The C3I Interoperability Requirements Applicability to CEV table identifies the communication interactions between the CEV and other systems of the Constellation Architecture. (CA0296 location CARD3.2)

3.2.10.1.1 Communication Security

CV0167 **Command Authentication**

The CEV shall authenticate commands received.

Rationale: Appropriate security measures need to be taken to ensure the security, safety, and success of the CEV during a mission. The CARD requires security measures for the prevention of unauthorized commanding and tampering with data. The noted Constellation C3I Interoperability Specification requirements specify the protocols and algorithms that elements must implement in order to provide authentication and integrity checking in a widely accepted, exportable, and standardized manner. (CV0646)

CV0168 **Command Link Encryption**

The CEV shall provide encryption and decryption for commands sent via RF between the CEV and other Constellation Systems and ISS.

Rationale: Some data sent to and from the CEV will require confidentiality and/or authentication. Authentication key management requires confidentiality because unauthorized access to keys can lead to impersonation and false commanding that could result in hazards. Additional parameters, including key management, will be specified by NASA in the Constellation C3I Interoperability Specification, based upon NSA provided recommendations. Medical information, private voice communications, and some science may also have confidentiality issues, but they are not covered by this requirement. This encryption requirement meets the flight vehicle portion of requirements associated with CxP 70070-ANX05, Constellation Program Management Plan, Annex 5: Security Management Plan, Section 2.3.1 Platform Security Functional Requirements. (CV0646)

CV0169 **Command Link for Reconfiguration**

The CEV shall manage the authentication and encryption system including exchange of security updates.

Rationale: The keys used for authentication and/or encryption should be updated over time to prevent the compromise of a key from jeopardizing a mission or leading to unauthorized access to sensitive data. Also, as new elements become operational, some management of the security associations on existing elements will be necessary. It may also be desirable to completely bypass the encryption system in an emergency. (CV0646)

3.2.10.1.2 Internet Protocol

CV0368 **Internet Protocol**

The CEV shall implement IP-based communications between Constellation Systems.

Rationale: IP provides end-to-end addressing capability and quality of service markings for data. As given in the C3I Interoperability Specification phasing and applicability matrices, IPv4 will be used for ISS missions and upgrade to IPv6 for Lunar missions. This requirement is the minimum compliance to the C3I Interoperability Specification. (CV0646)

3.2.10.1.3 Packet Loss Rate

CV0629 **CEV Packet Loss Rate**

The CEV shall provide an onboard network Packet Loss Rate of less than 10-6 (TBR-002-209) given 1500 byte packets.

Rationale: The onboard network is defined from the end user application to the input/output of the FEC encoder/decoder. It is necessary to specify performance of the packet loss rate for the onboard network for reliable delivery to and from the end user. The packet loss rate is based on a packet size of 1500 bytes which is consistent with CA3043. The PLR assumes that there are 3 hops in the end-to-end path with the same individual PLRs of 10-6 (TBR-002-209). (3.2 allocation CARD CA3043)

3.2.10.1.4 Multi-Hop Communication

CV0630 **CEV Multi-Hop Communication**

The CEV shall implement multi-hop communications between Systems.

Rationale: Not all Systems that need to communicate will be directly connected (e.g. the target System for a command may be behind the Moon as viewed from the Earth; missions operations will need to communicate with in-space Systems via tracking & comm. networks). This requirement ensures that Systems can use other Systems as intermediate relays to establish communications that would otherwise not be possible. (3.2 allocation CARD CA3051)

3.2.10.2 Point to Point Communication (RF)

3.2.10.2.1 S-Band System

CV0364 **S-Band Communication**

The CEV shall communicate at S-Band.

Rationale: The CEV will need to be able to transmit and receive S-band signals to other in-space systems and to Earth via various networks (Space Network, Ground Network, Deep Space Network, Lunar Relay, etc). Selecting one signal type reduces the burden on the CEV. Constellation SE&I performed a detailed study and selected the Space Network formats as the best approach. Common support through all networks using the Space Network formats requires the CEV to operate at compatible frequencies and with compatible modulations and channel coding schemes. The C3I Interoperability Standard specifies the data and signaling formats, and frequency allocations for all Constellation Systems. (CV0646)

3.2.10.2.2 Ka-Band System

CV0366 **Ka-Band Communication**

The CEV shall communicate at Ka-Band.

Rationale: The CEV will need to be able to transmit and receive a Ka-band signal to Earth via various networks (Space Network, Ground Network, Deep Space Network, Lunar Relay, etc). Support of high rate command and telemetry links for high resolution video and mission data requires Ka-band operations. Selecting one signal type that can be used through all of the networks reduces the burden on the CEV. Constellation SE&I performed a detailed study and selected the Space Network formats as the best approach. Common support through all networks (e.g. the Space Network, Ground Network and Deep Space Network) formats requires the CEV to operate at compatible frequencies and with compatible modulations and channel coding schemes. Compatibility with the Space Network (TDRSS) formats requires that the CEV operate with compatible frequencies, modulations and channel coding schemes. The C3I Interoperability Standard specifies the data and signaling formats, and frequency allocations for all Constellation Systems. (CV0646)

3.2.10.2.3 Rendezvous and Proximity Operations Communications

CV0534 **CEV Communication in Proximity of LSAM**

The CEV shall communicate with LSAM within 432 nmi (800 km) of the CEV at S-band.

Rationale: Provides support for nominal and contingency CEV-LSAM rendezvous in low lunar orbit. Ranges provided above support horizon tracking for lunar rendezvous at

53.96 nmi (100km) altitudes. This capability can be used to assist LSAM lunar descent/landing aborts and subsequent re-rendezvous with CEV. Additionally, this capability can be used as an alternative mechanism for LSAM communications with mission control via CEV relay when / if lunar relay satellites are not available. This is a point to point link between CEV and LSAM and uses SN formats per the Constellation C3I Interoperability specification.(derived project requirement)

CV0164 **CEV Communication in Proximity of ISS**

The CEV shall communicate with ISS within 16.2nmi (30 km) of the CEV at S-band.

Rationale: Exploration elements must be able to communicate with each other directly. The CEV needs to have direct point to point communications between CEV and ISS for ISS missions within a specified distance. Communication between CEV-ISS is required to support proximity operations such as rendezvous and docking. (derived project requirement)

3.2.10.2.4 Simultaneous Communication

CA3288-PO **CEV Simultaneous Communications with ISS**

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

Rationale: The CEV must communicate with MS to provide situational awareness and to enable ground commanding. The CEV must also communicate with ISS to accomplish rendezvous. The specified range is determined by analysis of Constellation FFBDs and by analysis of ISS visiting vehicle requirements and CEV design trades. The relative range was determined based on IDAC2 and CEV design trades as well as ISS visiting vehicle requirements.

CA3287-PO **CEV Simultaneous Communication with MS**

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

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

CV0490 **CEV Simultaneous Communications with LSAM**

The CEV shall communicate simultaneously with Mission Systems and the LSAM.

Rationale: The CEV must be able to communicate with Mission Control while at the same time supporting proximity, rendezvous, and lunar surface operations with LSAM. Details that are needed to support simultaneous communication between the CEV and LSAM, such as frequency allocation and reverse banding, are defined in the C3I Interoperability Standard.

3.2.10.2.5 Coverage

CV0362 **Communication Services**

The CEV shall provide spherical coverage for the different mission phases and links, excluding non-CEV structural blockage and re-entry plasma as given in Table 4 (TBR-002-235).

Rationale: The CEV needs to provide communications coverage based on mission phases and links involved. The data rates will be verified as part of the respective IRDs and is given here for completeness. (CA0296 location CARD3.2)

Table 4 Communication Coverage by Links and Mission Phases (TBR-002-235)

Mission Phase and Scenario	Link	Service	CEV Spherical Coverage
Prelaunch/Launch/Ascent	CEV - Earth UHF	Contingency/Dissimilar Voice	
	CEV - Earth S-band	Low Data Rate Link (18/24 kbps)	90%
		Operational Point-to-Point Link (72/192 kbps)	60%
		Operational Point-to-Point Link (1/1 Mbps)	N/A
	CEV - Earth Ka-band	High Data Rate Link (6/25 Mbps)	N/A
Low Earth Orbit	CEV - Earth UHF	Contingency/Dissimilar Voice	
	CEV - Earth S-band	Low Data Rate Link (18/24 kbps)	90%
		Operational Point-to-Point Link (72/192 kbps)	80%
		Operational Point-to-Point Link (1/1 Mbps)	80%
	CEV - Earth Ka-band	High Data Rate Link (6/25 Mbps)	70%
Trans-Lunar Orbit	CEV - Earth UHF	Contingency/Dissimilar Voice	
	CEV - Earth S-band	Low Data Rate Link (18/24 kbps)	90%
		Operational Point-to-Point Link (72/192 kbps)	80%
		Operational Point-to-Point Link (1/1 Mbps)	80%
	CEV - Earth Ka-band	High Data Rate Link (6/25 Mbps)	70%
Lunar Orbit	CEV - Earth UHF	Contingency/Dissimilar Voice	
	CEV - Earth S-band	Low Data Rate Link (18/24 kbps)	90%
		Operational Point-to-Point Link (72/192 kbps)	80%
		Operational Point-to-Point Link (1/1 Mbps)	80%
	CEV - Earth Ka-band	High Data Rate Link (6/25 Mbps)	70%
Earth return Orbit	CEV - Earth UHF	Contingency/Dissimilar Voice	90%
	CEV - Earth S-band	Low Data Rate Link (18/24 kbps)	90%
		Operational Point-to-Point Link (72/192 kbps)	80%
		Operational Point-to-Point Link (1/1 Mbps)	80%
	CEV - Earth Ka-band	High Data Rate Link (6/25 Mbps)	70%
Re-entry and Landing	CEV – Earth UHF	SAR/Recovery Communication Link	
	CEV - Earth UHF	Contingency/Dissimilar Voice	
	CEV - Earth S-band	Low Data Rate Link (18/24 kbps)	60%
		Operational Point-to-Point Link (72/192 kbps)	60%
		Operational Point-to-Point Link (1/1 Mbps)	N/A
	CEV - Earth Ka-band	High Data Rate Link (6/25 Mbps)	N/A
Rendezvous, Prox Ops	CEV - LSAM/ISS/CEV, UHF	Contingency/Dissimilar Voice	

	CEV - LSAM/ISS/CEV, S-band	Operational Point-to-Point Link (range 432 nmi to 16.2 nmi) *(data rates depend on range)*	90%
	CEV - LSAM/ISS/CEV, S-band	Operational Point-to-Point Link (range 16.2 nmi to docking) *(data rates depend on range)*	99%

Note. Data rates (forward/return bps) are here for completeness and will be verified by the IRDS.

CA0470-PO **CEV Low Rates Data Coverage**

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

Rationale: The CEV needs a reliable communications link that does not depend on active antenna pointing. CEV must communicate with MS through C&TN as CEV does not have a direct path to communicate with MS in flight. The low rate data will include critical voice, commands, tracking and telemetry. Percent coverage requirements are determined by analysis of Constellation Concept of Operations, Constellation FFBDs and CEV design trades, with the goal of achieving the highest possible coverage. Link data rate is specified in CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV). 90% (TBR-001-335) coverage is based on analysis in IDAC2, TDS SIG-13-201.

CA0470D-PO **PBS - CEV Low Rates Data Coverage**

The CEV shall transmit and receive with a geometric antenna coverage of 90% (TBR-001-335), excluding non-CEV structural blockage and re-entry plasma, for low-rate data as defined by the CxP 70118 Constellation-C&T Networks IRD Volume 1, Section 3.6.1.2.

Rationale: The CEV needs a reliable communications link that does not depend on active antenna pointing. CEV must communicate with MS through C&TN as CEV does not have a direct path to communicate with MS in flight. The low rate data will include critical voice, commands, tracking and telemetry. Percent coverage requirements are determined by analysis of Constellation Concept of Operations, Constellation FFBDs and CEV design trades, with the goal of achieving the highest possible coverage. Link data rate is specified in CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV). 90% (TBR-001-335) coverage is based on analysis in IDAC2, TDS SIG-13-201.

3.2.10.2.6 Radiometric Tracking

CV0374 **Radiometric Tracking**

The CEV shall transpond signals and provide radiometric measurements.

Rationale: The CEV will use radiometric measurements in addition to GPS for navigation during mission phases when GPS signals are available.(derived project requirement) (CV0646)

3.2.10.3 Hardline Communications

CV0373 **CEV Non-Deterministic Hardline Communications**

The CEV shall implement IP based communications for non-deterministic rate based hard-line connections between ISS and Constellation Systems as specified in CxP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1.

Rationale: Inter-system hard-line links should support the same functionality as RF links, such that all data, voice and commands can be transmitted either via RF or via hard-line. This provides *the greatest flexibility. C3I Interoperability Specification documents the CxP standard for IP usage in CxP. (CV0646)*

CV0751 **CEV Deterministic Hardline Communications**

The CEV shall implement SAE-AS5643 and SAE-AS5643/1 standards for deterministic rate based hard-line connections between Constellation Systems.

Rationale: Deterministic rate-based connection will be needed for interchange of time-critical data between directly connected Constellation Systems. This requirement is intended to be applicable for connectivity to flight Systems. (CV0646)

3.2.10.4 Audio and Motion Imagery

CV0834 **CEV Crew Audio Communications**

The CEV shall provide audio communications between crew members and Constellation Systems and ISS.

Rationale: The crew needs to be able to communicate and coordinate activities with Constellation Systems and ISS both when suited and when in a shirt sleeve environment. Verification Requirement - This requirement will be verified by test and demonstration. A test will be performed where two (TBD-002-237) crew will speak over the audio system and RF Link to another Cx System ""RIG"" (TBD-002-240) and the voice quality, and other (TBD-002-238) performance metrics will be measured. A demonstration will be performed where 6 crew will speak over the audio system and show that communications between the 6 crew members and Mission Systems via CTN occurs without disruption or degradation. This requirement will be successfully verified when the test and demonstration described here are successfully performed. (CA0476)

CV0178 **Private Audio and Motion Imagery Communication**

The CEV shall provide two-way private audio and motion imagery communication mode between the ground and crew.

Rationale: Provides capability for a single crewmember to a have a voice/imagery loop for private conversation for medical, family, and management conferences. It is understood that there is no guarantee of "privacy" onboard the CEV until the data gets into the audio/video system. (3.2 allocation CARD CA5817)

CV0631 **CEV Audio and Motion Imagery**

The CEV shall provide audio and high definition motion imagery for distribution to the public.

Rationale: Constellation program events, such as lunar landing, CEV / LSAM rendezvous, and all EVA are of national importance and must be documented as recorded or real-time motion imagery and audio. Meeting the program goal of promoting public participation [CxP-G14] and the objective to effectively communicate the benefits of exploration to the public [CxP-O08] dictates the employment of motion imagery and audio technology commensurate with the magnitude of the program events. High definition motion imagery and audio will be the norm in most US homes by first flight. (3.2 allocation CA5065)

CV0832 **Motion Imagery for Situational Awareness**

The CEV shall provide imagery of mission critical and safety related events.

Rationale: Imagery (motion and still) is an essential tool for evaluating nominal and off-nominal mission operations, for engineering analysis, and for verifying the health and safety of the crew and vehicle. Imagery options include external and internal sources.

CV0854 **Motion Imagery Recording**

The CEV shall record motion imagery and associated audio sources for a combined total record time of 8 (TBR-002-258) hours minimum.

Rationale: The CEV must have the capability to record motion imagery of significant events that occur when a high data rate link is not available for live downlink. Examples of motion imagery to be recorded includes high definition motion imagery of significant events of interest to the public such as ISS or LSAM rendezvous, docking/undocking, lunar surface imagery, etc. Other motion imagery sources to be recorded include standard definition or reduced frame rate motion imagery for situational awareness and contingency EVA's.

CV0752 **CEV Privacy of Crew Medical and Personal Data**

The CEV shall ensure the privacy of all crew medical and personal data.

Rationale: Provisions of the Privacy Act of 1974, as amended, as regarding control of records, information exchange, and release of crewmember health information to the public will be strictly followed. Communications pertaining to an individual's health care will be private as regulated by the controls, regulations, provisions, and penalties of the Privacy Act of 1974. Privacy is required to protect against unintentional distribution of private downlink crew medical and personal data within and external to Mission Systems(3.2 allocation CA5817)

CV0138 **Motion Imagery for Proximity Operations - Docking and Undock**

The CEV shall provide motion imagery for approach and departure proximity operations, docking and undocking to the crew, MS, ISS and LSAM.

Rationale: The crew, MS element, and ISS need to monitor the approach, docking, undocking, and separation in the event of proximity sensor or other problems affecting the trajectory. This viewing may be direct but also needs to be through motion imagery for the pressurized cargo delivery. The motion imagery also provides insight to the MS element and crew for the proximity operations and docking operations sufficient to permit piloting or backout/breakout decisions. (3.2 allocation CARD CA5820)

CV0176 **Transmit Motion Imagery**

The CEV shall provide motion imagery and associated audio to the ISS and other Constellation Systems.

Rationale: Motion imagery must be shared between operating systems to insure mission success. This includes both recorded and real time motion imagery. (CA5820)

3.2.10.5 Dissimilar Voice Communication

CA3280-PO **CEV Dissimilar Voice System**

The CEV shall communicate using an independent, dissimilar, voice only system.

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

3.2.10.6 Post-Landing and Recovery Communications

CV0179 **Recovery Force Communication - Nominal and Off-Nominal**

The CEV shall provide communications with recovery team at nominal and off-nominal landing sites.

Rationale: It is necessary to provide voice communications with recovery team for both nominal and off-nominal conditions where the CEV lands out of landing zone range for local radio communication.(derived project requirement)

CV0829 **Improper Radio Locator Beacon Activation**

The CEV shall automatically activate the radiolocator beacon(s).

Rationale: Establishing communications with recovery and/or SAR forces prior to landing is important to relay current observations by crew and recovery forces with each other. Enabling communications with SAR forces prior to landing provides some additional safety margin as system failures could take place due to landing impact g-forces. The beacon should be activated even if there is an off-nominal chute deployment.

CA0344-PO **CEV Off-Nominal Landing Communication**

The CEV shall maintain communications with Mission Systems for at least 36 hours post landing.

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

CV0784 **CEV Post-Landing Communications**

The CEV shall maintain voice communications with Mission Systems for at least 36 hours post landing, with a duty cycle of 90% receive and 10% transmit.

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

CV0180 **Search and Rescue Communication**

The CEV shall provide local voice communications with the Ground Systems Recovery and Retrieval Element, and contingency Search and Rescue (SAR) team while the CEV hatches are closed.

Rationale: Voice communication while the hatch is closed is necessary in case conditions external to the vehicle do not allow hatch opening during rescue and/or recovery. Local voice communication refers to line-of-sight communications.

CV0463 **SAR Interoperability**

The CEV shall provide local voice communication with the Ground Systems Recovery and Retrieval Element and contingency Search and Rescue (SAR) forces as defined in CxP 70022, C3I Interoperability Standards Book, Volume 1 , Table Appendix E-1 - C3I Interoperability Requirements Applicability to CEV.

Rationale: Local voice communication is necessary for the coordination of recovery and rescue efforts. Local voice communication refers to line-of-sight communications. CEV recovery operations may consist of a combination of U.S. Government, U.S. Civil, and international SAR personnel depending on the specific conditions of a landing. In order to ensure the greatest probability of successful recovery of crew and cargo, the CEV SAR systems must be compatible with a large number of existing SAR assets. U.S. and international standards already exist, for which commercial products are available, ensuring proven, reliable communication with SAR assets. The standards are specified in CxP 70022, C3I Interoperability Standard Volume 1.

CV0181 **Search and Rescue Locator Signal**

The CEV shall provide radiolocator beacon(s) as defined in the C3I Interoperability Specification, Volume 1, Table Appendix E-1 - C3I Interoperability Requirements Applicability to CEV, for nominal and off-nominal landing.

Rationale: During an emergency or other off-nominal landing, the CEV must provide location to the Recovery and Retrieval Element to assist in locating the CEV. EPIRB compatibility ensures that the landing event and location will be reported through COSPAS-SARSAT to the global Rescue Coordination Center network, and from there can be passed to Mission Systems and Ground Systems for dispatch of the Recovery and Retrieval Element to the correct landing site.

CV0787 **CEV Location Transmission**

The CEV shall transmit its location via the radiolocator beacon.

Rationale: CEV latitude and longitude, when transmitted to the COSPAS-SARSAT system during an off-nominal landing, will alert RCC of the need to dispatch a rescue to the correct location. In the event of GN&C failure, the COSPAS/SARSAT constellation can determine the location of the vehicle by on-board Doppler analysis of the received beacon signal, but requires two or three satellite passes to achieve an accurate fix.

CV0788 **CEV Locator Signal Operation**

The CEV radiolocator beacon(s) shall operate continuously for at least 36 hours post landing.

Rationale: CEV location must be provided throughout the maximum 36 hour recovery period. The location must be updated throughout the recovery period to account for drift.

CV0790 **Simultaneous Voice and Locator Signal Operations**

The CEV shall provide simultaneous voice communications and radiolocator beacon signal.

Rationale: The crew will need voice communications capability to coordinate with the recovery efforts in addition to the radiolocator beacons operation.

3.2.11 CEV GN&C

3.2.11.1 CEV Ascent GN&C

CA5921-PO **CEV Separation from CLV**

The CEV shall perform separation functions with the CLV.

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

CV0048 **CEV Translation after CLV Separation**

The CEV shall translate from the CLV with positive clearance margins following separation.

Rationale: The role of the CLV ends at the termination of the boost phase. A safe separation distance would be achieved using a defined profile which would avoid recontact and preclude initiation of the orbit insertion maneuver in proximity of the CLV.

CV0110 **CEV Independent Determination of CLV/CEV Trajectory**

The CEV shall independently determine the CLV/CEV integrated stack ascent trajectory, attitude, and attitude rates.

Rationale: The accuracy of the ascent trajectory (time, state vector, attitude/attitude rates, and acceleration) is an aggregate indicator of the performance of a range of critical CLV systems (e.g., propulsion, guidance, control, etc.). CEV onboard assessment of the CLV performance is a factor in the determination of the need for an ascent abort or early maneuver cutoff. (CA0325)

CV0590 **Manual CLV Steering Commands**

The CEV shall send manual steering commands to the CLV during ascent in response to crew input.

Rationale: This requirement completes the interface which allows the CEV to generate and pass steering commands to the CLV. These guidance steering commands are expected to be commanded using a crew interface device, such as a hand controller. The commands are expected to be passed into the CLV as roll, pitch, and yaw rates. The CLV will convert these commanded rates to commanded attitude. It will be up to the CLV to define the system/structural margins under which it will allow manual control by the crew. (CA0497)

CV0591 **Ascent Trajectory Targets**

The CEV shall provide updated ascent trajectory targets for the CEV/CLV integrated stack.

Rationale: The CEV has the capability of changing the ascent trajectory targets during the Ascent flight phase. This may take the form of the crew updating an engine cutoff state (for instance by changing the target insertion altitude) during second stage to account for performance of the day. In this way, the crew has "manual control" of the vehicle, because they can adjust the trajectory in real time. A second use of this requirement would be for Ascent Aborts. It has been shown on previous vehicles that while attached to the Integrated Stack changing the target plane after an engine malfunction (e.g. degraded performance) can yield earlier Abort-to-Orbit capability than if the target is not changed. (CA0497)

3.2.11.2 CEV Orbit Insertion and Transfer Maneuvers

CA5819-PO **CEV Performs TCM during TLC**

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

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

CA5819D-PO **PBS - CEV Performs Trajectory Correction Maneuvers during TLC**

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

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

CV0119 **CEV Translational Maneuver Target Computation**

The CEV shall compute translational maneuver targets.

Rationale: For LEO and Lunar missions the CEV must compute LEO deorbit maneuvers which can be calculated onboard for increased mission flexibility and are needed even without ground communications. In the case of the lunar mission, based on the Lunar Sortie and Lunar Outpost DRMs and consistent allocation of GN&C responsibilities among the flight elements the CEV will need to verify the LOI targets from the LSAM and generate TEI and TCM maneuvers without ground communications. These maneuvers must be capable of being performed for crew return in the absence of MS element communication. (CA0325)

CV0677 **CEV Trajectory Correction Maneuvers during Trans-Earth Coast**

The CEV shall perform Trajectory Correction Maneuvers (TCMs) during the Trans-Earth Coast (TEC).

Rationale: This requirement addresses the need to perform trans-Earth correction maneuvers during nominal Earth return (post-TEI) and aborted lunar transits (i.e., early return aborts post TLI time of ignition [TIG]). Lunar (outbound) aborts could occur from the time immediately following TLI TIG through arrival at mission destination requiring TCMs for the Earth return trajectory. For the lunar abort scenarios, if the LSAM is capable of performing the trans-Earth maneuvers, it may be jettisoned and disposed of before CEV begins Earth entry preparations; otherwise, LSAM disposal could precede the CEV-performed trans-Earth maneuvers. Since the reason for the abort may be mission-critical failures in the LSAM, the CEV must be able to perform the trans-Earth maneuvers prior to reaching the mission destination (as it would anyway, for nominal trans-Earth returns following TEI). (CA0325)

CA3204-PO **CEV ERO Transfer**

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

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

CA3207-PO **CEV Transfer from LLO to LRO**

The CEV shall perform the orbit transfer from Low Lunar Orbit (LLO) to the Lunar Rendezvous Orbit (LRO) for crewed lunar missions.

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

CA3209-PO **CEV TEI for Crewed Lunar Missions**

The CEV shall perform the Trans-Earth Injection (TEI) for crewed lunar missions.

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

CA0191-PO **CEV Perform Orbit Transfer**

The CEV shall perform the orbit transfer from the Ascent Target to ISS.

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

3.2.11.3 CEV Mated Configuration GN&C

CV0111 **CEV Independent Determination of EDS/LSAM/CEV Trajectory**

The CEV shall independently determine the integrated EDS/LSAM/CEV stack trajectory, attitude, and attitude rates.

Rationale: The CEV must have the insight into these data to monitor EDS performance during mated operations including the TLI maneuver for the EDS/LSAM/CEV stack and to verify or assume control on the mated CEV/LSAM stack after EDS separation. This assessment will form *part of the CEV onboard detection of conditions that require abort or early maneuver cutoff. (CA0333)*

CV0477 **CEV Independent Determination of LSAM/CEV Trajectory**

The CEV shall independently determine the integrated LSAM/CEV stack trajectory, attitude, and attitude rate.

Rationale: The CEV must have the insight into these data to monitor LSAM/CEV performance during transit to the moon and LSAM performance during course corrections and LOI maneuvers. This assessment will form part of the CEV onboard detection of conditions that require abort or early maneuver cutoff. (CA0333)

CA4128-PO **CEV Contingency Attitude Control with LSAM**

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

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

CA4128D-PO **PBS - CEV Attitude Control with LSAM/EDS**

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

Rationale: This capability is required in the event of a contingency with the LSAM in which the CEV must take over control of the CEV/LSAM stack post TLI. Propellant loading for this functionality should not be book-kept as an additional capability. Consistent with the Lunar Sortie and Lunar Outpost Crew DRMs, and CA5290; the LSAM normally performs this function.

CA0187-PO **CEV Nominal Attitude Control with LSAM**

The CEV shall perform attitude control of the CEV/LSAM mated configuration after docking in LLO.

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

3.2.11.4 CEV RPODU Maneuvers

CV0122 **CEV Backouts from Proximity Operations and Docking**

The CEV shall perform backouts during proximity operations and docking when functioning as the maneuvering vehicle.

Rationale: The CEV must be able to perform a backout during proximity operations & docking with the LSAM and with the ISS. For the ISS this would be within the (TBD-002-031) backout trajectory observing keep out zones as defined in the ISS-CEV IRD. There are a number of conditions under which this maneuver would be needed such as exceeding predefined limits and flight rules, exceeding the specified approach and departure corridors, and loss of communication specifically for the ISS pressurized cargo CEV. Note that a backout does not necessarily lead to a mission abort and may be part of contingency operations procedures within the scope of an otherwise nominal mission. (CA0059 and CA0081)

CV0126 **CEV Contingency Docking with LSAM in Unplanned Attitude**

The CEV shall perform proximity operations and docking with LSAM when it is in any inertial attitude with inertial rate less than 0.4 (TBR-002-056) deg/sec per axis.

Rationale: Protects for contingency docking scenarios where the LSAM in LLO is unable to maintain attitude control and any LSAM attitude could be realized within the rate limits defined. Crew transfer to the CEV in this scenario is necessary for safe return to Earth. (CA0369)

CV0129 **CEV Any-Attitude Undocking**

The CEV shall perform any-attitude undocking with a mated vehicle inertial attitude rate up to 2 deg/s (TBR-002-159).

Rationale: This undocking capability is needed at any point during the CEV/ISS or CEV/LSAM docking activities prior to and after CEV gaining structural attachment enough to allow CEV /ISS or CEV/LSAM interface to withstand the attitude control loads. This capability also covers the contingency cases of an ISS crew evacuation or separation from LSAM for early return or abort. The 2 deg/sec rate is the value validated and designed to for CRV analysis of ISS emergency separation. (CA0462)

CV0791 **CEV Breakouts from Proximity Operations and Docking**

The CEV shall perform breakouts during proximity operations and docking when functioning as the maneuvering vehicle.

Rationale: The CEV must be able to perform a breakout during proximity operations & docking with the LSAM and with the ISS. For the ISS this would be within the (TBD-002-235) breakout trajectory observing keep out zones as defined in the ISS-CEV IRD. There are a number of conditions under which this maneuver would be needed such as exceeding predefined limits and flight rules, exceeding the specified approach and departure corridors, and loss of communication specifically for the ISS pressurized cargo CEV. Note that a breakout does not necessarily lead to a mission abort and may be part of contingency operations procedures within the scope of an otherwise nominal mission. (CA0059 and CA0081)

CV0823 **Support Second Docking Attempt**

The CEV shall perform a second LSAM docking attempt within 2 orbits (TBR-002-251) after a first docking attempt is terminated for a lunar mission in LEO.

Rationale: A rendezvous and docking sequence may be delayed in response to any of several off-nominal conditions. Following such a delay, at the end of the TLI window, a second attempt must be made in order to achieve mission success. Adequate resources (such as electrical energy) must be available to support this second attempt. This does not levy any additional propellant requirements against the CEV.

CA3248-PO **CEV Rendezvous Maneuvers**

The CEV shall compute rendezvous maneuvers when performing relative navigation with the target vehicle.

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

CA3248D-PO **PBS - CEV Rendezvous Maneuvers**

The CEV shall compute rendezvous maneuvers with the target vehicle.

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

CA0059-PO **CEV as Maneuvering Vehicle with LSAM/EDS during RPODU**

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

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

CA0131-PO **CEV as Target Vehicle during LSAM RPOD in LRO**

The CEV shall function as the target vehicle during RPOD operations with the LSAM in LLO.

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

CA0369-PO **CEV Contingency RPOD with LSAM in LLO**

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

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

CA0369D-PO **PBS - CEV as Maneuvering Vehicle during RPOD with LSAM in LL**

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

Rationale: For nominal missions the CEV acts as the target during the rendezvous phase in LLO. This requirement covers the contingency case in which the LSAM has an under speed condition or other reason causing the LSAM to be placed in the incorrect orbit, but an orbit which is still accessible by the CEV within planned as well as reserve performance. It is assumed that at a minimum the LSAM has reached a stable orbit, can still communicate with the CEV, can support radiometric range measurements, and provides the CEV with bearing measurements sufficient for the CEV to execute the RPOD maneuvers. In this scenario, the CEV is remotely commanded to perform rendezvous maneuvers, including proximity operations. Docking may be completed via LSAM, remote control of the CEV, or via automated CEV. This is not intended as a separate delta-v requirement for CEV. It is intended to ensure that the CEV software and any RPOD hardware are capable of operating as the maneuvering vehicle for this contingency case.

CA0133-PO **CEV as Maneuvering Vehicle during Undocking and Separation w**

The CEV shall function as the maneuvering vehicle during undocking and departure proximity operations from LSAM, prior to TEI.

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

CA0081-PO **CEV as Maneuvering Vehicle with ISS during RPODU**

The CEV shall function as the maneuvering vehicle during RPODU operations with the ISS.

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

CV0127 **CEV Terminate Docking**

The CEV shall terminate docking upon receipt of command.

Rationale: Allows for human intervention of vehicle and docking mechanism docking activities such as mechanism operation and post-contact thrust. The CEV must terminate docking activities prior to initiating backouts and breakouts after a failed docking attempt. Scenarios where this apply include commands from the CEV crew, from the ISS crew for an ISS pressurized cargo docking and from the LSAM crew for a contingency LLO docking where the lunar mission CEV is the active vehicle docking with the crewed LSAM. The applicable mission duration of this command begin with the physical interaction of the docking mechanisms and ends with completed docking. (CA0059 and CA0081). The intent is to cover the time starting at contact to completion of docking.

CA5286-PO **CEV as Target Vehicle during LSAM Departure**

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

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

CV0450 **Un-crewed CEV Separation and Departure from Crewed LSAM in L**

The CEV shall undock, separate, and perform departure maneuver(s) from the crewed LSAM in LLO prior to lunar descent.

Rationale: By having the CEV leave the LSAM, the pre-separation state vector of the LSAM is unperturbed If the LSAM were to do this maneuver sequence then the navigation solution for the LSAM at lunar descent initiation would be degraded resulting in either a loss of performance or a need to take mission time to re-determine the LSAM navigation state. Note that when taken with CA5286-PO this provides the Constellation program with the operational flexibility to use CEV as either the target or maneuvering vehicle prior to lunar descent. (CA0082)

3.2.11.5 CEV GN&C Orbit Performance

CV0108 **CEV Onboard LLO Navigation**

The CEV shall calculate Low Lunar Orbit (LLO) navigation solutions for TEI sequence initiation in less than 6 hours.

Rationale: Supports TEI for autonomous aborts from Moon and requirements which place time constraints of 120 hours on nominal and abort return to Earth from the lunar surface. A 6 hour navigation solution time limit is based upon an assumed 84 hour Earth return trajectory, a 24 hour TEI sequence, a 6 hour period for executing LSAM ascent through docking and crew transfer with

*CEV, and three complete navigation solution opportunities in a two hour orbit in LLO (6 hours = 1 opportunity per orbit * 3 orbits * 2 hour orbit). (CA0416)*

3.2.11.6 CEV Navigation

CV0648 **CEV Time Scale**

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

Rationale: A single time reference will allow (1) multiple systems to be synchronized and (2) internal and external data to be exchanged and integrated. Traceability to UTC is required to exchange/integrate data with external entities such as C&TN that use UTC as a time reference. The word continuous requires a time representation that does not have discontinuities related to leap seconds or year-end roll-over, the details of which are to be resolved in consultation with Mission Systems, C&TN, and the NASA HQ Time and Frequency NASA Advisory Council. (3.3 allocation CARD CA5618)

CA3142-PO **CEV Navigation and Attitude Determination**

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

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

3.2.11.6.1 CEV Relative Navigation

CV0112 **CEV Maneuvering Vehicle Relative Navigation**

The CEV shall perform relative navigation for rendezvous, proximity operations and docking when functioning as the maneuvering vehicle.

Rationale: Relative navigation is an enabling capability required for rendezvous, proximity operations, and docking. Vehicle-based relative navigation sensors provide the most accurate close-range data on relative vehicle positions and relative rates for final rendezvous maneuvers and proximity operations. Relative navigation sensors also provide the only relative navigation data available when the vehicles are beyond the coverage of Earth-based sensors, such as on the far side of the Moon. (CA0059 and CA0081)

CV0116 **Target Vehicle Relative Position and Velocity Determination**

The CEV shall determine the position and velocity of the CEV relative to the target vehicle during PODU operations, when the CEV is the maneuvering vehicle.

Rationale: This is required for proximity, docking, and undocking operations to ensure collision avoidance, acceptable relative range rates, and proper alignment between the two vehicle docking mechanisms.

CV0117 **CEV Target Vehicle Relative Attitude and Attitude Rate Deter**

The CEV shall determine the attitude and attitude rate of the CEV relative to the target vehicle during LEO PODU operations, when the CEV is the maneuvering vehicle within 100 feet (TBR-002-210) of the target vehicle.

Rationale: This provides for confirmation of relative alignment during nominal proximity and docking operations in LEO to ensure collision avoidance and successful alignment *between the two vehicle docking mechanisms. This requirement supports mission success and recovery from failed capture.*

CV0540 **CEV Measurement of Bearing Angles with LSAM**

The CEV shall measure bearing angles between CEV and LSAM, when the two vehicles are within 432 nmi (800 km) to maintain a relative navigation state.

Rationale: Supports nominal rapid rendezvous with LSAM in low lunar orbit at anytime using the integrated sensor suite after LSAM lifts off the lunar surface. There is no implication that this determination be achieved by a preferred method. (CA0325)

CV0532 **CEV Rendezvous Navigation with LSAM**

The CEV shall measure range and range rate between CEV and LSAM, when the two vehicles are within 432 nmi (800 km) to maintain a relative navigation state.

Rationale: Supports contingency rendezvous with LSAM in low lunar orbit at anytime using the integrated sensor suite after LSAM lifts off the lunar surface. Ranges provided above support horizon tracking for lunar rendezvous at 100km altitudes. Accuracies are Apollo values. Navigation measurements support loss of comm lunar ascent operations. This capability allows for growth to support future local lunar vicinity navigation. The measurement capability and accuracies are specified with an assumption that the LSAM is actively cooperating by supporting radiometric tracking. (CA0325)

CV0597 **CEV Target Vehicle Relative Navigation**

The CEV shall perform relative navigation for rendezvous, proximity operations and docking as target vehicle when the LSAM is the active maneuvering vehicle.

Rationale: In order to support rapid contingency RPOD in the event of LSAM malfunction and to confirm LSAM disposal prior to TEI the CEV GN&C system must have relative navigation data of the LSAM. (CA0325)

CV0839 **Relative alignment in LLO**

The CEV shall determine the attitude and attitude rate of the CEV relative to the LSAM during LLO PODU operations, when the CEV is the maneuvering vehicle within 150 feet (TBR-002-210) of the target vehicle.

Rationale: This provides for confirmation of relative alignment during nominal and contingency proximity and docking operations in LLO to ensure collision avoidance and successful alignment between the two vehicle docking mechanisms. This requirement supports mission success and crew return in the event of a disabled LSAM.

3.2.11.7 CEV RPODU Constraints

CV0773 **RPODU Independent of Lighting**

The CEV shall perform RPODU independent of lighting conditions.

Rationale: This requirement preserves mission flexibility to rendezvous and dock between Systems during any part of the orbit. This also supports anytime abort from the lunar surface. Given the state of relative navigation sensor technology, it is expected that Systems can incorporate sensors or suites of sensors which enable the Systems to meet this requirement.

This does not necessarily dictate that each individual sensor must be capable of operating in any lighting condition.

Some lighting conditions (e.g. sun within sensor or crew field of view) may require closing rate decrease, null, or even temporary backout during proximity operations to ensure a safe trajectory during periods of degraded navigation, however a proximity operations abort is not required. This requirement is applicable in both Earth and lunar orbits. (3.2 allocation CARD CA0314)

CV0792 **Ground Overflight Constraints**

The CEV shall perform RPODU independent of ground overflight constraints.

Rationale: Independence from ground communication constraints increases the flexibility of where and when RPODU operations can be conducted. (CA5602).

CA0462-PO **CEV Emergency Any Attitude Undocking Capability**

The CEV shall function as the maneuvering vehicle during undocking and departure proximity operations from the target vehicle at any attitude, in case of an emergency.

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

CA0463-PO **CEV Undocking Time**

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

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

3.2.11.8 CEV Automated Orbit GN&C

CV0085 **CEV Automated Deorbit from LEO**

The CEV shall perform an automated deorbit maneuver sequence from LEO.

Rationale: The nominal deorbit maneuver sequence requires targeted deorbit burns by the CEV with a separation from the SM between the burns. This capability is required to return the spacecraft to a designated CONUS landing site on Earth from LEO which is done either for nominal/contingency return for ISS missions or an early return for lunar missions. The Crew to ISS DRM describes that the crew only authorizes the de-orbit burn, and the computer performs the actual de-orbit maneuver sequence. For the uncrewed CEV (ISS pressurized cargo mission), all operations within this time frame must be automated, not to exclude the capability for manual intervention from MS. (CA0388)

CV0601 **CEV Automated RPODU**

The CEV shall perform automated RPODU.

Rationale: Use of automated execution of RPOD is required to transport 0 crew to the ISS and for contingency RPOD in LLO. Use of automed RPOD in the ISS Crew Mission CEV vehicles with onboard crew oversight will build confidence and increase the probability of mission success for the uncrewed ISS pressurized cargo missions, as well as for the execution of contingency automated RPOD of the uncrewed CEV to the LSAM in LLO. Automation additionally reduces workload for the crew and the flight operations personnel. Automatic execution allows for thing such as ground-computed targets, commanded systems reconfiguration, etc. (CA0325 and CA0388)

3.2.11.9 CEV Visual Monitoring for RPODU

CV0139 **Crew Visual Observation of Proximity Operations and Docking**

The CEV shall provide the crew direct visual observation of the target vehicle during proximity operations, docking and undocking.

Rationale: The crew needs to monitor the approach/separation and docking/undocking in the event of proximity sensor or other problems affecting the approach/separation. This allows for the use of windows or periscopes to obtain a direct view of the proximity operations/docking maneuvers to ensure the vehicle is properly oriented for the docking and undocking operations. (CA0438)

CV0594 **CEV Lighting for Crew Identification**

The CEV shall be visually identifiable by a target vehicle crew at a distance of at least 3280 ft in any lighting conditions.

Rationale: The visual monitoring capability provides the LSAM or ISS crew with an independent means of grossly monitoring the CEV position as compared to the onboard navigated state. Visual monitoring provides independent cues that could trigger crew intervention, such as a backout command, if limits are exceeded. This applies to orbital day and night with the exception of small lighting exclusion periods where the lighting environment(including absence of sunlight) is too harsh for visual observation. (CA0131)

CV0595 **CEV Lighting for Orientation**

The CEV orientation shall be visually identifiable by a target vehicle crew at a distance of at least 800 ft in any lighting conditions.

Rationale: The visual monitoring capability provides the LSAM and ISS crew with an independent means of grossly monitoring the CEV position and attitude as compared to the onboard navigated state. Visual monitoring provides independent cues that could trigger crew intervention, such as a backout command, if limits are exceeded. This applies to orbital day and night with the exception of small lighting exclusion periods where the lighting environment (including absence of sunlight) is too harsh for visual observation. (CA0131)

3.2.11.10 CEV Entry Mode Definition

CV0083 **CEV Direct Entry for Trans-Earth Trajectories**

The CEV shall perform a direct entry for trans-Earth trajectories.

Rationale: Lunar missions may employ a direct entry trajectory or a skip entry trajectory as needed to access the designated Continental United States (CONUS) landing sites for a given mission. The additional downrange capability provided by skip entry is needed to provide guaranteed access to the designated CONUS landing sites for anytime Earth return for an arbitrary Earth-Moon orbital alignment. (CA0325)

CV0086 **CEV Skip Entry Performance**

The CEV shall perform skip entry into the Earth's atmosphere of up to 5,750 <TBR-002-023> nmi (10,650 km) from the entry interface from lunar mission trajectories.

Rationale: Long range skip trajectories will aid in achieving CONUS land landings for the full range of lunar antipodes. The 5,750 nmi maximum range requirement for skip entry covers a polar return Skip-Entry to the most northern site possible within western CONUS. (CA0325-PO)

CV0599 **CEV Direct Entry from LEO**

The CEV shall perform a direct entry from LEO.

Rationale: Direct entry is the only means of return from LEO and is required to return the crew for ISS missions. (CA0325 and CA0044)

3.2.11.11 CEV Entry and Landing Performance

CA0494-PO **CEV Landing Lighting Conditions**

The CEV shall perform Earth landing regardless of ambient lighting conditions.

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

CA0329-PO **CEV Landing Accuracy**

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

Rationale: Improved landing target accuracy increases the number of available landing sites and entry opportunities, thus reducing mission planning constraints and increasing crew survivability. Meeting this accuracy is dependent on having day of landing meteorological data available for the designated landing site. Landing target accuracy is limited by vehicle and parachute performance and atmospheric conditions. The specified accuracy is consistent with the state of the art for ballistic chutes and the limitations of potential landing sites.

CV0587 **CEV Accept Updates to Earth Landing Target Site**

The CEV shall accept updates to the designated Earth landing target site up to 1 hour prior to entry interface.

Rationale: Being able to re-designate landing sites prior to de-orbit, for a LEO return mission, or prior to EI, for a Lunar return mission, provides flexibility to avoid undesirable weather conditions and other unacceptable risks at the planned landing site. This requirement establishes the operational time window for final landing site adjustments and provides additional operational flexibility to address real-time landing site issues. This does not imply that a secondary land landing site will be immediately available for return from LEO; delayed return to land or water landing may be necessary.

CV0588 **CEV Accept Updates to Drogue Deployment Target**

The CEV shall accept updates to the designated drogue deployment target up to 1 hour prior to entry interface.

Rationale: Being able to designate the drogue deployment target prior to de-orbit, for a LEO return mission, or prior to EI, for a Lunar return mission, provides flexibility to adjust targets for expected weather conditions at the landing site. This requirement is need to improve landing accuracy. This requirement establishes the operational time window for final landing site adjustments and provides additional operational flexibility to address real-time landing site issues.

3.2.11.12 CEV Emergency Entry Mode GN&C

CV0755 **Emergency Entry Mode Manual RCS Jet Control**

The CEV shall provide manual control of the RCS jets in a dissimilar mode in the Emergency Entry Mode.

Rationale: The use of the primary RCS in a dissimilar (e.g. cold gas) mode provides minimal control authority of ballistic entry. This function could be used in the Emergency Entry Mode and other degraded entry modes. (CA0274 and CA0448)

CV0756 **Emergency Entry Mode GN&C Software Options**

The CEV emergency entry mode shall function without the use of the primary GN&C software.

Rationale: Emergency Entry Mode independence from primary GN&C software protects for common-mode failures of primary computers. Design implementations could include reboot into safe mode and use of BFCS. This increases crew survivability, since some computer functionality is required in the EEM. (CA0274)

CV0757 **Emergency Entry Mode Navigation Sensor Options**

The CEV shall provide a dissimilar IMU for the Emergency Entry Mode.

Rationale: Past failures of aircraft and launch vehicles have been attributed to common-mode failures of redundant navigation sensors. The use of a dissimilar backup navigation sensor is a common lesson learned from these failures, and increases the robustness of the Emergency Entry Mode. The dissimilar IMU will provide vehicle acceleration, attitude rate, and attitude data, supporting EEM functions and providing the crew with the situational awareness necessary to perform Emergency Entry operations. (CA0274)

CV0758 **Emergency Entry Mode Altimeter Options**

The CEV shall provide a hardware altimeter for crew situational awareness needed for manual activation of altitude sensitive events.

Rationale: Since parachute deployment, heatshield jettison, and landing attenuation is required for crew survival, a backup altitude sensor will increase crew survivability. This will provide the crew with the altitude data necessary for timing a manual parachute deployment activation, manual heatshield jettison or blowout of plugs, and possibly manual activation of the landing attenuation system. A barometric altimeter is an example of a dissimilar sensor. (CA0274)

CV0760 **Emergency Entry Mode Automatic Rate Control**

The CEV Emergency Entry Mode shall provide automated control for rate damping.

Rationale: It is unlikely that the crew could gain control of rates in all three axes in all possible vehicle states (e.g., rapid tumbling) resulting from severe vehicle failures and maintain the required level of rate damping throughout an Emergency Entry. Removing rate damping from the crew workload enables the crew to focus upon the other critical functions and events during an Emergency Entry required for crew survival. This does not preclude manual inputs to RCS jets, rather it is intended to augment manual control. This rate control augmentation must be independent from primary GN&C software and functional in a cold gas mode, and should not drive overall RCS fuel allocation for entry. The solution can include use of the system implemented to meet the software common cause failure protection requirement, CV0736. (CA0274)

CV0761 **Emergency Entry Mode SM/CM Separation**

The CEV shall provide at least 0.1 <TBR-002-211> ft/sec delta-V for separation of the CM and SM without the use of SM RCS.

Rationale: SM separation from the CM is required for crew survival of entry, and the CM requires a safe separation distance from the SM before orienting for entry. Due to the orientation of CM RCS jets, the CM can not separate itself from the SM. The impulse of the separation pyros or a simple, reliable mechanism (such as springs) for imparting a minimum relative separation rate between the SM and CM protects for the complete loss of SM RCS and provides adequate time for rotating the CM into an entry orientation. (CA0274)

3.2.11.13 CEV Manual Control

CV0120 **Manual Control during Orbit Operation**

The CEV shall provide manual control for RPODU.

Rationale: Rendezvous, proximity operations, docking, and undocking operations are critical functions required for crew survival and mission success. Manual control will improve the probabilities for mission success in the event automated functions are unable to perform the maneuvers. Manual control of rendezvous, proximity operations, and docking will improve confidence in achieving a successful and safe docking with the target and is required for human rating of the CEV and mission success. Degree and manner of manual control will be specified at a lower level. (CA0497 and CA0448)

CA0497-PO **CEV Manual Control**

The CEV shall provide manual control of flight path, attitude, and attitude rates when the human can operate the vehicle within system margins.

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

CV0071 **Observation of Earth Horizon**

The CEV shall provide direct visual observation of the Earth horizon line during the ascent and entry profile for crew manual control.

Rationale: Direct visual observation of the horizon for ascent/entry through available and strategically placed CEV cockpit/hatch/docking windows, scopes, etc. is desirable to allow crew intervention for a manual ascent/entry profile, if possible. The Earth's horizon is an excellent reference point for helping crew manually control CEV during ascent/entry, if required.

CV0589 **CEV Perform Manual Orbit Correction Maneuvers**

The CEV shall perform manual orbit correction maneuvers.

Rationale: Orbit insertion and orbit departure, mid-course corrections, prox-ops translational burns, etc are orbit correction maneuvers. These maneuvers must be capable of being controlled by the crew. Manual control of spacecraft provides additional margin for mission success and crew safety. Manual Control does not preclude computer aided control. (CA0497)

CV0754 **Manual Activation of Critical Events**

The CEV shall provide manual activation of critical events required for safe crew return without the use of primary software.

Rationale: Manual activation of critical events increases crew survivability by providing the crew with alternate means for safe ascent abort, entry, descent, and landing in the event of failures in a primary system(s). This manual function could be used in the Emergency Entry Mode, other degraded entry modes and during ascent. Critical event include but are not limited to SM separation, jettison of the docking mechanism, drogue parachute deployment, main parachute deployment, and LAS jettison. (CA0325 and CA0274)

3.2.12 CEV Reliability and Availability

CA0178-PO **CEV Launch Availability**

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

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

CV0632 **CEV Launch Opportunities for Lunar Sortie and Lunar Outpost**

The CEV shall provide launch opportunities for at least four consecutive days per TLI opportunity for the Lunar Sortie and Lunar Outpost Crew missions.

Rationale: This requirement reflects an approach meant to afford a high assurance of crew launch in a given month. Four days provides a balance between launch assurance and a reasonable duration for CEV consumables. (CA0125)

CV0633 **CEV Launch Opportunities for ISS Missions**

The CEV shall provide crew launch opportunities for at least four consecutive days per launch attempt for ISS missions.

Rationale: This requirement reflects an approach meant to afford a high assurance of crew launch for a given set of launch attempts. Four days provides a balance between launch assurance and a reasonable duration for CEV consumables. (CA0125)

CV0770 **Mission Turn Around Time**

The CEV shall be prepared, after a missed launch opportunity for a lunar mission, to launch again within 26 days (the beginning of the next TLI opportunity) using the same spacecraft elements.

Rationale: It is important to provide the capability to recycle the vehicles and mission elements in time to meet the next lunar launch window in the event of a missed window. The lunar launch windows are typically four days long and occur every 30 days. Recycle capability should include limited corrective maintenance actions as well as recycle from a weather delay. (3.2 allocation CARD CA0037)

CV0771 **Launch Ready State**

The CEV shall not require additional servicing or reconfiguration and remain in a launch ready state, exclusive of CEV system failures, for a minimum 2 hour period of time beginning with the Terminal Count through the end of the launch window.

Rationale: This requirement addresses CEVs ability to remain in a final launch ready state beginning with the Terminal Count (where the vehicle on-board systems are commanded to a flight status and the on-board systems assume primary processing functions for launch commands and other systems are ready to transition from ground system provided services to vehicle provided services) through the end of the Launch Window. This represents a time where no additional servicing or reconfiguration is required to support launch (except routine services nominally kept through T-0) regardless of the actual launch window determined from orbital mechanics. The companion rendezvous launch window requirement defines the actual launch vehicle window length based on system performance including yaw steering and downrange over-flight and impact points. (3.2 allocation CARD CA0071)

3.2.13 CEV Maintainability, Supportability and Logistics

CV0023 **Ground Processing Duration for CEV Reusable Elements**

The CEV shall limit ground processing to less than 45 workdays, to include operations from arrival at Assembly, Integration & Production facility through integration with the launch vehicle.

Rationale: The Constellation Architecture will require multiple element launches over a relatively short period of time, thus the ability to process and launch the elements on time is critical. Timely operational availability and reduced life cycle cost for flight elements are necessary for effective, sustainable and affordable mission support. All these factors will be important in optimizing ground processing to support the Exploration missions. The driver for this requirement is to design robustness into the spacecraft to optimize ground processing timelines. Although the intent is to limit the time required for ground processing, the mission manifest and flight rates will affect the actual ground processing timelines. Ground processing includes the integration timeline with the launch vehicle. Verification assumptions of this requirement should utilize a 5-day work week with 2 eight hour shifts/day. (CA0178)

CV0032 **Cargo Stowage**

The CEV shall provide for non-time critical nominal cargo loading at the spacecraft processing facility.

Rationale: Non-time critical cargo stowage will be required inside the CEV, therefore internal access capabilities at the CEV processing facility will be required to stow cargo in the CEV in support of the DRM's. (CA0547)

CV0192 **Transportation to Launch Site**

The CEV and associated support hardware shall be transportable from the manufacturer's site to the launch site per CxP 70028, Ground Systems Element to Crew Exploration Vehicle Interface Requirements Document.

Rationale: A transportation strategy will insure regulatory and programmatic requirements are identified and met. Specifying transportability requirements will insure that the system design considers limitations on size, weight, presence of hazardous commodities, and other factors which could impact shipping and handling from the manufacturing site to the launch site. The support hardware (such as GSE, trainers, mockups, etc.) and flight test articles also need to be designed so they can be transported to the site where they will be utilized. (CV0811)

CV0193 **Transportation from Recovery Site**

The CEV shall be transportable from its recovery location per CxP 70028, Ground Systems Element to Crew Exploration Vehicle Interface Requirements Document.

Rationale: The CEV elements that return to the earth and are recoverable must be recovered whether or not they are reusable. For the elements that are not reusable, recovery is needed to support post flight engineering analysis (i.e. to perform analysis of the TPS entry performance). (CA0410)

CV0723 **Tools**

The CEV shall provide all IVA tools required for CEV on-orbit maintenance and reconfiguration.

Rationale: Requiring CEV to provide the tools needed for that CEV's planned and unplanned on-orbit maintenance encourages the tool set to be minimized to conserve mass and volume. A minimal set of tools for CEV also reduces the training and support requirements for CEV. Other Constellation Systems will be encouraged to save weight and volume by establishing common tool usage with CEV during shared DRMs. Constellation tool lists will be managed within the frame work of the Constellation commonality database. (3.2 allocation CARD CA5935)

CV0778 **Launch Site Assembly**

The CEV shall be mated to the CLV at the Launch Site without requiring demating of elements and subsystems.

Rationale: Assembly of flight systems (e.g., CEV and CLV) and Ground Support Equipment (GSE) into flight configuration at the launch site must be achievable without expensive disassembly, reassembly, and recertification. These systems must fit together without violating physical envelopes when they are transferred to NASA ownership ("DD250'ed"). That is, assembly must be achievable with no routine de-integration of previously assembled (and certified) hardware during the flight hardware integration process. (3.2 allocation CARD CA5814)

CV0779 **Time-Critical Cargo**

The CEV shall provide access for integration of time-critical cargo components no later than 12 hours prior to a scheduled launch.

Rationale: There will be time-critical and perishable cargo provisioning to support ISS, Lunar Sortie and Lunar Outpost missions. These items cannot be integrated into the vehicle during normal processing but must be done at the pad near to the time of launch. In the event of a launch scrub, time-sensitive cargo may need to be removed and replaced to support subsequent launch attempts. (3.2 allocation CARD CA5815)

CV0835 **Maintenance Infrastructure**

The CEV shall provide CEV hardware and CEV GSE infrastructure to maintain systems through their operational life cycles.

Rationale: CEV will need to provide LRU hardware and GSE to meet the CARD opeational life maintenance requirement. (CA5710-PO)

CV0845 **Non-time critical cargo destow**

The CEV shall provide for non-time critical nominal cargo destow at the spacecraft processing facility.

Rationale: Non-time critical cargo destow will be required inside the CEV, therefore internal access capabilities at the CEV processing facility will be required to destow cargo in the CEV in support of the DRM's. (CA0140-PO)

CV0847 **CEV Testability**

The CEV shall provide the capability for ground facility test equipment to command, monitor, and stimulate the CEV.

Rationale: To support verification and validation of the CEV, there will be the need in ground facilities to command, monitor, and stimulate the CEV. For example, the CAIL will need the capability to save and load the vehicle state, synchronize time between the flight system and the facilities, stimulate the inertial systems, monitor data buses, patch flight software, peek/poke memory locations, all switch positions, uplink/downlink baseband data streams, etc. (project derived requirement)

CA5495-PO **CEV Sustain In-Space Operations**

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

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

CV0776 **Software Updates Without LRU Removal**

The CEV shall accept software updates without requiring LRU removal.

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

3.2.14 CEV Habitability & Human Factors

CV0718 **Ready-Access Stowage**

The vehicle shall provide 1.5 cubic feet of "ready-access" stowage volume allowing for suited crew access with one hand, without the use of tools and without removing panels.

Rationale: "Ready-access" stowage is necessary for the secure retention of items that will need to be accessed quickly by the crew based on planned operations and crew preferences. Such items may include unused emesis bags, checklists and cue cards, cameras and other types of audio/video equipment. The volume may be distributed within the portion of the habitable crew module volume that the crew can easily access without removing other equipment. This function is fulfilled on the Shuttle by the use of fabric bags and pouches, with secure velcro closures, that *are attached to the crew seats or by designated stowage lockers that are not behind close-out panels and are loaded per crew bench review preferences. The "ready access" stowage volume amount is based on Shuttle flight crew equipment experience with a crew size of 4 to 6. This is allocated from the previously defined crew equipment volume and mass. (CV0483)*

CV0727 **Cabin Depressurization Valve Hazardous Noise Limit**

The CEV shall limit the maximum A-weighted overall Sound Pressure Level (SPL), at the crewmember's head position, to 135 dBA or less, during cabin depressurization valve operations.

Rationale: This is CEV's allocation from the overall Constellation Architecture 105 dBA SPL limit in HS3082. Noise levels above 115 dBA have been shown to produce noise-induced hearing loss, and the 105 dBA limit allows headroom for alarms and voice communications. Historically, cabin depressurization valves have produced high level of noise. This limit does not apply to impulse noise. CEV assumes crew wears noise protection during the short period when cabin depress valve is operated. Noise protection of GFE communications headsets is allocated at 30 dB (TBR). HS3082 (CV0645)

CV0836 **CEV ECLSS EVA preparation time**

The CEV shall limit the time following suit donning to crewmember egress of the vehicle to 30 minutes, not inclusive of pre-breathe time in the event of an EVA.

Rationale: In the event of an EVA, it is desirable to limit the preparation time as much as possible. Vehicle functions such as purging the suit loop of nitrogen and depressurizing the cabin should take minimal crew time. This requirement is not meant to include pre-breathe time, which is determined independently. The intent of this requirement is to limit the overhead associated with performing an EVA.

CV0548 **Cabin Temperature Setpoint**

The CEV shall control cabin temperature per HSIR 3054 except during suited operations, while docked to the ISS with hatches open, lunar quiescent phase and post-landing.

Rationale: Sets the CEV cabin temperature setpoint control band for temperature ranges defined in CV0547 and is consistent with current ISS temperature control strategy. (CV0645)

CA0426-PO **Lunar CEV Habitable Volume**

The CEV Net Habitable Volume shall be no less than 10.76 m3 (380 ft3).

Rationale: Establishing a minimum net habitable volume ensures that the CEV protects for sufficient unencumbered volume for the crew to execute tasks safely and effectively, to include contingency response such as emergency egress. The

10.76 m3 (380 ft3) equals a DAC2 evaluated volume of 9.03 m3 (319 ft3) with an approximate 20% increase for task and analysis uncertainty. The 4-crew lunar configuration was selected based upon the longer mission duration, and greater number of undefined tasks with the expectation that the same volume will be adequate for a 6-crew ISS mission because of the shorter duration and fewer undefined tasks.

CA0426D-PO **PBS - Net Habitable Volume**

The CEV Net Habitable Volume shall be no less than 10.76 m3 (380 ft3).

Rationale: "Establishing a minimum net habitable volume ensures that the CEV protects for sufficient unencumbered volume for the crew to execute tasks safely and effectively, to include contingency response such as emergency egress. The

10.76 m3 (380 ft3) equals a DAC2 evaluated volume of 9.03 m3 (319 ft3) with an approximate 20% increase for task and analysis uncertainty. The 4-crew lunar configuration was selected based upon the longer mission duration, and greater number of undefined tasks with the *expectation that the same volume will be adequate for a 6-crew ISS mission because of the shorter duration and fewer undefined tasks."*

CA0288-PO **CEV Cabin Pressure Control**

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

Rationale: This is to provide pressure selectability to facilitate docking from the maximum ISS operational pressure to the minimum nominal limit with a 30% oxygen materials limit and 18 kPa (2.5 psia) ppO2 crew limit. This is to have common approach to cabin pressure management across Constellation architecture.

CV0084 **Atmosphere Pressurization Equalization**

The CEV shall provide negative pressure relief to maintain the differential pressure at less than 1 psid crush pressure.

Rationale: Equalization of pressure with the atmosphere is required to maintain structural integrity of the crew compartment. A value of 1 psid is believed to be achievable without a weight penalty and is consistent with the design of the Apollo and Space Shuttle Orbiter crew compartments.

CV0545 **Cabin Overpressure Relief**

The CEV shall not automatically relieve cabin pressure volume overboard at a pressure lower than 15.15 psia.

Rationale: Requires CEV to have the capability to prevent overpressurization. This is driven by an ISS requirement. ISS relief valves are set and the CEV must be set above theirs to ensure CEV will not inadvertently vent while at the ISS.

CA3105-PO **CEV Cabin Pressure Maintenance**

The CEV shall maintain the cabin environment at a pressure of no less than 55 kPa (8.0 psia) from an initial nominal cabin pressure with an equivalent cabin hole diameter of 0.64 (TBR-001-106) cm (0.25 in) to allow the crew time to don suits per CA3058-PO.

Rationale: This is one of the requirements that define vehicle response to a cabin leak. They will require the time the cabin pressure must me maintained to allow the crew to don suits, the time the cabin pressure must be maintained to pre-breathe, Suit pressure for depress events, and the number of cabin leak or cabin repress events the vehicle must support for either ISS or lunar missions. This requirement defines the cabin pressure maintenance required to allow time for the crew to don pressure suits. The 0.64 (TBR-001-106) cm (0.25 in) hole is derived from expected leak rates from lost seals on overboard hatches and feed-throughs and previous spaceflight precedent.

CV0793 **CEV Cabin Pressure Maintenance Time**

The CEV shall maintain the cabin environment at a pressure per CA3105-PO to allow the crew time to don suits and complete connections to life support in 1 (TBR-001-113) hour.

Rationale: The full crew must get into their suits while the CEV ECLS system a leak. CA3058-PO specifies that the EVA Systems shall provide spacesuits that can be donned by the full crew in 1 <TBR-001-113> hour.

CA3133-PO **CEV Cabin O2 Setpoint**

The CEV shall control cabin oxygen partial pressure to a selectable setpoint between 18 (TBR-001-124) kPa (2.6 psia) ppO2 and 21 (TBR-001-911) kPa (3.1 psia) ppO2 with 0.7 (TBR-001-912) kPa (0.1 psia) increments.

Rationale: This is to allow oxygen partial pressure selectability to facilitate operations from ambient ISS oxygen partial pressures to the ppO2 crew limit. This is to have common approach to cabin pressure management across Constellation architecture.

CA3061-PO **CEV Cabin Pressure Oxygen Concentration Limits**

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

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

CA3061D-PO **PBS - CEV Cabin Pressure Oxygen Concentration Limits**

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

Rationale: This is to keep the oxygen concentration from exceeding the materials certification limit. This is to have common approach to cabin pressure management across Constellation architecture.

CA5711-PO **CEV Habitable Environment Recovery**

The CEV shall return the CEV pressurized volume to a habitable environment following the contamination of the cabin atmosphere following a fire, toxic release, and docking with another vehicle that has suffered such an event.

Rationale: A contamination event should not automatically cause long-term contingency operations or termination of the mission. If all safety- and mission-critical systems and backups are still operational following cleanup, the crew and mission management should have the option of returning to normal operations and continuing with the mission.

CA0886-PO **CEV Vestibule Pressurization**

The CEV shall provide not less than two vestibule pressurization cycles per mission.

Rationale: The responsibility for vestibule pressurization must be allocated between the CEV and LSAM and between the CEV and ISS. This requirement allocates responsibility for two pressurization cycles to CEV. Primary and contingency vestibule pressurization should account for each docking in which the crewed CEV is the active vehicle. The LSAM will perform the vestibule pressurization when the crewed LSAM docks with the CEV. For missions to ISS, it is assumed that the ISS is also capable to perform vestibule repressurizations and could perform any additional contingency repressurizations of the vestibule.

CV0064 **Vestibule Pressure Monitoring**

The CEV shall measure pressure within the mated vestibule volume within (TBD-002-030) pressure range and with (TBD-002-039) measurement accuracy when the CEV docking hatch is closed.

Rationale: The pressure monitoring is needed to monitor the pressurization operations of the vestibule and to perform a leak check to ensure proper seal prior to hatch opening and prior to demating.

CV0068 **Vestibule Depressurization**

The CEV shall de-pressurize the vestibule to less than 0.1 psia within 4 min prior to demating.

Rationale: The vestibule between the two spacecraft must be de-pressurized prior to vehicle separation. In a nominal situation, time to depress the vestibule should occur within a reasonable amount of time such that a hatch leak check and undocking can be *performed shortly after vestibule depress, and, in an emergency situation, the vestibule should be de-pressurized within 4 min to satisfy undocking in an emergency undocking scenario. Reference CA0463-PO, CEV Undocking Time.*

CV0493 **Vestibule Pressurization Equalization**

The CEV shall provide a CEV-to-transfer vestibule differential pressure of 0.1 psi within 5 minutes of the command to equalize pressure for a vestibule of (TBD-002-233) cubic feet.

Rationale: To safely facilitate docked operations, the CEV will need to equalize pressure in the vestibule between vehicles prior to opening transfer hatches. This is similar to the pressure equalization time required for the Shuttle orbital docking system to equalize the docking vestibule from vacuum to within 0.1 psid of the Shuttle cabin pressure of 14.7 psia within 4 minutes.

CA3106-PO **CEV Cabin Pressure to Support Pre-Breathe**

The CEV shall maintain the cabin environment at a pressure to support pre-breathe as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section (TBD-001-962), with an equivalent cabin hole diameter of 0.64 (TBR-001-106) cm (0.25 in) and a suit pressure per CA5659-PO.

Rationale: This is one of the requirements that define vehicle response to a cabin leak. They will require the time the cabin pressure must be maintained to allow the crew to don suits, the time the cabin pressure must be maintained to pre-breathe, suit pressure for depress events, and the number of cabin leak or cabin repress events the vehicle must support for either ISS or lunar missions This requirement defines the cabin pressure maintenance required allows time for the crew to pre-breathe in order to de-nitrify their blood before they go to reduced pressures in the suit. The 0.64 (TBR-001-106) cm (0.25 in) hole is derived from expected leak rates from lost seals on overboard hatches and feed-throughs, and previous spaceflight precedent.

CV0794 **CEV Cabin Pressure to Support Pre-Breathe - Temporary Suit P**

The CEV shall maintain the cabin environment at a pressure per CA3106-PO, with a temporary contingency suit pressure of 8 <TBR-002-216> psid positive for up to (TBD-002-217) minutes.

Rationale: This requirement defines a temporary contingency suit pressure for a CEV cabin leak scenario. This requirement is not intended to define the pressure of the suit for EVA operations (contingency, unscheduled, or scheduled EVAs). The suit pressure in this requirement is primarily driven by the best method to protect the crew from decompression sickness given that a long prebreathe will not be possible (due to the vehicle limitations to feed a leak). The maximum pressure that the suit will be required to nominally operate is 4.3 psid.

CA3140-PO **CEV O2 and N2 Storage**

The CEV shall provide oxygen and nitrogen storage to survive from the largest gas consumable combination of two pressure events. (EVA, contaminated atmosphere, and unrecoverable cabin leak).

Rationale: Gas must be allocated to respond to cabin pressure events. The EVA event, which only applies to Lunar missions, includes gas for suit donning, suit purge, pre-breathe, cabin depress and cabin repress to 70 (TBR-001-127) kPa (10.2 psia). The contaminated atmosphere event includes gas for emergency breathing apparatus if applicable, and cabin depress/repress to initial pressure if applicable. Unrecoverable cabin leak includes gas required to maintain cabin at 55 kPa (8 psia) while crew dons suits, purges suit loop, and performs pre-breathe. Of the two pressure events, there can be more than one EVA event or contaminated atmosphere event. Once the vehicle volume and prebreathe details are known an analysis shall be performed to determine which scenarios are the driving cases for consumables sizing.

3.2.15 CEV Environmental Conditions

CA5555-PO **Induced Environments**

The CEV shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design.

CA5560-PO **Induced Environment Limits**

The CEV shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification.

Rationale: Induced environments can degrade system performance, shorten system life and lead to system or mission failure if not properly considered in the design. Therefore, the production of induced environments must be limited and controlled to allow proper performance and function of other sub-systems and other Systems when operating in mated configurations.

CA0374-PO **CEV Natural Environment Exposure**

The CEV shall meet its requirements during and after exposure to the environments defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, 3.3, 3.5, 3.6 and 3.7.

Rationale: The CEV will be exposed to a variety of natural environments that could make it unable to meet its requirements, potentially in combination with induced environments. This requirement defines the limits of these effects and assures that they will be mitigated by the design. Natural environment effects for the CEV also need to be considered for the integrated vehicle configurations: CEV/LSAM, CEV/LSAM/CaLV-EDS, CEV/CLV, CEV/CLV/GS and CEV/ISS.

CA0374D-PO **PBS - CEV Natural Environment Exposure**

The CEV shall meet its functional and performance requirements during and after exposure to the environments defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, 3.3, 3.5, 3.6 and 3.7.

Rationale: "The CEV will be exposed to a variety of natural environments that could make it unable to meet its requirements, potentially in combination with induced environments. This requirement defines the limits of these effects and assures that they will be mitigated by the design. Natural environment effects for the CEV also need to be considered for the integrated vehicle configurations: CEV/LSAM, CEV/LSAM/CaLV-EDS, CEV/CLV, CEV/CLV/GS and CEV/ISS."

CV0247 **MMOD Probability of No Penetration - ISS Mission**

The CEV shall provide a Probability of No Penetration (PNP) of 0.993 or greater over 5 years exposure to the Micrometeoroid and Orbital Debris (MMOD) environments as defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) section 3.3.6.

Rationale: This requirement establishes the minimum required protection from meteoroid and orbital debris penetration for Earth orbit CEV operations.

CV0248 **MMOD Probability of No Penetration - Lunar Mission**

The CEV shall provide a PNP of 0.999 or greater for the maximum lunar mission duration with exposure to the MMOD environments as defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) section 3.3.6.

Rationale: This requirement establishes the minimum required protection from meteoroid and orbital debris penetration for Lunar CEV missions.

3.3 CEV DESIGN & CONSTRUCTIONS STANDARDS

CV0268 **Operations Nomenclature Marking**

The CEV shall use nameplates and product markings using operational nomenclature registered in accordance with CXP-72019, Constellation Nomenclature Plan.

Rationale: Without the influence of this Constellation Program plan, it is likely that the CEV naming will be conducted without appropriate coordination with the Program or other elements. Lessons learned from previous programs encourage early, comprehensive, and aggressive nomenclature control across development and operations communities. HS7079 (CV0814)

CV0479 **Exposed Material Outgassing Limits**

The CEV shall meet the < 0.01% Collected Volatile Condensable Material (CVCM) limit per NASA STD 6016 section 4.2.3.6 for materials directly exposed to the external environment used in large quantity (> 1 Kg total mass or > 1 square meter total surface).

Rationale: This requirement covers exposed surface material. The intent is to generically select materials which are inherently stable in vacuum environments, and to therefore limit the cumulative volatized mass of total contaminants produced by CEV in order to protect sensitive surfaces of visiting vehicles (i.e. ISS, LSAM etc.). NASA STD 6016, Standard Materials and Process Requirements for Spacecraft, Sections 4.2.3.6 - Thermal Vacuum Stability and 4.2.3.7 – External Environment Survivability control the selection of CEV interior and exterior materials. (CV0814)

CV0480 **CEV Venting Pathways**

The CEV shall vent gases and vapors aft and away from ISS and other Constellation systems to which CEV is mated.

Rationale: Minimum exposure to the CEV venting ensures minimum contamination on sensitive surfaces of the ISS and other vehicles

CV0649 **Ground Support Equipment**

The CEV GSE shall comply with the provisions of NASA-STD-5005 Revision B Ground Support Equipment.

Rationale: This standard ensure that uniform engineering practices, methods and essential criteria are employed in the design of ground support equipment (GSE) used within NASA. (3.3 allocation CARD CA5680)

CV0822 **Part marking**

The identification and marking of CEV equipment shall be in accordance with MIL-STD-130M, Identification and Marking of U.S. Military Property.

CV0858 **Unexposed Material Outgassing Limits**

The CEV shall meet the < 0.1% Collected Volatile Condensable Material (CVCM) limit per NASA STD 6016 section 4.2.3.6 for materials internal to the outer shell of the spacecraft used in large quantity (> 1 Kg total mass or > 1 square meter total surface).

Rationale: This requirement covers all other vacuum exposed surface material. The intent is to generically select materials which are inherently stable in vacuum environments, and to therefore limit the cumulative volatized mass of total contaminants produced by CEV in order to protect sensitive surfaces of visiting vehicles (i.e. ISS, LSAM etc.). NASA STD 6016, Standard Materials and Process Requirements for Spacecraft, Sections 4.2.3.6 - Thermal Vacuum Stability and

4.2.3.7 – External Environment Survivability control the selection of CEV interior and exterior materials.

3.3.1 CEV Electrical

CV0855 **Electrical Bonding**

The CEV shall meet the electrical bonding requirements of NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, and Flight Equipment.

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

CV0856 **Power Quality Specification**

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

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

3.3.1.1 CEV Electromagnetic Environmental Effects

CV0661 **Electromagnetic Environment**

The CEV shall meet the requirements of CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document.

Rationale: All CEV systems, subsystems, and equipment will create a complex electromagnetic environment that will vary with time, mission phase, system operation, and so forth. Incompatibilities with this electromagnetic environment will impact CEV operations and performance. (CA0554)

3.3.2 CEV Structures and Mechanisms

CV0043 **Blast Overpressure**

The CEV shall withstand a maximum blast overpressure of 15 psid over ambient conditions without catastrophic failure

Rationale: The crew module needs to survive the overpressure environment due to a launch vehicle explosion. The maximum blast overpressure is a function of the launch abort system warning time and acceleration provided by the abort motor. Recent studies have indicated that primary structure may be capable of up to 15 psid without incurring any weight penalty (i.e. not a design driver less than 15 psid). (derived project requirement)

CV0255 **Mechanism Design Standards**

All safety-critical CEV mechanisms and all mission-critical CEV mechanisms shall comply with Sections 1-4 of NASA-STD-5017, Design and Development Requirements for Mechanisms.

Rationale: This standard sets forth requirements to be followed in the design, development, and testing of mechanical systems. NASA-STD-5017 represents the culmination of human spaceflight mechanical systems requirements developments that began with MIL-A-83577, "General Specification for Moving Mechanical Assemblies for Space and Launch Vehicles" (now cancelled), and progressed to TA-94-041, "Mechanical Systems Safety," dated June 9, 1994,and then to MA2-00-057, "Mechanical Systems Safety," dated September 28, 2000. The space station and space shuttle programs have used these requirements successfully for several years to reduce the occurrence of mechanical system failures. (CA3237)

CV0256 **Pressure Vessels, Pressurized Structures, and Pressure Compo**

The CEV pressure vessels, pressurized structures, and pressure components shall comply with ANSI/AIAA S-80-1998, Space Systems - Metallic Pressure Vessels, Pressurized Structures, and Pressure Components as tailored by CxP 70135 (SDVR)

Rationale: The document provides requirements for the design, development and testing of metallic pressure vessels, pressurized structures and pressure components for use in space flight systems. (derived project requirement)

CV0257 **Composite Overwrapped Pressure Vessels**

The CEV composite overwrapped pressure vessels shall comply with ANSI/AIAA S-081-2000, Space Systems - Composite Overwrapped Pressure Vessels (COPVs) as tailored by CxP 70135 (SDVR).

Rationale: The document provides requirements for the design, development, testing, inspection, operation and maintenance of composite overwrapped pressure vessels for use in space flight systems. (derived project requirement)

CV0259 **Loads**

The CEV shall be designed for the loading conditions defined per Table 5.

Rationale: The CEV will be exposed to many different types of static, transient, and random loads, pressure, and thermal effects during all phases of its hardware service life. The vehicle must be able to show that it can meet its performance requirements after exposure to these loading conditions. In certain cases different types of loads must be considered to act simultaneously. For example, during liftoff, both transient and random loads must be considered. During landing, both transient loads and thermally induced loads must be considered. The loads will have to be considered for all phases of hardware life, including roll-out, pre-launch, liftoff, ascent, abort, landing, trans-lunar injection, etc. (derived project requirement)

Table 5 Loading Conditions

Handling and transportation
Prelaunch
Liftoff
Nominal ascent
Ascent aborts
CLV Slow divergence failure at Max Q
CLV Hard over gimbal failure at Max Q
CLV Hard over gimbal failure at Stage 1 burnout
Pad abort
Abort at maximum drag
Abort at Max Q
High altitude abort
On-orbit
ISS docking
ISS undocking
LSAM docking
LSAM undocking
ISS induced loads
ISS maneuvers
LSAM maneuvers
TLI burn
LOI burn

TEI burn
Crew induced loads
Entry
ISS guided entry
ISS ballistic entry
Lunar direct guided entry
Lunar direct ballistic entry
Lunar skip entry
Entry from ascent abort
Landing and recovery
Nominal land landing
Land landing – one chute out (emergency case - assess as ultimate load)
Water landing
Water landing – one chute out (emergency case - assess as ultimate load)

CV0307 **Pyrotechnics**

The CEV pyrotechnics, associated electrical circuits and electronics shall conform to JSC 62809 Constellation Spacecraft Pyrotechnics Specification and JPR 8080.5 Pyrotechnics standards P-1 through P-7.

Rationale: This document provides requirements for all phases of pyrotechnics use, including design, development, qualification, production, acceptance, shipping, storage, handling, installation, and checkout for Constellation Program spacecraft and launch systems. It also contains requirements from the functional system level to those related to specific pyrotechnic devices and components thereof. Control avionics and circuitry, Ground Support Equipment (GSE), and launch accessory systems are also covered. The requirements of this specification apply to all pyrotechnic components (explosive-loaded and explosively-actuated, non-loaded devices) as well as providing definitions of pyrotechnic components. (CA3004)

CV0640 **Materials and Processes**

The CEV shall comply with NASA-STD-(I)-6016, Standard Material & Process Requirements for Spacecraft.

Rationale: This document defines the minimum requirements for manned spacecraft materials and processes (M&P) and provides a general control specification for incorporation into NASA program/project hardware procurements and technical programs. (CA3005)

CV0641 **Structural Design**

The CEV shall comply with CxP 70135, Structural Design and Verification Requirements.

Rationale: CxP 70135 Structural Design and Verification Requirements presents common structural design and verification requirements to ensure consistent design, development, and verification of Constellation hardware. This document describes general design requirements, design loads, factors of safety and margins of safety, design and stress analysis requirements, structural materials criteria and discusses secondary structure accommodation for human interface and nonstandard fasteners. When the various Constellation systems are assembled (e.g., CEV integrated with CLV) some analyses and/or tests of the integrated system are necessary to verify that the assembled system meets the requirements of CxP 70135, Structural Design and Verification Requirements. (CA3187)

CV0642 **Fracture Control**

The CEV shall comply with NASA-STD-(I)-5019, Fracture Control Requirements for Spaceflight Hardware.

Rationale: This document establishes the fracture control requirements for all human-rated spaceflight systems including payloads, propulsion systems, orbital support equipment, and planetary habitats. These requirements are not imposed on systems other than human-rated spaceflight but may be tailored for use in specific cases where it is prudent to do so, such as when national assets are at risk. (CA3193)

CV0643 **Glass, Window, and Ceramic Design Criteria**

The CEV shall comply with JSC 62550, Structural Design and Verification Criteria For Glass, Ceramics and Windows in Human Space Flight Applications.

Rationale: This document specifies the minimum structural design requirements for the design, development, and verification of flight windows, glass and ceramic structure included in the vehicle/element, Orbital Replacement Units, Orbital Support Equipment (OSE), and Flight Support Equipment (FSE). This document primarily addresses structural design requirements for glass and ceramics. This document does not apply to windows made from non-brittle materials. (3.3 allocation CARD CA3222)

3.3.3 CEV Interchangeability

CV0453 **Interchangeability**

The CEV shall interchange major elements (SM, CM, LAS, SA) from one assembled configuration to another without requiring rework or repair.

Rationale: This allows for streamlined ground processing. As an example, match drilling should not be used to install a LAS onto a CM or a Low Impact Docking System (LIDS) into a CM. (derived project requirement)

3.3.4 CEV Human Engineering

CV0142 **Crew Workstation**

The CEV shall provide redundant crew workstations to control and monitor CEV functions.

Rationale: The vehicle needs to be controlled and monitored from two different workstations to ensure mission success criteria. (CA0435)

CV0645 **Human System Integration Requirements**

The CEV shall comply with the human system integration requirements defined in HSIR CxP 70024, Appendix J, Allocation Matrix with the exception of HSIR requirements HS3015A, HS3037, HS3061, HS3065, HS3065A, HS3070, HS3072, HS3073, HS3074, HS3082, HS3083, HS3105, HS3108, HS4008, HS4008B, HS4008C, HS4012, HS4022, HS5010, HS5012, HS6032, HS6059, HS6060, HS6091, HS6097, HS6099, HS6101 and HS10008 that will be met in conjunction with other systems as specified in the CEV SRD and CxP IRDs.

Rationale: The HSIR requirements listed as exceptions are Constellation Architecture parent requirements for related children requirements that are contained in applicable Interface Requirements Documents and the Systems Requirements For The Crew Exploration Vehicle System CxP

72000. The human systems integration requirements define parameters of a habitable environment, capabilities and limitations of the flight and ground crew that drive the design of Constellation Architecture systems to achieve mission objectives, and provides the parameters that protects the health and safety of the crew and allow them to perform their functions in an efficient and effective manner. The HSIR defines requirements for anthropometry, biomechanics, strength and field of view, atmosphere, crew fire protection, potable water, thermal, acceleration, vibration, acoustics, ionizing and non-ionizing radiation, general safety, layout, orientation, translation, restraints and mobility, hatches, windows, lighting, food preparation, personal hygiene, body waste management, stowage and trash management, user interfaces, *maintenance and housekeeping, information management, and exercise and medical requirements. (3.3 allocation CARD CA0042)*

CV0795 **Toxic Level 4**

The CEV shall prevent Toxic Hazard Level 4 chemicals from vehicle systems, as defined in Table C-1 in Appendix C of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), from entering the habitable volume of the vehicle.

Rationale: Toxic hazard Level 4 compounds can pose an immediate risk to crew health and cannot be scrubbed from the environment. These compounds includes substances that (1) are considered extremely hazardous to the crew and a release of the substance will not allow for crew survival (via escape or isolation), and/or (2) cause permanent damage to life support systems to the extent that they are unable to maintain the atmosphere at a marginally acceptable level, and/or (3) cannot be removed from the atmosphere by the life support systems or the life support systems cannot restore the atmosphere to marginally acceptable levels in one week. The prevention of Toxic Hazard Level 4 chemicals from entering the habitable atmosphere from an external source will decrease the crew health risk to these chemicals. The CEV is not responsible for the primary containment of potentially hazardous payloads or non-vehicle GFE items. (HS3015A)

CV0796 **Linear Accelerations - Nominal Destination**

The CEV shall induce upon the crew linear accelerations of no greater than (TBD-002-219) from launch to mission destination while the CEV has control authority.

Rationale: This is CEV's allocation from the overall Constellation Architecture acceleration limits in HS3061. The dashed blue lines in Figures 3.2-1 through 3.2-5 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR) represent the maximum level of sustained acceleration allowed on a conditioned crewmember under nominal conditions. These crewmembers should not be exposed to higher acceleration limits depicted by the dashed blue lines in the charts. Exposure to g-forces greater than these limits could significantly affect human performance for maneuvering and interacting with the spacecraft. Each axis is to be analyzed separately, and conservatism in the limits for each axis covers any cumulative effect of acceleration in multiple axes. (HS3061)

CV0797 **Sustained Rotational Acceleration**

The CEV shall induce upon the crew sustained rotational accelerations of no greater than (TBD-002-220) degrees/s2 while the CEV has control authority.

Rationale: This is CEV's allocation from the overall Constellation Architecture sustained rotational acceleration limit of 115 degrees/s2 in HS3065. Crewmembers are not expected to be able to tolerate sustained rotational accelerations in excess of 115 degrees/s2 without significant discomfort and disorientation. (HS3065)

CV0798 **Transient Rotational Acceleration**

The CEV shall induce upon the crew transient rotational accelerations of no greater than (TBD-002-221) degrees/s2 while the CEV has control authority.

Rationale: This is CEV's allocation from the overall Constellation Architecture transient rotational acceleration limit of TBD degrees/s2 in HS3065A. Crewmembers may not tolerate rotational accelerations in excess of TBD degrees/s2 without discomfort, disorientation, and/or a reduction in performance readiness. This limit applies to both nominal and abort mission phases. The TBD degrees/s2 limit is less than twice that known to be innocuous during repeated exposures in non-human primates and is two-orders of magnitude below that known to cause severe brain injury in humans. (HS3065A)

CV0799 **Rotational Rates - Nominal Destination**

The CEV shall induce upon the crew yaw, pitch, or roll rates of no greater than (TBD-002-222) from launch to mission destination while the CEV has control authority.

Rationale: This is CEV's allocation from the overall Constellation Architecture yaw, pitch, or roll exposure rates in HS3070. Yaw, pitch, and roll rates are rotations about the body's z-, y-, and x-axes respectively, as shown in Figure C-2 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR). These limits apply to all three axes, and are conservative for yaw rates. The dashed blue line in Figure 3.2-6 of the HSIR represents the maximum level of sustained ascent rotational rates allowed on a conditioned crewmember under nominal conditions. Under nominal conditions, conditioned crewmembers should not be exposed to rotation rates greater than the limits depicted by the dashed blue line in the chart. This could significantly affect human performance for maneuvering and interacting with the spacecraft. (HS3070)

CV0802 **Impulse Noise Limits - Launch and Entry Phases**

The CEV spacecraft shall limit impulse noise at the crewmember's head position to less than 150 dB (TBR-002-249) peak overall SPL, during launch and entry phases including ascent abort.

Rationale: This is CEV's allocation from the overall Constellation Architecture crew impluse noise dose 140 dB limit in HS3074. A limit of 140 dB peak SPL for impulse noise will prevent trauma to the hearing organs caused by impulse noise. Ref. MIL-STD-1474D. The noise attenuation effectiveness of hearing protection or communications headsets may be used to satisfy this requirement. (HS3074)

CV0804 **Vibration Limits**

The CEV shall limit vibration to the crew in any axis to less than (TBD-002-227) g rms integrated from 0.0167 to 80 Hz over any one-minute interval during dynamic phases of flight.

Rationale: This is CEV's allocation from the overall Constellation Architecture crew vibration limit in HS3108. Low-frequency vibration, especially in the range between 0.1 and 0.63 Hz, has the potential to cause motion sickness over relatively short exposure periods. Note that this constant level is equivalent to adjusting the 2-hour curve from NASA-STD-3000 Fig 5.5.3.2.1-1 across the 0.1 to 0.63 Hz frequency range by the weighting for Wf described in ISO standard 2631-1:1997(E), where Wf applies to the vibration component normal to the supporting surface. (HS3108)

CV0805 **Electrical Hazard Potential**

The CEV shall protect the crew from electrical hazards per Tables 3.3-2 and 3.3-3 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).

Rationale: The values in the tables represent the currents beyond which a person is not able to release his/her grip if holding onto an electrically energized surface, due to involuntary muscle contraction. The threshold current for let-go is dependent on the frequency and wave shape of the current. (HS4008)

CV0806 **Chassis Leakage Current - Non-patient Equipment**

The CEV shall limit the chassis leakage current for non-patient equipment to less than the values in Table 3.3-4 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).

Rationale: Chassis leakage current for non-patient equipment must not be great enough to shock the crew. (HS4008B)

CV0807 **Touch Temperature Limits**

The CEV shall limit the temperature of surfaces to which the bare skin of crew are exposed to the limits defined in Table 3.3-6 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).

Rationale: High and low temperatures can cause discomfort and injury. They are especially troublesome in components of the user interface that the crew must touch to operate the vehicle. This also applies to a post-landing egress path of an Earth-entry vehicle, when the vehicle has experienced reentry heating. These temperature limits are derived from the NASA-STD-3000 Manned System Integration Standards and JSC Memo MA2-95-048, Thermal Limits for Intravehicular Activity (IVA) Touch Temperatures. (HS4012)

CV0809 **Exercise Availability**

The CEV shall allow aerobic and resistive exercise training for 30 continuous minutes each day per crewmember for missions greater than 8 continuous days.

Rationale: An exercise capability is not required on CEV missions to ISS or for missions with total durations of less than 8 days. Exercise is required on Lunar missions greater than 8 total days to maintain crew cardiovascular fitness (to aid in ambulation during g-transitions and to minimize fatigue), to maintain muscle mass and strength/endurance (to complete mission tasks such as EVA walk-back and contingency response capability) and for recovery from strenuous tasks, confined postures, and to rehabilitate minor muscle injuries. Per Apollo crew participating in the June 2006 Apollo Medical Summit (Houston, TX), exercise should be commenced as early as possible during the mission and continue throughout all mission phases. Exercise should start as early as possible during the mission but no later than flight day 4, until end of mission minus one day. Exercise is not envisioned for the mission day where LSAM docks with the CEV after a lunar surface mission. Expected CO2, heat and water output can be found in Table E-2 in Appendix E Crewmember Metabolic Profile in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR). (HS6032)

CV0810 **Emergency Equipment Access**

The CEV shall provide access to emergency equipment within the time to address the emergency.

Rationale: In the case of an emergency, access to emergency equipment must occur quickly, allowing the crew to take the proper actions to mitigate the situation. Each emergency may have a unique time requirement and access conditions as determined by hazard analysis. Access requirements for GFE emergency equipment are in CxP 72066. CFE requirements will be documented in lower level specifications. (HS4022)

CV0849 **Thermal control of unsuited crewmembers**

The CEV shall provide for thermal control of unsuited crewmembers such that heat stored remains within the range

4.7 kJ/kg (2 BTU/lb) > heat stored > -4.1 kJ/kg (- 1.76 BTU/lb) during off-nominal situations.

Rationale: While the nominal temperature range specified for CEV will maintain crew health and comfort, the CEV needs to maintain crewmember limits of heat stored during off nominal, unsuited operations in order to maintain crew health. This requirement allows for excursions from the nominal temperature range during off-nominal (unsuited) conditions. (meets HS3037)

CV0815 **Translation Path for Incapacitated Crewmember**

The CEV shall provide an in-space translation path for assisted ingress and egress of an incapacitated pressurized-suited crewmember.

Rationale: This is CEV's allocation from the Constellation Architecture requirement HS5010 for assisted ingress and egress of incapacitated crew while in-space. Incapacitated pressurized-

suited crewmembers may be unable to ingress the CEV on their own, and may also be in a constrained position that requires assistance. This may include ingress from EVA, or ingress/egress to/from the CEV from EVA or any vehicle or module to which the CEV is docked. Crew in a pressurized suit is the bounding case. This requirement also includes assisted ingress and egress for crew in an unpressurized suit as well as unsuited crew.

CV0816 **Translation Path for Incapacitated Crewmember**

The CEV shall provide a translation path for assisted ground egress or extraction of an incapacitated suited crewmember.

Rationale: This is CEV's allocation from the Constellation Architecture requirement HS5010 for assisted ingress and egress of incapacitated crew while on the ground. Incapacitated suited crewmembers may be unable to egress the vehicle on their own and may require assistance from other crew members or ground systems personnel. This is applicable to pre-launch and post-landing, although historically post-landing has seen the most need for assistance. Long-duration Russian and United States missions have shown that muscles atrophy and bones lose calcium in microgravity. Also, the heart adjusts to gravity-free pressures. On return to Earth and rapid onset of gravity, even healthy humans temporarily need assistance for some mobility tasks.

3.3.5 CEV Communication Standards

CV0749 **CEV Security Management**

The CEV shall protect systems and information as specified in the CxP 70070-ANX05, Book 1, Constellation Program Functional Security Requirements for Program Systems and Elements.

Rationale: The CEV is required to comply with Federal and Agency requirements, including NPR 2810.1, Security of Information Technology, and FIPS 200, Minimum Security Requirements for Federal Information and Information Systems, to protect against security threats that might degrade, disable, or destroy the operational capability of CEV. (3.2 allocation CA0383)

CV0646 **C3I Interoperability Standards**

The CEV shall comply with CxP 70022, C3I Interoperability Standards Book, as specified in Volume 1, Appendix E, Applicability Matrix.

Rationale: Communication is essential to successful mission execution. Communication between systems is necessary for accomplishment of all mission objectives and includes data, voice, and motion imagery. Requirements for specific communication links between systems are captured in the system-to-system IRDs. Link classes are defined in the CXP-70022 Constellation Command, Control, Communication and Information Interoperability Specification and include the RF Operational Point to Point, RF High Rate Point to Point, RF Contingency Voice, RF Recovery and Hardline classes. (3.3 allocation CARD CA5800, 3.2 allocation CARD CA3021)

3.3.6 EVA Standards

CV0647 **EVA Design and Construction Specification**

The CEV shall comply with the requirements defined in CxP 70130 Extravehicular Activity (EVA) Design and Construction Specification, Appendix B.

Rationale: Requirements that are driven by EVA but common across the Constellation architecture are included in the EVA Design & Construction Specification. All Constellation architecture systems that will or may interface with EVA crewmembers must conform to this EVA Specification. (CA3167)

3.3.7 CEV Applicable Documents

3.3.9 CEV Test Standard

CV0650 **CEQATR**

The CEV shall comply with CxP 70036 Constellation Environmental Qualification and Acceptance Testing Requirements (CEQATR).

Rationale: The CEQATR standard contains both qualification and acceptance testing requirements for natural & induced environments as well as minimum design screening requirements that are beyond the expected environments. As with other design and construction standards, the CEQATR will drive the design because the design must take into account that it will need to encompass a larger range of environments or minimum screening environments, which ever is greater, as part of the equipment's certification program. (3.3 allocation CARD CA4111)

3.4 CEV EXTERNAL INTERFACES

CV0483 **Portable Equipment Interface**

The CEV shall meet portable equipment interface requirements defined in the CxP 70035.

Rationale: Some Government provided portable equipment (including medical equipment) will require power and data interfaces. The interface may be established via utility panels distributed through out the cabin. (CV0011, CV0001)

CA0429-PO **CEV to CLV IRD**

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

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

CA0800-PO **CEV to LSAM IRD**

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

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

CV0720 **LIDS/APAS Adapter**

The CEV shall deliver a LIDS/APAS adapter to ISS.

Rationale: ISS has APAS and CEV will have LIDS. An adapter must be delivered to ISS to allow CEV to dock.

CV0721 **Top Mounted Adapter**

The CEV shall launch an ISS LIDS/APAS adapter on top of the CM under the LAS-to-CM fairing.

Rationale: A trade study of adapter launch options was performed. The top mounted option was chosen primarily for operational issues (e.g. No EVA or SSRMS ops). The adapter will only be launched on two missions. The CEV should optimize the design to minimize recurring impacts.

CV0722 **CEV Docking to ISS with LIDS/APAS**

The CEV shall manually dock the ISS LIDS/APAS adapter to a PMA via the APAS.

Rationale: The APAS mechanism cannot be berthed by the SSRMS. The CEV must dock the adapter to APAS in order to install it on ISS. (derived project requirement)

CV0814 **CEV to ISS IRD**

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

Rationale: The CEV and ISS share physical and functional interfaces which are identified in CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document. (3.4 allocation CARD CA0077)

CA0361-PO **CEV to CaLV IRD**

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

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

CA0894-PO **CEV to MS IRD**

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

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

CA0893-PO **CEV to GS IRD**

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

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

CV0098 **Post Landing Vehicle Recovery**

The CEV shall provide interfaces to support recovery of the CEV by the recovery personnel per CxP 70028, Ground Systems Element to Crew Exploration Vehicle Interface Requirements Document.

Rationale: The CEV must allow recovery forces to configure and prepare the CEV for transportation to a designated facility. The CEV and the recovery equipment must be designed to provide the recovery forces the tools/equipment and vehicle design features to recover and transport the CEV to a designated facility.

CV0817 **Recovery Services to Crew**

CEV shall provide post landing services, including power, resources and consumables for active cooling, air revitalization, fire detection, communication, lighting and critical avionics for at least 15 minutes (TBR-002-250) after landing.

CA0896-PO **CEV to C&T IRD**

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

Rationale: The CEV and C&TN share physical and functional interfaces which are identified in CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV).

CA0895-PO **CEV to EVA IRD**

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

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

3.5 CEV PHYSICAL CHARACTERISTICS

CA5933-PO **Smart Service Module**

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

Rationale: This requirement allows flexibility in the applicability of the CEV through the use of a "smart" Service Module (SM). The SM can serve as a propulsion stage or a spacecraft bus in support of missions other than the ones associated with the ISS, Lunar and Mars DRMs. As a standalone Element, the SM has the same general configuration as if integrated with the Crew Module (CM), but it can be augmented to carry any required CM equipment (avionics, power, thermal, GN&C, C&T) in a mission specific kit and a fairing to perform missions without the CM. Examples of applicable missions could include reservicing of the Hubble Space Telescope (HST), deorbiting of the HST, an ISS based space tug, a generic near earth space tug, long life multi-satellite smart dispenser, and delivery of new modules or other unpressurized cargo to the ISS.

CA5933D-PO **PBS - Smart Service Module**

The CEV shall include a Service Module (SM) that can be augmented to carry any required equipment (avionics, power, thermal, GN&C, C&T), in a mission specific kit, to allow the Service Module to operate as a standalone Element.

Rationale: This requirement allows flexibility in the applicability of the CEV through the use of a smart Service Module (SM). The SM can serve as a propulsion stage or a spacecraft bus in support of missions other than the ones associated with the ISS, Lunar and Mars DRMs. As a standalone Element, the SM has the same general configuration as if integrated with the Crew Module (CM), but it can be augmented to carry any required equipment (avionics, power, thermal, GN&C, C&T) in a mission specific kit and a fairing to perform missions without the CM. Examples of applicable missions could include an ISS based space tug, a generic near earth space tug, long life multi-satellite smart dispenser, and delivery of new modules or other unpressurized cargo to the ISS.

CA0386-HQ **CEV Physical Characteristics**

The CEV shall have an outer mold-line that is derived from the Apollo Command Module (CM) design as defined in CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line.

Rationale: By using a derivative of the same outer mold line as the Apollo CM, CEV designers will be able to utilize the aero/aerothermal databases and test/flight databases developed during the Apollo Program. The use of this flight-proven design is seen as a significant cost/schedule savings for the CEV development effort when compared with establishing a new design without flight heritage. The dimensions of the CEV will be based on the optimal size for meeting mission requirements.

3.6 RESERVED

3.7 SPACECRAFT AND GROUND SUPPORT EQUIPMENT REQUIREMENTS

Further allocation and decomposition of requirements for the CEV to perform its defined missions per the applicable DRM's can be found in the Lockheed Martin CEV Spacecraft System Specification and the Lockheed Martin CEV Ground Support Equipment System Specification.

3.7.1 Spacecraft Requirements

The CEV Spacecraft System Specification, CEV-T-031000, defines four (4) modules - a Crew Module (CM), an Service Module (SM), a Launch Abort System (LAS) module, and a Spacecraft Adapter (SA) to interface with the launch vehicle. This specification establishes and allocates requirements for these modules as appropriate. In addition, this specification defines and allocates requirements among the 14 defined CEV subsystems. Internal and external interface requirements are included in this specification including those related to the incorporation of Government Furnished equipment, components, and products.

3.7.2 Ground Support Equipment Requirements

The CEV Ground Support Equipment System Specification, CEV-T-031001, defines the technical requirements for the contractor provided GSE. Contractor provided GSE is the equipment and software provided to NASA in support of the CEV ground operations.

4 VERIFICATION

The verification strategy described in detail in CxP 72097 CEV MVP will ensure that the CEV design and performance requirements defined in Section 3 are met to ensure safe flight of the CEV system.

4.1 RESERVED

4.2 VERIFICATION MATRIX

A Verification Matrix (VM) is generated to show the requirement traceability and closure methodology. The VM for this document is shown in appendix E.

4.3 RESERVED

Reserved

4.4 RESERVED

Reserved

4.5 RESERVED

Reserved

4.6 RESERVED

Reserved

4.7 SPACECRAFT AND GROUND SUPPORT EQUIPMENT VERIFICATION

Further allocation and decomposition of CEV verification requirements can be found in the Lockheed Martin CEV Spacecraft System Specification and the Lockheed Martin CEV Ground Support Equipment System Specification.

4.7.1 Spacecraft Verification

The CEV Spacecraft is compliant with Section 3 of the CEV Spacecraft System Specification, CEV-T-031000, when all specification requirements have been verified by the methods identified in the Verification Matrix, Table 4-1 of this specification. Proof of compliance with specifications may be determined by a combination of test, analysis, demonstration and inspection. Lower level verifications will be accomplished before progressing to a higher level of assembly verifications, wherever possible.

4.7.2 Ground Support Equipment Verification

The CEV Ground Support Equipment is compliant with Section 3 of the CEV Ground Support Equipment System Specification, CEV-T-031001, when all specification requirements have been verified by application of one or more of the verification methods described in Section 4.2 of this specification.

5 PACKAGING

Reserved

6 NOTES

6.1 DEFINITIONS

Definitions for terms used in this document are listed in alphabetical order in the Constellation Architecture Glossary document, document number CP-DOC-00002.

APPENDIX A MISSION APPLICABILITY

Table 6 Mission Applicability Matrix

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CA0056-PO	CEV Return of Crew and Cargo from Lunar Rendezvous Orbit	The CEV shall return the crew and cargo from Lunar Rendezvous Orbit (LRO) to the Earth surface.			X
CA0091-PO	Transport to LDO	The CEV shall deliver the crew from the Earth surface to the Lunar Destination Orbit (LDO) for crewed lunar missions.			X
CV0001	Lunar Mission Transport Capacity	The CEV shall transport crews of 2, 3, and 4 crew members from Earth to Lunar Destination Orbit and from Lunar Destination Orbit to Earth in accordance with the capabilities listed in Table 1, Total Lunar DRM Crew, Destination Cargo, and Equipment Definition.			X
CA5312-PO	CEV Deliver Crew/Cargo - ISS	The CEV shall deliver the crew and pressurized cargo from the Earth surface to the ISS.	X	X	
CV0011	ISS Crew and Cargo Mission Transport Capacity	The CEV shall be configurable to deliver crewmembers and pressurized cargo from Earth to ISS and from ISS to Earth in accordance with the capabilities listed in Table 2, Total ISS DRM Crew, Destination Cargo, and Equipment Definition.	X		
CV0622	CEV Lunar Orbit Operations for Lunar Sortie Missions	The CEV shall operate in lunar orbit to support Lunar Sortie missions to any designated location on the lunar surface.			X
CV0623	CEV Lunar Orbit Operations for Lunar Outpost Missions	The CEV shall operate in Lunar orbit to support a Lunar Outpost located within 1.0 degrees latitude of the lunar South Pole (TBR-001-009).			X
CA3203-PO	CEV Return Crew/Cargo to Earth - ISS	The CEV shall return the crew and pressurized cargo from the ISS to the Earth surface.	X	X	
CA0088-PO	CEV Lunar Sortie Loss of Mission Risk	The CEV shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Sortie mission to no greater than 1 in 50 (TBR-001-058).			X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CA3023-PO	CEV LOM for Lunar Outpost Crew	The CEV shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Outpost Crew mission to no greater than 1 in (TBD-001-515).			X
CA0399-PO	CEV ISS Loss of Mission Risk	The CEV shall limit their contribution to the risk of loss of mission (LOM) for an ISS Crewed mission to no greater than 1 in 250 (TBR-001-056).	X		
CA3022-PO	CEV LOM for ISS Cargo	The CEV shall limit their contribution to the risk of loss of mission (LOM) for an ISS Cargo mission to no greater than 1 in (TBD-001-513).		X	
CV0097	Post Landing Safing Performance	The CEV shall provide safing of systems that pose hazards to flight and ground recovery crews within 5 minutes upon landing.	X	X	X
CA4154-PO	CEV Unpressurized Operations	The CEV shall perform the functions necessary to return the crew to the surface of the Earth in at least 120 (TBR-001-980) hours with an unpressurized cabin.	X		X
CA0274-PO	CEV Emergency Entry Modes	The CEV shall provide an Emergency Entry mode that is available from the command of SM separation through Earth landing.	X	X	X
CA0984-PO	CEV Crew Survival After Landing Environment	The CEV shall assure crew survival during landing touchdown in wind and sea state conditions as defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18, for all water landings.	X		X
CA0194-PO	CEV Crew Survival After Landing	The CEV shall provide for crew survival, without permanent crew disability, for at least 36 (TBR-001-045) hours with the hatch closed following a landing in the water.	X		X
CV0830	CEV Crew Survival After Landing	The CEV shall provide for crew survival, without permanent crew disability, for at least 36 hours with the hatch closed in sea state conditions defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Section 3.5.19, following a landing in the water.	X	X	X
CA0983-PO	CEV Launch Abort Environment	The CEV shall maintain structural integrity and float for a minimum of 36 hours in the wind and sea state conditions defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18, following a water landing.	X	X	X
CA3259-PO	CEV Landing Visual Aids	The CEV shall provide visual aids for search and recovery independent of ambient lighting conditions per standard (TBD-001-568).	X		X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CA0532-PO	CEV Unpressurized Cabin Crew Support	The CEV shall sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 120 (TBR-001-1006) hours.	X		X
CV0448	Unpressurized Crew Survival	The CEV shall provide hydration, breathable atmosphere, power, communication and thermal control for the suited crew in an unpressurized environment state for not less than 120 hours (TBR-002-036).	X		X
CA3108-PO	CEV Suit Stowage	The CEV shall provide suit stowage such that a suit can be accessed within 2 (TBR-001-157) minutes per crew member for donning.	X		X
CA3138-PO	CEV Fire Detection and Suppression	The CEV shall provide fire detection and suppression for the CEV pressurized volume.	X		X
CV0716	Affected Volumes	The CEV shall provide fire detection and suppression in all crew module volumes inside the crew cabin that contain both a potential ignition source and forced air flow.	X	X	X
CV0717	Materials Flammability â “ Enclosed Bays	For enclosed bays containing an ignition source and no forced air flow, the CEV shall provide a means of fire suppression within the bay OR all exposed components located within the bay shall be composed of materials that comply with NASA-STD-6016 materials flammability requirements at an atmospheric oxygen concentration that is 10% higher than the maximum O2 concentration expected within the bay during nominal operations.	X	X	X
CV0715	Fire Containment and Failure Reporting	For electrical and electro-mechanical equipment volumes containing an ignition source and no forced air flow, the CEV shall provide a fire containment enclosure or detect, isolate and report all failure modes for these volumes that may cause potential fire events within these volumes.	X	X	X
CA0493-PO	CEV ISS Crew Safe Haven Capability	The CEV shall provide a habitable environment for the assigned crew for a single event of at least 2 (TBR-001-002) hours in duration while the CEV is still docked to and isolated from the ISS.	X		X
CV0015	Safe Haven - Life Support Initiation	The CEV nominal cabin pressure regulation, temperature regulation, and a breathable atmosphere source for the crew shall be operational within one (TBR-002-017) minute of initiation of CEV life support system start up command in the case of an emergency requiring ISS evacuation to CEV.	X		
CA0325-PO	CEV Earth	The CEV shall provide for Earth landing	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Landing	throughout each mission phase.			
CV0713	Water Landing Mode	The CEV shall perform water landing.	X	X	X
CV0095	Vehicle Self-righting for Water Landing	The CEV shall be self-righting for water landing for at least 36 hours.	X	X	X
CA5913-PO	CEV Abort LOC Risk	The CEV shall limit the risk of loss of crew (LOC) during a pad or ascent abort to no greater than 1 in (TBD-001-947).	X		X
CA0501-PO	CEV Lunar Sortie Loss of Crew Risk	The CEV shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Sortie mission to no greater than 1 in 200 (TBR-001-057).			X
CA3040-PO	CEV LOC for Lunar Outpost Crew	The CEV shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Outpost Crewed Mission to no greater than 1 in (TBD-001-559).			X
CA0398-PO	CEV ISS Loss of Crew Risk	The CEV shall limit their contribution to the risk of loss of crew (LOC) for an ISS Crew mission to no greater than 1 in 1700 (TBR-001-055).	X		
CA0334-PO	CEV Flight Crew Unassisted Emergency Egress - Pre-Launch	The CEV shall provide the suited crew with the capability for unassisted emergency egress during pre-launch activities after hatch closure within 2 (TBR-001-122) minutes total starting from initiation of egress in the seated and restrained position to complete crew egress from the vehicle.	X		X
CV0857	Hatch - Emergency Operations Mode	The CEV shall provide a primary crew ingress/egress hatch with an emergency operations mode that will open the hatch within 5 seconds of initiation of the emergency mode during all ground operations at 30 psig (TBR-002-257).			
CV0818	Secondary Egress Path	The CEV shall provide a post landing alternate egress path for the un-pressurized suited crewmembers to egress from the inside of the vehicle.	X		X
CA0335-PO	CEV Ground and Flight Crew Unassisted Emergency Egress - Pre	The CEV shall provide two (TBR-001-545) ground crew and six suited flight crew with the capability for unassisted emergency egress during pre-launch pad activities prior to hatch closure within 2 (TBR-001-202) minutes total starting from initiation of egress to complete crew egress from vehicle.	X		X
CV0031	Ground Operations Personnel Emergency	The CEV shall provide for unassisted pre-launch emergency egress from the CEV of up to 6 ground operations personnel in not greater than 120 seconds.	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Egress				
CA0466-PO	CEV Flight Crew Unassisted Emergency Egress - Post Landing	The CEV shall provide for unassisted emergency egress for suited crew upon landing within (TBD-001-146) minutes.	X		X
CA0333-PO	CEV Abort Coverage	The CEV shall perform aborts from the time the CEV abort system is armed on the launch pad until the mission destination is reached.	X		X
CA0170-PO	CEV Automatic Abort Determination	The CEV shall automatically determine the need for an abort.	X	X	X
CV0660	Inhibit Automatic Abort	The CEV shall inhibit the automatic abort sequence upon receipt of the command from the crew, except for abort sequence initiated upon notification of FTS indication.	X		X
CV0837	Automated abort mode selection	The CEV shall automatically select abort modes.	X	X	X
CV0838	CEV Abort Maneuvers	The CEV shall automatically perform abort maneuvers.	X	X	X
CA0522-PO	CEV Automatic Abort Initiation for FTS	The CEV shall automatically initiate an ascent abort sequence upon notification of FTS indication.	X	X	X
CA5439-PO	CEV Automatic Abort Execution	The CEV shall automatically perform abort.	X	X	X
CV0053	CEV Automatically Initiated Ascent Abort	The CEV shall automatically initiate the ascent abort sequence.	X		X
CV0535	CEV Automatically Initiated Pad Abort	The CEV shall automatically initiate the pad abort sequence.	X		X
CV0045	Ground Systems Initiated Pad Abort	The CEV shall initiate the pad abort sequence upon receipt of the pad abort sequence command from Ground Systems.	X		X
CV0652	Mission Systems Initiated Abort	The CEV shall initiate the abort sequence upon receipt of the abort sequence command from Mission Systems.	X	X	X
CV0653	Crew Initiated Aborts	The CEV shall initiate the abort sequence upon receipt of the abort sequence command from the crew.	X	X	X
CV0654	Abort Mode Selection from	The CEV shall select abort modes upon receipt of the command from Mission	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Mission Systems	Systems.			
CV0735	Abort Mode Selection from the Crew	The CEV shall select abort modes upon receipt of the command from the crew.	X		X
CV0058	Abort Initiation Latency	The CEV shall achieve 80% (TBR-002-231) of required LAS thrust within 300 milliseconds (TBR-002-013) of CEV onboard abort command initiation, where the time measurement is taken from the time the initiated command has been received by the CEV.	X		X
CV0711	Pad Abort Performance	The CEV shall provide sufficient range and altitude performance during pad and low altitude aborts to achieve a water landing, with full Landing and Recovery System (LRS) deployment and functionality, for 95% (TBR-002-247) of the pad abort wind cases as defined in DSNE section (TBD-002-204) and thermal radiation environments as defined in the TBD, such that CEV landing ensures no greater than low risk of crew injury as defined by HSIR section 3.2.4.2.	X	X	X
CV0712	Positive Separation During Abort	For CEV ascent aborts during CLV first stage, the CEV shall exceed a minimum separation distance of 175 ft, relative to a CLV that is assumed to continue to accelerate along its planned trajectory, for all times greater than 3 seconds after abort motor initiation.	X	X	X
CV0841	Flight Separations	The CEV shall provide flight separations without re-contact with any flight hardware.	X	X	X
CV0052	CEV Ascent Abort Targeting	The CEV shall automatically calculate ascent abort targets.	X		X
CV0061	CEV Abort To Orbit Targeting	The CEV shall automatically calculate abort to orbit targets.	X	X	X
CA0579-PO	CEV Ascent Abort Landing Outside DAEZ	The CEV shall provide ascent aborts for ISS missions that result in landing outside the Down-range Abort Exclusion Zone (DAEZ).	X	X	
CA0498-PO	CEV Abort Without CLV Thrusts	The CEV shall abort without relying on thrust from the CLV.	X		X
CA5234-PO	CEV Landing Zone Capability	The CEV shall provide the capability for vehicle landing in zones for earth ascent aborts defined by Figure (TBD-001-076) for all lunar missions.			X
CV0008	Early Return After Achieving Mission Destination	The CEV shall provide for early return to Earth after achieving mission destination.			X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CA0416-PO	CEV Return to Earth Independent of Communications with MS	The CEV shall return the crew to the Earth surface independent of communications with the Mission Systems during all mission phases.	X	X	X
CA5237-PO	CEV Time Allotted for Return Crew to Earth	The CEV shall return the crew from Lunar Rendezvous Orbit (LRO) to the surface of the Earth within 118 (TBR-001-063) hours from docking with LSAM.			X
CA0447-PO	CEV LEO Crew Capability	The CEV shall have the capability to transport crews of 0, 1, 2, 3, 4, 5 and 6 into LEO with a single launch.	X		X
CA0868-PO	CEV Pressurized Cargo Return Mass	The CEV shall return at least 100 kg (220 lbm) of pressurized cargo from LRO to Earth for crewed lunar missions.			X
CA5155-PO	CEV Cargo Volume	The CEV shall provide return cargo volume of at least 0.075 (TBR-001-166) m3 (2.65 ft3) from the lunar orbit to the Earth during each crewed lunar mission.			X
CA3182-PO	CEV Cargo Delivery to ISS	The CEV shall deliver cargo from the Earth to the ISS for uncrewed ISS missions.		X	
CA0864-PO	CEV Pressurized Cargo Mass	The CEV shall deliver a crew of four with at least 365 kg (805 lbm) of pressurized cargo from Earth to ISS.	X		
CA0865-PO	CEV Pressurized Cargo Return Mass	The CEV shall return a crew of four along with at least 365 kg (805 lbm) of pressurized cargo from ISS to Earth.	X		
CA0866-PO	CEV Pressurized Cargo Delivery Mass	The CEV shall deliver at least 2850 kg (6,283 lbm) (gross) of pressurized cargo from the Earth to the ISS for an ISS Cargo mission.		X	
CA5233-PO	CEV Pressurized Cargo Return Mass	The CEV shall return at least 2,858 kg (6,283 lbm) of pressurized cargo from the ISS to the Earth for an uncrewed mission.		X	
CA0565-HQ	CEV ISS Cargo Volume Capability	The CEV shall deliver a volume of at least 10.76 (TBR-001-035) m3 (380 ft3) of pressurized and conditioned cargo to and from the ISS per ISS Cargo mission.		X	
CAxxxAD-PO	PBS - Unpressurized Cargo Data, Command, and Control Interfa	The CEV shall provide a data interface for unpressurized cargo.			
CV0763	Unpressurized Cargo Data,	The CEV shall provide a standard, redundant, non-flight critical data bus interface for	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Command, and Control Interface	unpressurized cargo			
CAxxxBD-PO	PBS - ISS Unpressurized Cargo	The CEV shall deliver unpressurized cargo to the ISS.			
CV0764	ISS Unpressurized Cargo Mass	The CEV shall deliver an unpressurized cargo mass of at least 590 <TBR-002-205> kg (1,300 lbs) (gross) to the ISS.	X	X	
CAxxxCD-PO	PBS - Lunar Unpressurized Cargo	The CEV shall deliver unpressurized cargo for lunar missions.			
CV0766	Lunar Unpressurized Cargo Mass Capability	The CEV shall deliver an unpressurized cargo mass of at least 413kg (909 lbm (gross) (TBR-002-206) to support the Lunar DRM.			X
CAxxxDD-PO	PBS - Electrical Power	The Constellation Architecture shall provide electrical power for unpressurized cargo.			
CV0762	Unpressurized Cargo Power	The CEV shall provide two independent, non-mission specific, electrical power interfaces designated for unpressurized cargo each capable of providing power up to 1.0 kW maximum.	X	X	X
CV0765	ISS Unpressurized Cargo Volume	The CEV shall provide a cubic volume of at least 1.54 m (5.1 ft) on a side (total of 3.68 m3 (130 ft3)) for delivery of un-pressurized cargo to ISS.	X	X	
CV0768	Lunar Unpressurized Cargo Volume	The CEV shall provide a contiguous volume of at least (TBR-002-207) 0.57 m3 (20 ft3) with (TBD-002-234)m per side for delivery of un-pressurized cargo to support the Lunar DRM.			X
CA0547-PO	CEV Science/Engineering Volume Allocation - Unpressurized	The CEV shall provide 0.57 (TBR-001-750) m3 (20 ft3) of volume allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure elements during the cruise and lunar orbit phases of lunar missions.			X
CV0010	ISS Mission Duration - Active	The CEV shall provide no less than 6 days of active vehicle transit operations during an ISS Crew Mission.	X	X	
CV0769	CEV Flight Rates	The CEV shall provide the capacity to perform missions according to the mission rates and opportunities specified in the CEV Flight Rate Table 3.	X	X	X
CA3164-PO	CEV Lunar Orbit Habitable Environment	The CEV shall provide a habitable environment for a crew of four for a minimum of 18 (TBR-001-128) days during each lunar			X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
		mission.			
CA0082-PO	CEV LLO Loiter Duration	The CEV shall loiter uncrewed in LLO for at least 210 (TBR-001-039) days.			X
CA0060-HQ	CEV/ISS Docked Mission Duration	The CEV shall remain docked to the ISS for at least 210 days.	X		
CV0012	ISS Mission Duration - Quiescent	The CEV shall provide at least 210 days of uncrewed operations while docked at the ISS.	X	X	
CV0077	CEV Hatch - EVA Crew Ingress	The CEV shall provide a hatch sized for egress and ingress by pressurized suited EVA crew per the CEV to EVA IRD, CxP 70033 Constellation Program Crew Exploration Vehicle (CEV) to Extravehicular Activity (EVA) Systems Interface Requirements Document (IRD).	X		X
CV0303	Maximum Design Pressure	The CEV crew module maximum design pressure (MDP) shall be 15.8 (TBR-002-245) psid.	X	X	X
CV0315	LIDS Interface	The CEV shall dock using the Low Impact Docking System (LIDS).	X	X	X
CV0811	Launch Site	The CEV shall launch from the KSC/Eastern Range.	X	X	X
CV0812	Protection of Internal Devices	The CEV shall protect devices internal to the pressurized volume that are intended to be connected and disconnected during a lunar mission from lunar dust contamination.			X
CA0351-PO	CEV Launch Lighting Conditions	The CEV shall launch independent of ambient lighting conditions.	X	X	X
CA0448-PO	CEV Single Crewmember Control	The CEV, when operated by the crew, shall be controllable by a single crewmember.	X		X
CA5240-PO	CEV Transfer from LLO to LSAM in LRO	The CEV shall perform an orbit transfer from Low Lunar Orbit to the LSAM in Lunar Rendezvous Orbit (LRO) in 6 (TBR-001-205) hours or less after the decision to return has been made.			X
CA5319-PO	CEV Ascent Target Transfer	The CEV shall complete the orbit transfer from the Ascent Target to a stable Low Earth Orbit (LEO) independent of communications with Mission Systems.	X	X	X
CA0324-PO	CEV Landing at CONUS Sites	The CEV shall return to Earth on land at designated CONUS landing sites.	X	X	X
CA3166-PO	CEV EVAs on Lunar Missions	The CEV shall provide for at least 2 (TBR-001-206) EVA operations of at least 4 (TBR-			X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
		001-207) hours duration each on lunar missions independent of other flight vehicles.			
CV0659	EVA Translation Paths	The CEV shall provide EVA translation paths as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Reqs Doc (IRD).	X	X	X
CV0672	EVA Egress	The CEV shall provide the infrastructure for the EVA crewmember to egress the vehicle as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Reqs Doc (IRD).	X	X	X
CV0673	EVA Ingress	The CEV shall provide the infrastructure for the EVA crewmember to ingress the vehicle as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Reqs Doc (IRD).	X		X
CV0674	Stabilization of EVA Crewmembers	The CEV shall provide infrastructure for EVA crewmembers to stabilize themselves while performing EVA tasks as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Reqs Doc (IRD).	X		X
CA3168-PO	CEV External Control for Cabin Depressurizatio n	The CEV shall provide an external control to depressurize the cabin that is operable by an EVA crewmember.			X
CV0075	Non-Propulsive CEV Cabin Depressurizatio n	The CEV shall provide non-propulsive CEV internal depressurization.	X		X
CA5148-PO	Three Concurrent CEV On-Orbit Missions	The CEV shall provide the infrastructure necessary for at least 3 (TBR-001-208) CEV vehicles operating in-space concurrently.	X	X	X
CA4152-PO	ISS Based EVAs on CEV	The CEV shall provide the infrastructure to perform ISS-based EVAs on ISS missions.	X	X	
CA0827-PO	Control Mass - CEV	The CEV shall have a Control Mass of 22,072 kg (48,570 lbm) at the Lunar Ascent Target.			X
CA4134-PO	CEV Control Mass Lunar Lift Off	The CEV shall have a Control Mass of 28,059 kg (61860 lbm) at Lift-Off for the Lunar Mission.			X
CA4135-PO	CEV LAS Jettison	The CEV shall jettison the LAS not later than 30 seconds after Upper Stage Engine ignition command.	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CA4139-PO	CEV Control Mass CaLV Rendezvous	The CEV shall have a Control Mass of 20,185 (TBR-001-159) kg (44,500 lbm) at the time of CaLV rendezvous.			X
CA4163-PO	CEV Control Mass ISS Lift Off	The CEV shall have a Control Mass of 25,331 kg (55,830 lbm) at Lift-Off for the ISS Mission.	X	X	
CA4164-PO	CEV Control Mass ISS Lift Off	The CEV shall have a Control Mass of 19,301 kg (42,540 lbm) at the ISS Ascent Target.	X	X	
CA0829-PO	CEV Delta-V for Lunar Missions	The CEV shall provide a minimum translational delta-V of 1760 (TBR-001-148) m/s (5776 ft/s) for lunar missions.	X	X	X
CV0853	Translational Delta-V Tank Size	The CEV shall provide a minimum translational delta-V tank size of 5293 (TBR-002-256) ft/s.	X	X	X
CA0436-PO	CEV Two Fault Tolerance for Catastrophic Hazards	The CEV shall provide two fault tolerance to catastrophic hazards except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance must be achieved without the use of EVA, emergency operations or emergency systems.	X		X
CV0772	Range Safety	The CEV shall comply with NPR 8715.5, Range Safety Program, Preface and sections 1.1-1.2, 1.3.7, 1.4, 2.1, 2.3-2.4, 3.1-3.2, 3.3-3.4, and Appendix A.	X	X	X
CV0775	CEV Module Disposal	The CEV shall dispose of expendable modules and other orbital debris in accordance with NPD 8710.3B, NASA Policy for Limiting Orbital Debris Generation.	X	X	X
CV0782	Safety Requirements	The CEV shall comply with the requirements from CxP-70059, SR&QA Technical Requirements document.	X	X	X
CV0821	Physical inhibits for ground testing	The CEV shall provide for control of ground safety hazards in accordance with document (TBD-002-236).	X	X	X
CV0850		The CEV shall dispose of expendable modules or debris without contacting the CLV during nominal liftoff and ascent operation	X	X	X
CV0851		The CEV shall dispose of expendable modules or debris without contacting the launch pad during nominal liftoff operation.	X	X	X
CA0435-PO	CEV Single Fault Tolerant for Critical Hazards	The CEV shall be single fault tolerant for critical hazards and loss of mission, except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance must be achieved without the use of EVA, emergency operations or emergency systems.	X	X	X
CA0437-PO	CEV	The CEV shall comply with the requirement in	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Redundancy Separation	JPR 8080.5, JSC Design and Procedural Standards, Section G-2.			
CV0575	Prevention of CEV Fault Propagation	The CEV shall prevent propagation of the effects for identified subsystem faults and component failures that, if propagated, could result in a catastrophic or critical hazard.	X	X	X
CV0736	Computer Based Control Common Cause Failure Protection	The CEV shall provide protection from the effects of software common cause failures when a failure of a system function results in loss of life.	X	X	X
CA3254-PO	Command Generation	The CEV shall generate commands.	X	X	X
CA3249-PO	CEV Command Generation Interface	The CEV shall provide an interface for the crew to generate commands	X	X	X
CV0552	Reception of Commands and Data	The CEV shall receive commands and data during all mission phases exclusive of interruptions caused by operational constraints.	X	X	X
CV0143	Reception of Crew Commands	The CEV shall receive commands from the crew.	X		X
CV0145	Reception of Commands and Data from Constellation	The CEV shall receive commands and data from other Constellation Systems.	X	X	X
CV0737	Reception of Commands and Data from ISS	The CEV shall receive commands and data from the ISS.	X	X	
CV0844	Safe configuration	The CEV shall maintain a safe configuration without ground and crew interaction for a period of no less than 12 hours during all mission phases following a failure of safety and mission critical functions.	X	X	X
CV0846	Command And Data Reception	The CEV shall receive commands and data during all ground operations and mission phases exclusive of interruptions caused by operational constraints.	X	X	X
CA0134-PO	Command Validation	The CEV shall execute commands valid in the current state.	X	X	X
CV0556	ISS Command Validation	The CEV shall validate commands received from the ISS.	X	X	
CV0560	Crew Command Validation	The CEV shall validate commands received from the crew.	X		X
CV0571	Constellation	The CEV shall validate commands received	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	System Command Validation	from the other Constellation Systems.			
CV0615	Command Notification	The CEV shall provide a notification for validity of commands.	X	X	X
CV0570	Command Execution Status	The CEV shall provide execution status of commands.	X	X	X
CA3255-PO	Command Execution	The CEV shall execute commands which are addressed to the CEV.	X	X	X
CV0569	Crew Command Execution	The CEV shall execute valid commands received from the crew.	X		X
CV0572	Constellation System Command Execution	The CEV shall execute valid commands received from Constellation Systems.	X	X	X
CV0738	ISS Command Execution	The CEV shall execute valid commands received from ISS.	X	X	
CV0612	Command Latency	The CEV shall have crew, Constellation Systems, and ISS initiated command latency no greater than 200ms (TBR-002-232) while processing commands, where the performance measurement is taken from the time the initiated command has been received by the CEV, to the time the command has been received by the target sub-system.	X	X	X
CV0739	Telemetry Data Latency	The CEV shall have a latency no greater than 1 <TBR-002-233> second while processing data destined for telemetry, where the performance measurement is taken from the time of subsystem data read to the time of data transmission from the CEV.	X	X	X
CV0740	Crew Status Data Latency	The CEV shall have a latency no greater than 1 <TBR-002-234> second while processing data destined for crew display, where the performance measurement is taken from the time of subsystem data read to the time data is presented to the crew.	X		X
CA0428-PO	CEV Generate Health and Status	The CEV shall generate Health and Status information.	X	X	X
CV0153	CEV Generate Health and Status for Safety and Mission Critic	The CEV shall generate the health and status information on active and standby equipment for safety and mission critical functions.	X	X	X
CV0172	Maintenance	The CEV shall provide equipment	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Data Collection and Storage	maintenance data for safety and mission critical systems.			
CV0539	Health and Status information to External Operators	The CEV shall provide health and status information to Constellation Systems and ISS.	X	X	X
CV0576	Data Quality Indication	The CEV shall provide data quality indicators (e.g. current or stale).	X	X	X
CV0831	Health and status information processing	The CEV shall process health and status information.	X	X	X
CV0820	Developmental Flight Instrumentation	The CEV shall generate engineering and developmental flight instrumentation data.	X	X	X
CA0427-PO	CEV Health and Status Information to the Crew	The CEV shall provide Health and Status information to the crew.	X	X	X
CV0156	Display of Health and Status Information to Crew	The CEV shall provide health and status information of the CEV, ISS, and other Constellation Systems to the crew.	X		X
CV0555	Shared Resources Crew Display	The CEV shall provide the real-time utilization of shared resources (e.g. Power, Thermal, Data) to the crew.	X		X
CV0813	Power and Data Ports	The CEV shall provide 6 quality of power and data ports in accordance with CxP 70035, Portable Equipment, Payloads, Cargo (PEPC) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).	X	X	X
CV0536	Health and Status Recording	The CEV shall record at least 8 Gigabytes of health and status information on CEV active and standby equipment for safety and mission critical functions.	X	X	X
CV0170	Onboard Telemetry Data Recording	The CEV shall provide capacity to record at least 12 hours telemetry data at 192 kbps at baseband onboard.	X	X	X
CV0171	Auxiliary Data Recording	The CEV shall provide capacity to record at least 12 Gigabytes of auxiliary data.	X	X	X
CV0843	Onboard Operational Parameter Loading	The CEV shall provide the capability to load operational parameters that have been written to non-volatile memory upon receipt of a command from the crew, ISS, or other Constellation Systems.	X	X	X
CV0550	Equipment	The CEV shall record equipment	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Maintenance Data	maintenance data for safety and mission critical systems.			
CA5039-PO	CEV Storage for Recording Digital Data	The CEV shall provide (TBD-001-220) bytes of digital storage for recording digital data received from other Constellation Systems.		X	X
CV0741	CLV Data Recording	The CEV shall record up to 20 Gigabytes of ascent data from CLV.	X	X	X
CA0511-PO	CEV Flight Data Recorder	The CEV shall record critical data for reconstruction of catastrophic events.	X	X	X
CV0173	Data Recording For Accident Investigation	The CEV shall record flight data essential for accident investigation during ascent and entry onto non-volatile memory that meets (TBD-002-232) hardening.	X	X	X
CA5040-PO	CEV Recording of Digital Data	The CEV shall record System-generated digital data received from other Constellation Systems.	X	X	X
CV0833	Time Stamping of Audio and Motion Imagery	The CEV shall time stamp audio and motion imagery.	X	X	X
CV0688	Time Stamp Precision	The CEV shall time stamp vehicle data to a precision that uniquely identifies every collected data set.	X	X	X
CV0689	Time Stamp Accuracy	The CEV shall time stamp vehicle data to an accuracy of +- (TBD-002-208) of maximum collection cycle rate for each collected data set.	X	X	X
CV0848	Time Synchronizatio n	The CEV shall synchronize vehicle time sources.	X	X	X
CA5901-PO	Data Reconfiguratio n of Stored Commands, Sequences, and Data	The CEV shall accept reconfiguration of stored commands, sequences and data.	X	X	X
CV0152	Software Update	The CEV shall update onboard software with uplinked software.	X	X	X
CV0616	Data Update	The CEV shall update onboard data parameters with uplinked values.	X	X	X
CV0627	Data Reconfiguratio n	The CEV shall provide data reconfiguration.	X	X	X
CV0549	Resource Monitoring	The CEV shall monitor the real-time utilization of shared resources.	X	X	X
CV0553	Vehicle Mode Transition	The CEV shall perform vehicle mode transitions.	X	X	X
CV0554	Mode	The CEV shall provide transition status for	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Transition Monitoring	any mode transition.			
CV0617	Functional Inhibits for the Current Operating Mode	The CEV shall inhibit functions that are invalid for the current operating mode.	X	X	X
CV0154	Operational Status Determination	The CEV shall determine the operational status of standby (powered on) redundant components prior to placing them into active status.	X	X	X
CV0204	Subsystem Checkout	The CEV shall provide a subsystem checkout capability initiated by the crew, ISS, or other Constellation Systems.	X	X	X
CV0819	Autonomous Mission Return	The CEV shall autonomously plan and execute safety critical resource usage to return to earth at any time during the mission.	X		X
CA0438-PO	CEV Fault Detection	The CEV shall detect system faults which result in loss of vehicle, loss of life and loss of mission.	X	X	X
CV0158	Fault Detection	The CEV shall detect faults to the subsystem or component active and standby (powered on) redundancy level that could result in Emergency, Warning, or Caution (Class 1, 2 or 3) events.	X	X	X
CV0580	Loss of Communication Detection	The CEV shall detect loss of communications with Mission Systems in the absence of a communication signal for more than 12 hours.	X	X	X
CV0541	Independent Detection of Faults	The CEV shall provide independent means for detection of a failure that could result in a catastrophic or critical hazard.	X	X	X
CA5465-PO	CEV Failure Isolation	The CEV shall isolate detected faults to the level required for recovery of function.	X	X	X
CV0159	Fault Identification	The CEV shall identify the source of detected subsystem faults and component failures.	X	X	X
CA5466-PO	CEV Recovery from Failure	The CEV shall provide recovery from isolated faults.	X	X	X
CV0160	Fault Recovery Using Available Redundancy	The CEV shall recover from isolated subsystem faults and component failures, where redundancy exists, to prevent a catastrophic or critical hazard.	X	X	X
CV0557	Reallocation of Shared Resources for Fault Recovery	The CEV shall reallocate the real-time utilization of shared resources (e.g. Power, Thermal, Data) in support of fault recovery.	X	X	X
CA5904-PO	Execute Reconfigurable Sequences	The CEV shall execute reconfigurable automation sequences valid in the current state.	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CV0824	Onboard Automation Sequence Scheduling	The CEV shall provide reconfigurable time and event scheduling for the execution of automation sequences.	X		X
CA3110-PO	CEV Control of Automation	The CEV shall accept Control of Automation.	X	X	X
CV0743	Initiate Selected Automated Functions	The CEV shall initiate the execution of selected automated CEV functions upon receipt of crew, ISS, or other Constellation System commands.	X		X
CV0150	Inhibit of Automated Operations	The CEV shall inhibit the execution of an automated CEV function upon receipt of the inhibit command for that function from the crew, ISS, or other Constellation Systems.	X	X	X
CV0544	Re-enable Inhibited Automated Functions	The CEV shall enable the execution of an automated CEV function that was previously inhibited, upon receipt of the enable command for that function from the crew, ISS, or other Constellation Systems.	X		X
CV0148	Override of Automated Functions	The CEV shall provide the crew, ISS, or other Constellation Systems with override of automated CEV functions that are physically and safely interruptible.	X	X	X
CV0747	Terminate Automated Functions	The CEV shall terminate the execution of an automated CEV function upon receipt of the terminate command for that function from the crew, ISS, or other Constellation Systems.	X		X
CV0558	Crew Commanded Flight Processor Vehicle Re-initialization	The CEV shall re-initialize the flight processor(s) into a predefined operating configuration upon receipt of an action from the crew.	X		X
CV0561	Externally Commanded Flight Processor Vehicle Re-initialization	The CEV shall re-initialize a single flight processor into a predefined operating configuration upon receipt of a command from the ISS and other Constellation Systems.	X	X	X
CV0562	Automated Vehicle Re-initialization During Uncrewed Operation	The CEV shall re-initialize the flight processors upon recovery from vehicle electrical power loss, to restore vehicle control and communication during uncrewed operations.	X	X	X
CV0842	Save Configuration Data	The CEV shall save configuration data upon receipt of the command from the crew or other Constellation Systems.	X	X	X
CV0563	Checkpoint	The CEV shall, upon receipt of a	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Generation	commanded, scheduled or triggered event, save the computational execution state information (checkpoint).			
CV0619	Checkpoint Exporting	The CEV shall export to external systems the saved computational execution state (checkpoint) data.	X	X	X
CV0618	Checkpoint Loading	The CEV shall load a computational execution state (checkpoint) specified by a ground facility operator in support of ground testing and training.	X	X	X
CV0564	CEV Restart from a Checkpoint	The CEV shall restart from a specified computational execution state (checkpoint) while assuring time synchronization between flight processors, subsystem hardware, and test equipment in support of ground testing and training.	X	X	X
CV0565	Restart Synchronization with Ground Facility Processors	The CEV shall provide the capability for the flight processors to be synchronized with ground facility processors upon flight processor restart from a checkpoint.	X	X	X
CV0750	CEV Communication Between Systems	The CEV shall communicate between Constellation Systems and ISS using the standards and protocols per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1; Interoperability Specification, Table Appendix E-1, C3I Interoperability Requirements Applicability to CEV.	X	X	X
CV0167	Command Authentication	The CEV shall authenticate commands received.	X	X	X
CV0168	Command Link Encryption	The CEV shall provide encryption and decryption for commands sent via RF between the CEV and other Constellation Systems and ISS.	X	X	X
CV0169	Command Link for Reconfiguration	The CEV shall manage the authentication and encryption system including exchange of security updates.	X	X	X
CV0368	Internet Protocol	The CEV shall implement IP-based communications between Constellation Systems.	X	X	X
CV0629	CEV Packet Loss Rate	The CEV shall provide an onboard network Packet Loss Rate of less than 10-6 (TBR-002-209) given 1500 byte packets.	X	X	X
CV0630	CEV Multi-Hop Communication	The CEV shall implement multi-hop communications between Systems.	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CV0364	S-Band Communication	The CEV shall communicate at S-Band.	X	X	X
CV0366	Ka-Band Communication	The CEV shall communicate at Ka-Band.	X	X	X
CV0534	CEV Communication in Proximity of LSAM	The CEV shall communicate with LSAM within 432 nmi (800 km) of the CEV at S-band.			X
CV0164	CEV Communication in Proximity of ISS	The CEV shall communicate with ISS within 16.2nmi (30 km) of the CEV at S-band.	X	X	X
CA3288-PO	CEV Simultaneous Communications with ISS	The CEV shall communicate simultaneously with ISS and Mission Systems when within 30 (TBR-001-917) km (16.2 nmi) of ISS.	X	X	
CA3287-PO	CEV Simultaneous Communication with MS	The CEV shall communicate simultaneously with Mission Systems, and with 2 (TBR-001-126) other Constellation in-space systems that are within 800 (TBR-001-165) km (432 nmi) of CEV.	X	X	X
CV0490	CEV Simultaneous Communications with LSAM	The CEV shall communicate simultaneously with Mission Systems and the LSAM.			X
CV0362	Communication Services	The CEV shall provide spherical coverage for the different mission phases and links, excluding non-CEV structural blockage and re-entry plasma as given in Table 4 (TBR-002-235).	X	X	X
CA0470-PO	CEV Low Rates Data Coverage	The CEV shall transmit and receive in any attitude with geometric antenna coverage of 90% (TBR-001-335) for low-rate data as defined by CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV), Section 3.6.1.2.	X	X	X
CV0374	Radiometric Tracking	The CEV shall transpond signals and provide radiometric measurements.	X	X	X
CV0373	CEV Non-Deterministic Hardline Communications	The CEV shall implement IP based communications for non-deterministic rate based hard-line connections between ISS and Constellation Systems as specified in CxP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1.	X	X	X
CV0751	CEV	The CEV shall implement SAE-AS5643 and	X		X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Deterministic Hardline Communications	SAE-AS5643/1 standards for deterministic rate based hard-line connections between Constellation Systems.			
CV0834	CEV Crew Audio Communications	The CEV shall provide audio communications between crew members and Constellation Systems and ISS.	X		X
CV0178	Private Audio and Motion Imagery Communication	The CEV shall provide two-way private audio and motion imagery communication mode between the ground and crew.	X		X
CV0631	CEV Audio and Motion Imagery	The CEV shall provide audio and high definition motion imagery for distribution to the public.	X	X	X
CV0832	Motion Imagery for Situational Awareness	The CEV shall provide imagery of mission critical and safety related events.	X	X	X
CV0854	Motion Imagery Recording	The CEV shall record motion imagery and associated audio sources for a combined total record time of 8 (TBR-002-258) hours minimum.			
CV0752	CEV Privacy of Crew Medical and Personal Data	The CEV shall ensure the privacy of all crew medical and personal data.	X		X
CV0138	Motion Imagery for Proximity Operations - Docking and Undock	The CEV shall provide motion imagery for approach and departure proximity operations, docking and undocking to the crew, MS, ISS and LSAM.	X	X	X
CV0176	Transmit Motion Imagery	The CEV shall provide motion imagery and associated audio to the ISS and other Constellation Systems.	X		X
CA3280-PO	CEV Dissimilar Voice System	The CEV shall communicate using an independent, dissimilar, voice only system.	X	X	X
CV0179	Recovery Force Communication - Nominal and Off-Nominal	The CEV shall provide communications with recovery team at nominal and off-nominal landing sites.	X		X
CV0829	Improper Radio Locator Beacon Activation	The CEV shall automatically activate the radiolocator beacon(s).	X	X	X
CA0344-PO	CEV Off-Nominal Landing	The CEV shall maintain communications with Mission Systems for at least 36 hours post landing.	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Communication				
CV0784	CEV Post-Landing Communications	The CEV shall maintain voice communications with Mission Systems for at least 36 hours post landing, with a duty cycle of 90% receive and 10% transmit.	X		X
CV0180	Search and Rescue Communication	The CEV shall provide local voice communications with the Ground Systems Recovery and Retrieval Element, and contingency Search and Rescue (SAR) team while the CEV hatches are closed.	X		X
CV0463	SAR Interoperability	The CEV shall provide local voice communication with the Ground Systems Recovery and Retrieval Element and contingency Search and Rescue (SAR) forces as defined in CxP 70022, C3I Interoperability Standards Book, Volume 1 , Table Appendix E-1 - C3I Interoperability Requirements Applicability to CEV.	X		X
CV0181	Search and Rescue Locator Signal	The CEV shall provide radiolocator beacon(s) as defined in the C3I Interoperability Specification, Volume 1, Table Appendix E-1 - C3I Interoperability Requirements Applicability to CEV, for nominal and off-nominal landing.	X	X	X
CV0787	CEV Location Transmission	The CEV shall transmit its location via the radiolocator beacon.	X	X	X
CV0788	CEV Locator Signal Operation	The CEV radiolocator beacon(s) shall operate continuously for at least 36 hours post landing.	X	X	X
CV0790	Simultaneous Voice and Locator Signal Operations	The CEV shall provide simultaneous voice communications and radiolocator beacon signal.	X		X
CA5921-PO	CEV Separation from CLV	The CEV shall perform separation functions with the CLV.	X	X	X
CV0048	CEV Translation after CLV Separation	The CEV shall translate from the CLV with positive clearance margins following separation.	X	X	X
CV0110	CEV Independent Determination of CLV/CEV Trajectory	The CEV shall independently determine the CLV/CEV integrated stack ascent trajectory, attitude, and attitude rates.	X		X
CV0590	Manual CLV Steering Commands	The CEV shall send manual steering commands to the CLV during ascent in response to crew input.	X		X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CV0591	Ascent Trajectory Targets	The CEV shall provide updated ascent trajectory targets for the CEV/CLV integrated stack.	X	X	X
CA5819-PO	CEV Performs TCM during TLC	The CEV shall perform Trajectory Correction Maneuvers (TCMs) during the Trans-Lunar Coast (TLC).			X
CV0119	CEV Translational Maneuver Target Computation	The CEV shall compute translational maneuver targets.	X	X	X
CV0677	CEV Trajectory Correction Maneuvers during Trans-Earth Coast	The CEV shall perform Trajectory Correction Maneuvers (TCMs) during the Trans-Earth Coast (TEC).			X
CA3204-PO	CEV ERO Transfer	The CEV shall perform the orbit transfer from the Ascent Target to the Earth Rendezvous Orbit (ERO) for crewed lunar missions.			X
CA3207-PO	CEV Transfer from LLO to LRO	The CEV shall perform the orbit transfer from Low Lunar Orbit (LLO) to the Lunar Rendezvous Orbit (LRO) for crewed lunar missions.			X
CA3209-PO	CEV TEI for Crewed Lunar Missions	The CEV shall perform the Trans-Earth Injection (TEI) for crewed lunar missions.			X
CA0191-PO	CEV Perform Orbit Transfer	The CEV shall perform the orbit transfer from the Ascent Target to ISS.	X	X	
CV0111	CEV Independent Determination of EDS/LSAM/CEV Trajectory	The CEV shall independently determine the integrated EDS/LSAM/CEV stack trajectory, attitude, and attitude rates.			X
CV0477	CEV Independent Determination of LSAM/CEV Trajectory	The CEV shall independently determine the integrated LSAM/CEV stack trajectory, attitude, and attitude rate.			X
CA4128-PO	CEV Contingency Attitude Control with LSAM	The CEV shall perform attitude control of the CEV/LSAM mated configuration after CaLV EDS undocking through CEV/LSAM separation in LLO.			X
CA0187-PO	CEV Nominal Attitude Control with LSAM	The CEV shall perform attitude control of the CEV/LSAM mated configuration after docking in LLO.			X
CV0122	CEV Backouts from Proximity	The CEV shall perform backouts during proximity operations and docking when	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Operations and Docking	functioning as the maneuvering vehicle.			
CV0126	CEV Contingency Docking with LSAM in Unplanned Attitude	The CEV shall perform proximity operations and docking with LSAM when it is in any inertial attitude with inertial rate less than 0.4 (TBR-002-056) deg/sec per axis.			X
CV0129	CEV Any-Attitude Undocking	The CEV shall perform any-attitude undocking with a mated vehicle inertial attitude rate up to 2 deg/s (TBR-002-159).	X	X	X
CV0791	CEV Breakouts from Proximity Operations and Docking	The CEV shall perform breakouts during proximity operations and docking when functioning as the maneuvering vehicle.	X	X	X
CV0823	Support Second Docking Attempt	The CEV shall perform a second LSAM docking attempt within 2 orbits (TBR-002-251) after a first docking attempt is terminated for a lunar mission in LEO.			X
CA3248-PO	CEV Rendezvous Maneuvers	The CEV shall compute rendezvous maneuvers when performing relative navigation with the target vehicle.	X	X	X
CA0059-PO	CEV as Maneuvering Vehicle with LSAM/EDS during RPODU	The CEV shall function as the maneuvering vehicle during RPODU operations with the LSAM/CaLV EDS mated configuration in LEO.			X
CA0131-PO	CEV as Target Vehicle during LSAM RPOD in LRO	The CEV shall function as the target vehicle during RPOD operations with the LSAM in LLO.			X
CA0369-PO	CEV Contingency RPOD with LSAM in LLO	The CEV shall function as a maneuvering vehicle while performing RPOD with the LSAM in LLO prior to crew transfer back to the CEV for crewed Lunar missions.			X
CA0133-PO	CEV as Maneuvering Vehicle during Undocking and Separation w	The CEV shall function as the maneuvering vehicle during undocking and departure proximity operations from LSAM, prior to TEI.			X
CA0081-PO	CEV as Maneuvering Vehicle with ISS during RPODU	The CEV shall function as the maneuvering vehicle during RPODU operations with the ISS.	X	X	
CV0127	CEV Terminate Docking	The CEV shall terminate docking upon receipt of command.		X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CA5286-PO	CEV as Target Vehicle during LSAM Departure	The CEV shall perform target vehicle functions during undocking and departure proximity operations from LSAM prior to lunar descent.			X
CV0450	Un-crewed CEV Separation and Departure from Crewed LSAM in L	The CEV shall undock, separate, and perform departure maneuver(s) from the crewed LSAM in LLO prior to lunar descent.			X
CV0108	CEV Onboard LLO Navigation	The CEV shall calculate Low Lunar Orbit (LLO) navigation solutions for TEI sequence initiation in less than 6 hours.			X
CV0648	CEV Time Scale	The CEV shall use a single, continuous (TBR-001-518) reference time scale traceable to Coordinated Universal Time (UTC) in accordance with CxP 70142, Constellation Program Navigation Standards Specification Document.	X	X	X
CA3142-PO	CEV Navigation and Attitude Determination	The CEV shall perform navigation and attitude determination during all mission phases including pre-launch.	X	X	X
CV0112	CEV Maneuvering Vehicle Relative Navigation	The CEV shall perform relative navigation for rendezvous, proximity operations and docking when functioning as the maneuvering vehicle.	X	X	X
CV0116	Target Vehicle Relative Position and Velocity Determination	The CEV shall determine the position and velocity of the CEV relative to the target vehicle during PODU operations, when the CEV is the maneuvering vehicle.	X	X	X
CV0117	CEV Target Vehicle Relative Attitude and Attitude Rate Deter	The CEV shall determine the attitude and attitude rate of the CEV relative to the target vehicle during LEO PODU operations, when the CEV is the maneuvering vehicle within 100 feet (TBR-002-210) of the target vehicle.	X	X	X
CV0540	CEV Measurement of Bearing Angles with LSAM	The CEV shall measure bearing angles between CEV and LSAM, when the two vehicles are within 432 nmi (800 km) to maintain a relative navigation state.			X
CV0532	CEV Rendezvous Navigation with LSAM	The CEV shall measure range and range rate between CEV and LSAM, when the two vehicles are within 432 nmi (800 km) to maintain a relative navigation state.			X
CV0597	CEV Target	The CEV shall perform relative navigation for			X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Vehicle Relative Navigation	rendezvous, proximity operations and docking as target vehicle when the LSAM is the active maneuvering vehicle.			
CV0839	Relative alignment in LLO	The CEV shall determine the attitude and attitude rate of the CEV relative to the LSAM during LLO PODU operations, when the CEV is the maneuvering vehicle within 150 feet (TBR-002-210) of the target vehicle.	X	X	X
CV0773	RPODU Independent of Lighting	The CEV shall perform RPODU independent of lighting conditions.	X	X	X
CV0792	Ground Overflight Constraints	The CEV shall perform RPODU independent of ground overflight constraints.	X	X	X
CA0462-PO	CEV Emergency Any Attitude Undocking Capability	The CEV shall function as the maneuvering vehicle during undocking and departure proximity operations from the target vehicle at any attitude, in case of an emergency.	X	X	X
CA0463-PO	CEV Undocking Time	The CEV shall provide for undocking within 10 (TBR-001-004) minutes of crew ingress and hatch closure.	X		X
CV0085	CEV Automated Deorbit from LEO	The CEV shall perform an automated deorbit maneuver sequence from LEO.	X	X	X
CV0601	CEV Automated RPODU	The CEV shall perform automated RPODU.	X	X	X
CV0139	Crew Visual Observation of Proximity Operations and Docking	The CEV shall provide the crew direct visual observation of the target vehicle during proximity operations, docking and undocking.	X		X
CV0594	CEV Lighting for Crew Identification	The CEV shall be visually identifiable by a target vehicle crew at a distance of at least 3280 ft in any lighting conditions.	X	X	X
CV0595	CEV Lighting for Orientation	The CEV orientation shall be visually identifiable by a target vehicle crew at a distance of at least 800 ft in any lighting conditions.	X	X	X
CV0083	CEV Direct Entry for Trans-Earth Trajectories	The CEV shall perform a direct entry for trans-Earth trajectories.			X
CV0086	CEV Skip Entry Performance	The CEV shall perform skip entry into the Earth's atmosphere of up to 5,750 <TBR-002-023> nmi (10,650 km) from the entry interface			X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
		from lunar mission trajectories.			
CV0599	CEV Direct Entry from LEO	The CEV shall perform a direct entry from LEO.	X	X	
CA0494-PO	CEV Landing Lighting Conditions	The CEV shall perform Earth landing regardless of ambient lighting conditions.	X	X	X
CA0329-PO	CEV Landing Accuracy	The CEV shall perform a guided entry that results in landing within 5 (TBR-001-040) km (2.7 nmi) of the intended target at a designated CONUS landing site.	X		X
CV0587	CEV Accept Updates to Earth Landing Target Site	The CEV shall accept updates to the designated Earth landing target site up to 1 hour prior to entry interface.	X	X	X
CV0588	CEV Accept Updates to Drogue Deployment Target	The CEV shall accept updates to the designated drogue deployment target up to 1 hour prior to entry interface.	X	X	X
CV0755	Emergency Entry Mode Manual RCS Jet Control	The CEV shall provide manual control of the RCS jets in a dissimilar mode in the Emergency Entry Mode.	X		X
CV0756	Emergency Entry Mode GN&C Software Options	The CEV emergency entry mode shall function without the use of the primary GN&C software.	X	X	X
CV0757	Emergency Entry Mode Navigation Sensor Options	The CEV shall provide a dissimilar IMU for the Emergency Entry Mode.	X	X	X
CV0758	Emergency Entry Mode Altimeter Options	The CEV shall provide a hardware altimeter for crew situational awareness needed for manual activation of altitude sensitive events.	X	X	X
CV0760	Emergency Entry Mode Automatic Rate Control	The CEV Emergency Entry Mode shall provide automated control for rate damping.	X	X	X
CV0761	Emergency Entry Mode SM/CM Separation	The CEV shall provide at least 0.1 <TBR-002-211> ft/sec delta-V for separation of the CM and SM without the use of SM RCS.	X	X	X
CV0120	Manual Control during Orbit Operation	The CEV shall provide manual control for RPODU.	X		X
CA0497-PO	CEV Manual	The CEV shall provide manual control of flight	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Control	path, attitude, and attitude rates when the human can operate the vehicle within system margins.			
CV0071	Observation of Earth Horizon	The CEV shall provide direct visual observation of the Earth horizon line during the ascent and entry profile for crew manual control.	X		X
CV0589	CEV Perform Manual Orbit Correction Maneuvers	The CEV shall perform manual orbit correction maneuvers.	X		X
CV0754	Manual Activation of Critical Events	The CEV shall provide manual activation of critical events required for safe crew return without the use of primary software.	X		X
CA0178-PO	CEV Launch Availability	The CEV shall have a launch availability of no less than 98% (TBR-001-041) per launch attempt, exclusive of weather, starting at (TBD-001-505) hours for "LCC Call to Station" and ending at close of day-of-launch window.	X		X
CV0632	CEV Launch Opportunities for Lunar Sortie and Lunar Outpost	The CEV shall provide launch opportunities for at least four consecutive days per TLI opportunity for the Lunar Sortie and Lunar Outpost Crew missions.			X
CV0633	CEV Launch Opportunities for ISS Missions	The CEV shall provide crew launch opportunities for at least four consecutive days per launch attempt for ISS missions.	X	X	
CV0770	Mission Turn Around Time	The CEV shall be prepared, after a missed launch opportunity for a lunar mission, to launch again within 26 days (the beginning of the next TLI opportunity) using the same spacecraft elements.			X
CV0771	Launch Ready State	The CEV shall not require additional servicing or reconfiguration and remain in a launch ready state, exclusive of CEV system failures, for a minimum 2 hour period of time beginning with the Terminal Count through the end of the launch window.	X	X	X
CV0023	Ground Processing Duration for CEV Reusable Elements	The CEV shall limit ground processing to less than 45 workdays, to include operations from arrival at Assembly, Integration & Production facility through integration with the launch vehicle.	X	X	X
CV0032	Cargo Stowage	The CEV shall provide for non-time critical nominal cargo loading at the spacecraft processing facility.	X	X	X
CV0192	Transportation to Launch Site	The CEV and associated support hardware shall be transportable from the manufacturer’s	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
		site to the launch site per CxP 70028, Ground Systems Element to Crew Exploration Vehicle Interface Requirements Document.			
CV0193	Transportation from Recovery Site	The CEV shall be transportable from its recovery location per CxP 70028, Ground Systems Element to Crew Exploration Vehicle Interface Requirements Document.	X	X	X
CV0723	Tools	The CEV shall provide all IVA tools required for CEV on-orbit maintenance and reconfiguration.	X	X	X
CV0778	Launch Site Assembly	The CEV shall be mated to the CLV at the Launch Site without requiring demating of elements and subsystems.	X	X	X
CV0779	Time-Critical Cargo	The CEV shall provide access for integration of time-critical cargo components no later than 12 hours prior to a scheduled launch.	X	X	X
CV0835	Maintenance Infrastructure	The CEV shall provide CEV hardware and CEV GSE infrastructure to maintain systems through their operational life cycles.	X	X	X
CV0845	Non-time critical cargo destow	The CEV shall provide for non-time critical nominal cargo destow at the spacecraft processing facility.	X	X	X
CV0847	CEV Testability	The CEV shall provide the capability for ground facility test equipment to command, monitor, and stimulate the CEV.	X	X	X
CA5495-PO	CEV Sustain In-Space Operations	The CEV shall sustain in-space operations using only onboard equipment and spares without resupply or support from personnel other than the crew.	X		X
CV0776	Software Updates Without LRU Removal	The CEV shall accept software updates without requiring LRU removal.	X	X	X
CV0718	Ready-Access Stowage	The vehicle shall provide 1.5 cubic feet of "ready-access" stowage volume allowing for suited crew access with one hand, without the use of tools and without removing panels.	X		X
CV0727	Cabin Depressurization Valve Hazardous Noise Limit	The CEV shall limit the maximum A-weighted overall Sound Pressure Level (SPL), at the crewmember's head position, to 135 dBA or less, during cabin depressurization valve operations.	X	X	X
CV0836	CEV ECLSS EVA preparation time	The CEV shall limit the time following suit donning to crewmember egress of the vehicle to 30 minutes, not inclusive of pre-breathe time in the event of an EVA.	X		X
CV0548	Cabin Temperature	The CEV shall control cabin temperature per HSIR 3054 except during suited operations,	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Setpoint	while docked to the ISS with hatches open, lunar quiescent phase and post-landing.			
CA0426-PO	Lunar CEV Habitable Volume	The CEV Net Habitable Volume shall be no less than 10.76 m3 (380 ft3).	X		X
CA0288-PO	CEV Cabin Pressure Control	The CEV shall control cabin pressure to a selectable setpoint between 103 (TBR-001-923) kPa (14.9 psia) to 58 (TBR-001-501) kPa (8.4 psia) with 0.7 (TBR-001-500) kPa (0.1 psia) increments.	X		X
CV0084	Atmosphere Pressurization Equalization	The CEV shall provide negative pressure relief to maintain the differential pressure at less than 1 psid crush pressure.	X	X	X
CV0545	Cabin Overpressure Relief	The CEV shall not automatically relieve cabin pressure volume overboard at a pressure lower than 15.15 psia.	X	X	
CA3105-PO	CEV Cabin Pressure Maintenance	The CEV shall maintain the cabin environment at a pressure of no less than 55 kPa (8.0 psia) from an initial nominal cabin pressure with an equivalent cabin hole diameter of 0.64 (TBR-001-106) cm (0.25 in) to allow the crew time to don suits per CA3058-PO.	X	X	X
CV0793	CEV Cabin Pressure Maintenance Time	The CEV shall maintain the cabin environment at a pressure per CA3105-PO to allow the crew time to don suits and complete connections to life support in 1 (TBR-001-113) hour.	X		X
CA3133-PO	CEV Cabin O2 Setpoint	The CEV shall control cabin oxygen partial pressure to a selectable setpoint between 18 (TBR-001-124) kPa (2.6 psia) ppO2 and 21 (TBR-001-911) kPa (3.1 psia) ppO2 with 0.7 (TBR-001-912) kPa (0.1 psia) increments.	X	X	X
CA3061-PO	CEV Cabin Pressure Oxygen Concentration Limits	The CEV shall limit the maximum oxygen concentration within the pressurized cabin to 30% (TBR-001-109) by volume.	X		X
CA5711-PO	CEV Habitable Environment Recovery	The CEV shall return the CEV pressurized volume to a habitable environment following the contamination of the cabin atmosphere following a fire, toxic release, and docking with another vehicle that has suffered such an event.	X		X
CA0886-PO	CEV Vestibule Pressurization	The CEV shall provide not less than two vestibule pressurization cycles per mission.	X		X
CV0064	Vestibule Pressure Monitoring	The CEV shall measure pressure within the mated vestibule volume within (TBD-002-030) pressure range and with (TBD-002-039)	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
		measurement accuracy when the CEV docking hatch is closed.			
CV0068	Vestibule Depressurization	The CEV shall de-pressurize the vestibule to less than 0.1 psia within 4 min prior to demating.	X	X	X
CV0493	Vestibule Pressurization Equalization	The CEV shall provide a CEV-to-transfer vestibule differential pressure of 0.1 psi within 5 minutes of the command to equalize pressure for a vestibule of (TBD-002-233) cubic feet.	X	X	X
CA3106-PO	CEV Cabin Pressure to Support Pre-Breathe	The CEV shall maintain the cabin environment at a pressure to support pre-breathe as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section (TBD-001-962), with an equivalent cabin hole diameter of 0.64 (TBR-001-106) cm (0.25 in) and a suit pressure per CA5659-PO.	X		X
CV0794	CEV Cabin Pressure to Support Pre-Breathe - Temporary Suit P	The CEV shall maintain the cabin environment at a pressure per CA3106-PO, with a temporary contingency suit pressure of 8 <TBR-002-216> psid positive for up to (TBD-002-217) minutes.	X		X
CA3140-PO	CEV O2 and N2 Storage	The CEV shall provide oxygen and nitrogen storage to survive from the largest gas consumable combination of two pressure events. (EVA, contaminated atmosphere, and unrecoverable cabin leak).	X		X
CA5555-PO	Induced Environments	The CEV shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification.	X	X	X
CA5560-PO	Induced Environment Limits	The CEV shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification.	X	X	X
CA0374-PO	CEV Natural Environment Exposure	The CEV shall meet its requirements during and after exposure to the environments defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, 3.3, 3.5, 3.6 and 3.7.	X	X	X
CV0247	MMOD Probability of No Penetration	The CEV shall provide a Probability of No Penetration (PNP) of 0.993 or greater over 5 years exposure to the Micrometeoroid and	X	X	

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	- ISS Mission	Orbital Debris (MMOD) environments as defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) section 3.3.6.			
CV0248	MMOD Probability of No Penetration - Lunar Mission	The CEV shall provide a PNP of 0.999 or greater for the maximum lunar mission duration with exposure to the MMOD environments as defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) section 3.3.6.			X
CV0268	Operations Nomenclature Marking	The CEV shall use nameplates and product markings using operational nomenclature registered in accordance with CXP-72019, Constellation Nomenclature Plan.	X	X	X
CV0479	Exposed Material Outgassing Limits	The CEV shall meet the < 0.01% Collected Volatile Condensable Material (CVCM) limit per NASA STD 6016 section 4.2.3.6 for materials directly exposed to the external environment used in large quantity (> 1 Kg total mass or > 1 square meter total surface).	X	X	X
CV0480	CEV Venting Pathways	The CEV shall vent gases and vapors aft and away from ISS and other Constellation systems to which CEV is mated.	X	X	X
CV0649	Ground Support Equipment	The CEV GSE shall comply with the provisions of NASA-STD-5005 Revision B Ground Support Equipment.	X	X	X
CV0822	Part marking	The identification and marking of CEV equipment shall be in accordance with MIL-STD-130M, Identification and Marking of U.S. Military Property.	X	X	X
CV0858	Unexposed Material Outgassing Limits	The CEV shall meet the < 0.1% Collected Volatile Condensable Material (CVCM) limit per NASA STD 6016 section 4.2.3.6 for materials internal to the outer shell of the spacecraft used in large quantity (> 1 Kg total mass or > 1 square meter total surface).			
CV0855	Electrical Bonding	The CEV shall meet the electrical bonding requirements of NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, and Flight Equipment.			
CV0856	Power Quality Specification	The CEV shall comply with CxP 70050-01, Constellation Program Electrical Power System Specification, Volume 1: Electrical Power Quality Performance for 28 VDC and CxP 70050-02, Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28 VDC.			

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CV0661	Electromagnetic Environment	The CEV shall meet the requirements of CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document.	X	X	X
CV0043	Blast Overpressure	The CEV shall withstand a maximum blast overpressure of 15 psid over ambient conditions without catastrophic failure	X		X
CV0255	Mechanism Design Standards	All safety-critical CEV mechanisms and all mission-critical CEV mechanisms shall comply with Sections 1-4 of NASA-STD-5017, Design and Development Requirements for Mechanisms.	X	X	X
CV0256	Pressure Vessels, Pressurized Structures, and Pressure Compo	The CEV pressure vessels, pressurized structures, and pressure components shall comply with ANSI/AIAA S-80-1998, Space Systems - Metallic Pressure Vessels, Pressurized Structures, and Pressure Components as tailored by CxP 70135 (SDVR)	X	X	X
CV0257	Composite Overwrapped Pressure Vessels	The CEV composite overwrapped pressure vessels shall comply with ANSI/AIAA S-081-2000, Space Systems - Composite Overwrapped Pressure Vessels (COPVs) as tailored by CxP 70135 (SDVR).	X	X	X
CV0259	Loads	The CEV shall be designed for the loading conditions defined per Table 5.	X	X	X
CV0307	Pyrotechnics	The CEV pyrotechnics, associated electrical circuits and electronics shall conform to JSC 62809 Constellation Spacecraft Pyrotechnics Specification and JPR 8080.5 Pyrotechnics standards P-1 through P-7.	X	X	X
CV0640	Materials and Processes	The CEV shall comply with NASA-STD-(I)-6016, Standard Material & Process Requirements for Spacecraft.	X	X	X
CV0641	Structural Design	The CEV shall comply with CxP 70135, Structural Design and Verification Requirements.	X	X	X
CV0642	Fracture Control	The CEV shall comply with NASA-STD-(I)-5019, Fracture Control Requirements for Spaceflight Hardware.	X	X	X
CV0643	Glass, Window, and Ceramic Design Criteria	The CEV shall comply with JSC 62550, Structural Design and Verification Criteria For Glass, Ceramics and Windows in Human Space Flight Applications.	X	X	X
CV0453	Interchangeability	The CEV shall interchange major elements (SM, CM, LAS, SA) from one assembled configuration to another without requiring rework or repair.	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
CV0142	Crew Workstation	The CEV shall provide redundant crew workstations to control and monitor CEV functions.	X		X
CV0645	Human System Integration Requirements	The CEV shall comply with the human system integration requirements defined in HSIR CxP 70024, Appendix J, Allocation Matrix with the exception of HSIR requirements HS3015A, HS3037, HS3061, HS3065, HS3065A, HS3070, HS3072, HS3073, HS3074, HS3082, HS3083, HS3105, HS3108, HS4008, HS4008B, HS4008C, HS4012, HS4022, HS5010, HS5012, HS6032, HS6059, HS6060, HS6091, HS6097, HS6099, HS6101 and HS10008 that will be met in conjunction with other systems as specified in the CEV SRD and CxP IRDs.	X	X	X
CV0795	Toxic Level 4	The CEV shall prevent Toxic Hazard Level 4 chemicals from vehicle systems, as defined in Table C-1 in Appendix C of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), from entering the habitable volume of the vehicle.	X	X	X
CV0796	Linear Accelerations - Nominal Destination	The CEV shall induce upon the crew linear accelerations of no greater than (TBD-002-219) from launch to mission destination while the CEV has control authority.	X		X
CV0797	Sustained Rotational Acceleration	The CEV shall induce upon the crew sustained rotational accelerations of no greater than (TBD-002-220) degrees/s2 while the CEV has control authority.	X		X
CV0798	Transient Rotational Acceleration	The CEV shall induce upon the crew transient rotational accelerations of no greater than (TBD-002-221) degrees/s2 while the CEV has control authority.	X		X
CV0799	Rotational Rates - Nominal Destination	The CEV shall induce upon the crew yaw, pitch, or roll rates of no greater than (TBD-002-222) from launch to mission destination while the CEV has control authority.	X		X
CV0802	Impulse Noise Limits - Launch and Entry Phases	The CEV spacecraft shall limit impulse noise at the crewmember's head position to less than 150 dB (TBR-002-249) peak overall SPL, during launch and entry phases including ascent abort.	X		X
CV0804	Vibration Limits	The CEV shall limit vibration to the crew in any axis to less than (TBD-002-227) g rms integrated from 0.0167 to 80 Hz over any one-minute interval during dynamic phases of flight.	X		X
CV0805	Electrical	The CEV shall protect the crew from electrical	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
	Hazard Potential	hazards per Tables 3.3-2 and 3.3-3 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).			
CV0806	Chassis Leakage Current - Non-patient Equipment	The CEV shall limit the chassis leakage current for non-patient equipment to less than the values in Table 3.3-4 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).	X	X	X
CV0807	Touch Temperature Limits	The CEV shall limit the temperature of surfaces to which the bare skin of crew are exposed to the limits defined in Table 3.3-6 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).	X	X	X
CV0809	Exercise Availability	The CEV shall allow aerobic and resistive exercise training for 30 continuous minutes each day per crewmember for missions greater than 8 continuous days.	X		X
CV0810	Emergency Equipment Access	The CEV shall provide access to emergency equipment within the time to address the emergency.	X	X	X
CV0849	Thermal control of unsuited crewmembers	The CEV shall provide for thermal control of unsuited crewmembers such that heat stored remains within the range 4.7 kJ/kg (2 BTU/lb) > heat stored > -4.1 kJ/kg (- 1.76 BTU/lb) during off-nominal situations.	X	X	X
CV0815	Translation Path for Incapacitated Crewmember	The CEV shall provide an in-space translation path for assisted ingress and egress of an incapacitated pressurized-suited crewmember.	X		X
CV0816	Translation Path for Incapacitated Crewmember	The CEV shall provide a translation path for assisted ground egress or extraction of an incapacitated suited crewmember.	X		X
CV0749	CEV Security Management	The CEV shall protect systems and information as specified in the CxP 70070-ANX05, Book 1, Constellation Program Functional Security Requirements for Program Systems and Elements.	X	X	X
CV0646	C3I Interoperability Standards	The CEV shall comply with CxP 70022, C3I Interoperability Standards Book, as specified in Volume 1, Appendix E, Applicability Matrix.	X	X	X
CV0647	EVA Design and Construction Specification	The CEV shall comply with the requirements defined in CxP 70130 Extravehicular Activity (EVA) Design and Construction Specification, Appendix B.	X	X	X
CV0650	CEQATR	The CEV shall comply with CxP 70036 Constellation Environmental Qualification and Acceptance Testing Requirements	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
		(CEQATR).			
CV0483	Portable Equipment Interface	The CEV shall meet portable equipment interface requirements defined in the CxP 70035.	X	X	X
CA0429-PO	CEV to CLV IRD	The CEV shall interface with the CLV per CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document.			
CA0800-PO	CEV to LSAM IRD	The CEV shall interface with the LSAM per CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).			
CV0720	LIDS/APAS Adapter	The CEV shall deliver a LIDS/APAS adapter to ISS.	X	X	
CV0721	Top Mounted Adapter	The CEV shall launch an ISS LIDS/APAS adapter on top of the CM under the LAS-to-CM fairing.	X	X	
CV0722	CEV Docking to ISS with LIDS/APAS	The CEV shall manually dock the ISS LIDS/APAS adapter to a PMA via the APAS.	X	X	
CV0814	CEV to ISS IRD	The CEV shall interface with ISS per CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document.	X	X	
CA0361-PO	CEV to CaLV IRD	The CEV shall interface with CaLV per CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD).			
CA0894-PO	CEV to MS IRD	The CEV shall interface with Mission Systems per CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD).			
CA0893-PO	CEV to GS IRD	The CEV shall interface with Ground Systems per CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).			
CV0098	Post Landing Vehicle Recovery	The CEV shall provide interfaces to support recovery of the CEV by the recovery personnel per CxP 70028, Ground Systems Element to Crew Exploration Vehicle Interface Requirements Document.	X	X	X
CV0817	Recovery Services to Crew	CEV shall provide post landing services, including power, resources and consumables for active cooling, air revitalization, fire	X	X	X

Requirement No.	Requirement Title	Description	ISS Crew	ISS Cargo	Lunar
		detection, communication, lighting and critical avionics for at least 15 minutes (TBR-002-250) after landing.			
CA0896-PO	CEV to C&T IRD	The CEV shall interface with the Communications and Tracking Network per CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV).			
CA0895-PO	CEV to EVA IRD	The CEV shall interface with EVA Systems per CxP 70033, Constellation Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document.			
CA5933-PO	Smart Service Module	The CEV shall (TBD-001-1019) include a Service Module (SM) that is configurable as a standalone Element.			
CA0386-HQ	CEV Physical Characteristics	The CEV shall have an outer mold-line that is derived from the Apollo Command Module (CM) design as defined in CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line.	X	X	X

APPENDIX B TBD MATRIX

Table 7 TBD Matrix

TBD Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
TBD-001-009	CV0623	3.2	Rationale: Polar Regions of the moon present unique opportunities for lunar resource utilization, scientific investigations, advantages for transportation system flexibility, efficiency. Specific outpost site selection criteria will be developed and documented in a separate (TBD-001-009) HQ controlled document as was done during Apollo. (CA0014)		
TBD-002-030	CV0064	3.2.14	The CEV shall measure pressure within the mated vestibule volume within (TBD-002-030) pressure range and with (TBD-002-039) measurement accuracy when the CEV docking hatch is closed.	Analysis - Human Systems	
TBD-002-204	CV0711	3.2.2.2	The CEV shall provide sufficient range and altitude performance during pad and low altitude aborts to achieve a water landing, with full Landing and Recovery System (LRS) deployment and functionality, for 95% (TBR-002-247) of the pad abort wind cases as defined in DSNE section (TBD-002-204) and thermal radiation environments as defined in the TBD, such that CEV landing ensures no greater than low risk of crew injury as defined by HSIR section 3.2.4.2.	Analysis - LAS	ODAC-1 Pad Abort TDS
TBD-002-208	CV0689	3.2.8	The CEV shall time stamp vehicle data to an accuracy of +- (TBD-002-208) of maximum collection cycle rate for each collected data set.	Analysis - Avionics/Flt SW	IDAC-3 / ODAC-1 TDS
TBD-002-217	CV0794	3.2.14	The CEV shall maintain the cabin environment at a	Analysis - Human Systems	

TBD Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
			pressure per CA3106-PO, with a temporary contingency suit pressure of 8 <TBR-002-216> psid positive for up to <TBD-002-217> minutes.		
TBD-002-219	CV0796	3.3.4	The CEV shall induce upon the crew linear accelerations of no greater than (TBD-002-219) from launch to mission destination while the CEV has control authority.	Analysis - IVPA	
TBD-002-220	CV0797	3.3.4	The CEV shall induce upon the crew sustained rotational accelerations of no greater than (TBD-002-220) degrees/s2 while the CEV has control authority.	Analysis - IVPA	
TBD-002-221	CV0798	3.3.4	The CEV shall induce upon the crew transient rotational accelerations of no greater than (TBD-002-221) degrees/s2 while the CEV has control authority.	Analysis - IVPA	
TBD-002-222	CV0799	3.3.4	The CEV shall induce upon the crew yaw, pitch, or roll rates of no greater than (TBD-002-222) from launch to mission destination while the CEV has control authority.	Analysis - IVPA	
TBD-002-227	CV0804	3.3.4	The CEV shall limit vibration to the crew in any axis to less than (TBD-002-227) g rms integrated from 0.0167 to 80 Hz over any one-minute interval during dynamic phases of flight.	Analysis - IVPA	
TBD-002-231	CV0122	3.2.11.4	Rationale: The CEV must be able to perform a backout during proximity operations & docking with the LSAM and with the ISS. For the ISS this would be within the (TBD-002-031) backout trajectory observing keep out zones as defined in the ISS-CEV IRD. There are a number of conditions under which this maneuver would be needed such as exceeding predefined limits and flight rules, exceeding the specified		

TBD Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
			approach and departure corridors, and loss of communication specifically for the ISS pressurized cargo CEV. Note that a backout does not necessarily lead to a mission abort and may be part of contingency operations procedures within the scope of an otherwise nominal mission. (CA0059 and CA0081)		
TBD-002-232	CV0173	3.2.8.7	The CEV shall record flight data essential for accident investigation during ascent and entry onto non-volatile memory that meets (TBD-002-232) hardening.	Analysis - Avionics/Flt SW	
TBD-002-233	CV0493	3.2.14	The CEV shall provide a CEV-to-transfer vestibule differential pressure of 0.1 psi within 5 minutes of the command to equalize pressure for a vestibule of (TBD-002-233) cubic feet.	Analysis	
TBD-002-234	CV0768	3.2.4	The CEV shall provide a contiguous volume of at least (TBR-002-207) 0.57 m3 (20 ft3) with (TBD-002-234)m per side for delivery of un-pressurized cargo to support the Lunar DRM.		
TBD-002-235	CV0791	3.2.11.4	Rationale: The CEV must be able to perform a breakout during proximity operations & docking with the LSAM and with the ISS. For the ISS this would be within the (TBD-002-235) breakout trajectory observing keep out zones as defined in the ISS-CEV IRD. There are a number of conditions under which this maneuver would be needed such as exceeding predefined limits and flight rules, exceeding the specified approach and departure corridors, and loss of communication specifically for the ISS pressurized cargo CEV. Note that a breakout		

TBD Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
			does not necessarily lead to a mission abort and may be part of contingency operations procedures within the scope of an otherwise nominal mission. (CA0059 and CA0081)		
TBD-002-236	CV0821	3.2.7	The CEV shall provide for control of ground safety hazards in accordance with document (TBD-002-236).	Analysis	
TBD-002-237	CV0834	3.2.10	Rationale: The crew needs to be able to communicate and coordinate activities with Constellation Systems and ISS both when suited and when in a shirt sleeve environment. Verification Requirement - This requirement will be verified by test and demonstration. A test will be performed where two (TBD-002-237) crew will speak over the audio system and RF Link to another Cx System ""RIG"" (TBD-002-240) and the voice quality, and other (TBD-002-238) performance metrics will be measured. A demonstration will be performed where 6 crew will speak over the audio system and show that communications between the 6 crew members and Mission Systems via CTN occurs without disruption or degradation. This requirement will be successfully verified when the test and demonstration described here are successfully performed. (CA0476)		
TBD-002-238	CV0834	3.2.10	Rationale: The crew needs to be able to communicate and coordinate activities with Constellation Systems and ISS both when suited and when in a shirt sleeve environment. Verification Requirement - This requirement will be verified by test and demonstration. A test will be performed where two (TBD-002-237) crew will speak		

TBD Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
			over the audio system and RF Link to another Cx System ""RIG"" (TBD-002-240) and the voice quality, and other (TBD-002-238) performance metrics will be measured. A demonstration will be performed where 6 crew will speak over the audio system and show that communications between the 6 crew members and Mission Systems via CTN occurs without disruption or degradation. This requirement will be successfully verified when the test and demonstration described here are successfully performed. (CA0476)		
TBD-002-239	CV0064	3.2.14	The CEV shall measure pressure within the mated vestibule volume within (TBD-002-030) pressure range and with (TBD-002-039) measurement accuracy when the CEV docking hatch is closed.	Analysis - Human Systems	
TBD-002-240	CV0834	3.2.10	Rationale: The crew needs to be able to communicate and coordinate activities with Constellation Systems and ISS both when suited and when in a shirt sleeve environment. Verification Requirement - This requirement will be verified by test and demonstration. A test will be performed where two (TBD-002-237) crew will speak over the audio system and RF Link to another Cx System ""RIG"" (TBD-002-240) and the voice quality, and other (TBD-002-238) performance metrics will be measured. A demonstration will be performed where 6 crew will speak over the audio system and show that communications between the 6 crew members and Mission Systems via CTN occurs without disruption or degradation. This requirement		

TBD Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
			will be successfully verified when the test and demonstration described here are successfully performed. (CA0476)		

APPENDIX C TBR MATRIX

Table 8 TBR Matrix

TBR Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
TBR-001-009	CV0623	3.2	The CEV shall operate in Lunar orbit to support a Lunar Outpost located within 1.0 degrees latitude of the lunar South Pole (TBR-001-009).	Analysis - Flight Dynamics/GNC	Lunar Outpost SRR
TBR-001-113	CV0793	3.2.14	The CEV shall maintain the cabin environment at a pressure per CA3105-PO to allow the crew time to don suits and complete connections to life support in 1 (TBR-001-113) hour.	Analysis - Human Systems	IDAC-3
TBR-001-518	CV0648	3.2.11.6	The CEV shall use a single, continuous (TBR-001-518) reference time scale traceable to Coordinated Universal Time (UTC) in accordance with CxP 70142, Constellation Program Navigation Standards Specification Document.	Analysis - Flight Dynamics/GNC	IDAC-3 MID TERM
TBR-002-013	CV0058	3.2.2.2.2.3	The CEV shall achieve 80% (TBR-002-231) of required LAS thrust within 300 milliseconds (TBR-002-013) of CEV onboard abort command initiation, where the time measurement is taken from the time the initiated command has been received by the CEV.	Analysis - LAS	ODAC-1 TDS
TBR-002-017	CV0015	3.2.2	The CEV nominal cabin pressure regulation, temperature regulation, and a breathable atmosphere source for the crew shall be operational within one (TBR-002-017) minute of initiation of CEV life support system start up command in the case of an emergency requiring ISS evacuation to CEV.	Analysis - Human Systems	ODAC-1 TDS
TBR-	CV0086	3.2.11.10	The CEV shall perform skip	Analysis - Flight	ODAC-1

TBR Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
002-023			entry into the Earth's atmosphere of up to 5,750 <TBR-002-023> nmi (10,650 km) from the entry interface from lunar mission trajectories.	Dynamics/GNC	TDS
TBR-002-036	CV0448	3.2.2	The CEV shall provide hydration, breathable atmosphere, power, communication and thermal control for the suited crew in an unpressurized environment state for not less than 120 hours (TBR-002-036).	Analysis - IVPA	ODAC-1 TDS update if needed
TBR-002-056	CV0126	3.2.11.4	The CEV shall perform proximity operations and docking with LSAM when it is in any inertial attitude with inertial rate less than 0.4 (TBR-002-056) deg/sec per axis.	Analysis - Flight Dynamics/GNC	
TBR-002-159	CV0129	3.2.11.4	The CEV shall perform any-attitude undocking with a mated vehicle inertial attitude rate up to 2 deg/s (TBR-002-159).	Analysis - Flight Dynamics/GNC	
TBR-002-205	CV0764	3.2.4.2	The CEV shall deliver an unpressurized cargo mass of at least 590 <TBR-002-205> kg (1,300 lbs) (gross) to the ISS.	Analysis - Service Module	
TBR-002-206	CV0766	3.2.4	The CEV shall deliver an unpressurized cargo mass of at least 413kg (909 lbm (gross) (TBR-002-206) to support the Lunar DRM.	Analysis - Service Module	
TBR-002-207	CV0768	3.2.4	The CEV shall provide a contiguous volume of at least (TBR-002-207) 0.57 m3 (20 ft3) with (TBD-002-234)m per side for delivery of un-pressurized cargo to support the Lunar DRM.	Analysis - Service Module	
TBR-002-209	CV0629	3.2.10.1.3	The CEV shall provide an onboard network Packet Loss Rate of less than 10-6 (TBR-002-209) given 1500 byte packets.	Analysis - Flight Dynamics/GNC	IDAC-3 / ODAC-1 TDS
TBR-002-210	CV0117	3.2.11.6.1	The CEV shall determine the attitude and attitude rate of the	Analysis - Flight Dynamics/GNC	

TBR Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
			CEV relative to the target vehicle during PODU operations, when the CEV is the maneuvering vehicle within 100 feet (TBR-002-210) of the target vehicle.		
TBR-002-210	CV0839	3.2.11	The CEV shall determine the attitude and attitude rate of the CEV relative to the LSAM during LLO PODU operations, when the CEV is the maneuvering vehicle within 150 feet (TBR-002-210) of the target vehicle.	Analysis - Flight Dynamics/GNC	
TBR-002-211	CV0761	3.2.11.12	The CEV shall provide at least 0.1 <TBR-002-211> ft/sec delta-V for separation of the CM and SM without the use of SM RCS.	Analysis - Flight Dynamics/GNC	
TBR-002-216	CV0794	3.2.14	The CEV shall maintain the cabin environment at a pressure per CA3106-PO, with a temporary contingency suit pressure of 8 <TBR-002-216> psid positive for up to <TBD-002-217> minutes.	Analysis - Human Systems	
TBR-002-231	CV0058	3.2.2.2.2.3	The CEV shall achieve 80% (TBR-002-231) of required LAS thrust within 300 milliseconds (TBR-002-013) of CEV onboard abort command initiation, where the time measurement is taken from the time the initiated command has been received by the CEV.	Analysis - LAS	
TBR-002-232	CV0612	3.2.8.5	The CEV shall have crew, Constellation Systems, and ISS initiated command latency no greater than 200ms (TBR-002-232) while processing commands, where the performance measurement is taken from the time the initiated command has been received by the CEV, to the time the command has been received by the target sub-system.	Analysis - Avionics/Flt SW	IDAC-3 / ODAC-1 TDS
TBR-	CV0739	3.2.8.5	The CEV shall have a latency	Analysis - Avionics/Flt	

TBR Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
002-233			no greater than 1 <TBR-002-233> second while processing data destined for telemetry, where the performance measurement is taken from the time of subsystem data read to the time of data transmission from the CEV.	SW	
TBR-002-234	CV0740	3.2.8.5	The CEV shall have a latency no greater than 1 <TBR-002-234> second while processing data destined for crew display, where the performance measurement is taken from the time of subsystem data read to the time data is presented to the crew.	Analysis - Avionics/Flt SW	
TBR-002-235	CV0362	3.2.10.2.5	The CEV shall provide spherical coverage for the different mission phases and links, excluding non-CEV structural blockage and re-entry plasma as given in Table 4 (TBR-002-235).	Analysis - Avionics/Flt SW	
TBR-002-245	CV0303	3.2.6	The CEV crew module maximum design pressure (MDP) shall be 15.8 (TBR-002-245) psid.	Analysis	
TBR-002-247	CV0711	3.2.2.2.2.3	The CEV shall provide sufficient range and altitude performance during pad and low altitude aborts to achieve a water landing, with full Landing and Recovery System (LRS) deployment and functionality, for 95% (TBR-002-247) of the pad abort wind cases as defined in DSNE section (TBD-002-204) and thermal radiation environments as defined in the TBD, such that CEV landing ensures no greater than low risk of crew injury as defined by HSIR section 3.2.4.2.	Analysis - LAS	
TBR-002-249	CV0802	3.3.4	The CEV spacecraft shall limit impulse noise at the crewmember's head position to less than 150 dB (TBR-002-249) peak overall SPL, during	Analysis - Human Systems	

TBR Number	Req Number	Document Para. #	Description	Requirement Owner / Closure Method	Resolution Date
			launch and entry phases including ascent abort.		
TBR-002-250	CV0817	3.4	CEV shall provide post landing services, including power, resources and consumables for active cooling, air revitalization, fire detection, communication, lighting and critical avionics for at least 15 minutes (TBR-002-250) after landing.	Analysis	
TBR-002-251	CV0823	3.2.11	The CEV shall perform a second LSAM docking attempt within 2 orbits (TBR-002-251) after a first docking attempt is terminated for a lunar mission in LEO.	Analysis	
TBR-002-256	CV0853	3.2.6.2	The CEV shall provide a minimum translational delta-V tank size of 5293 (TBR-002-256) ft/s.	Analysis	
TBR-002-257	CV0857	3.2.2.2.1	The CEV shall provide a primary crew ingress/egress hatch with an emergency operations mode that will open the hatch within 5 seconds of initiation of the emergency mode during all ground operations at 30 psig (TBR-002-257).		
TBR-002-258	CV0854	3.2.10.4	The CEV shall record motion imagery and associated audio sources for a combined total record time of 8 (TBR-002-258) hours minimum.		

APPENDIX D REQUIREMENTS TRACEABILITY MATRIX (RTM)

The first table in this appendix, shown below, outlines the traceability from each of the child requirements (shown in the left-hand column) to their respective parent requirements (shown in the right-hand column).

The second table in this appendix, shown below, outlines the traceability from each of the parent requirements (shown in the left-hand column) down to their respective child requirements (shown in the right-hand column).

Table 9 Requirement Traceability Matrix (RTM)

Child Requirement	Parent Requirement
CV0001	CA0091-PO
CV0008	CA0325-PO
CV0010	CA0892-HQ
CV0011	CA5312-PO
CV0012	CA0060-HQ
CV0015	CA0493-PO
CV0023	CA0178-PO
CV0031	CA0335-PO
CV0032	CA0547-PO
CV0043	Derived project requirement
CV0045	CA0449-PO
CV0048	CA5921-PO
CV0052	CA5439-PO
CV0053	CA5439-PO
CV0058	Derived project requirement
CV0061	CA5439-PO
CV0064	CA0886-PO
CV0068	CA0886-PO
CV0071	CA0497-PO
CV0075	CA3168-PO
CV0077	CA3166-PO
CV0083	CA0325-PO
CV0084	CA0288-PO
CV0085	CA0388-HQ
CV0086	CA0325-PO
CV0095	CA0325-PO
CV0097	Derived project requirement
CV0098	CA0893-PO
CV0108	CA0416-PO
CV0110	CA0325-PO
CV0111	CA0333-PO
CV0112	CA0059-PO, CA0081-PO
CV0116	CV0112
CV0117	CV0112
CV0119	CA0325-PO
CV0120	CA0448-PO, CA0497-PO

Child Requirement	Parent Requirement
CV0122	CA0059-PO, CA0081-PO
CV0126	CA0369-PO
CV0127	CA0081-PO
CV0129	CA0462-PO
CV0138	CA5820-PO
CV0139	CA0438-PO
CV0142	CA0435-PO
CV0143	CV0552
CV0145	CV0552
CV0148	CA3110-PO
CV0150	CA3110-PO
CV0152	CA5901-PO
CV0153	CA0428-PO
CV0154	CA0428-PO
CV0156	CA0427-PO
CV0158	CA0438-PO
CV0159	CA5465-PO
CV0160	CA5466-PO
CV0164	Derived project requirement
CV0167	CV0646
CV0168	CV0646
CV0169	CV0646
CV0170	CA0993-PO
CV0171	CA0993-PO
CV0172	CA0428-PO
CV0173	CA0511-PO
CV0176	CA5820-PO
CV0178	CV0752
CV0179	Derived project requirement
CV0180	CA0344-PO
CV0181	CA0344-PO
CV0192	CV0811
CV0193	Derived project requirement
CV0204	CA0428-PO
CV0247	CA0374-PO
CV0248	CA0374-PO
CV0255	CA3237-PO
CV0256	Derived project requirement
CV0257	Derived project requirement
CV0259	Derived project requirement
CV0268	CV0814
CV0303	Derived project requirement
CV0307	CA3004-PO
CV0315	CV0001, CA0011-HQ
CV0362	CA0296-HQ
CV0364	CV0646
CV0366	CV0646
CV0368	CV0646
CV0373	CV0646
CV0374	CV0646

Child Requirement	**Parent Requirement**
CV0448	CA0532-PO
CV0450	CA5286-PO
CV0453	Derived project requirement
CV0463	CA0344-PO
CV0477	CA0333-PO
CV0479	CV0814
CV0480	CV0814
CV0483	CV0001, CV0011
CV0490	CA3287-PO
CV0493	CA0886-PO
CV0532	CA0325-PO
CV0534	Derived project requirement
CV0535	CA5439-PO
CV0536	CA0993-PO
CV0539	CA0428-PO
CV0540	CA0325-PO
CV0541	CA0438-PO
CV0544	CA3110-PO
CV0545	CA0288-PO
CV0548	CV0645
CV0549	CA0428-PO
CV0550	CA0993-PO
CV0552	Derived project requirement
CV0553	CA0428-PO
CV0554	CA0428-PO
CV0555	CA0427-PO
CV0556	CA0134-PO
CV0557	CA5466-PO
CV0558	Derived project requirement
CV0560	CA0134-PO
CV0561	Derived project requirement
CV0562	Derived project requirement
CV0563	Derived project requirement
CV0564	Derived project requirement
CV0565	Derived project requirement
CV0569	CA3255-PO
CV0570	Derived project requirement
CV0571	CA0134-PO
CV0572	CA3255-PO
CV0575	CA0437-PO
CV0576	CA0428-PO
CV0580	CA0438-PO
CV0587	CA0329-PO
CV0588	CA0329-PO
CV0589	CA0497-PO
CV0590	CA0497-PO
CV0591	CA0497-PO
CV0594	CA0131-PO
CV0595	CA0131-PO
CV0597	CA0325-PO

Child Requirement	**Parent Requirement**
CV0599	CA0044-PO, CA0325-PO
CV0601	CA0325-PO, CA0388-HQ
CV0612	Derived project requirement
CV0615	Derived project requirement
CV0616	CA5901-PO
CV0617	CA3110-PO
CV0618	Derived project requirement
CV0619	Derived project requirement
CV0622	CA0013-HQ
CV0623	CA0014-HQ
CV0627	CA3007-PO
CV0629	CA3043-PO
CV0630	CA3051-PO
CV0631	CA5820-PO
CV0632	CA0125-PO
CV0633	CA0125-PO
CV0640	CA3005-PO
CV0641	CA3187-PO
CV0642	CA3193-PO
CV0643	CA3222-PO
CV0645	CA0042-PO
CV0646	CA3021-PO, CA5800-PO
CV0647	CA3167-PO
CV0648	CA5618-PO
CV0649	CA5680-PO
CV0650	CA4111-PO
CV0652	CA0449-PO
CV0653	CA0449-PO
CV0654	CA0333-PO
CV0659	CA3166-PO
CV0660	CA3110-PO
CV0661	CA0554-PO
CV0672	CA3166-PO
CV0673	CA3166-PO
CV0674	CA3166-PO
CV0677	CA0325-PO
CV0688	Derived project requirement
CV0689	Derived project requirement
CV0711	CA0333-PO
CV0712	CA0333-PO
CV0713	CA0325-PO
CV0715	CA3138-PO
CV0716	CA3138-PO
CV0717	CA3138-PO
CV0718	CA3138-PO
CV0720	Derived project requirement
CV0721	CV0720
CV0722	CV0720
CV0723	CA5935-PO
CV0727	CV0645

Child Requirement	Parent Requirement
CV0735	CA0333-PO
CV0736	CA0437-PO
CV0737	CV0552
CV0738	CA3255-PO
CV0739	Derived project requirement
CV0740	Derived project requirement
CV0741	CA5039-PO
CV0743	CA3110-PO
CV0747	CA3110-PO
CV0749	CA0383-PO
CV0750	CA0296-HQ
CV0751	CV0646
CV0752	CA5817-PO
CV0754	CA0274-PO, CA0325-PO
CV0755	CA0274-PO, CA0448-PO
CV0756	CA0274-PO
CV0757	CA0274-PO
CV0758	CA0274-PO
CV0760	CA0274-PO
CV0761	CA0274-PO
CV0762	CAxxxDD-PO
CV0763	CAxxxAD-PO
CV0764	CAxxxBD-PO
CV0765	Derived project requirement
CV0766	CAxxxCD-PO
CV0768	No parent
CV0769	CA0036-HQ
CV0770	CA0037-PO
CV0771	CA0071-PO
CV0772	CA0100-HQ
CV0773	CA0314-PO
CV0775	CA0569-PO
CV0776	CA5495-PO
CV0778	CA5814-PO
CV0779	CA5815-PO
CV0782	CA5915-PO
CV0784	CA0344-PO
CV0785	CA0344-PO
CV0786	CA0344-PO
CV0787	CA0344-PO
CV0788	CA0344-PO
CV0789	CA0344-PO
CV0790	CA0344-PO
CV0791	CA0059-PO, CA0081-PO
CV0792	CA5602-PO
CV0793	CA3105-PO
CV0794	CA3106-PO
CV0795	CV0645
CV0796	CV0645
CV0797	CV0645

Child Requirement	Parent Requirement
CV0798	CV0645
CV0799	CV0645
CV0802	CV0645
CV0804	CV0645
CV0805	CV0645
CV0806	CV0645
CV0807	CV0645
CV0809	CV0645
CV0810	CV0645
CV0811	Derived project requirement
CV0812	CA0021-PO
CV0813	CA0427-PO
CV0814	CA0077-HQ
CV0815	No parent
CV0816	No parent
CV0817	CA0893-PO
CV0818	No parent
CV0819	CA0416-PO
CV0820	No parent
CV0821	No parent
CV0822	No parent
CV0823	No parent
CV0824	CA5904-PO
CV0829	No parent
CV0830	CA0194-PO
CV0831	CA0217-PO
CV0832	No parent
CV0833	No parent
CV0834	CA0476-PO
CV0835	CA5710-PO
CV0836	No parent
CV0837	CA5439-PO
CV0838	CA5439-PO
CV0839	No parent
CV0841	No parent
CV0842	No parent
CV0843	No parent
CV0844	CA5466-PO
CV0845	CA0140-PO
CV0846	No parent
CV0847	Derived project requirement
CV0848	Derived project requirement
CV0849	No parent
CV0850	No parent
CV0851	No parent
CV0853	CA0829-PO
CV0854	No parent
CV0855	No parent
CV0856	No parent
CV0857	CA0334-PO

Child Requirement	Parent Requirement
CV0858	CV0814

APPENDIX E VERIFICATION CROSS REFERENCE MATRIX (VCRM)

Table 10 Verification Cross Reference Matrix (VCRM)

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
3.2	CA0056-PO	The CEV shall return the crew and cargo from Lunar Rendezvous Orbit (LRO) to the Earth surface.	Analysis	The requirement for the CEV to return crew and cargo from the LRO to the Earth surface for crewed lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-397) probability with a confidence of 90% (TBR-001-xxx) that the CEV vehicle can successfully return the crew and cargo from LRO to the Earth surface for crewed lunar missions.
3.2	CA0091-PO	The CEV shall deliver the crew from the Earth surface to the Lunar Destination Orbit (LDO) for crewed lunar missions.	Analysis	The requirement for the CEV to deliver crew and cargo from the Earth surface to the Lunar Destination Orbit (LDO) for lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-397) probability that the CEV vehicle can successfully deliver crew and cargo from the Earth surface to the Lunar Destination Orbit (LDO) for lunar missions.

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
3.2	CV0001	The CEV shall transport crews of 2, 3, and 4 crew members from Earth to Lunar Destination Orbit and from Lunar Destination Orbit to Earth in accordance with the capabilities listed in Table 1, Total Lunar DRM Crew, Destination Cargo, and Equipment Definition.	Analysis, Inspection	The capability of the CEV to accommodate the specified crew, cargo, and equipment shall be verified by analysis and inspection. The verification shall be considered successful when a) the vehicle structural loads analysis incorporates a case with the maximum crew, cargo, and equipment mass identified in Table 1 and b) inspection of crew module drawings identifies stowage volumes for the maximum crew, cargo, and equipment volumes listed in Table 1.
3.2	CA5312-PO	The CEV shall deliver the crew and pressurized cargo from the Earth surface to the ISS.	Inspection	The ability of the CEV to deliver the crew and pressurized cargo from the Earth surface to ISS shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include earth orbit, entry, and landing capabilities. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-375) probability that the CEV can deliver the crew and pressurized cargo from the Earth surface to the ISS and meet the RPOD requirements of the CEV/ISS IRD.
3.2	CV0011	The CEV shall be configurable to deliver crewmembers and pressurized cargo from Earth to ISS and from ISS to Earth in accordance with the capabilities listed in Table 2, Total ISS DRM Crew, Destination Cargo, and Equipment Definition.	Analysis, Inspection	Verification shall be by Analysis and Inspection. The capability of the CEV to accommodate the specified crew, cargo, and equipment shall be determined by a loads analysis and inspection of engineering drawings showing stowage volumes. The verification shall be considered successful when a) the vehicle structural loads analysis incorporates a case with the maximum crew, cargo, and equipment mass identified in Table 2 and b) inspection of the crew module drawings identifies stowage volumes for the maximum crew, cargo, and equipment volumes listed in Table 2.
3.2	CV0622	The CEV shall operate in lunar orbit to support Lunar Sortie missions to any designated location on the lunar surface.	Analysis	Verification shall be by analysis. An analysis of engineering documentation shall show that the CEV has the capability to perform lunar sortie missions to any location on the surface

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				of the moon. Verification shall be considered successful when the analysis shows that the CEV can perform a lunar sortie mission anywhere on the moon's surface.
3.2	CV0623	The CEV shall operate in Lunar orbit to support a Lunar Outpost located within 1.0 degrees latitude of the lunar South Pole (TBR-001-009).	Analysis	Verification shall be by analysis. An analysis of engineering documentation shall show that the CEV has the capability to support a Lunar Outpost within 5 degrees of Lunar South Pole. Verification shall be considered successful when the analysis shows that the CEV can support a Lunar Outpost within 5 degrees of Lunar South Pole.
3.2	CA3203-PO	The CEV shall return the crew and pressurized cargo from the ISS to the Earth surface.	Analysis	The ability of the CEV to return the crew and pressurized cargo from ISS to Earth surface shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include earth orbit, entry, and landing capabilities. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-375) probability with a 90% confidence that the CEV can return the crew and pressurized cargo from ISS to the Earth surface.
3.2.1	CA0088-PO	The CEV shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Sortie mission to no greater than 1 in 50 (TBR-001-058).	Analysis	Lunar Sortie LOM due to the CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows (a (TBD-001-1012) probability) that LOM for a Lunar Sortie mission due to the CEV is no greater than 1 in 50 (TBR-001-058).
3.2.1	CA3023-PO	The CEV shall limit their contribution to the risk of loss of mission (LOM) for a Lunar Outpost Crew mission to no greater than 1 in (TBD-001-515).	Analysis	Lunar Outpost Crew LOM due to the CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows a (TBD-001-932) probability that LOM for a Lunar Outpost Crew mission

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				due to CEV is not greater than 1 in (TBD-001-515).
3.2.1	CA0399-PO	The CEV shall limit their contribution to the risk of loss of mission (LOM) for an ISS Crewed mission to no greater than 1 in 250 (TBR-001-056).	Analysis	ISS Crew LOM due to the CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70087, Constellation Program Reliability and Maintainability (R&M) Plan. Verification shall be successful when the analysis shows (a TBR-001-956 probability) that LOM for an ISS Crew mission due to the CEV is no greater than 1 in 250 (TBR-001-056).
3.2.1	CA3022-PO	The CEV shall limit their contribution to the risk of loss of mission (LOM) for an ISS Cargo mission to no greater than 1 in (TBD-001-513).	Analysis	ISS Cargo Mission LOM due to the CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows (a TBD-001-931 probability) that LOM for an ISS Cargo Mission due to the CEV is no greater than 1 in (TBD-001-513).
3.2.2	CV0097	The CEV shall provide safing of systems that pose hazards to flight and ground recovery crews within 5 minutes upon landing.	Test	Verification shall be by test. A test on a demonstration unit shall be performed that will include CEV performing a landing, where a the automatic safing of the vehicle will take place within 5 minutes of landing. Verification will be considered successful when CEV has perform an as planned, landing and an inspection has been performed on the vehicle following the landing to insure the return of the CEV, and initiation of safing protocols within the 5 min. timeframe.
3.2.2	CA4154-PO	The CEV shall perform the functions necessary to return the crew to the surface of the Earth in at least 120 (TBR-001-980) hours with an unpressurized cabin.	Analysis	The ability of the CEV to return the crew to Earth with an unpressurized cabin for at least 120 (TBR-001-1006) hours shall be verified by analysis. The analysis shall consist of a review of documentation that the CEV System can provide those critical functions necessary to return the CEV and crew back to Earth while the CEV habitable volume is depressurized. The verification shall be considered successful when the analysis confirms the functions can be performed simultaneously when the vehicle is depressurized

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				for at least 120 (TBR-001-980) hours.
3.2.2	CA0274-PO	The CEV shall provide an Emergency Entry mode that is available from the command of SM separation through Earth landing.	Analysis	The CEV Emergency Entry mode capabilities shall be verified by Analysis. The analysis shall review the performance of the CEV software and hardware intended to support the entry and landing of an earth returning crew in an Emergency Entry mode situation. The analysis shall be considered successful when it shows a probability of 99.73% (TBR-001-308) with a 90% confidence that the relevant software and hardware can successfully achieve a survivable entry and landing for predicted emergency entry modes when applying at least a minimum emergency design margin on subsystems.
3.2.2	CA0984-PO	The CEV shall assure crew survival during landing touchdown in wind and sea state conditions as defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18, for all water landings.	Analysis, Test	The crew survival during landing touchdown shall be verified by test and analysis. The test shall verify that the CEV can withstand the loads associated with landing impact, considering the wind speed, trajectory, and sea conditions. The test shall include instrumentation of the internal CEV elements, including physical crew interfaces. The analysis will combine the lower level test data and other vehicle performance measures to verify the loads transmitted through the vehicle and the essential crew systems such as ECLSS shall remain functioning after landing touchdown. The analysis shall verify that the loads within the CxP 70024, Constellation Human-Systems Integration Requirements (HSIR) are not exceeded. The verification shall be considered successful when the test and analyses demonstrate the CEV shall assure crew survival during landing touchdown in the wind and sea states as specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), 3.5.18 and 3.6.18.
3.2.2	CA0194-PO	The CEV shall provide for crew survival, without permanent crew disability, for at least 36 (TBR-001-045) hours with the hatch closed following a landing in the	Analysis	The CEV crew survival following a landing on water shall be verified by analysis. The analysis shall assess that the CEV design for power, ventilation, and thermal conditioning provides a physical

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
		water.		environment that does not lead to crew loss or permanent disability of suited crew, as specified in CxP 70024, Constellation Human-Systems Integration Requirements (HSIR), for up to 36 hours with the hatch closed following a landing on water, considering relevant contingency and environmental conditions as specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Section 3.5.19. The analysis shall audit the CEV provision of food, potable water, waste management, and emergency supplies for up to 36 hours with the hatch closed following a landing on water. The verification shall be considered successful when the analysis shows the CEV provides for suited crew survival, without permanent disability, for up to 36 hours with the hatch closed following a landing on water.
3.2.2	CV0830	The CEV shall provide for crew survival, without permanent crew disability, for at least 36 hours with the hatch closed in sea state conditions defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Section 3.5.19, following a landing in the water.	Analysis	Verification shall be by Analysis. The analysis will use engineering released drawings, habitable design documents, and validated models to determine that the CEV has the infrastructure to support 36 hours of post landing operations in the water. This will include but not be limited to appropriate EPS, ECLSS, TCS, C&T, and C&DH systems. The verification shall be considered successful when analysis shows that the CEV has the infrastructure and resourses to provide post landing operations for 36 hours without affecting nominal operations of the CEV.
3.2.2	CA0983-PO	The CEV shall maintain structural integrity and float for a minimum of 36 hours in the wind and sea state conditions defined in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18, following a water landing.	Analysis	The CEV structural integrity and ability to float shall be verified by analysis. The analysis shall indicate the CEV floats and maintains structural integrity after landing on water and exposed to the full range of wind and sea states specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18. The analysis shall show that the CEV floats and

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				maintains structural integrity for a minimum of 36 hours and shall also indicate any time beyond the 36 hour minimum in which the CEV meets these criteria to establish the maximum floatation duration. The verification shall be considered successful when the analyses indicate that the design precludes structural compromise and floats for a minimum of 36 hours while exposed to the full range of wind and sea states specified in CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.5.18 and 3.6.18.
3.2.2	CA3259-PO	The CEV shall provide visual aids for search and recovery independent of ambient lighting conditions per standard (TBD-001-568).	Inspection	CEV visual aids for contingency landings shall be verified by inspection. The inspection shall consist of review of allocated requirements from CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element. The verification shall be considered successful when the inspection determines that the CEV System complies with (TBD-001-568) Standard for SAR visual aids.
3.2.2	CA0532-PO	The CEV shall sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 120 (TBR-001-1006) hours.	Analysis	The ability of the CEV to sustain life of the suited crew without permanent disability in an unpressurized cabin for at least 120 (TBR-001-1006) hours shall be verified by analysis. The analysis shall consist of documentation that the CEV System can provide the following simultaneous functions while the CEV habitable volume is depressurized: - Breathing gas quantity, flowrates, and scrubbing to the suited crew for 120 (TBR-001-1006) hours to meet medical standards as defined per CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section 3.2.1 Natural and Induced Envrionments, Atmosphere and Section 3.5.4.3 Environmental Loads, and in accordance with suit pressure defined in CA5659. - Thermal conditioning to the suited crew for 120 (TBR-001-1006) hours to meet medical standards as defined in CxP

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section 3.2.3 Thermal Environment and 3.5.4.3 Environmental Loads. - Power to the suited crew for 120 (TBR-001-1006) hours per CxP 70033, Constellation Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document. - Nutritional, medical, and hydration needs to the suited crew for 120 (TBR-001-1006) hours to meet medical standards as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR). - Communication (voice, suit and biomed data) with the suited crew for 120 (TBR-001-1006) hours as defined in CxP 70033, Constellation Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document. - Seat ingress and harness securing with a pressurized suited crewmember and ability to readjust harness upon re-entry when suit becomes unpressurized. - Ability for interfacing CEV systems to operate and remove ammonia/body contaminates in return breathing gas for 120 (TBR-001-1006) hours. The verification shall be considered successful when the analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized for 120 (TBR-001-1006) hours.
3.2.2	CV0448	The CEV shall provide hydration, breathable atmosphere, power, communication and thermal control for the suited crew in an unpressurized environment state for not less than 120 hours (TBR-002-036).	Analysis, Test	Verification shall be by analysis and test. An analysis of CEV hardware and software systems shall be performed to ensure that CEV ECLSS systems can support suited crew for 120 hours in an unpressurized environment. Verification shall be successful when the analysis shows the CEV has the suit infrastructure resources to provide 120 hours of crew life support in an unpressurized cabin environment. A test requiring CEV suits and a cabin like, unpressurized environment will be able to provide the life support

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				resources to support crew life for at least 120 hours. Test results shall provide data and robustness to analysis models to better ensure mission success. Verification shall be successful when results show CEV infrastructure can provide life support to suited crew in an unpressurized environment for at least 120 hours.
3.2.2	CA3108-PO	The CEV shall provide suit stowage such that a suit can be accessed within 2 (TBR-001-157) minutes per crew member for donning.	Analysis, Demonstration	The ability of the CEV to provide suit stowage such that a suit can be accessed within 2 (TBR-001-157) minutes per crew member for donning shall be verified by demonstration and analysis. The demonstration shall consist of 1-g suit donning evaluations using flight or training quality suits in a representative CEV volume mockup, with the suits stowed in the designated CEV stowage location, performed by two different sets of crewmembers (six crewmembers per set) with two runs performed by each set, and collection of task time for suit retrieval, donning, pressurization, and any other tasks required by the crew to complete the suit donning and pressurization process. The analysis shall consist of examination of task time collected during the 1-g demonstration, applying a program approved in-space extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments. The verification will be considered successful when the analysis determines that each suit can be retrieved from stowage within 2 (TBR-001-157) minutes.
3.2.2	CA3138-PO	The CEV shall provide fire detection and suppression for the CEV pressurized volume.	Analysis, Inspection, Test	The fire detection and suppression for the pressurized volume shall be verified by analysis, supported by inspection and test. The analysis shall show that the CEV detects events indicating fire and limits propagation of a fire in the pressurized volume of the CEV. The analysis shall utilize results from CEV children requirements compliance with CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element fire detection and

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				suppression criteria. An inspection of drawings shall be performed to verify that the fire detection and suppression hardware has been installed in the pressurized volume of the CEV. A test of a simulated smoke alarm and vehicle response shall show that an impending fire in the cabin or avionics bay can be detected, suppressed, and the atmosphere restored. The verification shall be considered successful when the analysis, inspection, and test show that a fire in the pressurized volume of the CEV can be detected and suppressed before it can propagate.
3.2.2	CV0715	For electrical and electro-mechanical equipment volumes containing an ignition source and no forced air flow, the CEV shall provide a fire containment enclosure or detect, isolate and report all failure modes for these volumes that may cause potential fire events within these volumes.	Analysis	Verification shall be by Analysis. The Analysis shall be performed using engineering drawings, schematics, and safety data (FMEA's) of the Fire Detection system to show that these volumes can be isolated and safed in the event of a fire. Verification shall be considered successful when the analysis proves the all cases can be safed in the event of a fire.
3.2.2	CV0716	The CEV shall provide fire detection and suppression in all crew module volumes inside the crew cabin that contain both a potential ignition source and forced air flow.	Analysis	Verification shall be by Analysis. The Analysis shall be performed using engineering drawings, schematics, and safety data (FMEA's) of the Fire Detection system and the Fire suppression hardware (i.e.- fire extinguishers) to show that these volumes can be isolated and safed in the event of a fire. Verification shall be considered successful when the Fire Detection system and Fire suppression hardware analysis proves the all cases can be safed in the event of a fire.
3.2.2	CV0717	For enclosed bays containing an ignition source and no forced air flow, the CEV shall provide a means of fire suppression within the bay OR all exposed components located within the bay shall be composed of materials that comply with NASA-STD-6016 materials flammability requirements at an	Analysis, Test	Verification shall be by Test and Analysis. The Analysis shall be performed using engineering drawings to show that all materials contained within these volumes comply with NASA-STD-6001 materials flammability requirements at 40% (TBR-002-202) O2 concentration. Testing shall be performed on materials to show compliance with NASA-STD-6001. Verification shall be considered successful when the Testing and Analysis prove that all materials

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		atmospheric oxygen concentration that is 10% higher than the maximum O2 concentration expected within the bay during nominal operations.		contained within these volumes comply with NASA-STD-6001 materials flammability requirements at 40% (TBR-002-202) O2 concentration.
3.2.2	CA0493-PO	The CEV shall provide a habitable environment for the assigned crew for a single event of at least 2 (TBR-001-002) hours in duration while the CEV is still docked to and isolated from the ISS.	Analysis	The CEV habitable environment during an ISS isolation event shall be verified by analysis. The analysis shall assess that the CEV design for power, thermal, atmosphere, and waste management ensures a habitable environment, as specified in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), for the assigned crew for 2 hours while the CEV is still docked to the ISS, but the crew is isolated from the ISS. The analysis shall audit the CEV provision of food, water, and emergency supplies for the assigned crew for 2 hours while the crew is isolated from the ISS. The verification shall be considered successful when the analysis shows the CEV provides a habitable environment for the assigned crew for a single event of at least 2 hours in duration while the CEV is still docked to the ISS, but the crew is isolated from the ISS.
3.2.2	CV0015	The CEV nominal cabin pressure regulation, temperature regulation, and a breathable atmosphere source for the crew shall be operational within one (TBR-002-017) minute of initiation of CEV life support system start up command in the case of an emergency requiring ISS evacuation to CEV.	Demonstration, Test	The requirement shall be verified by a functional test of the life support and associated subsystems in an actual or qual CEV with activation procedures demonstrated by human operators. The verification shall be considered successful when the CEV is shown to provide a habitable environment within the time limit during the test and demonstration. Risk can be reduced by preliminary subsystem testing, demonstration in a mockup and inspection of CEV system drawings and operating procedures. Reference section TBD in the HSIR for specific criteria for what a habitable environment constitutes.
3.2.2	CA0325-PO	The CEV shall provide for Earth landing throughout each mission phase.	Analysis	The capability to provide Earth landing throughout all mission phases shall be verified by analysis using a NASA-

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				accredited digital orbital and entry simulation. Analysis will cover abort and early return from any point along LEO and Lunar DRM's, and will include performance from SM separation to landing. Verification shall be considered successful when analysis of all scenarios with system and environmental dispersions shows a 99.73% (TBR-001-309) probability with a 90% confidence of achieving a survivable Earth landing within appropriate abort targeting constraints.
3.2.2	CV0095	The CEV shall be self-righting for water landing for at least 36 hours.	Analysis, Test	Verification shall be by analysis, and testing. The combination of analysis and testing shall examine the ability of an overturned CEV to upright itself when in water and once upright, maintain the vehicle in an upright position. Verification shall be considered successful when the combination of analysis and test indicates that the CEV can CEV can successfully upright itself when in water and once upright, maintain the vehicle in an upright position for at least 36 hours.
3.2.2	CV0713	The CEV shall perform water landing.	Analysis, Test	The capability of the CEV to perform a water landing shall be verified by analysis. [1] The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CM/SM and the CM as separate configurations in the trans-Earth, LEO, and entry environments. The analysis shall include both nominal and off-nominal returns from LEO and the moon. The analysis shall include both direct entry and skip entry trajectory conditions. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can successfully perform water landings following guided direct or skip entries. [2] The analysis shall be performed using a NASA-accredited,

Document Section	Requirement Number	Requirement Text	Verification Method	Verification Text
				6-DOF simulation (with primary and the emergency entry mode flight software installed) that models the dynamics of the CM/SM and the CM as separate configurations in the trans-Earth, LEO, and entry environments. The analysis shall include dispersions about the nominal trajectories from LEO and the moon. The analysis shall include both direct entry and skip entry trajectory conditions. The analysis shall include ballistic down-mode at various points along the entry trajectories starting just after SM separation. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analyses show that the CEV can successfully perform water landings following a direct or skip entry that resulted in a ballistic down-mode. [A successful guided direct or skip entry is defined as a trajectory that results in a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.] [A successful direct or skip entry that resulted in a ballistic down-mode is defined as a trajectory that results in a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.]
3.2.2.1	CA5913-PO	The CEV shall limit the risk of loss of crew (LOC) during a pad or ascent abort to no greater than 1 in (TBD-001-947).	Analysis	Ascent abort LOC shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows a (TBD-001-1000) probability that

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				LOC for an ISS Crew Mission is no greater than 1 in (TBD-001-947).
3.2.2.1	CA0501-PO	The CEV shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Sortie mission to no greater than 1 in 200 (TBR-001-057).	Analysis	Lunar Sortie LOC due to CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows (a (TBD-001-957) probability) that LOC for a Lunar Sortie due to the CEV is not greater than 1 in 200 (TBR-001-057).
3.2.2.1	CA3040-PO	The CEV shall limit their contribution to the risk of loss of crew (LOC) for a Lunar Outpost Crewed Mission to no greater than 1 in (TBD-001-559).	Analysis	Lunar Outpost Crew LOC due to the CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70017, Constellation Program Probabilistic Risk Assessment (PRA) Methodology Document. Verification shall be successful when the analysis shows a (TBD-001-939) probability that LOC for a Lunar Outpost Crew mission due to the CEV is not greater than 1 in (TBD-001-559).
3.2.2.1	CA0398-PO	The CEV shall limit their contribution to the risk of loss of crew (LOC) for an ISS Crew mission to no greater than 1 in 1700 (TBR-001-055).	Analysis	ISS Crew LOC due to the CEV shall be verified by analysis. Analysis shall be performed in accordance with CxP 70087, Constellation Program Reliability and Maintainability (R&M) Plan. Verification shall be successful when the analysis shows a (TBD-001-955) probability that LOC for an ISS Crew mission due to the CEV is no greater than 1 in 1700 (TBR-001-055).
3.2.2.2				
3.2.2.2.1	CA0334-PO	The CEV shall provide the suited crew with the capability for unassisted emergency egress during pre-launch activities after hatch closure within 2 (TBR-001-122) minutes total starting from initiation of egress in the seated and restrained position to complete crew egress from the vehicle.	Analysis, Demonstration	The suited crew capability for unassisted emergency egress from the vehicle during pre-launch activities shall be verified by demonstration and analysis. The demonstration shall consist of evaluations using CEV by performing a minimum of two runs with two different sets of suited crew members and collecting the task time for crew egress from CEV. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for all practical anthropometric crew assignments. The analysis shall

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				consist of the EVA, CLV and CEV system documentation review that meets unobstructed egress for the suited crew through the closure in the allocated CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) requirements. The verification shall be considered successful when the analysis determines the demonstration meets emergency egress within 2 (TBR-001-122) minutes and the allocated children requirements have been closed.
3.2.2.2.1	CV0857	The CEV shall provide a primary crew ingress/egress hatch with an emergency operations mode that will open the hatch within 5 seconds of initiation of the emergency mode during all ground operations at 30 psig (TBR-002-257).	Test	Verification shall be by test. Testing will be performed to actuate the ingress/egress hatch emergency operation system under the specified pressure and including worst-case ground operations conditions. Verification shall be successful when testing under these conditions proves the CEV hatch will open within 5 seconds of emergency mode initiation.
3.2.2.2.1	CV0818	The CEV shall provide a post landing alternate egress path for the un-pressurized suited crewmembers to egress from the inside of the vehicle.	Analysis, Demonstration	Verification shall be by Analysis and Demonstration. Analysis shall be performed on CEV released engineering drawings and schematics to ensure that the CEV design has provided a post landing alternate egress path for the un-pressurized suited crewmembers. Analysis on alternate egress hatch configuration, CEV volume for suited crew maneuvering, and ability to open an alternate egress hatch while suited will be completed. A demonstration shall be performed by un-pressurized suited crewmembers. Verification shall be considered successful when the analysis of engineering data and demonstration results sufficiently document CEV infrastructure to support crewmember egress.
3.2.2.2.1	CA0335-PO	The CEV shall provide two (TBR-001-545) ground crew and six suited flight crew with the capability for unassisted emergency egress during pre-launch pad	Analysis, Demonstration	The CEV providing two (TBR-001-545) ground crew and six suited flight crew the capability for unassisted emergency egress during pre-launch activities shall be verified by demonstration and analysis. The demonstration shall

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		activities prior to hatch closure within 2 (TBR-001-202) minutes total starting from initiation of egress to complete crew egress from vehicle.		consist of evaluations using two ground crew and six suited flight crew by performing a minimum of two runs with two different sets of crew members and collecting the task time for crew egress from CEV. The analysis will then apply a program approved extrapolation factor as appropriate, and accounting for practical anthropometric crew assignments. The analysis shall consist of the EVA and CEV system documentation review that meets unobstructed egress for two ground crew and six suited flight crew through the closure in the allocated CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) requirements. The verification shall be considered successful when the analysis determines the demonstration meets emergency egress prior to hatch closure within 2 (TBR-001-202) minutes total starting from initiation of egress to complete ground crew and suited flight crew egress from vehicle and the allocated children requirements have been closed.
3.2.2.2.1	CV0031	The CEV shall provide for unassisted pre-launch emergency egress from the CEV of up to 6 ground operations personnel in not greater than 120 seconds.	Demonstration	Verification shall be by demonstration. The verification shall be considered successful when 6 ground operations personnel demonstrate the capability to egress unassisted from the CEV during pre-launch preparation activities in a maximum of 120 seconds.
3.2.2.2.1	CA0466-PO	The CEV shall provide for unassisted emergency egress for suited crew upon landing within (TBD-001-146) minutes.	Analysis, Demonstration	The CEV capability for unassisted emergency egress for suited crew upon landing shall be verified by demonstration and analysis. The design of seat restraints, capsule orientation at rest, hatch mechanisms and egress paths in the 1 g nominal orientation and worst case off nominal orientation will allow the crew to egress without ground crew assistance. The demonstration shall consist of evaluations using CEV and performing a minimum of two runs with two different sets of suited crew members and collecting the task time for crew egress from CEV. The analysis will then

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				apply a program approved extrapolation factor as appropriate, and accounting for practical anthropometric crew assignments. The verification shall be considered successful when the demonstration and analysis shows that CEV supports the capability for unassisted emergency egress for suited crew upon landing.
3.2.2.2.2	CA0333-PO	The CEV shall perform aborts from the time the CEV abort system is armed on the launch pad until the mission destination is reached.	Analysis, Test	The CEV abort capability shall be verified by test and analysis. Abort testing shall be conducted in a SIL (or equivalent) for ascent aborts LEO aborts and lunar transit aborts. Ascent abort testing in the SIL shall include models of the launch vehicle and the CEV launch abort system (LAS). LEO and transit abort testing shall include aborts to the nominal landing site, as well as other land and water sites. LEO and transit abort testing shall include models of separation dynamics from any attached vehicles (e.g. ISS, LSAM, LSAM/EDS). Transit abort testing shall include the targeting and execution of abort burns from TLI to the mission destination. Analysis for ascent aborts shall be conducted using NASA-accredited digital simulations with dispersed parameters for all flight phases to mission destination. The verification testing shall be considered successful when the all test results successfully return the crew to a land or water landing. The verification analysis shall be considered successful when the analysis shows that there is a 95% (TBR-001-311) probability of crew survival for aborts.
3.2.2.2.2	CA0170-PO	The CEV shall automatically determine the need for an abort.	Analysis, Test	This verification shall be satisfied by test and analyses. A) Tests shall be performed using the flight assets and associated CxP systems (Ground Systems and Mission Systems) under actual flight conditions to validate simulation testing. B) Abort Determination shall be verified with simulation tests. Simulation tests shall be performed for all nominal and off-nominal profiles, all possible boundaries, modes, variable ranges and accuracy identified in (TBD-

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				001-277) Document(s). (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing). The verification shall be considered successful when: 1) The CEV performs the abort determination function(s) through an internal algorithm using internal or external data sources. 2) The CxP Architecture elements receive notification from the CEV of the need for an abort through the C3I infrastructure. 3) All possible profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-277) Document(s).
3.2.2.2.2.1	CV0660	The CEV shall inhibit the automatic abort sequence upon receipt of the command from the crew, except for abort sequence initiated upon notification of FTS indication.	Test	Verification shall be by test. The test shall make data available that indicates an automatic abort sequence was inhibited by the crew. Verification shall be considered successful when the CEV responds to the automatic abort conditions by inhibiting the initiation of any abort sequence, except for abort sequence initiated upon notification of FTS indication.
3.2.2.2.2.1	CV0837	The CEV shall automatically select abort modes.	Test	The intelligibility verification shall be considered successful when the ANSI intelligibility score is 90% or greater when tested with the worst case expected vehicle internal ambient noise and worst case RF channel packet loss rate conditions of 1x10e-5.
3.2.2.2.2.1	CV0838	The CEV shall automatically perform abort maneuvers.	Test	The internal voice quality verification shall be considered successful when a Mean Opinion Score (MOS) of "Excellent" in accordance with ITU-T-P.800 when tested with the worst case expected vehicle internal ambient noise and worst case RF channel packet loss rate conditions of 1x10e-5.
3.2.2.2.2.1	CA0522-PO	The CEV shall automatically initiate an ascent abort sequence upon notification	Test	The verification of Automatic Aborts upon FTS Indication shall be satisfied by test.

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		of FTS indication.		Tests shall be performed using the flight assets under simulated flight conditions and certified Ground Systems during integrated ground checkout. Simulation tests shall be performed for nominal and off-nominal profiles, the boundaries, modes, variable ranges and accuracy identified in (TBD-001-803) Document(s). (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing.) This verification shall be considered successful when: 1) Telemetry shows the presence of the FTS indication. 2) That the FTS indication is valid. 3) That the CEV automatically initiates the Ascent Abort Sequence. 4) That the abort sequence initiated by the CEV is appropriate for the specific mission phase described in (TBD-001-803) Document(s).
3.2.2.2.2.1	CA5439-PO	The CEV shall automatically perform abort.	Test	The verification of Automatic Aborts shall be satisfied by test. Tests shall be performed using the flight assets and associated CxP elements (Ground Systems and Mission Systems) under simulated flight conditions during integrated ground checkout. Simulation tests shall be performed for the nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-795) Document(s). (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing). The verification shall be considered successful when: 1) Telemetry shows that the vehicle and associated CxP systems involved with the Automatic Abort function(s) successfully executes the Automatic Aborts modes provided in (TBD-001-795) Document(s). 2) The profiles, boundaries, variable ranges and accuracy specified in (TBD-001-795) Document(s) are verified.

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3.2.2.2.2.1	CV0053	The CEV shall automatically initiate the ascent abort sequence.	Analysis	The automatic initiation of an ascent abort by the CEV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation with primary flight software installed that models the dynamics of the CEV/CLV stack and the data interface between the CEV and the CLV. The analysis shall include different types of ascent aborts. The verification shall be considered successful when the analysis shows that the probability is at least 0.9973 (TBR) with 90% confidence that the CEV, without crew or ground input, automatically initiated the correct ascent abort for the conditions. [The different types of ascent aborts and the conditions under which they are valid are provided in lower-level documents, like the Spacecraft Specification or the GN&C Subsystem Specification.]
3.2.2.2.2.1	CV0535	The CEV shall automatically initiate the pad abort sequence.	Test	Verification shall be by Test. For all identified pad abort conditions, the test shall make data available to the CEV indicating those aborts conditions exist. Verification shall be considered successful when the CEV response to the pad abort conditions is an automatic initiation of a pad abort sequence.
3.2.2.2.2.2	CV0045	The CEV shall initiate the pad abort sequence upon receipt of the pad abort sequence command from Ground Systems.	Test	Verification shall be by test. For each possible abort mode, covering all mission phases, data shall be made available that indicates the crew has initiated an abort sequence for the CEV. Verification shall be considered successful when 1) The CEV response to the abort command shall be the initiation of the appropriate abort sequence. 2) The appropriate abort sequence shall be the predetermined abort mode unless a commanded abort mode was selected.
3.2.2.2.2.2	CV0652	The CEV shall initiate the abort sequence upon receipt of the abort sequence command from Mission Systems.	Test	Verification shall be by test. For each possible abort mode, covering all mission phases, the test shall make data available that indicates an abort sequence was commanded from Mission Systems to the CEV. Verification shall be considered successful when

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				1) The CEV response to the abort command is initiation of the appropriate abort sequence. 2) The appropriate abort sequence is a predetermined abort mode unless a commanded abort mode was selected.
3.2.2.2.2.2	CV0653	The CEV shall initiate the abort sequence upon receipt of the abort sequence command from the crew.	Test	Verification shall be by test. The test shall make data available that indicates an abort sequence was commanded from the crew to the CEV. Verification shall be considered successful when the CEV responds to the abort command with the appropriate abort sequence.
3.2.2.2.2.2	CV0654	The CEV shall select abort modes upon receipt of the command from Mission Systems.	Test	Verification by test. For each valid abort mode, the test shall make data available to indicate that the abort mode was commanded by Mission Systems. The verification shall be considered successful when the CEV makes data available to indicate that the commanded abort mode has been selected for the subsequent abort sequence.
3.2.2.2.2.2	CV0735	The CEV shall select abort modes upon receipt of the command from the crew.	Test	The selection of abort modes upon receipt of the command from the crew shall be verified by test. The test shall be conducted in a CEV avionics-type facility that includes the crew interface for selecting an abort mode. The test shall use a crewmember to send abort mode selection commands, covering all available abort commands, to the CEV. The test shall record the crew abort mode selection command and the response of the CEV to the command. Verification shall be considered successful when the CEV response to the crew abort mode selection command is always selection of the specified abort mode.
3.2.2.2.2.3	CV0058	The CEV shall achieve 80% (TBR-002-231) of required LAS thrust within 300 milliseconds (TBR-002-013) of CEV onboard abort command initiation, where the time measurement is taken from the time the initiated command has been received by the CEV.	Analysis, Test	The LAS thrust buildup to the 80% (TBR) level of required LAS thrust within 300 milliseconds (TBR-002-013) shall be verified by analysis and test. The analysis shall review lower-level test data from actual LAS engine firings to determine the time required to achieve the 80% thrust level. The analysis shall combine all 80% thrust-buildup times by computing the average and reporting the maximum time

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				measured. A test shall be performed in a CEV avionics-type facility to measure the time between the initiation of the abort command by the CEV and the time of LAS engine start. The test shall collect a sample set of 10 (TBR) measurements. The test shall combine all command transport times by computing the average and reporting the maximum time measured. The verification shall be considered successful when the maximum 80% thrust-buildup time determined by the analysis and maximum command transport time measured by the test sum to less than 300 milliseconds.
3.2.2.2.2.3	CV0711	The CEV shall provide sufficient range and altitude performance during pad and low altitude aborts to achieve a water landing, with full Landing and Recovery System (LRS) deployment and functionality, for 95% (TBR-002-247) of the pad abort wind cases as defined in DSNE section (TBD-002-204) and thermal radiation environments as defined in the TBD, such that CEV landing ensures no greater than low risk of crew injury as defined by HSIR section 3.2.4.2.	Analysis, Test	Verification shall be by Test and Analysis. The analysis will use engineering, validated models and Flight test data to show that the CEV system is properly sized to land in water. Verification shall be considered successful when the Test and Analyses confirm that the CEV is properly sized to achieve a water landing with full LRS deployment and functionality.
3.2.2.2.2.3	CV0712	For CEV ascent aborts during CLV first stage, the CEV shall exceed a minimum separation distance of 175 ft, relative to a CLV that is assumed to continue to accelerate along its planned trajectory, for all times greater than 3 seconds after abort motor initiation.	Analysis	During CLV first stage ascent aborts, the minimum separation distance of 175 ft, determined for all times greater than 3 seconds after abort motor initiation, of the CEV relative to the CLV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of both the CEV and CLV as independent vehicles and includes a thrust model for the LAS. The analysis shall include nominal and off-nominal thrust levels of the LAS. The analysis shall cover all CLV first stage ascent abort conditions. A subsequent analysis

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				shall also be performed using a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the CLV. The analysis shall use the trajectories and attitudes of the two vehicles from the simulations of the previous analysis and determine the separation distance between the structures of the two vehicles for all times greater than 3 seconds after abort motor initiation. Verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can achieve a minimum separation distance of 175 ft from the CLV during first stage ascent aborts for all times greater than 3 second after abort motor initiation.
3.2.2.2.2.3	CV0841	The CEV shall provide flight separations without re-contact with any flight hardware.	Analysis	The flight separations without re-contact with any flight hardware shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV, including vehicle components that are jettisoned, and CLV as independent vehicles. The analysis shall generate trajectories and attitude timelines of the vehicles and vehicle components once they have separated. This analysis will include both nominal and abort scenarios. A subsequent analysis shall be performed using a 3-D graphical modeling tool that includes NASA-accredited models of the CEV, including vehicle components that are jettisoned, and the CLV. The analysis shall use the trajectories and attitudes of the vehicles and vehicle components from the first analysis and determine the closest approach between the structures of the objects after the initial separation. Verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that positive clearance margins can be achieved and no re-contact has occurred with flight hardware for all flight separation sequences.

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3.2.2.2.2.3	CV0052	The CEV shall automatically calculate ascent abort targets.	Analysis	The automatic calculation of ascent abort targets by the CEV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed). The analysis shall include both nominal and off-nominal trajectories. The analysis shall include both ISS and lunar ascent trajectories. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV has automatically calculated the ascent abort targets that meet vehicle design constraints.
3.2.2.2.2.3	CV0061	The CEV shall automatically calculate abort to orbit targets.	Analysis, Test	The automatic performance of targeting and maneuvers for abort to orbit by the CEV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation with primary flight software installed that models the dynamics of the CEV/CLV stack and the CEV as an independent vehicle. The verification shall be considered successful when the analysis shows that the probability is at least 0.9973 (TBR) with 90% confidence that the CEV, without crew or ground input, has automatically calculated the correct targets and performed the maneuvers for abort-to-orbit trajectories. The performance accuracy of the targeting is provided in lower-level documents, like the Spacecraft Specification or the GN&C Subsystem Specification. The maneuver is defined to be correct when it is consistent with the targeting and is within the performance accuracy defined in lower-level documents, like the Spacecraft Specification or the GN&C Subsystem Specification. [The maneuver must result in the successful achievement of orbit, which is defined as an altitude from which a subsequent burn will raise the perigee such that the CEV doesn't re-entry the atmosphere.]
3.2.2.2.2.3	CA0579-PO	The CEV shall provide ascent aborts for ISS missions that result in landing outside	Analysis	The ability of the CEV to land outside the Downrange Exclusion Zone during ISS mission shall be verified by

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		the Down-range Abort Exclusion Zone (DAEZ).		analysis. The analysis shall be conducted in a NASA-accredited digital simulation, including models of the ascent vehicle and separation dynamics. The verification shall be considered successful when the analysis shows that there is a 95% (TBR-001-321) probability that the CEV lands outside the Downrange Exclusion Zone.
3.2.2.2.2.3	CA0498-PO	The CEV shall abort without relying on thrust from the CLV.	Analysis	The ability of the CEV to perform aborts without CLV thrust shall be verified by analysis. The analysis shall show that all ascent aborts can by accomplished without the use of CLV thrust using a NASA-accredited digital simulation including models of the Crew launch vehicle.
3.2.2.2.2.3	CA5234-PO	The CEV shall provide the capability for vehicle landing in zones for earth ascent aborts defined by Figure (TBD-001-076) for all lunar missions.	Analysis	The ability of the CEV to perform abort landings within allowable areas shall be verified by analysis. The analysis shall be conducted in a NASA-accredited digital simulation, including models of the ascent vehicle, separation dynamics, and CEV dynamics. The verification shall be considered successful when the analysis shows that there is a 95% (TBR-001-467) probability that the CEV lands within the allowable areas.
3.2.2.2.3	CV0008	The CEV shall provide for early return to Earth after achieving mission destination.	Analysis	The early return to Earth of the CEV after achieving the mission destination shall be verified by analysis. [1] The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CM/SM in the LEO environment and the CM in the entry environment. The analysis shall include both nominal and off-nominal conditions. The analysis shall cover direct entry returns from the ISS. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analyses show that the probability of successful guided direct entries for early returns from the ISS is at least 0.9987 (TBR) with 90% confidence. [2] The

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				analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV/LSAM-AS in the LLO environment, the CM/SM in the trans-Earth and LEO environments, and the CM in the entry environment. The analysis shall include both nominal and off-nominal conditions. The analysis shall cover both direct and skip entry returns from the full range of lunar antipodes. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analyses show that the probability of successful guided direct or skip entries for early returns from the moon is at least 0.9987 (TBR) with 90% confidence. NOTES: A successful guided direct entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system. A successful guided skip entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.
3.2.2.2.3	CA0416-PO	The CEV shall return the crew to the Earth surface independent of communications with the Mission Systems during all mission phases.	Analysis	The ability of the CEV to return the crew to the Earth surface independent of communications with MS during all mission phases shall be verified by analysis. The analysis shall be performed using a NASA-accredited digital simulation, including models of navigation subsystems that impact the

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				ability of the vehicle to navigate independent of MS, and models of systems and elements on which the CEV depends to perform this task. The analysis shall include Monte Carlo dispersions of mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis shows there is a 99.73% (TBR-001-314) probability with a 90% confidence that the CEV can return the crew to the Earth surface independent of communications with the MS during all mission phases.
3.2.2.2.3	CA5237-PO	The CEV shall return the crew from Lunar Rendezvous Orbit (LRO) to the surface of the Earth within 118 (TBR-001-063) hours from docking with LSAM.	Analysis, Test	The CEV expedited return from lunar orbit capability shall be verified by analysis and test. The analysis shall be conducted using a NASA-accredited digital simulation with dispersed parameters. The testing shall be conducted using a SIL (or equivalent) with models of the CEV as well as the LSAM in lunar orbit. The verification shall be considered successful when the test shows that the CEV can return the crew from lunar orbit to the Earth surface within 118 (TBR-001-063) hours under nominal conditions. The analysis shall be considered successful when the results show that there is a 99.73% (TBR-001-972) probability of successful with a 90% confidence for return of the CEV from low lunar orbit to the Earth surface within 118 (TBR-001-063) hours in the presence of dispersions.
3.2.3	CA0447-PO	The CEV shall have the capability to transport crews of 0, 1, 2, 3, 4, 5 and 6 into LEO with a single launch.	Analysis	The capability to transport crews of 0, 1, 2, 3, 4, 5 and 6 into LEO with a single launch shall be verified by analysis. The analysis shall include the following functions: Flight performance/upmass, center of gravity, ECLSS resources, thermal, CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR) verification for anthropometry, cockpit design, the capability to accommodate (physically in terms of space) min and max crews, plus, reconfiguration capability to cover in-between configurations and (TBD-001-637). The analysis shall also

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				include the zero crew case in terms of automated functions, but not the crew accommodations. Verification shall be considered successful when the analysis shows that the CEV can perform the transportation of the specified number of crew within its performance limits.
3.2.4				
3.2.4.1	CA0868-PO	The CEV shall return at least 100 kg (220 lbm) of pressurized cargo from LRO to Earth for crewed lunar missions.	Analysis	The CEV Mass Returned requirement from the Lunar Rendezvous Orbit (LRO) to Earth for crewed lunar missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows that the calculated Mass Returned capability of the CEV is equal to or greater than the Mass Returned requirement for 99.73% (TBR-001-331) of the simulations with a 90% confidence.
3.2.4.1	CA5155-PO	The CEV shall provide return cargo volume of at least 0.075 (TBR-001-166) m3 (2.65 ft3) from the lunar orbit to the Earth during each crewed lunar mission.	Analysis	The ability of the CEV to return cargo volume from the lunar orbit to the Earth shall be verified by analysis. The Analysis shall consist of a review of cargo bays/stowage locations drawings and a calculation of the volume capability of the cargo bays/stowage locations. The verifications shall be considered successful when the analysis confirms the volume calculated is equal to or greater than the requirement during each crewed mission.
3.2.4.1	CA3182-PO	The CEV shall deliver cargo from the Earth to the ISS for uncrewed ISS missions.	Analysis	The CEV requirement to deliver cargo from the Earth to ISS in an uncrewed configuration shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations for the CEV/CLV ascent and CEV on-orbit
3.2.4.1	CA0864-PO	The CEV shall deliver a crew of four with at least 365 kg (805 lbm) of pressurized	Analysis	The CEV pressurized Mass Delivered requirement from Earth to ISS for crewed missions shall be verified by

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		cargo from Earth to ISS.		analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows that the Mass Delivered capability of the CEV is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-330) of the simulations with a 90% confidence.
3.2.4.1	CA0865-PO	The CEV shall return a crew of four along with at least 365 kg (805 lbm) of pressurized cargo from ISS to Earth.	Analysis	The CEV Mass Returned requirement from ISS to Earth for crewed missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows that the calculated Mass Returned capability of the CEV is equal to or greater than the Mass Returned requirement for 99.73% (TBR-001-920) of the simulations with a 90% confidence.
3.2.4.1	CA0866-PO	The CEV shall deliver at least 2850 kg (6,283 lbm) (gross) of pressurized cargo from the Earth to the ISS for an ISS Cargo mission.	Analysis	The CEV pressurized Cargo Mass Delivered requirement from Earth to the ISS for ISS Cargo Missions shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows that the calculated Mass Delivered capability of the CEV is equal to or greater than the Mass Delivered requirement for 99.73% (TBR-001-921) of the simulations with a 90% confidence.
3.2.4.1	CA5233-PO	The CEV shall return at least 2,858 kg (6,283 lbm) of pressurized cargo from the ISS to the Earth for an uncrewed mission.	Analysis	The CEV Mass Returned requirement from ISS to Earth for uncrewed Cargo missions shall be verified by analysis. This analysis shall be performed using the results of NASA

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				accredited digital flight simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows that the Mass Returned capability of the CEV is equal to or greater than the Mass Returned requirement for 99.73% (TBR-001-922) of the simulations with a 90% confidence.
3.2.4.1	CA0565-HQ	The CEV shall deliver a volume of at least 10.76 (TBR-001-035) m3 (380 ft3) of pressurized and conditioned cargo to and from the ISS per ISS Cargo mission.	Analysis	The ability of the CEV to deliver a volume of 10.76 (TBR-001-035) m3 (380 ft3) of pressurized delivery to and from the ISS per ISS Cargo mission shall be verified by analysis. The analysis shall consist of a review of cargo bays/stowage locations drawings and a calculation of the volume capability of the cargo bays/stowage locations. The verification shall be considered successful when the analysis confirms the volume calculated is equal to or greater than the requirement during each cargo mission. The ability of the CEV to deliver a volume of 10.76 (TBR-001-035) m3 (380 ft3) of pressurized and conditioned delivery to and from the ISS per ISS Cargo mission shall be verified by analysis. The analysis shall consist of a review of cargo bays/stowage locations drawings and a calculation of the volume capability of the cargo bays/stowage locations. The verification shall be considered successful when the analysis confirms the volume calculated is equal to or greater than 10.76 (TBR-001-035) m3 (380 ft3).
3.2.4.2	CAxxxAD-PO	The CEV shall provide a data interface for unpressurized cargo.		
3.2.4.2	CV0763	The CEV shall provide a standard, redundant, non-flight critical data bus interface for unpressurized cargo	Inspection	Verification shall be by inspection. The inspection shall be performed using engineering drawings and documentation of the CEV C&DH system. Verification shall be considered successful when the inspection shows that the SM provides standard redundant, non-flight critical data bus interface for unpressurized cargo.

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3.2.4.2	CAxxxBD-PO	The CEV shall deliver unpressurized cargo to the ISS.		
3.2.4.2	CV0764	The CEV shall deliver an unpressurized cargo mass of at least 590 <TBR-002-205> kg (1,300 lbs) (gross) to the ISS.	Analysis	The requirement for the CEV to deliver 590 kg (TBR) unpressurized mass to the ISS shall be verified by analysis. A mass properties and ascent performance analysis of the CEV shall be used to verify a capability to deliver 590 Kg (TBR) to ISS. Verification shall be considered complete when the analysis reveals a capability to deliver a minimum of 590 Kg unpressurized cargo (TBR) to the ISS.
3.2.4.2	CAxxxCD-PO	The CEV shall deliver unpressurized cargo for lunar missions.		
3.2.4.2	CV0766	The CEV shall deliver an unpressurized cargo mass of at least 413kg (909 lbm (gross) (TBR-002-206) to support the Lunar DRM.	Analysis	Verification of deliverable mass by the CEV shall be by analysis. An analysis of the mass properties and ascent performance of the CEV should prove the vehicle capable of delivering a minimum mass of 450 kg to Lunar orbit. Verification will be complete when the analysis proves the vehicle capable of delivering a minimum of 450 kg of unpressurized cargo in support of the Lunar DRM.
3.2.4.2	CAxxxDD-PO	The Constellation Architecture shall provide electrical power for unpressurized cargo.		
3.2.4.2	CV0762	The CEV shall provide two independent, non-mission specific, electrical power interfaces designated for unpressurized cargo each capable of providing power up to 1.0 kW maximum.	Analysis, Test	The requirement for the Service Module to provide two independent non-mission electrical power interfaces capable of 1.3 kW of continuous power will be verified by analysis and test. An analysis of engineering drawings will verify that the electrical power interfaces are independent. A test of the electrical interfaces will verify that this will be capable of providing 1.3 kW continuous power to unpressurized cargo. Verification will be considered complete when the test results and engineering drawings prove independent power interfaces capable of providing the 1.3 kW of power.
3.2.4.2	CV0765	The CEV shall provide a cubic volume of	Analysis	Verification of unpressurized cargo volume shall be by

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		at least 1.54 m (5.1 ft) on a side (total of 3.68 m3 (130 ft3)) for delivery of un-pressurized cargo to ISS.		analysis. An analysis of the engineering drawings of the unpressurized portion of the CEV shall prove that a minimum of 3.68 m3 is available for unpressurized cargo. Verification shall be complete when the analysis shows the minimum cubic volume of 3.68 m3 is met.
3.2.4.2	CV0768	The CEV shall provide a contiguous volume of at least (TBR-002-207) 0.57 m3 (20 ft3) with (TBD-002-234)m per side for delivery of un-pressurized cargo to support the Lunar DRM.	Analysis	Verification of deliverable unpressurized volume by the CEV in support of Lunar DRM shall be by analysis. An analysis of the engineering drawings of the CEV should prove the vehicle capable of providing a minimum unpressurized contiguous volume of 0.57 m3 (20 ft3) to Lunar orbit. Verification will be complete when the analysis proves the vehicle capable of delivering a minimum of unpressurized contiguous volume of 0.57 m3 (20 ft3) in support of Lunar DRM.
3.2.4.2	CA0547-PO	The CEV shall provide 0.57 (TBR-001-750) m3 (20 ft3) of volume allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure elements during the cruise and lunar orbit phases of lunar missions.	Analysis	CEV 0.57 (TBR-001-750) m3 (20 ft3) of volume, (TBD-001-390) kg ((TBD-001-390) lb) mass, and (TBD-001-391) services allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure elements during the cruise and lunar orbit phases of lunar missions shall be verified by analysis. The analysis shall consist of a review of programmatic manifesting documentation. The verification shall be considered successful when the analysis shows that all of the programmatic manifesting documentation meet CEV 0.57 (TBR-001-750) m3 (20 ft3) of volume, (TBD-001-390) kg ((TBD-001-390) lb) mass, and (TBD-001-391) services allocated to science, engineering demonstrations, development test objectives, and deployment of lunar infrastructure elements during the cruise and lunar orbit phases of lunar missions.
3.2.5	CV0010	The CEV shall provide no less than 6 days of active vehicle transit operations during an ISS Crew Mission.	Analysis, Test	The capability of the CEV to provide for no less than 6 (TBR-002-011) days of active vehicle transit operations during an ISS Crew Mission shall be verified by analysis and test. The analysis shall be performed on the CEV

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				subsystem capabilities, CEV subsystem reliabilities, and the planned quantities of onboard consumables. Functional and environmental tests of the CEV spacecraft shall be conducted for a 6-day (TBR-002-011) period. The verification shall be considered successful when the analysis shows that the CEV and all critical CEV subsystems can function reliably for at least 6 (TBR-002-011) days and that the planned onboard consumable quantities are sufficient for at least 6 (TBR-002-011) days of operation. The verification shall be considered successful when the tests show that the CEV spacecraft can function reliably in a relevant environment for at least 6 (TBR-002-011) days.
3.2.5	CV0769	The CEV shall provide the capacity to perform missions according to the mission rates and opportunities specified in the CEV Flight Rate Table 3.	Analysis	Verification shall be by Analysis. Analysis shall be performed on the flight rates in the table with respect to nominal flight rate plus a surge capacity accounting for the maximum flight rate in conjunction with the minimum interval. Manufacturing plans and production delivery schedules will be reviewed for compliance and support with these flight rates including projected budgets providing the opportunities for flight rate surges. Projected intervals between launch to launch of each system, ISS crew rotations and lunar missions length, and operational tempo of CEV utilization will be considered. Verification shall be considered successful when review of the manufacturing, production, delivery, and utilization schedules indicate that the CEV will support mission rates defined in CEV SRD, Table 3.
3.2.5	CA3164-PO	The CEV shall provide a habitable environment for a crew of four for a minimum of 18 (TBR-001-128) days during each lunar mission.	Analysis	The CEV's provision of a habitable environment for a lunar mission shall be verified by analysis. The analysis shall assess that the CEV design for atmosphere control and quality, potable water, atmosphere temperature, humidity and ventilation, food, body waste and trash management provides a habitable environment, as specified in CxP

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				70024, Constellation Program Human-Systems Integration Requirements (HSIR), for 4 crew for a minimum of 18 (TBR-001-128) days. The analysis will be supported by component and subsystem tests and analyses. The verification shall be considered successful when the analysis shows the CEV provides a habitable environment for up to 4 crew for a minimum of 18 (TBR-001-128) days in duration for a lunar mission.
3.2.5	CA0082-PO	The CEV shall loiter uncrewed in LLO for at least 210 (TBR-001-039) days.	Analysis	The ability for the CEV to loiter uncrewed in LLO for at least 210 (TBR-001-039) days shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include lunar gravity affects and vehicle subsystem models. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, vehicle consumables, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-304) probability with a 90% confidence that the CEV can loiter uncrewed in LLO for at least 210 days.
3.2.5	CA0060-HQ	The CEV shall remain docked to the ISS for at least 210 days.	Analysis	The ability of the CEV to remain at the ISS for 210 days shall be verified by analysis. Verification shall include analysis of component lifetimes (including planned preventive maintenance) and consumables margins. The verification shall be considered successful when the analysis shows that CEV can remain at the ISS for 210 days.
3.2.5	CV0012	The CEV shall provide at least 210 days of uncrewed operations while docked at the ISS.	Analysis, Test	Verification shall be by Analysis and Test. An analysis shall be performed on CEV engineering released drawings and habitable design documents to determine that the CEV has the infrastructure to support 7 months of quiescent operations while docked to the ISS. This will include but not limited to appropriate EPS, ECLSS, TCS, and C&DH system taking into account the spacecraft mass, air purification systems, and thermal protection system

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				performance over a long duration. A test should be run on the CEV to perform quiescent operations for a TBD duration. This duration does not need to be 7 months as a shorter test duration can provide valuable data to support a more thorough analysis of this requirement. The verification shall be considered successful when test and analysis shows that the CEV has the infrastructure and resources to provide quiescent operation for 7 months without adversely affecting nominal operations of the CEV following 210 days attached to the ISS.
3.2.6	CV0077	The CEV shall provide a hatch sized for egress and ingress by pressurized suited EVA crew per the CEV to EVA IRD, CxP 70033 Constellation Program Crew Exploration Vehicle (CEV) to Extravehicular Activity (EVA) Systems Interface Requirements Document (IRD).	Analysis, Demonstration	Verification shall be by analysis and demonstration. Analysis will be performed on CEV engineering released drawing to show the size of the CEV hatch and a determination will be made whether EVA suited crew can egress and ingress. Verification shall be successful when analysis prove that the CEV hatch is capable of allowing EVA suited crewmembers to egress and ingress during contingency EVAs. Demonstration shall be performed by a suited crew-member and a hatch demonstration unit to verify that a suited crewmember can egress and ingress through the hatch. Verification shall be successful when a crew representative verifies hatch access capability.
3.2.6	CV0303	The CEV crew module maximum design pressure (MDP) shall be 15.8 (TBR-002-245) psid.	Test	Verification shall be by a test. A test shall be performed on the systems responsible for maintaining cabin pressure (i.e. ECLSS, C&DH, EPS, etc.). The test shall be considered successful when TBD tests are run and the results show that CEV systems will not automatically relieve cabin pressure volume overboard when internal pressure is less than 15.05 psia (778 mm Hg) (TBR).
3.2.6	CV0315	The CEV shall dock using the Low Impact Docking System (LIDS).	Analysis	Verification shall be by analysis. The analysis shall consist of (a) review of the CEV and LIDS released engineering drawings and models and (b) analysis consisting of modeling and simulation of the docking and structural connection between CEV and ISS and between CEV and

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				LSAM. Verification shall be considered successful when the completed analyses show that (a) CEV systems correctly interface and integrate with corresponding LIDS components in accordance with the interface requirements between the CEV and LIDS as defined in CxP 70032 Constellation Program Low Impact Docking System (LIDS) Interface Definition Document (IDD) and (b) the docking and structural connection between CEV and ISS using a LIDS does not exceed the certification limits of ISS, LSAM or LIDS.
3.2.6	CV0811	The CEV shall launch from the KSC/Eastern Range.	Analysis	Verification shall be by analysis. The analysis shall be conducted using engineering drawings, schematics and other data to prove that the KSC launch site is proper site to launch from. The verification shall be declared successful when the analysis proves that the KSC/Eastern Range is the proper site to launch from.
3.2.6	CV0812	The CEV shall protect devices internal to the pressurized volume that are intended to be connected and disconnected during a lunar mission from lunar dust contamination.	Test	Verification shall be by test. The test shall be conducted using flight-like hardware being tested in an equivalent lunar dust environment. The verification shall be declared successful when the hardware tested performs satisfactorily in the simulated lunar dust environment.
3.2.6	CA0351-PO	The CEV shall launch independent of ambient lighting conditions.	Analysis	The CEV capability to launch independent of ambient lighting conditions shall be verified by analysis. The Analysis shall review the Ground Systems operational acceptance test to show that the ground facilities, facility systems and GSE will be able to provide launch capabilities independent of lighting conditions. The analysis shall include a review of vehicle systems, including but not limited to, vehicle tracking, recovery aids and imagery, to show that the flight systems, facility, facility systems and GSE that will be used to launch flight systems successful operations and performance determination are independent of ambient lighting conditions are built and certified. These facilities, flight systems and GSE requirements will be identified and

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				characterized in CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element, CxP 72006, Ground Systems Requirements Document (SRD) and CxP (TBD-001-1067), Ground Systems - Sub-Systems Requirements Document. The verification shall be considered successful when the analysis show that the flight and ground systems are ready to support flight systems launch for the CEV Architecture independent of ambient lighting conditions.
3.2.6	CA0448-PO	The CEV, when operated by the crew, shall be controllable by a single crewmember.	Analysis, Demonstration	The capability to control the CEV system by a single crew member shall be verified by demonstration and analysis. The demonstration shall include crew in the loop testing in a NASA accredited high fidelity lab and shall verify a single crew member can monitor and operate all critical functions of the CEV from one console. The demonstration shall use these facilities to capture data and analyze manual control performance of the vehicle for all nominal and abort flight phases that are determined appropriate for single human piloting and other critical CEV operations, and shall include system and environment dispersions. The analysis shall utilize the test data to show the single human piloting maneuvers does not violate the CEV structural, thermal or performance margins for all relevant flight phases. The verification shall be considered successful when the demonstration and analysis show that a single crew member can operate all critical functions of the CEV including flight path and attitude control where manual control does not violate structural, thermal or performance margins for all relevant flight phases.
3.2.6	CA5240-PO	The CEV shall perform an orbit transfer from Low Lunar Orbit to the LSAM in Lunar Rendezvous Orbit (LRO) in 6 (TBR-001-205) hours or less after the decision to return has been made.	Analysis	The CEV capability to perform orbit transfer from Low Lunar Orbit (LLO) to Lunar Rendezvous Orbit (LRO) in 6 hours (TBR-001-205) or less shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations for the CEV orbit transfer mission phase.

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				The simulation shall include timing of the orbit transfer maneuver. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters, and trans-lunar and multi-body gravity effects. The verification analysis shall be considered successful when the analysis shows that there is a 99.73% (TBR-001-471) chance of successful orbit transfer from LLO to LRO in 6 (TBR-001-205) hours or less in the presence of dispersions with a confidence of 90% (TBR-001-973).
3.2.6	CA5319-PO	The CEV shall complete the orbit transfer from the Ascent Target to a stable Low Earth Orbit (LEO) independent of communications with Mission Systems.	Analysis	The CEV orbital transfer from the Ascent Target to a stable Low Earth Orbit (LEO) independent of communications with Mission Systems shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations for the CEV orbit transfer mission phase. The simulation shall include Navigation System performance, specifically in the case where no ground update of state vector is performed. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The analysis will review the software's capability to successfully perform this function without updates from MS. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-507) probability with a 90% confidence that the vehicle can successfully perform the orbit transfer from Ascent Target to stable LEO independent of communications with Mission Systems.
3.2.6	CA0324-PO	The CEV shall return to Earth on land at designated CONUS landing sites.	Analysis	The capability to land at designated CONUS locations shall be verified by analysis. The analysis shall be performed using a NASA-accredited digital orbital and entry simulation. Analysis will cover LEO and Lunar DRMs to designated CONUS sites, and will include performance from SM separation to landing. Verification shall be considered successful when analysis of DRMs with system and environmental dispersions shows a 99.73% (TBR-001-472)

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				probability with a 90% confidence of achieving a nominal entry and landing at each of the designated CONUS sites (as appropriate to the specific DRM) within targeting constraints.
3.2.6	CA3166-PO	The CEV shall provide for at least 2 (TBR-001-206) EVA operations of at least 4 (TBR-001-207) hours duration each on lunar missions independent of other flight vehicles.	Analysis, Demonstration, Test	The ability of the CEV to perform EVAs on lunar missions at least 2 (TBR-001-206) EVA operations of at least 4 (TBR-001-207) hours duration each independent of other vehicles shall be verified by analysis, demonstration, and test. The analysis shall prove that the CEV System can provide the following functions while the CEV habitable volume is depressurized: - Ability for the crew to depress (external and internal to vehicle) and repress the vehicle cabin (internal to vehicle). - Atmospheric consumables to repress the vehicle two times to from 0 psia to standard cabin pressure as specified in CA0288-PO. - Compliance to EVA specifications per CxP 70130, Constellation Program Extravehicular Activity (EVA) Design and Construction Specification, section (TBD-001-1051). - Internal volume to egress and ingress the vehicle with a full complement of crewmembers - Provide consumables to support 4 crewmembers for 2 (TBR-001-206) EVAs (4 (TBR-001-207) hours per EVA) - Translation paths to and stabilization for Contingency and Unscheduled EVA tasks - Hatch operable with pressure suits - Egress and ingress paths with pressure suits. The analysis shall prove that the CEV System can provide the following functions for 16 (TBR-001-538) hours for 4 crewmembers while the CEV habitable volume is depressurized: - EVA System oxygen quantity and flow rates - EVA System breathing gas scrubbing - EVA System fluid flow rates and temperatures - EVA System power

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				- Communication (voice, suit and biomed data) with EVA System - Provide the functions simultaneously during the 4 hour EVA for 2 EVA crewmembers with an umbilical length of 30 (TBR-001-409) feet and 2 EVA crewmembers with an umbilical length of 10 (TBR-001-410) feet. The demonstration shall consist of neutral buoyancy evaluations, with the CEV mockups outfitted with the proper internal volume, internal handrails, seats, volumetric mockups of all internal areas, umbilicals, operable hatch, all loose stowage items (which would normally be not stowed away for an EVA), translation path, worksite, simulated EVA tasks, and all external appendages as identified in the CEV drawings, using flight like EVA suits (pressurized). The demonstration will consist of crewmembers opening and closing the hatch, egressing and ingressing the mockup, evaluation of translation paths between hatch and worksites, worksite stabilization, worksite tasks, and reach and visibility to all vehicle controls necessary during an EVA (depress and repress controls, displays, etc). The demonstration will be repeated by at least three different sets of crewmembers (for a total of six crewmembers to perform the demonstration). During egress and ingress phases of the demo, there will be at least four suited subjects (or two volumetric representations of suited subjects) located inside the CEV. The test shall consist of CEV flight or flight equivalent hardware with a full complement of EVA System flight or flight equivalent hardware. The suits will be fully pressurized and receiving all functions from the CEV at ambient conditions for the following sequences. 1. Four suits (and crewmembers) will be connected to all short umbilical positions with the suits performing simultaneously. 2. Four suits (and crewmembers) will be connected to the

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				two long umbilical locations and two to short umbilical locations. All suits will operate in the sequences of sufficient duration to obtain steady state with the sequence repeated until all suits have been swapped and operated simultaneously at all umbilical locations. The verification shall be considered successful when: - The analysis confirms the functions listed can be performed simultaneously with the vehicle depressurized. - The demonstration reflects crew subjective acceptability for CEV ingress, egress, vehicle displays and controls, translations, worksite stability, and worksite tasks as documented in the Crew Consensus report. - The test data confirms all CEV and EVA System conform to CEV/EVA IRD specifications of all four suits simultaneously.
3.2.6	CV0659	The CEV shall provide EVA translation paths as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Reqs Doc (IRD).	Analysis, Demonstration	Verification shall be by Analysis and Demonstration. Analysis shall be performed on engineering data with respect to contingency EVA infrastructure to translation along pre-determined pathways. Mission plans, operating principles, and EVA suit capability will be examined to support contingency EVA translation. Drawings and schematics will be utilized in the analysis for inclusion of sufficient stability points of attachment for EVA crewmembers to utilize. Demonstration of flight crew ability to use the translate along mission prescribed pathways may be demonstrated in a NASA-accredited simulator (NBL). Verification shall be considered successful when the analysis of engineering data and demonstration results sufficiently document CEV infrastructure to support contingency EVAs.
3.2.6	CV0672	The CEV shall provide the infrastructure for the EVA crewmember to egress the vehicle as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV)	Analysis, Demonstration	Verification shall be by Analysis and Demonstration. Analysis shall be performed on engineering data with respect to EVA infrastructure to support to contingency EVAs, specifically crew egress from the CEV. Analysis on

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		to Extravehicular Activity (EVA) Sys Interface Reqs Doc (IRD).		hatch configuration, CEV volume for suited crew maneuvering, and ability to open side hatch while suited (CV0567) will be completed. Drawings and schematics will be inspected with regards to human factors. Demonstration of flight crew ability and CEV capability to use support EVA may be verified in a NASA accredited simulator (NBL). Verification shall be considered successful when the analysis of engineering data and demonstration results sufficiently document CEV infrastructure to support contingency EVA ingress.
3.2.6	CV0673	The CEV shall provide the infrastructure for the EVA crewmember to ingress the vehicle as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Reqs Doc (IRD).	Analysis	Verification shall be by Analysis. Analysis shall be performed on engineering data with respect to EVA infrastructure to support to contingency EVAs, specifically crew ingress to the CEV. Analysis on hatch configuration, CEV volume for suited crew maneuvering, and ability to secure side hatch while suited (CV0567) will be completed. Drawings and schematics will be inspected with regards to human factors and demonstration of flight crew ability and CEV capability to use support EVA may be verified in a NASA accredited simulator (NBL). Verification shall be considered successful when the analysis of engineering data and demonstration results sufficiently document CEV infrastructure to support contingency EVA ingress.
3.2.6	CV0674	The CEV shall provide infrastructure for EVA crewmembers to stabilize themselves while performing EVA tasks as defined in the CEV to EVA IRD, CxP 70033 Crew Exp Vehicle (CEV) to Extravehicular Activity (EVA) Sys Interface Reqs Doc (IRD).	Analysis, Demonstration	Verification shall be by Analysis and Demonstration. Analysis shall be performed on engineering data with respect to EVA infrastructure to support to contingency EVAs. Drawings and schematics will be inspected for inclusion of sufficient stability points of attachment for EVA crewmembers to utilize. Demonstration of flight crew ability to use the stability infrastructure may be verified in a NASA accredited simulator (NBL). Verification shall be considered successful when the analysis of engineering data and demonstration results sufficiently document CEV infrastructure to support contingency EVAs.

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	CA3168-PO	The CEV shall provide an external control to depressurize the cabin that is operable by an EVA crewmember.	Analysis, Demonstration	The ability of the CEV to provide an external control to depressurize the cabin that is operable by an EVA crewmember shall be verified by analysis, and demonstration. The analysis shall prove that the CEV System can provide the following functions: - Ability to depress the vehicle to vacuum through an external method - Adherence to CxP 70130, Constellation Program Extravehicular Activity (EVA) Design and Construction Specification, section (TBD-001-468) The demonstration shall consist of neutral buoyancy evaluations, with a CEV external mockup outfitted with the external repress mechanism, translation path and all external appendages as identified in the CEV drawings, using flight like pressurized EVA suits, to evaluate reach and visibility to external vehicle depress operations by at least six crewmembers The verification shall be considered successful when the analysis confirms the functions listed can be performed, and the demonstration reflects acceptable human engineering evaluation for external depressurization reach and access as documented in the Crew Consensus report.
3.2.6	CV0075	The CEV shall provide non-propulsive CEV internal depressurization.	Analysis, Test	Verification shall be by test and analysis. A test shall be performed on flight-like hardware of the depressurization process in a vacuum chamber. Verification shall be successful when analysis shows that the net translational force is less than TBD Newtons and the net rotational torque is less than TBD Newton-meters. Testing may not require a vacuum chamber if analysis of atmospheric testing can be proven sufficient.
3.2.6	CA5148-PO	The CEV shall provide the infrastructure necessary for at least 3 (TBR-001-208) CEV vehicles operating in-space	Analysis, Test	The ability of CEV project to provide the infrastructure necessary to concurrently operate at least 3 (TBR-001-208) CEV in-space vehicles shall be verified by analysis and test.

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		concurrently.		The testing shall consist of an end-to-end data flow that exercises major functionalities of concurrent mission operations of at least 3 (TBR-001-208) CEVs in-space. Analysis consists of a review of the CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element and IRDs which describe CEV infrastructure necessary to identify and control specific vehicles (e.g. CEV-1, CEV-2). Verification shall be considered successful when the analysis and test confirms the infrastructure necessary to concurrently operate at least 3 (TBR-001-208) CEV in-space vehicles.
3.2.6	CA4152-PO	The CEV shall provide the infrastructure to perform ISS-based EVAs on ISS missions.	Analysis, Demonstration	The ability of the CEV to provide the infrastructure to perform ISS-based EVAs on ISS missions shall be verified by analysis and demonstration. The analysis shall prove that the CEV System can provide the following functions: - The exterior of the CEV complies to EVA specifications as invoked per CxP 70130, Constellation Program Extravehicular Activity (EVA) Design and Construction Specification compliance applicability. - EVA translation paths as specified per CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD). The demonstration shall consist of neutral buoyancy evaluations, with the CEV mockups outfitted with external translation paths, and all external appendages as identified in the CEV drawings, using flight like EVA suits (pressurized). The demonstration will consist of crewmembers evaluating the translation paths between hatch and worksites. The demonstration will be repeated by at least three different sets of crewmembers (for a total of six crewmembers to perform the demonstration). The verification shall be considered successful when the analysis confirms the functions listed can be performed and the demonstration reflects crew subjective acceptability for

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				CEV translations as documented in the Crew Consensus report.
3.2.6.1	CA0827-PO	The CEV shall have a Control Mass of 22,072 kg (48,570 lbm) at the Lunar Ascent Target.	Analysis, Test	The Control Mass requirement of the CEV upon arrival at the Ascent Target for Lunar missions shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse-case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of the CEV upon arrival at the Ascent Target for Lunar Missions is less than or equal to the required Control Mass.
3.2.6.1	CA4134-PO	The CEV shall have a Control Mass of 28,059 kg (61860 lbm) at Lift-Off for the Lunar Mission.	Analysis	The Control Mass requirement of the CEV at Lift-Off for Lunar Missions shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of the CEV at Lift-Off for Lunar Missions is less than or equal to the required Control Mass.
3.2.6.1	CA4135-PO	The CEV shall jettison the LAS not later than 30 seconds after Upper Stage Engine ignition command.	Analysis, Demonstration	The LAS jettison time shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations for the CLV/CEV ascent phase. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis results show there

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				is a 99.73% (TBR-001-963) probability that the vehicle can successfully perform the LAS jettison within the required amount of time following the CLV Upper Stage ignition.
3.2.6.1	CA4139-PO	The CEV shall have a Control Mass of 20,185 (TBR-001-159) kg (44,500 lbm) at the time of CaLV rendezvous.	Analysis, Test	The Control Mass requirement of the CEV at the time of CaLV rendezvous shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of the CEV at the time of CaLV rendezvous is less than or equal to the required Control Mass.
3.2.6.1	CA4163-PO	The CEV shall have a Control Mass of 25,331 kg (55,830 lbm) at Lift-Off for the ISS Mission.	Analysis, Test	The Control Mass requirement of the CEV at Lift-Off for the ISS Mission shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse case mass uncertainties associated with the tests and analyses shall be added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of the CEV at Lift-Off for the ISS Mission is less than or equal to the required Control Mass.
3.2.6.1	CA4164-PO	The CEV shall have a Control Mass of 19,301 kg (42,540 lbm) at the ISS Ascent Target.	Analysis, Test	The Control Mass requirement of the CEV at the ISS Ascent Target shall be verified by a combination of test and analysis. Hardware that can be safely and practically weighed shall have their mass determined by test. Items that cannot be safely or practically weighed shall have their mass determined by analysis. All worse case mass uncertainties associated with the tests and analyses shall be

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				added to the measured and calculated masses to obtain the total predicted mass. The verification shall be considered successful when the total predicted mass of the CEV at the ISS Ascent Target is less than or equal to the required Control Mass.
3.2.6.2	CA0829-PO	The CEV shall provide a minimum translational delta-V of 1760 (TBR-001-148) m/s (5776 ft/s) for lunar missions.	Analysis	The CEV translational Delta-V requirement shall be verified by analysis. This analysis shall be performed using the results of NASA accredited digital flight and performance simulations. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis shows that the calculated translational Delta-V of the CEV is equal to or greater than the translational Delta-V requirement for 99.73% (TBR-001-474) of the simulations with a 90% confidence.
3.2.6.2	CV0853	The CEV shall provide a minimum translational delta-V tank size of 5293 (TBR-002-256) ft/s.	Analysis	Verification shall be by analysis. The analysis shall be performed using engineering data to prove that the propellant tank size provides mission flexibility to allow global access lunar sorties. Verification shall be considered successful when the analysis shows that mission flexibility is available.
3.2.7	CA0436-PO	The CEV shall provide two fault tolerance to catastrophic hazards except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance must be achieved without the use of EVA, emergency operations or emergency systems.	Analysis	The two fault tolerance for catastrophic hazard shall be verified by analysis. The analysis shall review the results of the CEV System hazard analysis, and FMEA/CIL for two fault tolerance compliance. The verification shall be considered successful when the analysis shows that catastrophic hazards are controlled by three or more methods and all DFMR items are approved in the Hazard Reports per CxP 70038, Constellation Program Hazard Analyses Methodology.
3.2.7	CV0772	The CEV shall comply with NPR 8715.5, Range Safety Program, Preface and	Analysis	Verification shall be by Analysis. Analysis shall be conducted reviewing the requirements of NPR 8715.5,

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		sections 1.1-1.2, 1.3.7, 1.4, 2.1, 2.3-2.4, 3.1-3.2, 3.3-3.4, and Appendix A.		sections explicitly referenced and those applied by reference, as they pertain to CEV compliance with guidelines contained there in. A review of CEV flight profiles processes, documents and personnel considerations for agreement with those required by NPR8715.5 will be conducted for specificity and tailoring toward CEV. Analysis to support the verification of this requirement will require the review of developed documents IAW NPR 8715.5 and NPR 8710.3. Analysis will include all CEV subsystem operational flight configurations, pre- and post-orbital considerations. Verification shall be considered successful when review provides evidence of and supporting documents of CEV compliance to NPR8715.5 and associated derived requirements.
3.2.7	CV0775	The CEV shall dispose of expendable modules and other orbital debris in accordance with NPD 8710.3B, NASA Policy for Limiting Orbital Debris Generation.	Analysis	Verification shall be by Analysis. Analysis shall be conducted reviewing the requirements of NPR 8710.3, sections explicitly referenced and those applied by reference, as they pertain to CEV compliance with guidelines contained there in. A review of CEV flight profiles processes, operational documents and personnel considerations for agreement with those required by NPR8710.3 will be conducted for specificity and tailoring toward CEV. Analysis to support the verification of this requirement will require the review of developed documents IAW NPR 8710.3. Analysis will include all CEV subsystem operational flight configurations, pre- and post-orbital considerations. Verification shall be considered successful when review provides evidence of and supporting documents of CEV compliance to NPR8710.3 and associated derived requirements.
3.2.7	CV0782	The CEV shall comply with the requirements from CxP-70059, SR&QA Technical Requirements document.	Analysis	Verification shall be by analysis. The analysis shall be performed using engineering data to prove that the CEV has been built in compliance with the SR&QA Technical Requirements document. The verification shall be deemed

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				successful when the analysis proves that the CEV has been designed to meet the SR&QA Technical Requirements document.
3.2.7	CV0821	The CEV shall provide for control of ground safety hazards in accordance with document (TBD-002-236).	Analysis	Verification shall be by analysis. The analysis shall be performed to show that the CEV systems meet the intent of the requirements defined in the (TBD). The verification shall be considered successful when the analysis proves that the intent of the requirements have been met.
3.2.7	CV0850	The CEV shall dispose of expendable modules or debris without contacting the CLV during nominal liftoff and ascent operation	Analysis	Verification shall by analysis. The analysis will be performed using data from previous flight test. Verification shall be considered successful when the analysis proves that he CEV can dispose of expendable modules or debris without contacting the CLV during nominal liftoff and ascent operation.
3.2.7	CV0851	The CEV shall dispose of expendable modules or debris without contacting the launch pad during nominal liftoff operation.	Analysis	Verification shall by analysis. The analysis will be performed using data from previous flight test. Verification shall be considered successful when the analysis proves that the CEV shall dispose of expendable modules or debris without contacting the launch pad during nominal liftoff operation.
3.2.7	CA0435-PO	The CEV shall be single fault tolerant for critical hazards and loss of mission, except for areas approved to use Design for Minimum Risk Criteria. The fault tolerance must be achieved without the use of EVA, emergency operations or emergency systems.	Analysis	The single fault tolerance for critical hazard shall be verified by analysis. The analysis shall review the CEV System hazard analysis and FMEA/CIL for single fault tolerance compliance. The verification shall be considered successful when the analysis shows that critical hazards are controlled by two or more methods and all DFMR items are approved in the Hazard Reports per CxP 70038, Constellation Program Hazard Analyses Methodology.
3.2.7	CA0437-PO	The CEV shall comply with the requirement in JPR 8080.5, JSC Design and Procedural Standards, Section G-2.	Analysis	The separation or protection of redundant systems shall be verified by FMEA and CIL analysis. The analysis shall review the CEV System-level FMEA/CILs for compliance with JPR 8080.5, section G-2. The verification shall be considered successful when the integrated analysis shows

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				that redundant systems are separated or protected.
3.2.7	CV0575	The CEV shall prevent propagation of the effects for identified subsystem faults and component failures that, if propagated, could result in a catastrophic or critical hazard.	Analysis, Test	Verification shall be by Test and Analysis. Engineering drawings, hazard reports, FEMAs and related documentation shall be examined to consider catastrophic or critical hazards. For each propagated failure that could result in a catastrophic or critical hazard, the failure shall be initiated by establishing data that indicates a fault to a specific item of equipment. The CEV shall be observed to detect and react accordingly for each fault. Verification shall be considered successful when the following criteria are met. For each document analyzed, no component or system failure shall propagate such that it results in a catastrophic or critical hazard. For each fault tested, the CEV shall respond with proper detection and commanding.
3.2.7	CV0736	The CEV shall provide protection from the effects of software common cause failures when a failure of a system function results in loss of life.	Analysis, Test	Verification shall be by analysis and test. Analysis shall describe and quantify the protection mechanisms for common cause software failures. Test shall initiate a common cause software failure both in loss of output and erroneous output cases. Verification shall be considered successful when the test and analyses show that the CEV responds in a manner that does not result in a loss of life.
3.2.8				
3.2.8.1	CA3254-PO	The CEV shall generate commands.	Test	The generation of commands by the CEV shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. All applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. All applicable commands defined in (TBD-001-742) document(s) shall be generated by the CEV. (Exhaustive verification (test) of each command is not required since this will have been accomplished by lower level testing). All safety critical commands shall be generated. The verification shall be considered successful

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				when the Test shows that all of the applicable commands identified in (TBD-001-742) document(s): - are generated by the CEV in every applicable mission phase, state and mode
3.2.8.1	CA3249-PO	The CEV shall provide an interface for the crew to generate commands	Test	The CEV crew interface to generate commands shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-750) document(s) shall be generated by crew surrogates. (Exhaustive verification (test) of each command is not required since this will have been accomplished by lower level testing). Each safety critical command shall be generated. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-750) document(s): - are generated by crew surrogates in the CEV in each applicable mission phase, state and mode - and that the crew displays reflect the status of the commands.
3.2.8.2	CV0552	The CEV shall receive commands and data during all mission phases exclusive of interruptions caused by operational constraints.	Test	This requirement shall be verified by test. Tests shall be conducted to show for all applicable mission phases, modes, and configurations the CEV receives commands and data during the mission phases exclusive of interruptions caused by operational constraints. Verification shall be considered successful when the tests confirm the CEV meets the requirement for all applicable mission phases, modes, and configurations.
3.2.8.2	CV0143	The CEV shall receive commands from the crew.	Test	Verification shall be by Test. Tests shall be conducted to show the CEV receives commands from the crew for all applicable flight phases, modes, and configurations. Tests may include subsystem qualification and integrated avionics verification (IAV). Verification shall be successful when the

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				tests confirm the CEV meets the CV0143 requirement for all applicable flight phases, modes, and configurations.
3.2.8.2	CV0145	The CEV shall receive commands and data from other Constellation Systems.	Analysis, Test	This requirement shall be verified by TEST and ANALYSIS.ANALYSES shall be conducted on the CEV design/implementation to show the CEV receives commands and data from other Constellation Systems for all applicable mission phases, modes, and configurations. TESTS shall be conducted to show the CEV receives commands and data from other Constellation Systems for selected (TBD) applicable mission phases, modes, and configurations. TESTS may include subsystem qualification and integrated avionics verification (IAV). Verification shall be successful when the TESTS and ANALYSES confirm the CEV meets the requirement for all applicable mission phases, modes, and configurations.
3.2.8.2	CV0737	The CEV shall receive commands and data from the ISS.	Analysis, Test	Verification shall be by Test and Analysis. ANALYSES shall be conducted on the CEV design/implementation to show the CEV receives commands and data from the ISS for all applicable mission phases, modes, and configurations. TESTS shall be conducted to show the CEV receives commands and data from the ISS for selected (TBD) applicable mission phases, modes, and configurations. TESTS may include subsystem qualification and integrated avionics verification (IAV). Verification shall be successful when the TESTS and ANALYSES confirm the CEV meets the CV0737 requirement for all applicable mission phases, modes, and configurations.
3.2.8.2	CV0844	The CEV shall maintain a safe configuration without ground and crew interaction for a period of no less than 12 hours during all mission phases following a failure of safety and mission critical functions.	Test	Verification shall be by Test. The test shall make data available to the CEV that indicates a failure of safety and mission critical functions. Verification shall be considered successful when the CEV maintains a safe configuration without ground and crew interaction for a period of at least 12 hours.

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3.2.8.2	CV0846	The CEV shall receive commands and data during all ground operations and mission phases exclusive of interruptions caused by operational constraints.	Analysis, Test	This requirement shall be verified by TEST and ANALYSIS.ANALYSES shall be conducted on the CEV design/implementation to show the CEV receives commands and data from Ground Ops Systems. TESTS shall be conducted to show the CEV receives commands and data from Ground Ops Systems. TESTS may include subsystem qualification and integrated avionics verification (IAV). Verification shall be successful when the TESTS and ANALYSES confirm the CEV meets the requirement for all applicable configurations.
3.2.8.3	CA0134-PO	The CEV shall execute commands valid in the current state.	Test	The CEV crew interface to generate commands shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-325) document(s) shall be generated by crew surrogates. (Exhaustive verification (test) of each H&S command is not required since this will have been accomplished by lower level testing). Each safety critical command shall be generated. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-325) document(s): - are generated by crew surrogates in the CEV in each applicable mission phase, state and mode - the crew displays reflect the status and effects of the commands.
3.2.8.3	CV0556	The CEV shall validate commands received from the ISS.	Analysis, Test	Verification shall be by test and analysis. Test shall be conducted to show the capability to validate commands from the ISS for selected mission phases, modes, and configurations. Analyses shall be conducted on the CEV design/implementation to show the capability to validate commands from the ISS for all applicable mission phases, modes, and configurations. Verification shall be considered

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				successful when the tests and analyses confirm the CEV validates all commands received from ISS.
3.2.8.3	CV0560	The CEV shall validate commands received from the crew.	Analysis, Test	Verification shall be by test and analysis. Test shall be conducted to show the capability to validate commands from the crew for selected mission phases, modes, and configurations. Analyses shall be conducted on the CEV design/implementation to show the capability to validate commands from the crew for all applicable mission phases, modes, and configurations. Verification shall be considered successful when the tests and analyses confirm the CEV validates all commands received from crew.
3.2.8.3	CV0571	The CEV shall validate commands received from the other Constellation Systems.	Analysis, Test	Verification shall be by Test and Analysis. Tests shall be conducted to show the capability to validate commands received from other Constellation Systems for selected applicable mission phases, modes, and configurations. Analyses shall be conducted on the CEV design/implementation to show the capability to validate commands from other Constellation Systems for all applicable mission phases, modes, and configurations. Verification shall be successful when the tests and analyses confirm the CEV validates commands received from the other Constellation Systems.
3.2.8.3	CV0615	The CEV shall provide a notification for validity of commands.	Analysis, Test	Verification shall be by test and analysis. Tests shall be conducted to show the CEV provides a notification to the crew, ground, and command initiator for validity of commands for selected applicable mission phases, modes, and configurations. Analyses shall be conducted on the CEV design/implementation to show the CEV provides a notification to the crew, ground, and command initiator for validity of commands for all applicable mission phases, modes, and configurations. Verification shall be successful when the tests and analyses confirm the CEV provides a notification to the crew, ground, and command initiator for validity of commands.

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3.2.8.4	CV0570	The CEV shall provide execution status of commands.	Analysis, Test	Verification shall be by Test and Analysis. Tests shall be conducted to show the capability to provide execution status (including in-progress status and completion status) of commands for selected applicable mission phases, modes, and configurations. Analyses shall be conducted on the CEV design/implementation to show the capability to provide execution status (including in-progress status and completion status) of commands for all applicable mission phases, modes, and configurations. Verification shall be successful when the tests and analyses confirm the CEV provides execution status of commands.
3.2.8.4	CA3255-PO	The CEV shall execute commands which are addressed to the CEV.	Analysis, Test	The execution of commands by the CEV which are addressed to the CEV shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable commands defined in (TBD-001-759) document(s) shall be executed by the CEV. (Exhaustive verification (Test) of each command is not required since this will have been accomplished by lower level testing). Each safety critical command shall be executed. The CEV shall be sent every command addressed to it and a subset of all the commands addressed to other systems. The verification shall be considered successful when the Test shows that the applicable commands identified in (TBD-001-759) document(s): - are executed by the CEV when valid in the current state in each applicable mission phase, state and mode and the effect of the command is properly seen to the commanding System. - are rejected by the CEV when not valid in the current state in each applicable mission phase, state and mode or not properly addressed to the CEV.

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3.2.8.4	CV0569	The CEV shall execute valid commands received from the crew.	Analysis, Test	Verification shall be by Test and Analysis. Tests shall be conducted to show the capability to execute valid commands received from the crew for selected applicable mission phases, modes, and configurations. Analyses shall be conducted on the CEV design/implementation to show the capability to execute valid commands received from the crew for all applicable mission phases, modes, and configurations. Verification shall be successful when the tests and analyses confirm the CEV executes valid commands received from the crew.
3.2.8.4	CV0572	The CEV shall execute valid commands received from Constellation Systems.	Analysis, Test	Verification shall be by Test and Analysis. Tests shall be conducted to show the capability to execute valid commands received from other Constellation Systems for selected applicable mission phases, modes, and configurations. Analyses shall be conducted on the CEV design/implementation to show the capability to execute valid commands from other Constellation Systems for all applicable mission phases, modes, and configurations. Verification shall be successful when the tests and analyses confirm the CEV execute valid commands received from the other Constellation Systems.
3.2.8.4	CV0738	The CEV shall execute valid commands received from ISS.	Analysis, Test	Verification shall be by test and analysis. Tests shall be conducted to show the CEV executes valid commands from ISS for selected applicable mission phases, modes, and configurations. Analyses shall be conducted on the CEV design/implementation to show the CEV executes valid commands from ISS for all applicable mission phases, modes, and configurations. Verification shall be successful when the tests and analyses confirm the CEV executes valid commands from ISS.
3.2.8.5	CV0612	The CEV shall have crew, Constellation Systems, and ISS initiated command latency no greater than 200ms (TBR-002-232) while processing commands, where	Analysis, Test	Verification shall be by test and analysis. The end-to-end test shall measure each command available for execution by the CEV and show that every command from either crew input or external systems will take no longer than the time

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		the performance measurement is taken from the time the initiated command has been received by the CEV, to the time the command has been received by the target sub-system.		specified between the time endpoints given. The requirement shall additionally be verified by first testing the worst-case latency for all segments of the end-to-end command path, and then by analyzing that the summation of each component's worst-case latency lies within the 300 ms latency requirement.
3.2.8.5	CV0739	The CEV shall have a latency no greater than 1 <TBR-002-233> second while processing data destined for telemetry, where the performance measurement is taken from the time of subsystem data read to the time of data transmission from the CEV.	Test	Verification shall be by test. The test shall show that no telemetered value has a latency greater than 1 sec (TBR) . Verification shall be considered successful when the test prove that the CEV can maintain a telemetered data latency not exceeding 1 sec (TBR) under all combinations of CPU and I/O loading.
3.2.8.5	CV0740	The CEV shall have a latency no greater than 1 <TBR-002-234> second while processing data destined for crew display, where the performance measurement is taken from the time of subsystem data read to the time data is presented to the crew.	Test	Verification shall be by test. The test shall show that no value destined for display has a latency greater than 1 sec (TBR) . Verification shall be considered successful when the test prove that the CEV can maintain a displayed data latency not exceeding 1 sec (TBR) under all combinations of CPU and I/O loading.
3.2.8.6	CA0428-PO	The CEV shall generate Health and Status information.	Test	The generation of health and status information by the CEV shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable health and status data defined in (TBD-001-330) document(s) shall be generated by the CEV. (Exhaustive verification (Tests) of each H&S parameter is not required since this will have been accomplished by lower level testing). The verification shall be considered successful when the Test shows that the health and status data identified in

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				(TBD-001-330) document(s): - is generated by the CEV in each applicable mission phase, state and mode. - agrees with the actual health and status of the CEV.
3.2.8.6	CV0153	The CEV shall generate the health and status information on active and standby equipment for safety and mission critical functions.	Test	Verification shall be by Test. Tests shall be performed to verify that CEV software is capable of generating health and status data for safety and mission critical functions on active and standby equipment. Verification shall be considered successful when comparison between the data at the source generation point with the data made available by the CEV for output is equivalent.
3.2.8.6	CV0172	The CEV shall provide equipment maintenance data for safety and mission critical systems.	Test	Verification shall be by Test. Verification shall be by test. A test shall be performed to verify that the CEV can collect, store, and report equipment failure data and maintenance information for a TBD time and TBD quantity. Need to determine the number and type of interfaces. The test shall be considered successful when the recorder plays back TBD quantity of data with a error of TBD or less.
3.2.8.6	CV0539	The CEV shall provide health and status information to Constellation Systems and ISS.	Test	Verification shall be by test. The test shall identify all health and status information provided to the Constellation Systems. The test shall identify all health and status information provided to the ISS. Verification shall be considered successful when the data made available to the CEV interface to the ISS and other Constellation Systems accurately depicts the health and status data provided by the CEV.
3.2.8.6	CV0576	The CEV shall provide data quality indicators (e.g. current or stale).	Test	Verification shall be by test. The tests shall force the data to predefined data quality conditions. Verification shall be considered successful when CEV data quality indicators reflect the expected data quality conditions.
3.2.8.6	CV0831	The CEV shall process health and status information.	Test	Verification shall be by Test. Tests shall be performed to verify that CEV software is capable of processing health and status data. Verification shall be considered successful

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				when comparison between the data at the source generation point with the data processed by the CEV for output is equivalent.
3.2.8.6	CV0820	The CEV shall generate engineering and developmental flight instrumentation data.	Test	Verification shall be by Test. The verification is considered successful when the CEV generates engineering and developmental flight instrumentation data.
3.2.8.6	CA0427-PO	The CEV shall provide Health and Status information to the crew.	Test	The provision of health and status data by the CEV to the crew shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable health and status data defined in (TBD-001-287) document(s) shall be observed by crew surrogates. (Exhaustive verification (Tests) of each H&S parameter is not required since this will have been accomplished by lower level testing). The verification shall be considered successful when the Test shows that the health and status data identified in (TBD-001-287) document(s): - is observed by crew surrogates in the CEV in each applicable mission phase, state and mode. - agrees with the actual health and status of the CEV.
3.2.8.6	CV0156	The CEV shall provide health and status information of the CEV, ISS, and other Constellation Systems to the crew.	Test	Verification shall be by Test. 1.) Health and status information for CEV, ISS, and other Constellation Systems shall be made available for display in a manner consistent with display formats documented in the appropriate CEV System Requirements Specification. 2.) CEV, ISS, and other Constellation Systems health and status data made available for display shall represent both nominal and off nominal conditions. 3.) Health and status data for CEV, ISS, and other Constellation Systems made available for display shall be in accordance with the respective Interface

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				Requirements Document (IRD). Verification shall be successful when the data made available for display accurately depicts the health and status of CEV, ISS, and other Constellation Systems.
3.2.8.6	CV0555	The CEV shall provide the real-time utilization of shared resources (e.g. Power, Thermal, Data) to the crew.	Test	Verification shall be by Test. 1.) The test setup shall ensure that real-time utilization of shared resources is presented to the crew in a manner consistent with display formats documented in the appropriate CEV System Requirements Specification. 2.) The test setup shall ensure that real-time utilization of shared resources data presented to the crew represents both nominal and off nominal conditions. Verification shall be considered successful when display formats presented to the crew accurately reflect the real-time utilization of shared resources.
3.2.8.6	CV0813	The CEV shall provide 6 quality of power and data ports in accordance with CxP 70035, Portable Equipment, Payloads, Cargo (PEPC) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).	Inspection, Test	Verification shall be by test and inspection. Inspection shall be performed on the CEV released drawings and schematics to show that the power and data ports meet the connectivity requirements of CxP 70035. Tests shall be conducted to prove that the ports meet all interface requirements identified in CxP 70035. Verification shall be considered successful when the ports are shown to meet all the requirements of CxP 70035.
3.2.8.7	CV0536	The CEV shall record at least 8 Gigabytes of health and status information on CEV active and standby equipment for safety and mission critical functions.	Analysis	Verification shall be by Analysis. Analysis shall be performed to determine if the CEV recording function for dual/alternate systems as documented in engineering released drawings and equipment interface specifications will meet functional and performance requirements as required by NPR 8705.2A, Sections 3.2.1 and 3.3.1. Verification shall be considered successful when analysis provides confirmation that both crew and ground systems can monitor the recorded health and status information on active and standby systems in accordance with NPR 8705.2A, sections 3.2.1 and 3.3.1.

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3.2.8.7	CV0170	The CEV shall provide capacity to record at least 12 hours telemetry data at 192 kbps at baseband onboard.	Test	Verification shall be by test. A test shall be performed to verify that the flight data recorder records 192 kbps telemetry for 12 or more hours. Verification shall be successful when CEV records 192 kbps of telemetry data for 12 or more hours.
3.2.8.7	CV0171	The CEV shall provide capacity to record at least 12 Gigabytes of auxiliary data.	Test	Verification shall be by test. A test shall be performed to verify that the CEV records 12 GB or more of auxiliary data. Verification shall be successful when CEV records 12 GB or more of auxiliary data.
3.2.8.7	CV0843	The CEV shall provide the capability to load operational parameters that have been written to non-volatile memory upon receipt of a command from the crew, ISS, or other Constellation Systems.	Test	Verification shall be by Test. The test shall make available data that indicates a command to load configuration data has been received. Verification shall be considered successful when the data has been loaded.
3.2.8.7	CV0550	The CEV shall record equipment maintenance data for safety and mission critical systems.	Test	Verification shall be by Test. The test shall cause the CEV to record and report equipment maintenance data for safety and mission critical systems. Verification shall be considered successful when all recorded equipment and maintenance data is extracted and verified to be accurate.
3.2.8.7	CA5039-PO	The CEV shall provide (TBD-001-220) bytes of digital storage for recording digital data received from other Constellation Systems.	Demonstration, Inspection	CEV shall provide (TBD-001-220) bytes of digital storage for recording digital data received from other Constellation Systems. The provision of (TBD-001-220) bytes of digital storage for recording digital data shall be verified by Inspection and Demonstration. An inspection shall be conducted on the systems digital storage system implementation. A demonstration shall be performed using flight or similar assets in a SIL (or equivalent) with data received from a simulated "other" system. The receiving system shall record until full. The verification shall be considered successful when a) the inspection shows that (TBD-001-220) bytes are allocated for the storage of digital data received from other Constellation Systems, and b) the demonstration shows that the receiving

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				system records at least (TBD-001-220) bytes of "other" system data and an audit of the data shows it to be correct.
3.2.8.7	CV0741	The CEV shall record up to 20 Gigabytes of ascent data from CLV.	Test	Verification shall be by test. A test shall be performed to verify that the CEV records 20 GB of CLV data. Verification shall be considered successful when CEV records 20 GB of CLV data.
3.2.8.7	CA0511-PO	The CEV shall record critical data for reconstruction of catastrophic events.	Test	The recording of critical data for reconstruction of catastrophic events by the CEV shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. Applicable mission phases, states and modes shall be simulated for both nominal and off-nominal conditions at least twice. The applicable critical data defined in (TBD-001-291) document(s) shall be recorded by the CEV. (Exhaustive verification (tests) of each parameter is not required since this will have been accomplished by lower level testing). The verification shall be considered successful when the Test shows that the critical data identified in (TBD-001-291) document(s): - is available for retrieval after the flight hardware has been subjected to the environmental conditions specified in the CEV SRD.
3.2.8.7	CV0173	The CEV shall record flight data essential for accident investigation during ascent and entry onto non-volatile memory that meets (TBD-002-232) hardening.	Test	Verification shall be by test. A test shall be performed to verify that the CEV records flight data, pre-defined as essential for accident investigation, for the ascent and entry mission durations in non-volatile memory. Verification shall be considered successful when the pre-defined flight data has been recorded in non-volatile memory.
3.2.8.7	CA5040-PO	The CEV shall record System-generated digital data received from other Constellation Systems.	Demonstration	The recording of System-generated digital data received from other Constellation Systems shall be verified by demonstration. The demonstration shall be conducted in a SIL (or equivalent) using flight or similar assets. Test objectives

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				shall be prepared using IRDs and SRDs to identify source systems for data recording and the data content to be recorded. The source system may be simulated but should be certified. The source data shall be transmitted for no less than 4 hours or for an entire mission phase, if shorter, at least twice. The verification shall be considered successful when the demonstration shows a) source data is received for an entire mission phase or at least 4 hours, b) demonstration is performed twice, c) all received data is recorded, and d) an audit of the recorded data shows it to be correct.
3.2.8.8	CV0833	The CEV shall time stamp audio and motion imagery.	Test	Verification shall be by Test. Testing shall verify CEV has the capability to time stamp audio and motion imagery. Verification shall be considered successful when the test shows audio and motion imagery is time stamped.
3.2.8.8	CV0688	The CEV shall time stamp vehicle data to a precision that uniquely identifies every collected data set.	Analysis, Test	Verification shall be by Test. The test shall capture CEV produced time stamps, examine the time stamps, and show that the time stamp data format contains the required precision representation. Verification shall be considered successful when the test is completed and demonstrates that the time stamp data format contains the required precision representation.
3.2.8.8	CV0689	The CEV shall time stamp vehicle data to an accuracy of +- (TBD-002-208) of maximum collection cycle rate for each collected data set.	Analysis, Test	Verification shall be by Test and Analysis. The test shall measure, or capture, the actual system time and the time stamp generated time, compare the actual system time to the time stamp, and show that the time stamp is within the required accuracy. Analyses of the test data shall be performed to determine the accuracy of the time stamp. Verification shall be considered successful when the test and analyses is complete and demonstrates that the time stamp meets the specified accuracy.
3.2.8.8	CV0848	The CEV shall synchronize vehicle time sources.	Test	Verification shall be by Test. The test shall collect time data from each time source on the CEV. Verification shall be

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				considered successful when the data indicates the time sources are synchronized.
3.2.8.9	CA5901-PO	The CEV shall accept reconfiguration of stored commands, sequences and data.	Demonstration	The CEV capability to reconfigure stored commands, sequences and data shall be verified by demonstration. The demonstration shall use the flight CEV or flight equivalent hardware in simulated mission conditions. The CEV shall be preloaded with a set of stored commands, sequences and data. The subset of stored commands, sequences and data identified in (TBD-001-993) documents shall then be reconfigured. (Exhaustive verification of each reconfiguration item is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that the stored commands, sequences and data identified in (TBD-001-993) documents have been successfully reconfigured on the CEV and that they properly reflect the updated values.
3.2.8.9	CV0152	The CEV shall update onboard software with uplinked software.	Test	Verification shall be by Test. Ground based Tests shall be performed to verify that CEV software update/patch capability to change onboard software by receiving uplinks from the Mission Planning, Training & Flight Operations (MPTFO) element. The test shall require simulated uplinks to be made to CEV baselined software to ensure that software updates and patches can be received and installed by CEV systems in response to MPTFO uplinks. Tests will be performed in a CAIL like Facility. Verification will be successful when CEV software has installed updates/patches accurately, when compared to original software, in response to simulated uplinks. Specific criteria and data fidelity will be captured in a future CEV MPTFO IRD.
3.2.8.9	CV0616	The CEV shall update onboard data parameters with uplinked values.	Test	Verification will be by test. Data destined for uplink to the CEV from ground systems will be identified. Verification shall be considered successful when each type of data (i.e.

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				files, configuration parameters, others as identified) is successfully received and updated by the CEV from ground sources both in a software verification environment and a system validation environment.
3.2.8.9	CV0627	The CEV shall provide data reconfiguration.	Test	Verification shall be by test. The test shall verify the ability to reconfigure software, and data associated between at least two different missions. Verification shall be successful when execution of an end-to-end (ground through simulated flight) reconfiguration cycle is correctly performed.
3.2.9				
3.2.9.1	CV0549	The CEV shall monitor the real-time utilization of shared resources.	Test	Verification shall be by Test. The test shall initiate fluctuations in shared resources. Verification shall be considered successful when the data provided by the CEV monitoring shared resources is equivalent with the actual resource availability and usage.
3.2.9.1	CV0553	The CEV shall perform vehicle mode transitions.	Test	Verification shall be by Test. The test shall make data available to the CEV indicating, in turn, all valid CEV mode transitions. Verification shall be considered successful when all valid CEV mode transitions result in accurate reconfiguration of the targeted systems.
3.2.9.1	CV0554	The CEV shall provide transition status for any mode transition.	Test	Verification shall be by Test. 1) The test shall make data available to initiate all valid CEV mode transitions. 2) The test shall make data available to initiate all invalid CEV mode transitions. Verification shall be considered successful when the following criteria are met. 1) All valid CEV mode transitions resulted in the CEV confirming the mode transition. 2) Invalid mode transition attempts were accurately identified and rejected by the CEV.
3.2.9.1	CV0617	The CEV shall inhibit functions that are invalid for the current operating mode.	Test	Verification shall be by test. 1) The test shall enter each CEV mode. 2) In each mode, the test shall initiate invalid functions. Verification shall be considered successful when invalid functions are successfully inhibited.

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3.2.9.1	CV0154	The CEV shall determine the operational status of standby (powered on) redundant components prior to placing them into active status.	Test	Verification shall be by Test. Tests shall be performed to verify that CEV systems/software is capable of determining the operational status and health of non-operating redundant component before they are placed into active status. The test shall require an independent (separate from CEV systems/software) means of determining operational readiness and health of non-operating redundant components, which will be compared to the determination made by CEV systems/software. Verification will be successful when CEV redundant components' operational status is compared to data collected by the independent system and its accuracy has been determined to meet a TBD fidelity.
3.2.9.1	CV0204	The CEV shall provide a subsystem checkout capability initiated by the crew, ISS, or other Constellation Systems.	Test	Verification shall be by Test. For each sub-system within CEV, data shall be made available to indicate a request to perform a self-test. 1) Each subsystem shall provide data to the CEV indicating completion of the self-test with no failures. 2) Each subsystem shall provide data to the CEV indicating failure of the subsystem. Verification shall be considered successful when the following criteria are met. 1) The successful self-test results shall be seen for each of the CEV sub-systems in the data made available. 2) Failed subsystem self-test results shall be seen for each of the CEV subsystems in the data made available.
3.2.9.2	CV0819	The CEV shall autonomously plan and execute safety critical resource usage to return to earth at any time during the mission.	Test	Verification shall be by Test. The test shall make data available that indicates the mission abort with no communication with mission systems. Verification shall be considered successful when the crew is able to plan and execute critical resource usage to return to earth at any time during the mission without external communication.
3.2.9.2	CA0438-PO	The CEV shall detect system faults which result in loss of vehicle, loss of life and loss of mission.	Test	The provision of fault detection by the CEV shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in

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				(TBD-001-906) document(s) for each applicable simulated mission phases, states, and modes for the CEV at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-906) document(s) are detected by the CEV in every applicable mission phase, state and mode.
3.2.9.2	CV0158	The CEV shall detect faults to the subsystem or component active and standby (powered on) redundancy level that could result in Emergency, Warning, or Caution (Class 1, 2 or 3) events.	Test	Verification shall be by Test. Subsystem or component faults that result in a Class 1, 2, or 3 event, shall be initiated. The CEV shall be observed to detect each fault to the subsystem or component level. ¶¶Verification shall be considered successful when the following criteria are met. For each fault, the CEV shall identify the subsystem or component that faulted.
3.2.9.2	CV0541	The CEV shall provide independent means for detection of a failure that could result in a catastrophic or critical hazard.	Test	Verification shall be by Test. For each detectable failure that could result in a catastrophic or critical hazard, the test shall make data available to the CEV indicating each failure. 1) The test shall properly induce each failure. 2) The test shall induce a failure in one path. The test will ensure that only the failed indicator signals the false failure and at least one other indicator is independently signaling nominal operation. Verification shall be considered successful when the following criteria are met. For each failure, the CEV shall respond with proper detection. 1) The CEV indicates a failure. 2) The data shows the independence of the various means of detection.
3.2.9.2	CV0580	The CEV shall detect loss of communications with Mission Systems in the absence of a communication signal for more than 12 hours.	Test	Verification shall be by Test. The test shall make data available to the CEV which indicates communication with Mission systems has been lost for 12 hours. Verification shall be considered successful when the CEV detects and identifies a loss of communications with Mission Systems of more than 12 hours.
3.2.9.2	CA5465-PO	The CEV shall isolate detected faults to the level required for recovery of function.	Test	The provision of fault isolation by the CEV shall be verified by Test. The Test shall use the flight CEV or flight

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				equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-452) document(s) for applicable simulated mission phases, states, and modes for the CEV at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-452) document(s) are isolated by the CEV in each applicable mission phase, state and mode.
3.2.9.2	CV0159	The CEV shall identify the source of detected subsystem faults and component failures.	Test	Verification shall be by Test. For detected subsystem faults and components failures, the fault or failure shall be initiated by establishing data that indicates a fault or failure to the specific item. Verification shall be considered successful when the following criteria are met. For each fault or failure, the CEV shall properly identify the faulty item.
3.2.9.2	CA5466-PO	The CEV shall provide recovery from isolated faults.	Test	The provision of fault recovery by the CEV shall be verified by Test. The Test shall use the flight CEV or flight equivalent hardware in simulated mission conditions. The Test shall induce the identified faults and fault scenarios in (TBD-001-454) document(s) for applicable simulated mission phases, states, and modes for the CEV at least twice. The verification shall be considered successful when the Test shows that the fault and fault scenarios identified in (TBD-001-454) document(s) are recovered from by the CEV in each applicable mission phase, state and mode.
3.2.9.2	CV0160	The CEV shall recover from isolated subsystem faults and component failures, where redundancy exists, to prevent a catastrophic or critical hazard.	Test	Verification shall be by Test. For each failure of a redundant item of equipment that could result in a catastrophic or critical hazard, the failure shall be initiated by establishing data that indicates a fault. Verification shall be considered successful when, for each fault, the CEV recovers the function by switching to the redundant item.
3.2.9.2	CV0557	The CEV shall reallocate the real-time utilization of shared resources (e.g. Power, Thermal, Data) in support of fault	Test	Verification shall be by test. The test shall make data available to indicate each fault that impacts shared resources. Verification shall be considered successful when

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		recovery.		the CEV reallocates the shared resource in support of fault recovery.
3.2.9.3	CA5904-PO	The CEV shall execute reconfigurable automation sequences valid in the current state.	Demonstration	The CEV capability to execute reconfigurable automation sequences shall be verified by demonstration. The demonstration shall use the flight CEV or flight equivalent hardware in simulated mission conditions. The command sequences identified in (TBD-001-996) documents shall be executed by the CEV. In addition, the subset of command sequences identified in (TBD-001-996) documents shall be reconfigured prior to execution. (Exhaustive verification of each automation sequence is not required since this will have been accomplished by lower level testing.) The verification shall be considered successful when the demonstration shows that: - the command sequences have been executed without human intervention - the end state of the CEV at the end of the sequence execution is the same as if the commands had been executed manually - the reconfigured command sequences execute the updated commands - sequences are only executed when they are valid in the current state and are rejected otherwise
3.2.9.3	CV0824	The CEV shall provide reconfigurable time and event scheduling for the execution of automation sequences.	Test	Verification shall be by Test. The test shall make data available to indicate reconfiguration of time and event scheduling. Verification shall be considered successful when the CEV provides reconfigurable time and event scheduling for the execution of automation sequences.
3.2.9.3	CA3110-PO	The CEV shall accept Control of Automation.	Test	The requirement for the CEV to Accept Control of Automation shall be verified by test. A) Tests shall be performed using the flight assets and associated CxP elements (Crew, Ground Systems and Mission Systems) under simulated flight conditions during integrated ground testing. B) Simulation tests shall be performed for the

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				nominal and off-nominal profiles, and the boundaries, modes, variable ranges and accuracy identified in (TBD-001-914) Document(s) for which the control of automation will be performed. The verification shall be considered successful when: 1) The vehicle's running function is halted by the authorized Constellation System assuming vehicle control. 2) When the monitored telemetry shows the completed automated function leaves the vehicle in a proper state for the follow on task. 3) The applicable vehicle profiles, boundaries, modes, variable ranges and accuracy are verified within the specified (TBD-001-914) Document(s).
3.2.9.3	CV0148	The CEV shall provide the crew, ISS, or other Constellation Systems with override of automated CEV functions that are physically and safely interruptible.	Test	Verification shall be by Test. Data shall be made available which indicates that the crew, ISS and other Constellation System, respectively, commanded override of an automated function that is currently executing. The test shall be performed for all automated functions and the CEV response shall be recorded. Verification shall be considered successful when the following criteria are met. The CEV response to the override command by the crew, ISS or other Constellation System, to each executing automated function, shall be to stop, safe, or switch to manual control of function execution, as appropriate.
3.2.9.3	CV0150	The CEV shall inhibit the execution of an automated CEV function upon receipt of the inhibit command for that function from the crew, ISS, or other Constellation Systems.	Test	Verification shall be by Test. Data shall be made available which indicates that the crew, ISS and other Constellation System, respectively, commanded initiation of an automated function that was previously inhibited. The test shall be performed for all automated functions. Verification shall be considered successful when the following criteria are met. The CEV response to the initiated command by the crew, ISS or other Constellation System, to each inhibited automated function, shall be failure to initiate the function.
3.2.9.3	CV0544	The CEV shall enable the execution of an	Test	Verification shall be by Test. The test shall make data

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		automated CEV function that was previously inhibited, upon receipt of the enable command for that function from the crew, ISS, or other Constellation Systems.		available which indicates that the crew, ISS and other Constellation System, respectively, commanded an automated function that was previously inhibited to be enabled and then commanded initiation of that function. The test shall be performed for all automated functions. Verification shall be considered successful when the CEV initiates the function.
3.2.9.3	CV0743	The CEV shall initiate the execution of selected automated CEV functions upon receipt of crew, ISS, or other Constellation System commands.	Test	Verification shall be by test. The test shall make data available which indicates that the crew, ISS and other Constellation System have selected each automated function and commanded initiation of the function. Verification shall be considered successful when the CEV initiates the execution of the selected functions.
3.2.9.3	CV0747	The CEV shall terminate the execution of an automated CEV function upon receipt of the terminate command for that function from the crew, ISS, or other Constellation Systems.	Test	Verification shall be by test. The test shall make data which indicates that the crew, ISS and other Constellation System have commanded the termination of each automated function. Verification shall be considered successful when the CEV terminates the selected functions.
3.2.9.4	CV0558	The CEV shall re-initialize the flight processor(s) into a predefined operating configuration upon receipt of an action from the crew.	Test	Verification shall be by test. The test shall make data available that indicates the crew has re-initialized the flight processors to a pre-defined operating configuration, individually and in combination. Verification shall be considered successful when the CEV flight processors have initialized to the expected predefined configuration.
3.2.9.4	CV0561	The CEV shall re-initialize a single flight processor into a predefined operating configuration upon receipt of a command from the ISS and other Constellation Systems.	Test	Verification shall be by test. The test shall make data available that indicates receipt of a command from the ISS, or other Constellation Systems, to re-initialize a flight processor to a pre-defined operating configuration. Verification shall be considered successful when the CEV flight processor has initialized to the expected predefined configuration.
3.2.9.4	CV0562	The CEV shall re-initialize the flight processors upon recovery from vehicle	Test	Verification shall be by Test. 1) The test shall make data available to indicate the power was cycled to the flight

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		electrical power loss, to restore vehicle control and communication during uncrewed operations.		processors, and 2) the test shall make data available to indicate the CEV is uncrewed. Verification shall be considered successful when 1) CEV has completed re-initialization following restoration of power; 2) that vehicle control has been restored; and 3) that communications have been restored.
3.2.9.4	CV0842	The CEV shall save configuration data upon receipt of the command from the crew or other Constellation Systems.	Test	Verification shall be by Test. The test shall make available data that indicates a command to save configuration data has been received. Verification shall be considered successful when the data has been saved.
3.2.9.4	CV0563	The CEV shall, upon receipt of a commanded, scheduled or triggered event, save the computational execution state information (checkpoint).	Test	Verification shall be by Test. The test shall make data available to indicate the CEV has responded to a commanded, scheduled and triggered event and has successfully saved the computational execution state as a checkpoint. Verification shall be successful when it has been shown that the execution state information, that is required to re-initialize the vehicle to the same state that existed at the time the checkpoint was commanded, has been saved.
3.2.9.4	CV0619	The CEV shall export to external systems the saved computational execution state (checkpoint) data.	Test	Verification shall be by Test. The test shall make data available to indicate that the CEV has been requested, by a ground facility operator, to export a specified computational execution state (checkpoint). Verification shall be successful when the comparison of test data verifies that the CEV has exported the specified computational execution state (checkpoint) to an external system(s)
3.2.9.4	CV0618	The CEV shall load a computational execution state (checkpoint) specified by a ground facility operator in support of ground testing and training.	Test	Verification shall be by Test. The test shall make data available to indicate that the CEV has been requested, by a ground facility operator, to load from the specified computational execution state (checkpoint). Verification shall be successful when the comparison of test data verifies that the CEV has loaded the specified computational execution state (checkpoint).

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3.2.9.4	CV0564	The CEV shall restart from a specified computational execution state (checkpoint) while assuring time synchronization between flight processors, subsystem hardware, and test equipment in support of ground testing and training.	Analysis, Test	Verification shall be by Test. The test shall make data available to indicate that the CEV has been restarted from the specified computational execution state (checkpoint). Verification shall be successful when the comparison of test data verifies that the flight processors have been restarted to the exact state stored in the checkpoint and that time synchronization has been reestablished between the flight processors, subsystem hardware and ground test equipment.
3.2.9.4	CV0565	The CEV shall provide the capability for the flight processors to be synchronized with ground facility processors upon flight processor restart from a checkpoint.	Test	Verification shall be by Test. The test shall make data available to indicate that the CEV has been restarted from the specified computational execution state (checkpoint). Verification shall be successful when the comparison of test data verifies that the flight processors have been restarted to the exact state stored in the checkpoint and that time synchronization has been reestablished between the flight processors and ground facility processors.
3.2.10				
3.2.10.1	CV0750	The CEV shall communicate between Constellation Systems and ISS using the standards and protocols per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1; Interoperability Specification, Table Appendix E-1, C3I Interoperability Requirements Applicability to CEV.	Analysis, Test	Verification shall be by analysis and test. The analysis and testing shall be performed per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1; Interoperability Specification, Table Appendix E-1. Verification shall be considered successful when the analysis and testing shows compliance with requirements specified in CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1; Interoperability Specification, Table Appendix E-1.
3.2.10.1.1	CV0167	The CEV shall authenticate commands received.	Test	This requirement shall be verified by TEST. TESTS shall be conducted to show the capability to authenticate commands received for selected (TBD) applicable mission phases, modes, and configurations. TESTS may include subsystem

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				qualification and integrated avionics verification (IAV). Verification shall be successful when the TESTS confirm the CEV meets the requirement for all applicable mission phases, modes, and configurations.
3.2.10.1.1	CV0168	The CEV shall provide encryption and decryption for commands sent via RF between the CEV and other Constellation Systems and ISS.	Analysis, Inspection, Test	Verification shall be by Analysis, Test, and Inspection. Analysis shall verify that the command is encrypted to TBD standards. Tests shall be performed to verify the command link is performed as defined in FIPS 197, Advanced Encryption Standard using parameters as specified in P-00101, Constellation Command, Control, Communication, and Information (C3I) Interoperability Specification. Inspection will verify proper controls and planning for security key handling. Verification shall be successful when all assembled commands are accurately received by CEV and CEV is able to transmit appropriate commands; all commands, whether, transmitted or received are encrypted per the standards outlined in FIPS 197 and CXP-00101.
3.2.10.1.1	CV0169	The CEV shall manage the authentication and encryption system including exchange of security updates.	Analysis, Inspection, Test	Verification shall be by Analysis, Test, and Inspection. Analysis shall verify that the command is encrypted to TBD standards. Tests shall be performed to verify the command link performs to TBD and does not degrade after the encryption reconfiguration. Inspection will verify proper controls and planning for security key handling. Verification shall be successful when the CEV can reconfigure command encryption using parameters TBD as specified in FIPS 197 and CXP-00101.
3.2.10.1.2	CV0368	The CEV shall implement IP-based communications between Constellation Systems.	Inspection, Test	Verification shall be by Inspection and Test. Inspection shall be performed against the compliance record from the vendor if the IP stack is COTS. Compatibility testing will be performed to verify that the protocols meet the requirements for IPv4/IPv6 given in the CxP 70022, Volume 1. Verification shall be considered successful when an inspection and test show that CEV has correctly implemented IPv4/IPv6. (IPv4 is for ISS and IPv6 is for

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				Lunar)
3.2.10.1.3	CV0629	The CEV shall provide an onboard network Packet Loss Rate of less than 10-6 (TBR-002-209) given 1500 byte packets.	Test	The verification of the CEV onboard network Packet Loss Rate shall be by test. A packet loss rate test shall be performed on the CEV for each of the receiving links specified in the applicable Interface Requirements Documents (IRDs) to verify that the packet loss rate is less than 1x10E-06 when the input signal at the receiver input as specified in the IRD. Packet size of 1500 bytes shall be used as test data. The verification shall be considered successful when the result of the test on the CEV for each of the receiving links shows that the packet loss rate is less than 1x10E-06.
3.2.10.1.4	CV0630	The CEV shall implement multi-hop communications between Systems.	Analysis, Test	Verification shall be by test. A test of the CEV communication system shall demonstrate a successful multi-hop of signal transmission. Verification shall be considered successful when test demonstrates successful multi-hop for communications.
3.2.10.2				
3.2.10.2.1	CV0364	The CEV shall communicate at S-Band.	Analysis, Test	Verification of the CEV's ability to communicate at S-band shall be by Analysis and Test. Analysis shall be performed on CEV released engineering drawings, software files, and electrical schematics to ensure that the CEV design has provided the necessary infrastructure to communicate using S-band per CxP-70022 Volume 1, Constellation Program C3I Interoperability Standards Book: Interoperability Specification, and CxP-70022 Volume 2, Constellation Program C3I Interoperability Standards Book: Spectrum and Channel Plan. Tests shall be performed on the CEV communication system to verify its ability to communicate at S-band per CXP-70022 Volume 1 and Volume 2 and to verify its compatibility with the C&T Networks. The tests will require interfacing with the C&T Networks, other Cx Systems, and ISS using an RF path. The verification shall

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				be considered successful when analysis and test shows that the CEV communicates at S-band per CxP-70022 Volume 1 and Volume 2.
3.2.10.2.2	CV0366	The CEV shall communicate at Ka-Band.	Analysis, Test	Verification of the CEV's ability to communicate at Ka-band shall be by Analysis and Test. Analysis shall be performed on CEV released engineering drawings, software files, and electrical schematics to ensure that the CEV design has provided the necessary infrastructure to communicate using Ka-band per CxP-70022 Volume 1, Constellation Program C3I Interoperability Standards Book: Interoperability Specification, and CxP-70022 Volume 2, Constellation Program C3I Interoperability Standards Book: Spectrum and Channel Plan. Tests shall be performed on the CEV communication system to verify its ability to communicate at Ka-band per CXP-70022 Volume 1 and Volume 2 and to verify its compatibility with the C&T Networks. The tests will require interfacing with the C&T Networks, and other Cx Systems using an RF path. The verification shall be considered successful when analysis and test shows that the CEV communicates at Ka-band per CxP-70022 Volume 1 and Volume 2.
3.2.10.2.3	CV0534	The CEV shall communicate with LSAM within 432 nmi (800 km) of the CEV at S-band.	Analysis, Test	Verification shall be by test and analysis. Analyses shall be conducted on the CEV design/implementation to show the capability to communicate with LSAM at 432 nmi (800 km) from the CEV at S-band. Results from the analysis will be used to conduct tests to show that the CEV communicates with LSAM at S-band without interference. Verification shall be successful when the analyses and tests confirm that the CEV can communicate with the LSAM at 432 nmi (800 km).
3.2.10.2.3	CV0164	The CEV shall communicate with ISS within 16.2nmi (30 km) of the CEV at S-band.	Analysis, Test	Verification shall be by test and analysis. Analyses shall be conducted on the CEV design/implementation to show the capability to communicate with ISS at 16.2 nmi (30 km) from the CEV at S-band. Results from the analysis will be used to conduct tests to show that the CEV

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				communicates with ISS at S-band without interference. Verification shall be successful when the analyses and tests confirm that the CEV can communicate with the ISS at 16.2 nmi (30 km).
3.2.10.2.4	CA3288-PO	The CEV shall communicate simultaneously with ISS and Mission Systems when within 30 (TBR-001-917) km (16.2 nmi) of ISS.	Analysis, Test	Simultaneous communication by CEV with ISS and MS as specified shall be verified by analysis and test. Analysis of the specified data links shall be performed. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links. The verification shall be considered a success when a) testing shows the system can simultaneously exchange data at the maximum data rates with the specified systems for a period of 20 (TBR-001-405) minutes without apparent degradation, b) analysis shows that no degradation is predicted if the test time were indefinite with data maintained at the maximum data rate, and c) analysis shows that forward and received link margins are sufficient to support communication at the distances specified.
3.2.10.2.4	CA3287-PO	The CEV shall communicate simultaneously with Mission Systems, and with 2 (TBR-001-126) other Constellation in-space systems that are within 800 (TBR-001-165) km (432 nmi) of CEV.	Analysis, Test	Simultaneous communication by CEV with MS and 2 (TBR-001-126) other systems in space as specified shall be verified by analysis and testing. Analysis of the specified data links shall be performed. The test shall be conducted on flight or flight-like systems and simulated systems over simulated space links. The verification shall be considered a success when a) testing shows the system can simultaneously exchange data at the maximum data rates with the specified systems for a period of 20 (TBR-001-418) minutes without apparent degradation b) analysis shows that no degradation is predicted if the test time were indefinite with data maintained at the maximum data rate, and c) analysis shows that forward and received link margins are sufficient to support communication at the distances specified.
3.2.10.2.4	CV0490	The CEV shall communicate	Analysis, Test	Verification shall be by analysis and test. Analysis shall be

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		simultaneously with Mission Systems and the LSAM.		performed using models and simulation. Multiple scenarios must be pre-determined and run on the model to verify that the CEV can communicate simultaneously with Mission Systems and LSAM. Test shall consist of integrated end-to-end testing. Verification shall be successful when tests and analysis show CEV systems can communicate simultaneously with Mission Systems and LSAM.
3.2.10.2.5	CV0362	The CEV shall provide spherical coverage for the different mission phases and links, excluding non-CEV structural blockage and re-entry plasma as given in Table 4 (TBR-002-235).	Analysis, Test	Verification shall be by test and analysis. Tests of the CEV antenna patterns shall be performed to determine the antenna gain patterns of the antennas mounted on the CEV vehicle. Link margin analysis shall be performed to determine the antenna gain needed to provide the specified CEV link performance. The results of the antenna pattern test and circuit margin analysis will be used in a coverage analysis. The coverage analysis shall determine the spherical coverage for the different mission phases and links, excluding non-CEV structural blockage and re-entry plasma. The verification shall be considered successful when the analysis shows that the CEV systems provide at least the coverage listed in Table 4.
3.2.10.2.5	CA0470-PO	The CEV shall transmit and receive in any attitude with geometric antenna coverage of 90% (TBR-001-335) for low-rate data as defined by CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV), Section 3.6.1.2.	Analysis, Test	The ability of the CEV to transmit and receive with geometric antenna coverage of 90% (TBR-001-335), excluding non-CEV structural blockage and re-entry plasma, for low rate data as defined by the CxP 70118, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Section 3.6.1.2 shall be verified by test and analysis. The antenna to be used by the CEV shall be tested in an anechoic chamber or similar test bed to determine its innate geometric transmission and reception characteristics. This shall be accomplished by rotating the antenna and measuring the signal strength received from a fixed source. The analysis shall use the tested geometric characteristics of the antenna to predict the coverage of the antenna, for all

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				attitudes, excluding non-CEV structural blockage and re-entry plasma, as mounted on the CEV. The analysis shall also determine the needed signal strength and quality to provide 90% (TBR-001-335) coverage. A field test shall be conducted on and installed antenna in a simulated CEV mount [either in an anechoic chamber or in an open area]. Measurements shall be recorded for system signal strength and quality of radiated low rate data. Measurement shall be recorded for received low rate data transmitted with an attenuated test signal as defined by the analysis and transmitted from a representative set of points as determined by analysis. An independent measurement of the transmitted signal strength at a fixed location shall also be recorded as a calibration witness. The verification shall be considered successful when (1) the analysis of mounted antenna coverage for low rate data, excluding non-CEV structural blockage and re-entry plasma, is shown to be greater than 90% (TBR-001-335), (2) the field tests of the mounted antenna measured against transmissions from the representative points show antenna gain in accord with the analysis for that set of points and (3) the transmitted signal is received with sufficient strength and quality above the expected analyzed minima for all measured locations.
3.2.10.2.6	CV0374	The CEV shall transpond signals and provide radiometric measurements.	Test	Verification shall be by test. Tests shall be performed on CEV to verify that it correctly receives, transmits and complies with Space Network signal protocols for radiometric tracking. Tests shall also be performed to verify that the CEV can compute the range and range rate correctly. Verification shall be successful when tests show that the CEV transmits, receives and complies with Space Network signal protocols for radiometric tracking and that the CEV computes the range and range rate correctly.
3.2.10.3	CV0373	The CEV shall implement IP based	Test	Verification shall be by test. The CEV non-deterministic

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		communications for non-deterministic rate based hard-line connections between ISS and Constellation Systems as specified in CxP-70022, Constellation Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1.		hardline communication shall be verified by test. A test shall be performed to transport data through the inter-element hardlines. The verification shall be considered successful when the test shows that the hardline interface correctly transports non-time critical data using IP based processes.
3.2.10.3	CV0751	The CEV shall implement SAE-AS5643 and SAE-AS5643/1 standards for deterministic rate based hard-line connections between Constellation Systems.	Analysis, Test	Verification shall be by analysis and test. The analysis and testing shall be performed per CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1; Interoperability Specification, Section 4.2.3. Verification shall be considered successful when the analysis and testing shows compliance with requirements specified in CxP 70022-01, Constellation Program Command, Control, Communication, and Information (C3I) Interoperability Standards Book, Volume 1; Interoperability Specification, Section 4.2.3.
3.2.10.4	CV0834	The CEV shall provide audio communications between crew members and Constellation Systems and ISS.	Demonstration, Test	Verification shall be by test and demonstration. Speech intelligibility and voice quality testing shall be performed. Intelligibility testing shall be performed for internal crew voice communications and two-way voice communications between the CEV and other Constellation Systems. Intelligibility testing shall be verified by using the methodology for a Modified Rhyme Test (MRT) as specified in ANSI S.3.2-1989.
3.2.10.4	CV0178	The CEV shall provide two-way private audio and motion imagery communication mode between the ground and crew.	Analysis, Test	Verification shall be by Test and Analysis. A Test shall be performed on all CEV communication systems to show its capacity to provide two-way private audio and motion imagery communication between the ground and crew. CEV qualification communication system(s) will provide flight like services showing its capability for private, secure communications with ground. Once the CEV system has shown evidence of private communications with the ground

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				and ground to CEV and verification of privacy through independent communication check out (analyses), this requirement will be successful.
3.2.10.4	CV0631	The CEV shall provide audio and high definition motion imagery for distribution to the public.	Analysis, Test	Verification shall be by analysis and test. An analysis of the CEV engineering design shall demonstrate a means for providing audio and high resolution motion imagery for downlink. A test of the CEV system shall prove that the system can provide audio and imagery for downlink to Mission Systems. Verification shall be considered successful when the test and analysis prove that audio and motion imagery can be downlinked to Mission Systems.
3.2.10.4	CV0832	The CEV shall provide imagery of mission critical and safety related events.	Analysis, Test	Verification shall be by Test and Analysis. A test shall be performed on CEV cameras showing that they provide the necessary resolution, depth of field, and field of view. Analysis shall use models to simulate the expected views and scenarios. Analysis shall be used to verify that the provided views are adequate for imaging of mission critical events. Verification shall be considered successful when testing and analysis shows the imagery provides the appropriate views.
3.2.10.4	CV0854	The CEV shall record motion imagery and associated audio sources for a combined total record time of 8 (TBR-002-258) hours minimum.	Analysis, Test	Verification shall be by analysis and test. A test shall demonstrate that the CEV is capable of recording motion imagery and associated audio. An analysis shall demonstrate that there is sufficient capacity to store at least 8 hours of motion imagery and audio data. Verification shall be considered successful when it is shown that the CEV has recorded the motion imagery and audio sources and analysis shows the capability to record a minimum of 8 hours of motion imagery and audio data.
3.2.10.4	CV0752	The CEV shall ensure the privacy of all crew medical and personal data.	Analysis	Verification shall be by analysis. The analysis shall be performed using engineering data to show that health and status data is securely protected as specified in the CxP 70070-ANX05, Book 1, Constellation Program Management

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				Plan, Annex 5: Security Management Plan. The verification shall be considered successful when the analysis proves that the data is protected as specified in the CxP 70070-ANX05, Book 1, Constellation Program Management Plan, Annex 5: Security Management Plan.
3.2.10.4	CV0138	The CEV shall provide motion imagery for approach and departure proximity operations, docking and undocking to the crew, MS, ISS and LSAM.	Analysis, Test	Verification shall be by Analysis and Test. A test shall be performed on CEV cameras, showing that they are capable of capturing actual prox ops and docking maneuvers. Analysis shall be performed on the prox ops camera data to verify that all scenarios are viable. Verification shall be successful when motion imagery is evaluated for expected accuracy and coverage by Prox Ops and docking specialists.
3.2.10.4	CV0176	The CEV shall provide motion imagery and associated audio to the ISS and other Constellation Systems.	Test	Verification shall be by test. A test will performed to verify the CEV avionics system transmits the on-board video to the MPTFO element. The test shall be considered successful if the quality of the received video is equal to or better than TBD standards.
3.2.10.5	CA3280-PO	The CEV shall communicate using an independent, dissimilar, voice only system.	Analysis, Demonstration	The use of a dissimilar voice communication system by CEV as specified shall be verified by Analysis and Demonstration. The analysis shall be performed on the CEV voice communication systems. The demonstration shall be performed on the CEV dissimilar voice system. The verification shall be considered successful when a) the demonstration verifies that the dissimilar voice system provides system-to-system communication using communication infrastructure paths, and b) the analysis shows the dissimilar system is independent when compared to the prime CEV voice communication system.
3.2.10.6	CV0179	The CEV shall provide communications with recovery team at nominal and off-nominal landing sites.	Demonstration, Test	Verification shall be by Demonstration and Test. A Test shall be performed, at the component level, on all CEV communication systems to show its capacity to communication with the recovery teams pre-and post-

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				landing. A demonstration on CEV integrated qualification communication systems providing flight like services will show its capability to communicate with the recovery personnel before and after landing activities. A simulation shall be run to demonstrate this function, where simulated Search and Rescue (SAR) communications will take place between CEV and the appropriate SAR systems.
3.2.10.6	CV0829	The CEV shall automatically activate the radiolocator beacon(s).		Recommending delete - duplicate of CV0789.
3.2.10.6	CA0344-PO	The CEV shall maintain communications with Mission Systems for at least 36 hours post landing.	Analysis, Test	The CEV maintaining communications with Mission Systems for at least 36 hours post landing shall be verified by analysis and test. The power budget and transmission power requirement for nominal operation with worst case reserve for the post-landing period will be analyzed. The flight unit or similar units will be tested under simulated communications for the required period of time with sufficient radiated power to maintain communication with the communication infrastructure(s) measuring power consumption. The flight unit or similar units will be tested with Mission Systems and demonstrated in recovery exercises. The verification shall be considered successful when a) analysis shows that there is sufficient power and reserve based on planned system status after re-entry to maintain communications with Mission Systems for 36 hours of continuous operation, b) analysis shows that Mission Systems can maintain communications with the simulated CEV with no more than 2 (TBR-001-541) breaks of no more than 2 (TBR-001-312) minutes each during a worst case landing location scenario, and c) testing shows CEV communication with Mission Systems for the 36 hour duration can be maintained in a simulated recovery exercise.
3.2.10.6	CV0180	The CEV shall provide local voice communications with the Ground	Demonstration, Test	Verification shall be by Demonstration and Test. A Test shall be performed, at the component level, on all CEV

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		Systems Recovery and Retrieval Element, and contingency Search and Rescue (SAR) team while the CEV hatches are closed.		communication systems to show its capacity to communication with the recovery teams pre-and post-landing. A demonstration on CEV integrated qualification communication systems providing flight like services will show its capability to communicate with the recovery personnel before and after landing activities. A simulation shall be run to demonstrate this function, where simulated Search and Rescue (SAR) communications will take place between CEV and the appropriate SAR systems.
3.2.10.6	CV0181	The CEV shall provide radiolocator beacon(s) as defined in the C3I Interoperability Specification, Volume 1, Table Appendix E-1 - C3I Interoperability Requirements Applicability to CEV, for nominal and off-nominal landing.	Test	Verification shall be by test. The CEV radiolocator beacon compliance with the CxP 70022 Volume I, C3I Interoperability Specification shall be verified by integrated tests with the ground systems. Verification shall be successful when the tests confirm that the CEV radiolocator beacon(s) meet the C3I Interoperability Specification and communicates successfully with the ground systems.
3.2.10.6	CV0463	The CEV shall provide local voice communication with the Ground Systems Recovery and Retrieval Element and contingency Search and Rescue (SAR) forces as defined in CxP 70022, C3I Interoperability Standards Book, Volume 1 , Table Appendix E-1 - C3I Interoperability Requirements Applicability to CEV.	Test	Verification shall be by test. A Test shall be performed, to show the CEV local voice communication system's capacity to communicate with the recovery and SAR team and comply with C3I Interoperability Standards. The verification shall be considered successful when tests show the CEV local voice communication with the recovery and SAR team complies with C3I Interoperability Standards.
3.2.10.6	CV0784	The CEV shall maintain voice communications with Mission Systems for at least 36 hours post landing, with a duty cycle of 90% receive and 10% transmit.	Analysis, Test	Verification shall be by test and analysis. The test shall be conducted using flight like hardware to prove that voice communication can be maintained for 36 hours upon landing. The analysis will use engineering data to prove that the system design is capable of maintaining voice communication for 36 hrs. Verification shall be considered successful when the analysis and test data prove that voice communication will be maintained between the CEV and Mission Systems for 36 hrs.

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3.2.10.6	CV0787	The CEV shall transmit its location via the radiolocator beacon.	Test	Verification shall be by test. The test shall be conducted using flight hardware to prove that the radiolocator beacon transmits its location. The verification shall be considered successful when the test data proves that the CEV transmitted its location via the radiolocator beacon.
3.2.10.6	CV0788	The CEV radiolocator beacon(s) shall operate continuously for at least 36 hours post landing.	Analysis, Test	Verification shall be by test and analysis. The test shall be conducted using flight-like hardware to prove that the radiolocator beacon operates for 36 hours post landing. Analysis on the battery power allocation and nominal/off nominal operation shall be performed to show that the allocation is adequate for worse case 36 hour operation. The verification shall be considered successful when the test data and analysis proves that the CEV radiolocator beacon operates for 36 hours.
3.2.10.6	CV0790	The CEV shall provide simultaneous voice communications and radiolocator beacon signal.	Test	Verification shall be by test. The test shall be conducted using flight- like hardware to prove that simultaneous voice communications and radiolocator beacon signal can be provided by the CEV without interference. The verification shall be considered successful when the test proves that voice communications and radiolocator beacon operate simultaneously.
3.2.11				
3.2.11.1	CA5921-PO	The CEV shall perform separation functions with the CLV.	Analysis	The ability for the CEV to separate from the CLV shall be verified by analysis. The analysis shall be performed using the results of NASA-accredited digital flight simulations of the integrated CLV/CEV. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis results shows a 99.73% (TBR-001-977) probability with a confidence of 90% (TBR-001-978) that the CEV can separate from the CLV.
3.2.11.1	CV0048	The CEV shall translate from the CLV	Analysis	The positive clearance margin from the translation following

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		with positive clearance margins following separation.		CEV separation from the CLV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of both the CEV and CLV as independent vehicles. The analysis shall generate trajectories and attitude timelines of the two vehicles once they have separated. A subsequent analysis shall be performed using a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the CLV. The analysis shall use the trajectories and attitudes of the two vehicles from the first analysis and determine the closest approach between the structures of the two vehicles after the initial separation. Verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that positive clearance margins can be achieved and no re-contact has occurred between the vehicles
3.2.11.1	CV0110	The CEV shall independently determine the CLV/CEV integrated stack ascent trajectory, attitude, and attitude rates.	Analysis, Inspection	The independently determined ascent trajectory, attitude, and attitude rates of the CLV/CEV integrated stack shall be verified by inspection and analysis. The inspection shall be performed on CEV/CLV ICDs and IRDs, system design documents, and the flight software to determine if the CEV is using any sensor data from the CLV navigation sensors or derived-navigation parameters from the CLV. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV/CLV stack and the CEV nav sensors. The analysis shall include nominal and off-nominal trajectories. The verification shall be considered successful when the inspection shows that the CEV-derived ascent trajectory, attitude, and attitude rates are independent of the CLV-derived ascent trajectory, attitude, and attitude rates. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR)

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				with 90% confidence that the CEV-derived ascent trajectory, attitude, and attitude rates are accurate. NOTES: The required accuracy of the information is provided in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, GN&C Subsystem Specification.
3.2.11.1	CV0590	The CEV shall send manual steering commands to the CLV during ascent in response to crew input.	Test	The manual steering commands from the CEV crew, sent to the CLV during ascent, shall be verified by test. The test shall be performed in a CEV avionics-type facility that includes the crew manual steering interface and an emulation of the CLV interface. The test shall record the CLV manual steering commands generated by the crew at different points along the ascent trajectory. The verification shall be considered successful when the test shows that the crew manual steering commands are passed to the CLV interface. [The resulting trajectory is defined to be correct when the resultant state vector, attitude, and attitude rates are consistent with the steering commands and are within the performance accuracy defined in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.]
3.2.11.1	CV0591	The CEV shall provide updated ascent trajectory targets for the CEV/CLV integrated stack.	Analysis, Test	The updated ascent trajectory targets for the CEV/CLV integrated stack, provided by the CEV, shall be verified by analysis and test. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV/CLV stack during ascent, an emulation of any crew or external interfaces required to implement this requirement, and an emulation of the CLV interface. The analysis shall include both nominal and off-nominal ascent trajectories covering all possible abort situations. The test shall be conducted in a CEV avionics-type facility that includes the crew interface. The test shall use a crewmember to

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				generate updated ascent trajectory targets via the crew interface. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV provides updated ascent trajectory targets for the CEV/CLV integrated stack that either result in successful achievement of orbit or successful aborts. The verification shall be considered successful when the test shows that the crew input for ascent trajectory targets is passed to the CLV interface. [The successful achievement of orbit is defined as an altitude from which a subsequent burn will raise the perigee such that the CEV doesn't re-entry the atmosphere. The successful abort is defined as a water landing where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal constraints on the vehicle are met.]
3.2.11.2	CA5819-PO	The CEV shall perform Trajectory Correction Maneuvers (TCMs) during the Trans-Lunar Coast (TLC).	Analysis	The ability of the CEV to perform TCMs during TLC shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include multi-body gravity effects experienced during the TLC. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-377) probability that the CEV can perform the TCMs during TLC.
3.2.11.2	CV0119	The CEV shall compute translational maneuver targets.	Analysis	The CEV-computed translational maneuver targets shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the LEO, trans-lunar, and LLO environments. The analysis shall include all maneuver types (i.e., LEO deorbit, LLO burns, TEI burns, and RPOD burns) and all vehicle configurations (i.e., EDS/LSAM/CEV, CEV/LSAM, and CEV). The verification shall be considered successful when the analysis shows that the probability is at

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				least 0.9987 (TBR) with 90% confidence that the translational maneuver targets have been computed and executed within specified dispersion limits for all maneuver types and vehicle configurations. NOTES: The performance accuracy of the translational maneuver targets is provided in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.
3.2.11.2	CV0677	The CEV shall perform Trajectory Correction Maneuvers (TCMs) during the Trans-Earth Coast (TEC).	Analysis	The trajectory correction maneuvers (TCMs) performed by the CEV during trans-Earth coast (TEC) shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV/LSAM in the LLO and trans-Earth environments, the CM/SM in the trans-Earth and LEO environments, and the CM in the entry environment. The analysis shall include nominal lunar returns, aborted lunar returns, and early lunar returns. The analysis shall cover both direct and skip entry returns from the full range of lunar antipodes. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that the trajectory correction maneuvers result in successful guided direct or skip entries from the moon. [A successful guided direct entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.] [A successful guided skip entry is

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				defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.]
3.2.11.2	CA3204-PO	The CEV shall perform the orbit transfer from the Ascent Target to the Earth Rendezvous Orbit (ERO) for crewed lunar missions.	Analysis	The CEV orbital transfer from the Ascent Target to the Earth Rendezvous Orbit (ERO) for crewed lunar missions shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations for the CEV orbit transfer mission phase. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-376) probability with a 90% confidence that the vehicle can successfully perform the orbit transfer from Ascent Target to ERO for crewed lunar missions.
3.2.11.2	CA3207-PO	The CEV shall perform the orbit transfer from Low Lunar Orbit (LLO) to the Lunar Rendezvous Orbit (LRO) for crewed lunar missions.	Analysis	The ability of the CEV to perform the orbit transfer from LLO to LRO for crewed lunar missions shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include multi-body gravity effects. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-971) probability that the CEV can perform the orbit transfer from LLO to LRO for crewed lunar missions.
3.2.11.2	CA3209-PO	The CEV shall perform the Trans-Earth Injection (TEI) for crewed lunar missions.	Analysis	The ability of the CEV to perform TEI for crewed lunar missions shall be verified by analysis. The analysis will be performed using a NASA-accredited digital flight simulation, which shall include multi-body gravity effects experienced during trans-Earth coast. The analysis shall include Monte

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				Carlo dispersions on mass properties, engine performance, and GN&C parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-380) probability with a 90% confidence that the CEV can perform the TEI for crewed lunar missions.
3.2.11.2	CA0191-PO	The CEV shall perform the orbit transfer from the Ascent Target to ISS.	Analysis	The CEV orbital transfer from the Ascent Target to ISS requirement shall be verified by analysis. The analysis shall be performed using NASA-accredited digital flight simulations for the CEV orbit transfer mission phase. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. The verification shall be considered successful when the analysis results show there is a 99.73% (TBR-001-480) probability with a 90% confidence that the vehicle can successfully perform the orbit transfer from Ascent Target to ISS.
3.2.11.3	CV0111	The CEV shall independently determine the integrated EDS/LSAM/CEV stack trajectory, attitude, and attitude rates.	Analysis, Inspection	The independently determined trajectory, attitude, and attitude rates of the integrated EDS/LSAM/CEV stack shall be verified by inspection and analysis. The inspection shall be performed on CEV/LSAM/EDS ICDs and IRDs, system design documents, and the flight software to determine if the CEV is using any sensor data from the EDS/LSAM navigation sensors or derived-navigation parameters from the EDS/LSAM. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the EDS/LSAM/CEV stack. The analysis shall include nominal and off-nominal trajectories. The verification shall be considered successful when the inspection shows that the CEV-derived trajectory, attitude, and attitude rates are independent of the EDS/LSAM-derived trajectory, attitude, and attitude rate. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV-

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				derived trajectory, attitude, and attitude rates compare with the simulation environment-derived trajectory, attitude, and attitude rates. NOTES: The accuracy of the comparison is provided in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, GN&C Subsystem Specification.]
3.2.11.3	CV0477	The CEV shall independently determine the integrated LSAM/CEV stack trajectory, attitude, and attitude rate.	Analysis, Inspection	The independently determined trajectory, attitude, and attitude rates of the integrated LSAM/CEV stack shall be verified by inspection and analysis. The inspection shall be performed on CEV/LSAM ICDs and IRDs, system design documents, and the flight software to determine if the CEV is using any sensor data from the LSAM navigation sensors or derived-navigation parameters from the LSAM. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV/LSAM stack. The analysis shall include nominal and off-nominal trajectories. The verification shall be considered successful when the inspection shows that the CEV-derived trajectory, attitude, and attitude rates are independent of the LSAM-derived trajectory, attitude, and attitude rates. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV-derived trajectory, attitude, and attitude rates compare with the simulation environment-derived trajectory, attitude, and attitude rates. [The accuracy of the comparison is provided in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.]
3.2.11.3	CA4128-PO	The CEV shall perform attitude control of the CEV/LSAM mated configuration after CaLV EDS undocking through CEV/LSAM separation in LLO.	Analysis	The CEV performance of attitude control of the CEV/LSAM mated configuration after CaLV EDS undocking through CEV/LSAM separation in LLO shall be verified by analysis. The CEV attitude control analysis shall be conducted in a NASA-accredited digital simulation. The analysis shall

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				include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, and environmental parameters for both CEV and LSAM. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) is greater than 99.73% (TBR-001-509) with a 90% confidence.
3.2.11.3	CA0187-PO	The CEV shall perform attitude control of the CEV/LSAM mated configuration after docking in LLO.	Analysis	The CEV performance of attitude control of the CEV/LSAM mated configuration after docking in LLO shall be verified by analysis. The CEV attitude control analysis shall be conducted in a NASA-accredited digital simulation. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, and environmental parameters for both CEV and LSAM. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) is greater than 99.73% (TBR-001-508) with a 90% confidence.
3.2.11.4	CV0122	The CEV shall perform backouts during proximity operations and docking when functioning as the maneuvering vehicle.	Analysis	The backouts during proximity operations and docking by the CEV when functioning as the maneuvering vehicle shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the target vehicle (i.e., EDS/LSAM, ISS, or LSAM-AS) in the LEO and LLO environments. The analysis shall include nominal and off-nominal proximity operations and docking conditions. The analysis shall include backouts during the proximity operations as well as backouts during docking. The analysis shall also be performed using a 3-D graphical modeling tool that includes NASA-accredited

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				models of the CEV and the target vehicles to look for unplanned contact between the CEV and the target vehicles. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the maneuvering CEV is capable of successfully performing backouts, with no unplanned contact between vehicles, from proximity operations and docking for all target vehicles (i.e., ISS, EDS/LSAM, or LSAM-AS). NOTES: A successful backout from ISS during proximity operations and docking is defined as any trajectory that avoids the keep out zones defined in the ISS-CEV IRD and results in no unplanned contact between the CEV and the ISS. A successful backout from EDS/LSAM or LSAM-AS during proximity operations and docking is defined as any trajectory that results in no unplanned contact between the CEV and the EDS/LSAM or LSAM-AS. The backouts during proximity operations and docking by the CEV when functioning as the maneuvering vehicle shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the target vehicle (i.e., EDS/LSAM, ISS, or LSAM-AS) in the LEO and LLO environments. The analysis shall include nominal and off-nominal proximity operations and docking conditions. The analysis shall include backouts during the proximity operations as well as backouts during docking. The analysis shall also be performed using a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the target vehicles to look for unplanned contact between the CEV and the target vehicles. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the maneuvering CEV is capable of successfully performing backouts, with no

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				unplanned contact between vehicles, from proximity operations and docking for all target vehicles (i.e., ISS, EDS/LSAM, or LSAM-AS). NOTES: A successful backout from ISS during proximity operations and docking is defined as any trajectory that avoids the keep out zones defined in the ISS-CEV IRD and results in no unplanned contact between the CEV and the ISS. A successful backout from EDS/LSAM or LSAM-AS during proximity operations and docking is defined as any trajectory that results in no unplanned contact between the CEV and the EDS/LSAM or LSAM-AS.
3.2.11.4	CV0126	The CEV shall perform proximity operations and docking with LSAM when it is in any inertial attitude with inertial rate less than 0.4 (TBR-002-056) deg/sec per axis.	Analysis	The CEV proximity operations and docking with LSAM-AS, when it is in any inertial attitude with inertial rates less than 0.4 (TBR-002-056) deg/sec per axis, shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the LSAM-AS in the LLO environment. The analysis shall include various inertial attitudes and inertial attitude rates per axis (less than 0.4 (TBR-002-056) deg/sec) and other nominal and off-nominal proximity operations and docking conditions. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV is capable of performing proximity operations and docking with LSAM-AS when the LSAM-AS is in any inertial attitude with inertial attitude rates less than 0.4 (TBR-002-056) deg/sec per axis.
3.2.11.4	CV0129	The CEV shall perform any-attitude undocking with a mated vehicle inertial attitude rate up to 2 deg/s (TBR-002-159).	Analysis	The any-attitude undocking of the CEV with a mated-vehicle, inertial attitude rate up to 2 deg/sec (TBR-002-159) shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the mated vehicle (i.e., ISS, EDS/LSAM, LSAM-AS) in the LEO and LLO environments. The analysis

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				shall include various inertial attitude and inertial attitude rate combinations. The analysis shall include nominal and off-nominal undocking conditions. The analysis shall also be performed using a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the target vehicles as well as a collision model for detecting closest approach between the CEV and each of the target vehicles. The analysis shall use trajectories from the previous analysis and propagate these for 4 (TBR) orbits to determine that no re-contact has occurred. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can safely perform any-attitude undocking from the mated vehicle (i.e., ISS, EDS/LSAM, LSAM-AS) with a mated-vehicle inertial attitude rate up to 2 deg/sec (TBR-002-159). The undocking is considered safe when no re-contact has occurred between the two vehicles after 4 (TBR) orbits.
3.2.11.4	CV0791	The CEV shall perform breakouts during proximity operations and docking when functioning as the maneuvering vehicle.	Analysis	The breakouts from proximity operations and docking by the CEV when functioning as the maneuvering vehicle shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the target vehicle (i.e., ISS, EDS/LSAM, or LSAM-AS) as independent vehicles. The analysis shall include the LEO and LLO environments and cover nominal and off-nominal proximity operations and docking conditions. The analysis shall also be performed using a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the target vehicles (i.e., ISS, EDS/LSAM, or LSAM-AS). The analysis shall use the trajectories and attitudes of the two vehicles from the simulations of the previous analysis and determine the closest approach between the structures of the two vehicles. The verification

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				shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV is capable of successful breakouts, with no unplanned contact between vehicles, from proximity operations and docking for all target vehicles (i.e., ISS, EDS/LSAM, or LSAM-AS) under nominal and off-nominal proximity operations and docking conditions.
3.2.11.4	CV0823	The CEV shall perform a second LSAM docking attempt within 2 orbits (TBR-002-251) after a first docking attempt is terminated for a lunar mission in LEO.	Analysis	The ability of the CEV to perform a second LSAM docking attempt within 2 orbits after a first docking attempt shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation that includes primary flight control software and that models the on-orbit dynamics of the CEV and the target as individual vehicles, the LEO environment, the nav-aid sensors/targets of the target vehicles, and the emulated manual controls for RPODU. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that a second LSAM docking attempt can be performed within 2 orbits (TBR) after the first docking attempt is terminated for a lunar mission in LEO.
3.2.11.4	CA3248-PO	The CEV shall compute rendezvous maneuvers when performing relative navigation with the target vehicle.	Analysis	The CEV maneuver targeting capability shall be verified by analysis. The analysis shall be accomplished using a NASA Accredited dynamic simulation of all the relevant Constellation Architecture flight systems. The dynamic simulation and analysis shall verify the accuracy of the CEV maneuver targeting capability by taking error data from component level navigation sensor testing and processing this data with a dynamic model of the orbit dynamics during all mission phases. The verification shall be considered successful when the analysis and simulation has shown that the criteria for maneuver targeting capability as specified in CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element have been met.
3.2.11.4	CA0059-PO	The CEV shall function as the	Analysis,	The ability of the CEV to actively accomplish rendezvous,

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		maneuvering vehicle during RPODU operations with the LSAM/CaLV EDS mated configuration in LEO.	Demonstration, Test	proximity operations, dock, and undock with the LSAM/EDS shall be verified by test, demonstration and analysis. Docking and undocking tests and demonstrations shall be conducted with the CEV and EDS/LSAM docking interface hardware. Final approach and separation tests and demonstrations shall be conducted with the relative navigation sensor hardware. Rendezvous, proximity operations and docking/separation tests and analysis shall be conducted using certified digital simulations. Docking Hardware The docking/undocking interface hardware verification shall include capture envelope testing, and demonstration of the docking/undocking hardware with simulated closed loop control. The capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV and EDS/LSAM in a 6-DOF test facility. The docking test shall be successful when it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. The undocking test shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and LSAM that are within the specifications of CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. The docking/undocking hardware demonstration shall be conducted in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the CEV and EDS/LSAM navigation, guidance and control software. The docking demonstration shall be considered successful when docking is achieved under both (1) automated

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				simulation control and (2) pilot-in-the-loop control. The docking demonstration shall be conducted with nominal vehicle health status and under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. The undocking demonstration shall be considered successful when the simulation results show that undocking separation and relative angular rates are within bounds specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. Relative Navigation Sensors Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 30.48 (TBR-001-441) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect docking. Testing shall be conducted under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. Testing shall be considered successful when the simulation achieves docking contact conditions for all tests with initial conditions inside the docking corridor defined by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. Relative navigation sensor demonstration shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 30.48 (TBR-001-441) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor

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				measurements and relative vehicle state estimates. The vehicle simulation will accept and react to inputs from a pilot-in-the-loop. The demonstration shall be conducted under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. The demonstration shall be considered successful when the simulation achieves docking contact conditions for all demonstrations with initial conditions inside the docking corridor defined by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. SIL (or equivalent) Avionics The rendezvous, proximity operations, docking, and undocking tests shall be conducted within a SIL (or equivalent). The SIL (or equivalent) simulation shall include models of the LSAM/EDS vehicle attitude control systems and dynamics. These tests shall include one or more rendezvous and docking tests as well as one or more undocking tests conducted under nominal conditions. The rendezvous and docking test shall be considered successful when required docking contact conditions are demonstrated with no violations of trajectory or vehicle constraints. The undocking test shall be considered successful when undocking and departure proximity operations are demonstrated without re-contact and without violations of vehicle or trajectory constraints. Analysis The rendezvous, proximity operations, docking and undocking analysis shall be conducted using a NASA-accredited digital simulation including models of both the CEV and LSAM/EDS vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. Analysis shall be performed for rendezvous, proximity operations, and docking as well as undocking and departure proximity operations. The rendezvous and

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				docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.73% (TBR-001-442) with a 90% confidence. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without re-contact is greater than 99.73% (TBR-001-443) with a 90% confidence.
3.2.11.4	CA0131-PO	The CEV shall function as the target vehicle during RPOD operations with the LSAM in LLO.	Analysis, Inspection, Test	The ability for the CEV to perform target vehicle functions during RPOD with the LSAM shall be verified by inspection, docking mechanism tests, CEV attitude control tests, and CEV attitude control analysis. CEV design documentation shall be inspected to show that any CEV hardware required for proper functioning of the LSAM sensors or navigation system is present and mounted in accordance with the CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD). The docking capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV and EDS/LSAM in a 6-DOF test facility. The docking test shall be successful when it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD). The CEV attitude hold tests shall be conducted within a SIL (or equivalent). The SIL (or equivalent) shall include models of environmental attitude disturbances, as well as models of the LSAM vehicle, including LSAM thruster plumes. One or more tests shall be conducted for all nominal LSAM approach trajectories. The attitude hold tests shall be considered successful when the results show that CEV

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				attitude errors and angular rate errors remain within the limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. The CEV attitude control analysis shall be conducted in a NASA-accredited digital simulation. The simulation shall include models of environmental attitude disturbances, as well as models of the LSAM vehicle, including LSAM thruster plumes. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance, GN&C parameters, environmental parameters and LSAM plume impingement parameters. The analysis shall be considered successful when the results show that probability of remaining within the attitude limits specified by CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) is greater than 99.73% (TBR-001-444) with a 90% confidence.
3.2.11.4	CA0369-PO	The CEV shall function as a maneuvering vehicle while performing RPOD with the LSAM in LLO prior to crew transfer back to the CEV for crewed Lunar missions.	Analysis, Demonstration, Test	The ability of the CEV to actively accomplish rendezvous, proximity operations, and docking, with the LSAM in LLO shall be verified by test, demonstration and analysis. Docking tests and demonstrations shall be conducted with the CEV and LSAM docking interface hardware. Final approach tests and demonstrations shall be conducted with the relative navigation sensor hardware. Rendezvous, proximity operations and docking tests and analysis shall be conducted using certified digital simulations. The docking interface hardware verification shall include capture envelope testing, and demonstration of the docking hardware with simulated closed loop control. The docking capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for LSAM and CEV in a 6-DOF test facility. The docking test shall be successful when

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				it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD) requirements. The docking hardware demonstration shall be conducted in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the LSAM and CEV navigation, guidance and control software. The docking demonstration shall be conducted with nominal vehicle health status. The docking demonstration shall be considered successful when docking is achieved using real-time control inputs. Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 10.36 (TBR-001-451) m (100 ft) of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect docking. Testing shall be considered successful when the simulation achieves docking contact conditions for all tests with initial conditions inside the docking corridor defined by (TBD-001-1003) LSAM-CEV IRD requirements. Relative navigation sensor demonstration shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 10.36 (TBR-001-451) m (100 ft) of the approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor measurements and relative vehicle state estimates. The vehicle simulation will accept and implement real-time control inputs. The demonstration shall be considered successful when the

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				simulation achieves docking contact conditions for all demonstrations with initial conditions inside the docking corridor defined by (TBD-001-1003) CEV-LSAM IRD requirements. The rendezvous, proximity operations, and docking shall be conducted within a SIL (or equivalent). The LSAM SIL simulation shall include models of the CEV vehicle attitude control systems and dynamics. These tests shall include one or more rendezvous and docking tests conducted under nominal conditions. The rendezvous and docking test shall be considered successful when required docking contact conditions are demonstrated with no violations of trajectory or vehicle constraints. The rendezvous, proximity operations and docking analysis shall be conducted using a NASA-accredited digital simulation including models of both the LSAM and CEV vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters and environmental parameters. Analysis shall be performed for rendezvous, proximity operations, and docking. The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.73% (TBR-001-450) with a 90% confidence.
3.2.11.4	CA0133-PO	The CEV shall function as the maneuvering vehicle during undocking and departure proximity operations from LSAM, prior to TEI.	Analysis, Demonstration, Test	The ability of the CEV to actively accomplish undocking with the LSAM in LLO shall be verified by test, demonstration and analysis. Undocking tests and demonstrations shall be conducted with the CEV and LSAM docking interface hardware. Separation tests and demonstrations shall be conducted with the relative navigation sensor hardware. Separation tests and analysis shall be conducted using certified digital simulations. Docking/Undocking Hardware: the docking/undocking hardware testing shall consist of ground tests, using flight-

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				equivalent docking adaptors for CEV and LSAM in a 6-DOF test facility. The undocking tests shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and LSAM that are within the specifications of (TBD-001-655) LSAM-CEV IRD requirements. Relative Navigation Sensors: Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the first 30.48 (TBR-001-542) m (100 ft) of the post-undocking separation. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect undocking and separation. Testing shall be conducted under (TBD-001-608) range of lighting conditions spanning the operational range of the sensors. Initial conditions for the tests shall be derived from the range of undocking separation forces and moments determined from the hardware tests. Testing shall be considered successful when the simulation achieves safe separation without re-contact for all tests. SIL (or equivalent) Avionics: The undocking tests shall be conducted within a SIL (or equivalent). The SIL (or equivalent) simulation shall include models of the LSAM vehicle attitude control systems and dynamics. These tests shall include one or more undocking tests conducted under nominal conditions. The undocking test shall be considered successful when undocking and departure proximity operations are demonstrated without re-contact and without violations of vehicle or trajectory constraints. Analysis: The undocking analysis shall be conducted using a NASA-accredited digital simulation including models of both the CEV and LSAM vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine

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				performance, GN&C parameters and environmental parameters. Analysis shall be performed for undocking and departure proximity operations. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without re-contact is greater than 99.73% (TBR-001-449) with a 90% confidence.
3.2.11.4	CA0081-PO	The CEV shall function as the maneuvering vehicle during RPODU operations with the ISS.	Analysis, Demonstration, Test	The ability of the CEV to actively accomplish rendezvous, proximity operations, dock, and undock with the ISS shall be verified by test, demonstration and analysis. Docking and undocking tests and demonstrations shall be conducted with the CEV and ISS docking interface hardware. Final approach and separation tests and demonstrations shall be conducted with the relative navigation sensor hardware. Rendezvous, proximity operations and docking/separation tests and analysis shall be conducted using certified digital simulations. The docking/undocking interface hardware verification shall include capture envelope testing, and demonstration of the docking/undocking hardware with simulated closed loop control. The docking/undocking capture envelope testing shall consist of ground tests, using flight-equivalent docking adaptors for CEV and ISS in a 6-DOF test facility. The docking test shall be successful when it is demonstrated that the docking mechanisms function properly under worst-case contact conditions as specified in CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. The undocking test shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and ISS that are within the specifications of CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements

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				Document requirements. The docking/undocking hardware demonstration shall be conducted in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the CEV and ISS navigation, guidance and control software. The docking demonstration shall be considered successful when docking is achieved under both (1) automated simulation control, (2) CEV pilot-in-the-loop control, and (3) remote pilot-in-the-loop control (from ISS). The docking demonstration shall be conducted with nominal vehicle health status and under (TBD-001-325) range of lighting conditions spanning the operational range of the sensors. The undocking demonstration shall be considered successful when the simulation results show that undocking separation and relative angular rates are within bounds specified in CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. Relative navigation sensor testing shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 100 (TBR-001-246) ft of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving and processing relative navigation sensor measurements to effect docking. Testing shall be conducted under (TBD-001-325) range of lighting conditions spanning the operational range of the sensors. Testing shall be considered successful when the simulation achieves docking contact conditions for all tests with initial conditions inside the docking corridor defined by CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. Relative navigation sensor demonstration shall be conducted in a 6-DOF test facility with range of motion capable of executing the final 100

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				(TBR-001-246) ft of the final approach. The motion of the relative navigation sensor suite shall be driven by a NASA-accredited digital vehicle simulation capable of receiving, processing, and displaying relative navigation sensor measurements and relative vehicle state estimates. The vehicle simulation will accept and react to inputs from a pilot-in-the-loop, both on board CEV and remote pilot commanding from ISS. The demonstration shall be conducted under (TBD-001-325) range of lighting conditions spanning the operational range of the sensors. The demonstration shall be considered successful when the simulation achieves docking contact conditions for all demonstrations with initial conditions inside the docking corridor defined by CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document requirements. The rendezvous, proximity operations, docking, and undocking tests shall be conducted within the a SIL (or equivalent). The SIL (or equivalent) simulation shall include models of the ISS vehicle attitude control systems and dynamics. These tests shall include one or more rendezvous and docking tests as well as one or more undocking tests conducted under nominal conditions. The rendezvous and docking test shall be considered successful when required docking contact conditions are demonstrated with no violations of trajectory or vehicle constraints. The undocking test shall be considered successful when undocking and departure proximity operations are demonstrated without re-contact and without violations of vehicle or trajectory constraints. The rendezvous, proximity operations, docking and undocking analysis shall be conducted using a NASA-accredited digital simulation including models of both the CEV and ISS vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance,

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				GN&C parameters and environmental parameters. Analysis shall be performed for rendezvous, proximity operations, and docking as well as undocking and departure proximity operations. The rendezvous and docking analysis shall be considered successful when the analysis shows that the probability of successful rendezvous and docking is greater than 99.73% (TBR-001-247) with a 90% confidence. The undocking and separation analysis shall be considered successful when the analysis shows that the probability of successful undocking and separation without re-contact is greater than 99.73% (TBR-001-248) with a 90% confidence.
3.2.11.4	CV0127	The CEV shall terminate docking upon receipt of command.	Test	The termination of docking by the CEV upon receipt of command shall be verified by test. The test shall be performed in a CEV avionics-type facility that includes the crew command interfaces, an emulation of the external operator (i.e., ISS and LSAM-AS) interfaces, and an emulation of the docking mechanism interfaces. The test shall record the status of the docking terminate command (issued via each of the command interfaces) and the state of the docking terminate signal at the emulated docking mechanism interface. The verification shall be considered successful when the test shows that the CEV always generates the docking terminate signal at the docking mechanism interface on command whether commanded by the crew or an external operator (i.e., ISS or LSAM-AS).
3.2.11.4	CA5286-PO	The CEV shall perform target vehicle functions during undocking and departure proximity operations from LSAM prior to lunar descent.	Analysis	The ability of the CEV to perform target vehicle functions during undocking and departure proximity operations from LSAM prior to lunar descent shall be verified by analysis. The analysis shall be performed using a NASA-accredited digital simulation of the CEV and LSAM vehicles. The analysis shall focus on the ability of the CEV to maintain attitude such that the relative navigation of the vehicles ensures no recontact. The analysis shall include Monte Carlo dispersions on mass properties, RCS performance,

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				GN&C parameters, and environmental parameters for both CEV and LSAM. The verification shall be considered successful when the analysis shows that there is a 99.73% (TBD-001-901) probability with a 90% confidence that the CEV can support target vehicle functions during LSAM undock and departure proximity operations.
3.2.11.4	CV0450	The CEV shall undock, separate, and perform departure maneuver(s) from the crewed LSAM in LLO prior to lunar descent.	Analysis	The CEV undock, separation, and departure maneuver(s) from the crewed LSAM in LLO prior to lunar descent shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of both the CEV and LSAM as individual vehicles in the LLO environment. The analysis shall include nominal and off-nominal undocking conditions. The analysis shall also include a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the LSAM as well as a collision model for detecting closest approach between the CEV and the LSAM. The analysis shall use trajectories from the first analysis and propagate them for 4 (TBR) orbits to determine the points of closest approach. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can successfully undock, separate, and depart from the crewed LSAM in LLO. [A successful undock, separation, and departure is defined as the release of the docking mechanisms from each other, the resulting initial separation without any CEV thruster firings, and any departure maneuver(s) that leaves the nav state of the LSAM undisturbed and a resulting trajectory that has no re-contact with the LSAM after 4 (TBR) orbits.]
3.2.11.5	CV0108	The CEV shall calculate Low Lunar Orbit (LLO) navigation solutions for TEI sequence initiation in less than 6 hours.	Analysis	The time to calculate the LLO navigation solutions for TEI sequence initiation in less than 6 hours shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software

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				installed) that models the dynamics of the CEV/LSAM-AS in the LLO, the CM/SM in the trans-Earth and LEO environments, and the CM in the entry environment. The analysis shall include both nominal and off-nominal conditions. The analysis shall cover both direct and skip entry returns from the full range of lunar antipodes. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the LLO navigation solutions have been computed in less than 6 hours and that the TEI burn has resulted in a successful guided direct or skip entry. NOTES: A successful guided direct entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system. A successful guided skip entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.
3.2.11.6	CV0648	The CEV shall use a single, continuous (TBR-001-518) reference time scale traceable to Coordinated Universal Time (UTC) in accordance with CxP 70142, Constellation Program Navigation Standards Specification Document.	Inspection, Test	The single, continuous (TBR-001-518) reference time scale of the CEV, traceable to Coordinated Universal Time (UTC), in accordance with CxP 70142, Constellation Program Navigation Standards Specification Document, shall be verified by inspection and test. The inspection shall be performed on CEV system design documents and the flight

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				software to determine if the CEV is using a single, continuous reference time scale. A test shall be performed in a CEV avionics-type facility to record the reference time of the CEV. The verification shall be considered successful when the inspection shows that the CEV is using a single, continuous reference time scale, and when the test shows that the recorded reference time meets the requirements in CxP 70142, Constellation Program Navigation Standards Specification Document.
3.2.11.6	CA3142-PO	The CEV shall perform navigation and attitude determination during all mission phases including pre-launch.	Analysis, Test	The CEV navigation and attitude determination capability shall be verified by analysis and component testing. The analysis and testing shall be accomplished using flight sensor hardware in a NASA accredited dynamic hardware-in-the-loop simulation of the CEV. The dynamic simulation, analysis, and hardware-in-the-loop tests shall verify the accuracy of the CEV navigation and attitude determination capability by taking error data from component level navigation and attitude sensor testing and processing this data with a dynamic model of the orbit and attitude dynamics and disturbances during all mission phases. The verification shall be considered successful when the analysis, simulation, and testing has shown that the criteria as specified in the CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element for the navigation and attitude determination capability has been met.
3.2.11.6.1	CV0112	The CEV shall perform relative navigation for rendezvous, proximity operations and docking when functioning as the maneuvering vehicle.	Analysis	The relative navigation for rendezvous, proximity operations and docking when the CEV is the maneuvering vehicle shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the relative navigation sensors of the CEV, any cooperative sensors on the target vehicles (i.e., ISS, EDS/LSAM, LSAM-AS), and includes the LEO and LLO environments. The analysis shall be performed for each

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				target vehicle and include both nominal and off-nominal conditions. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the relative navigation correctly supports rendezvous, proximity operations and docking with all target vehicles (i.e., ISS, EDS/LSAM, LSAM-AS).
3.2.11.6.1	CV0116	The CEV shall determine the position and velocity of the CEV relative to the target vehicle during PODU operations, when the CEV is the maneuvering vehicle.	Analysis	The position and velocity of the CEV relative to the target vehicle, when the CEV is functioning as the maneuvering vehicle during PODU operations, shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the relative navigation sensors of the CEV and any cooperative sensors on the target vehicles (i.e., EDS/LSAM, LSAM-AS, and ISS). The analysis shall be performed for each target vehicle and include both nominal and off-nominal PODU conditions. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the position and velocity of the CEV relative to all target vehicles (i.e., EDS/LSAM, LSAM-AS, and ISS) correctly supports PODU operations.
3.2.11.6.1	CV0117	The CEV shall determine the attitude and attitude rate of the CEV relative to the target vehicle during LEO PODU operations, when the CEV is the maneuvering vehicle within 100 feet (TBR-002-210) of the target vehicle.	Analysis	The CEV estimate of attitude and attitude rate of the CEV relative to the target vehicle during PODU operations when the CEV is functioning as the maneuvering vehicle within 100 feet (TBR-002-210) of the target vehicle shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the relative navigation sensors of the CEV and any cooperative sensors on the target vehicles (i.e., ISS, EDS/LSAM, LSAM-AS). The analysis shall be performed for each target vehicle and include both nominal and off-nominal conditions. The

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				verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV correctly computes the attitude and attitude rate of all CEV relative to the target vehicles (i.e., ISS, EDS/LSAM, LSAM-AS) during PODU operations when maneuvering within 100 feet (TBR-002-210) of the target vehicle. NOTES: The performance accuracy of the attitude and attitude rate of the CEV relative to the target vehicle is provided in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.
3.2.11.6.1	CV0540	The CEV shall measure bearing angles between CEV and LSAM, when the two vehicles are within 432 nmi (800 km) to maintain a relative navigation state.	Analysis, Test	The CEV measurement of the bearing angles between the CEV and the LSAM, when the two vehicles are within 432 nmi (800 km) of each other, to maintain a relative navigation state shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the LSAM-AS as individual vehicles in the LLO environment. The analysis shall include nominal and off-nominal trajectories. The analysis shall be performed with both the CEV and the LSAM-AS acting as the chaser vehicle. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the LSAM as individual vehicles in the LLO environment. The analysis shall include nominal and off-nominal trajectories. The analysis shall be performed with the CEV as the active vehicle as it separates from the LSAM. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can accurately measure the bearing angles between the CEV and either the LSAM-AS or the LSAM, when the two

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				vehicles are within 432 nmi (800 km) of each other. NOTES: The performance accuracy of the bearing angle measurements is provided in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.
3.2.11.6.1	CV0532	The CEV shall measure range and range rate between CEV and LSAM, when the two vehicles are within 432 nmi (800 km) to maintain a relative navigation state.	Analysis, Test	The CEV measurement of the range and range rate between the CEV and the LSAM, when the two vehicles are within 432 nmi (800 km) of each other, used to maintain a relative navigation state shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the LSAM-AS as individual vehicles in the LLO environment. The analysis shall include nominal and off-nominal trajectories. The analysis shall be performed with both the CEV and the LSAM-AS acting as the chaser vehicle. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the LSAM as individual vehicles in the LLO environment. The analysis shall include nominal and off-nominal trajectories. The analysis shall be performed with the CEV as the active vehicle as it separates from the LSAM. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can accurately measure the range and range rate between the CEV and either the LSAM or LSAM-AS, when the two vehicles are within 432 nmi (800 km) of each other. NOTES: The performance accuracy of the measured range and range rate is provided in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.

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3.2.11.6.1	CV0597	The CEV shall perform relative navigation for rendezvous, proximity operations and docking as target vehicle when the LSAM is the active maneuvering vehicle.	Analysis	The CEV relative navigation during rendezvous, proximity operations, and docking, when the CEV is the target vehicle and the LSAM is the maneuvering vehicle, shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models dynamics of the CEV and the LSAM-AS as individual vehicles in the LLO environment and the relative navigation sensors of the CEV and any cooperative sensors on the LSAM-AS vehicle. The analysis shall include both nominal and off-nominal RPOD conditions. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the relative navigation successfully supports rendezvous, proximity operations, and docking.
3.2.11.6.1	CV0839	The CEV shall determine the attitude and attitude rate of the CEV relative to the LSAM during LLO PODU operations, when the CEV is the maneuvering vehicle within 150 feet (TBR-002-210) of the target vehicle.	Analysis	The ability of the CEV to determine the attitude and attitude rate of the CEV relative to the target vehicle during LEO PODU operations within 100 feet shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the target vehicle, and the sensor hardware used to measure relative attitude and attitude rate. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can determine the attitude and attitude rate of the CEV relative to the target vehicle during LEO PODU operations within 100 feet.
3.2.11.7	CV0773	The CEV shall perform RPODU independent of lighting conditions.	Analysis	The ability of the CEV to perform RPODU independent of lighting conditions shall be verified by analysis. The analysis of automated RPODU shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the

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				target (ISS, EDS/LSAM, or LSAM-AS) as individual vehicles in the LEO and LLO environments and the nav-aid sensors/targets of the target vehicles. The analysis shall include nominal and off-nominal RPODU conditions, including various lighting conditions. The analysis of manual RPODU shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the target (ISS or EDS/LSAM) as individual vehicles in the LEO environment, the nav-aid sensors/targets of the target vehicles, and the emulated manual controls for RPODU. The analysis shall include nominal and off-nominal RPODU conditions, including various lighting conditions. The analysis shall also use a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the target (ISS or EDS/LSAM). The analysis shall be performed using crewmembers in the loop, viewing simulated "out the window scenes" from the CEV of the approaching the target vehicle. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that automated RPODU of the CEV with the target vehicle, independent of lighting conditions, is successful for each target vehicle (ISS, EDS/LSAM, or LSAM-AS). The verification shall be considered successful when the analysis of the manual RPODU shows that successful RPODU of the CEV with the target vehicle, independent of lighting conditions, occurs at least 95% (TBR) of the time for each target vehicle (ISS or EDS/LSAM).
3.2.11.7	CV0792	The CEV shall perform RPODU independent of ground overflight constraints.	Analysis	The ability of the CEV to perform RPODU independent of ground overflight constraints shall be verified by analysis. The analysis of automated RPODU shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the on-orbit dynamics

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				of the CEV and the target (ISS, EDS/LSAM, or LSAM-AS) as individual vehicles, the LEO and LLO environments, and the nav-aid sensors/targets of the target vehicles. The analysis shall include nominal and off-nominal RPODU conditions, including various ground overflights. The analysis of manual RPODU shall be performed using a NASA-accredited, 6-DOF simulation, with primary flight software installed, that models the on-orbit dynamics of the CEV and the target (ISS or EDS/LSAM) as individual vehicles, the LEO environment, the nav-aid sensors/targets of the target vehicles, and the emulated manual controls for RPODU. The analysis shall include nominal and off-nominal RPODU conditions, including various ground overflights. The analysis shall also use a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the target (ISS or EDS/LSAM). The analysis shall be performed using crewmembers in the loop, viewing "out the window scenes" from the CEV of the approaching the target vehicle. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that automated RPODU of the CEV with the target vehicle, independent of ground overflights, is successful for each target vehicle (ISS, EDS/LSAM, or LSAM-AS). The verification shall be considered successful when the analysis of the manual RPODU shows that successful RPODU of the CEV with the target vehicle, independent of ground overflights, occurs at least 95% (TBR) of the time for each target vehicle (ISS or EDS/LSAM).
3.2.11.7	CA0462-PO	The CEV shall function as the maneuvering vehicle during undocking and departure proximity operations from the target vehicle at any attitude, in case of an emergency.	Analysis, Test	The ability of the CEV to function as a maneuvering vehicle during undocking and departure proximity operations from the target vehicle at any attitude in case of an emergency shall be verified by analysis and test. The analysis shall be conducted using a NASA-accredited digital simulation

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				including models of the CEV, LSAM/CaLV EDS, and the ISS vehicles. The analysis shall include Monte Carlo dispersions on mass properties, engine performance, GN&C parameters, and environmental parameters and shall span nominal attitude and attitude rates. The analysis shall also include undocking cases initiated prior to and after rigidization of the docking mechanism is complete. The analysis shall be considered successful when the analysis shows that the probability of successful undocking and departure proximity operations without violation of clearance requirements, as listed in the appropriate IRD, is greater than 99.73% (TBR-001-319) with a 90% confidence for the following emergency undocking scenarios: (1) CEV undocking from LSAM/CaLV EDS, (2) CEV undocking from LSAM, and (3) CEV undocking from ISS. The test shall be conducted with the CEV docking interface hardware in conjunction with both LSAM and ISS docking interface hardware. The test shall be conducted with CEV, LSAM, and ISS docking interface hardware in a 6-DOF test facility driven by a NASA-accredited digital simulation including models of the CEV, LSAM, CaLV EDS, ISS navigation, guidance and control software. The undocking test shall be conducted with nominal environmental and vehicle conditions. The undocking test shall be conducted with a set of initial attitude and attitude rates that span nominal conditions. The undocking test shall include undocking cases initiated prior to and after rigidization of the docking mechanism is complete. The undocking test shall be considered successful when it is demonstrated that the mechanisms impart forces and moments to the CEV and the LSAM or ISS (as appropriate) that are within the specifications of the IRD requirements as appropriate to the vehicle configuration under test. The undocking test shall be conducted for the scenarios: (1) CEV undocking from

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				LSAM/CaLV EDS, (2) CEV undocking from LSAM, and (3) CEV undocking from ISS.
3.2.11.7	CA0463-PO	The CEV shall provide for undocking within 10 (TBR-001-004) minutes of crew ingress and hatch closure.	Analysis, Demonstration	The ability for the CEV to undock post crew ingress and hatch closure in less than 10 (TBR-001-004) minutes shall be verified by analysis and demonstration. The analysis shall calculate the overall time necessary to power up systems. The demonstration shall use integrated Constellation flight systems in simulated mission conditions. The demonstration shall consist of performing a minimum of four runs using a NASA accredited simulator with two different sets of crew and collecting the task time for undocking post crew ingress and hatch closure. The verification shall be considered successful when the analysis determines that undocking post crew ingress and hatch closure time required is less than 10 (TBR-001-004) minutes and demonstration determines that undocking post crew ingress and hatch closure time required is less than 10 (TBR-001-004) minutes for 4 consecutive runs.
3.2.11.8	CV0085	The CEV shall perform an automated deorbit maneuver sequence from LEO.	Analysis, Demonstration	The automated de-orbit maneuver sequence from LEO performed by the CEV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CM/SM and the CM as separate configurations and includes the LEO and entry environments. The analysis shall include both nominal and off-nominal conditions. The de-orbit shall target both CONUS and water landings. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV has automatically performed the de-orbit maneuver sequence that resulted in

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				successful guided direct entries. NOTES: A successful guided direct entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, Section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.
3.2.11.8	CV0601	The CEV shall perform automated RPODU.	Analysis	The automated RPODU of the CEV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV, EDS/LSAM, and ISS as individual vehicles in the LEO environment and all relative navigation sensors on the vehicles. The analysis shall be performed for each target vehicle and include both nominal and off-nominal RPODU conditions. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the LSAM-AS as individual vehicles in the LLO environment and all relative navigation sensors on the vehicles. The analysis shall include both nominal and off-nominal RPODU conditions. The analysis shall also be performed using a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the target vehicles (i.e., EDS/LSAM, LSAM-AS, and ISS). The analysis shall use the trajectories and attitudes of the CEV and each target vehicle from the simulations of the first two analyses and determine the closet approach between the structures of the CEV and each target vehicle. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV automatically and successfully performed the RPODU operations without unplanned contact with the EDS/LSAM,

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				ISS, or the LSAM-AS.
3.2.11.9	CV0139	The CEV shall provide the crew direct visual observation of the target vehicle during proximity operations, docking and undocking.	Analysis, Demonstration	The direct visual observation of the target vehicle by the crew during proximity operations, docking, and undocking shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of both the CEV and the target vehicles (ISS, EDS/LSAM, LSAM-AS) as individual vehicles and includes both the LEO and LLO environments. The analysis shall include nominal and off-nominal proximity operations and docking conditions. The analysis shall also include a 3-D graphical modeling tool that includes NASA-accredited models of the CEV, the target vehicles, their nav visual aids, and the visualization effects (such as reflectivity) as it impacts the ability of the crew to observe the target. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the direct visual observation of the target vehicle by the crew leads to successful proximity operations, docking, and undocking without unplanned contact.
3.2.11.9	CV0594	The CEV shall be visually identifiable by a target vehicle crew at a distance of at least 3280 ft in any lighting conditions.	Analysis	The visual identification of the CEV by a target vehicle crew, at a distance of at least 3280 feet in any lighting conditions, shall be verified by analysis. The analysis shall be performed on released engineering products and lower-level illumination test reports to ensure that the CEV provides sufficient illumination so that a target vehicle crew (ISS or LSAM-AS) can visually identify the CEV up to a distance of at least 3280 feet. The verification shall be considered successful when the analysis shows that a target vehicle crew can visually identify the CEV up to a distance of at least 3280 feet.
3.2.11.9	CV0595	The CEV orientation shall be visually identifiable by a target vehicle crew at a distance of at least 800 ft in any lighting	Analysis	The visual identification by a target vehicle crew of the CEV orientation at a distance of at least 800 feet shall be verified by analysis. The analysis shall be performed on released

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		conditions.		engineering products and lower-level illumination test reports to ensure that the CEV provides sufficient illumination and are adequately located so that a target vehicle crew (ISS or LSAM-AS) can visually identify the CEV orientation at distances of at least 800 feet. The analysis shall also be performed using a 3-D graphical modeling tool that includes a NASA-accredited model of the CEV. The analysis shall position the vehicle at various distances up to 800 feet and in various orientations. The analysis shall include different light conditions (i.e., sunrise, sunset, high noon, orbit midnight, against the backdrop of deep space, against the backdrop of the sunlit Earth, against the backdrop of a dark moon, against the backdrop of a sunlit moon). The analysis shall include human subjects that will determine the CEV's orientation based on the visualization provided by the 3-D graphical modeling tool. The verification shall be considered successful when the analyses show that a target vehicle crew can roughly determine the CEV orientation up to a distance of at least 800 feet. [The performance accuracy of the orientation determination is provided in lower-level specifications, such as CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.]
3.2.11.10	CV0083	The CEV shall perform a direct entry for trans-Earth trajectories.	Analysis	The direct entry for trans-Earth trajectories by the CEV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with the primary flight software installed) that models the dynamics of the CM/SM and the CM as separate configurations in the trans-Earth, LEO, and entry environments. The analysis shall include both nominal and off-nominal conditions. The analysis shall include direct entries from the full range of lunar antipodes. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine

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				the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that successful guided direct entries have been achieved. NOTES: A successful guided direct entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.
3.2.11.10	CV0086	The CEV shall perform skip entry into the Earth's atmosphere of up to 5,750 <TBR-002-023> nmi (10,650 km) from the entry interface from lunar mission trajectories.	Analysis	The skip entry into the Earth's atmosphere, by the CEV from lunar mission trajectories for up to 5,750 (TBR-002-023) nmi (10,650 km) from the entry interface shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CM/SM and the CM as separate configurations in the trans-Earth, LEO, and entry environments. The analysis shall include both nominal and off-nominal conditions. The analysis shall include skip entries from the full range of lunar antipodes and vary the skip entry point for up to 5,750 (TBR-002-023) nmi from the entry interface. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that successful guided skip entries have been achieved. NOTES: A successful guided skip entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) where the entry

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				and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.
3.2.11.10	CV0599	The CEV shall perform a direct entry from LEO.	Analysis	The direct entry from LEO by the CEV shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CM/SM and the CM as separate configurations in the LEO and entry environments. The analysis shall include nominal and off-nominal conditions. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that successful guided direct entries have been achieved. [A successful guided direct entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.]
3.2.11.11	CA0494-PO	The CEV shall perform Earth landing regardless of ambient lighting conditions.	Test	The capability to perform Earth landing regardless of ambient lighting conditions shall be verified by Analysis. The analysis shall review the performance of the CEV software, hardware and operations concepts intended to support Earth landing, assessing potential sensitivity to ambient lighting conditions. The analysis shall be considered successful when it shows that the relevant software, hardware and operations can successfully support entry and landing within design limits, regardless of ambient lighting

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				conditions.
3.2.11.11	CA0329-PO	The CEV shall perform a guided entry that results in landing within 5 (TBR-001-040) km (2.7 nmi) of the intended target at a designated CONUS landing site.	Analysis	Guided entry landing accuracy shall be verified by analysis using a NASA-accredited digital entry simulation. Verification shall be considered successful when analysis of nominal direct and skip entry DRMs with system and environment dispersions shows a 99.73% (TBR-001-310) probability with a 90% confidence of achieving the required landing target accuracy at each of the designated CONUS landing sites (as appropriate to the specific DRM).
3.2.11.11	CV0587	The CEV shall accept updates to the designated Earth landing target site up to 1 hour prior to entry interface.	Analysis, Test	The CEV's acceptance of updates to the designated Earth landing target site up to 1 hour prior to entry interface shall be verified by analysis and test. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CM/SM and the CM as separate configurations in the LEO and entry environments and includes an emulation of the interface for updating the Earth landing target site. The analysis shall include nominal and off-nominal trajectories. The analysis shall include direct entry trajectory conditions from ISS. The analysis shall include both direct entry and skip entry trajectory conditions from the moon. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The test shall be performed in a CEV avionics-type facility that includes the interfaces for updating the designated Earth landing target site. The test shall record the update to the designated landing target site and the response of the CEV to each method of updating the designated Earth landing target site. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can accept an update to the designated Earth landing target site up to 1 hour prior to entry interface and

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				result in a successful guided direct or skip entry. The verification shall be considered successful when the test shows that the CEV response to the update is the correct designated Earth landing target site information. [A successful guided direct or skip entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.]
3.2.11.11	CV0588	The CEV shall accept updates to the designated drogue deployment target up to 1 hour prior to entry interface.	Analysis, Test	The CEV's acceptance of updates to the designated drogue deployment target up to 1 hour prior to entry interface shall be verified by analysis and test. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CM/SM and the CM as separate configurations in the LEO and entry environments and includes an emulation of the interface for updating the drogue deployment target. The analysis shall include nominal and off-nominal conditions. The analysis shall include direct entry trajectory conditions from ISS. The analysis shall include both direct entry and skip entry trajectory conditions from the moon. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CM during entry using trajectories from the previous analysis. The test shall be performed in a CEV avionics-type facility that includes the interfaces for updating the drogue deployment target. The test shall record the updates to the drogue deployment target and the response of the CEV to each method of updating the drogue deployment target. The verification shall be considered successful when the analyses show that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can

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				accept an update to the drogue deployment target up to 1 hour prior to entry interface and result in a successful guided direct or skip entry. [A successful guided direct or skip entry is defined as a trajectory that results in a CONUS landing (within ±5 km of the intended target) or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CM are within the limits of the thermal protection system.]
3.2.11.12	CV0755	The CEV shall provide manual control of the RCS jets in a dissimilar mode in the Emergency Entry Mode.	Analysis, Test	The CEV manual control of the RCS jets in a dissimilar mode in the Emergency Entry Mode shall be verified by analysis and test. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with both the primary and EEM flight software installed) that models the entry dynamics of the CEV, models both the nominal and dissimilar modes of the RCS jets, and includes the emulated manual control hardware. The analysis shall start out on a nominal entry trajectory and engage the EEM at various points along the trajectory. The analysis shall include dispersions about the nominal trajectory consistent with the definition of the EEM. The analysis shall include both CONUS and water landing trajectories. The analysis shall also include nominal and off-nominal performance of the RCS jets in the dissimilar mode. The analysis shall be performed with a pilot in the loop. The test shall be performed in a CEV avionics-type facility that includes the manual control hardware for commanding the RCS jets in the dissimilar mode. The test shall also include nominal performance of the RCS jets in the dissimilar mode. The test shall be performed with a pilot in the loop. The verification shall be considered successful when the analysis shows that the emulated manual control hardware is capable of controlling the CEV using the RCS jets in the

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				dissimilar mode and that the pilot was able to successfully perform the manual control of the CEV consistent with NPR 8705A, Human-Rating Requirements for Space Systems, Section 3.4. The verification shall be considered successful when the test shows that the manual control hardware is capable of controlling the CEV using the RCS jets in the dissimilar mode and that the pilot was able to successfully perform the manual control of the CEV consistent with a Cooper-Harper Level 2 rating.
3.2.11.12	CV0756	The CEV emergency entry mode shall function without the use of the primary GN&C software.	Analysis, Inspection, Test	The independence of the Emergency Entry Mode (EEM) from the primary GN&C software shall be verified by inspection, analysis, and test. The inspection shall be performed on the primary GN&C and EEM software to determine that there are no common software modules between the two systems. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with only the EEM flight software installed) that models the entry dynamics of the CEV, includes models of the hardware used by the EEM, and an emulation of the crew's manual interfaces available during the EEM. The analysis shall start out at various points along a nominal entry trajectory with the EEM engaged. The analysis shall include dispersions about the nominal trajectory consistent with the definition of the EEM. The analysis shall include both CONUS and water landing trajectories. The analysis shall use a pilot in the loop. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CEV during entry using trajectories from the previous analysis. The test shall be performed in a CEV avionics-type facility that includes the hardware used by the EEM and the crew's manual interfaces available during the EEM. The test shall include dispersions about the nominal trajectory consistent with the

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				definition of the EEM. The test shall be performed with a pilot in the loop. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CEV during entry using trajectories from the previous test. The verification shall be considered successful when the inspection shows that the primary GN&C and EEM do not share any software modules. The verification shall be considered successful when the analyses and test show that successful ballistic landings using the emergency entry mode are possible. NOTES: A successful ballistic landing is defined as a trajectory that results in either a CONUS landing or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CEV are within the limits of the thermal protection system.
3.2.11.12	CV0757	The CEV shall provide a dissimilar IMU for the Emergency Entry Mode.	Analysis, Inspection	The use of a dissimilar IMU for the Emergency Entry Mode (EEM) shall be verified by inspection and analysis. The inspection shall be performed on the engineering drawings, software specification for the EEM, and the end-item specification for the dissimilar IMU to determine that a dissimilar IMU has been included in the design, its signals are being provided to the EEM, the primary IMU signals are not being provided to the EEM, and the EEM software is using the dissimilar IMU signals in its calculations. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with only the EEM flight software installed) that models the entry dynamics of the CEV and the performance characteristics of the dissimilar IMU. The analysis shall start out at various points along a nominal entry trajectory with the EEM engaged. The analysis shall include dispersions about the nominal trajectory consistent with the definition of the EEM as well as nominal and off-

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				nominal dissimilar IMU performance. The analysis shall include both CONUS and water landing trajectories. A subsequent analysis shall include a NASA-accredited, body-point heating model and determine the thermal loads and heating rates on the CEV during entry using trajectories from the previous analysis. The verification shall be considered successful when the inspection shows that the EEM software is using signals from the dissimilar IMU and not the primary IMUs. The verification shall be considered successful when the analyses show that successful ballistic landings using the dissimilar IMU during the emergency entry mode are possible. NOTES: A successful ballistic landing is defined as a trajectory that results in either a CONUS landing or a water landing on the Earth where the entry and landing accelerations on the crew satisfy CxP 70024, Human Systems Integration Requirements, section 3.2.4, and the thermal loads and heating rates on the CEV are within the limits of the thermal protection system.
3.2.11.12	CV0758	The CEV shall provide a hardware altimeter for crew situational awareness needed for manual activation of altitude sensitive events.	Inspection	The use of a hardware altimeter for crew situational awareness needed for manual activation of altitude sensitive events shall be verified by inspection. The inspection shall be performed on the engineering drawings and the end-item specification for the hardware altimeter to determine that a hardware altimeter has been included in the design and its information is being displayed to the crew. The verification shall be considered successful when the inspection shows that a hardware altimeter has been included in the design and its information is being displayed to the crew.
3.2.11.12	CV0760	The CEV Emergency Entry Mode shall provide automated control for rate damping.	Analysis	The automated rate damping control of the CEV by the Emergency Entry Mode shall be verified by analysis. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with only the EEM flight software installed) that models the entry dynamics of the CEV and the performance characteristics of the dissimilar IMU. The

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				analysis shall start out at various points along a nominal entry trajectory with the EEM engaged. The analysis shall include dispersions about the nominal trajectory consistent with the definition of the EEM as well as nominal and off-nominal dissimilar IMU performance. The analysis shall include both CONUS and water landing trajectories. The verification shall be considered successful when the analysis shows that the CEV can automatically damp rates during the Emergency Entry Mode.
3.2.11.12	CV0761	The CEV shall provide at least 0.1 <TBR-002-211> ft/sec delta-V for separation of the CM and SM without the use of SM RCS.	Analysis	The delta-V of at least 0.1 (TBR-002-211) ft/sec for the separation of the CM from the SM, without the use of SM RCS, shall be verified by analysis. [1] The analysis shall be performed on lower-level CM/SM separation mechanism test reports to determine the minimum resultant delta-V. Verification shall be considered successful when the minimum delta-V from the CM/SM separation mechanism is at least 0.1 (TBR-002-211) ft/sec. [2] The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with flight software installed) that models the dynamics of both the CM and the SM as individual vehicles and the CM/SM separation mechanism dynamics. The analysis shall examine the trajectories of the two vehicles once they have separated and determine the translational separate rates. The analysis shall include both nominal and off-nominal separation conditions. The analysis shall also be performed using a 3-D modeling tool that includes NASA-accredited models of the CM and the SM. The analysis shall use the trajectories and attitudes of the two vehicles from the simulations of the previous analysis and determine the closest approach between the structures of the two vehicles. Verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that successful separation of the CM from the SM with a minimum delta-V of 0.1 (TBR-002-211)

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				ft/sec is possible without re-contact.
3.2.11.13	CV0120	The CEV shall provide manual control for RPODU.	Analysis, Test	The CEV manual control for RPODU shall be verified by analysis and test. The analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the target vehicle (i.e., EDS/LSAM, ISS, or LSAM-AS) in the LEO and LLO environments and includes the emulated manual control hardware. The analysis shall include nominal and off-nominal RPODU conditions. The analysis shall also use a 3-D graphical modeling tool that includes NASA-accredited models of the CEV and the target vehicles to look for unplanned contact between the CEV and the target vehicles. The analysis shall be performed with a pilot in the loop. The test shall be performed in a CEV avionics-type facility that includes the manual control hardware for RPODU, the relative nav sensors of the CEV, and the simulated visuals and nav-aid sensors of the target vehicles. The test shall be performed with a pilot in the loop. The test shall include different target vehicles (i.e., EDS/LSAM, ISS, or LSAM-AS). The verification shall be considered successful when the analysis shows that the emulated manual control hardware is capable of meeting all specified maneuver dispersions and achieving docking interface contact within the docking system capture envelope under nominal conditions and achieving breakout and backout conditions under off-nominal conditions. The verification shall be considered successful when the test shows that the RPODU manual control hardware is capable of meeting dispersion specifications and docking conditions operations for all target vehicles under a reduced set of nominal conditions and backout and breakout under off-nominal RPODU conditions (i.e., a set selected from those run during the analysis) and that the pilot was able to successfully perform the RPODU operations consistent with

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				NPR 8705.2A, Human-Rating Requirements for Space Systems, Section 3.4.
3.2.11.13	CA0497-PO	The CEV shall provide manual control of flight path, attitude, and attitude rates when the human can operate the vehicle within system margins.	Analysis, Test	The capability to manually control the CEV when the human pilot can operate the vehicle within predefined limits shall be verified by testing and analysis. The testing shall use a NASA-accredited digital CEV GN&C simulation integrated with a NASA-accredited pilot-in-the-loop test facility, with flight-like hand controllers, displays and out the window scenes. Testing shall use these facilities to capture and analyze manual control performance of the vehicle for all nominal and abort flight phases that are determined appropriate for human piloting, and shall include system and environment dispersions. The verification shall be considered successful when analysis of the results shows that manual control does not violate structural, thermal or performance margins for all relevant flight phases.
3.2.11.13	CV0071	The CEV shall provide direct visual observation of the Earth horizon line during the ascent and entry profile for crew manual control.	Analysis, Inspection	Verification shall be by analysis and inspection. Inspection and analysis shall be performed on CEV released engineering drawings evaluating the placement of windows and seated crewmembers in order to develop a flight like simulator. This assessment will be compared with analyses performed on CEV trajectories during ascent and entry to determine the scope of direct visual observation of the earth horizon line by the crew.
3.2.11.13	CV0589	The CEV shall perform manual orbit correction maneuvers.	Analysis, Demonstration, Test	The manual orbit correction maneuvers by the CEV shall be verified by test. The test shall be performed in a CEV avionics-type facility that includes the crew manual orbit correction maneuver interface. The test shall include all types of orbit correction maneuvers (such as, orbit insertion, orbit departure, mid-course corrections, and prox-ops translational burns). The test shall record the manual orbit correction inputs from the crew and the resulting orbital changes. The verification shall be considered successful when the test shows that the crew can change the orbit via

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				manual orbit correction and that the resulting maneuvers are executed within the dispersions specified in CEV-T-31000, CEV Spacecraft System Specification . [The resulting maneuver execution is defined to be correct when the resultant state vector, orbital elements, attitude, and attitude rates are within the performance accuracy defined in lower-level documents, like CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.]
3.2.11.13	CV0754	The CEV shall provide manual activation of critical events required for safe crew return without the use of primary software.	Inspection, Test	The manual activation of the critical events required for crew return without the use of primary software shall be verified by inspection and test. The inspection shall be performed on the design drawings, wiring diagrams, and the primary software to determine that the method of activation of the critical events is independent of the primary software. The test shall be conducted in a CEV avionics-type facility that includes the crew interface for manual activation of the critical events required for crew return. The test shall include different trajectories, including one using the Emergency Entry Mode, that cover these critical events. The test shall record the crew input and the response of the CEV to the manual activation of each of the critical events. The test shall be performed with a crewmember in the loop. Verification shall be considered successful when the inspection shows that the manual activation of the critical events required for crew return is independent of the primary software. Verification shall be considered successful when the test shows that the CEV response to the manual activation for each of the critical events required for crew return is the appropriate event.
3.2.12	CA0178-PO	The CEV shall have a launch availability of no less than 98% (TBR-001-041) per launch attempt, exclusive of weather, starting at (TBD-001-505) hours for "LCC	Analysis	The ability of CEV to have a launch availability of no less than 98% at a 50% confidence (TBR-001-041) exclusive of weather and range safety shall be verified by analysis. Analysis shall assess the CEV level 3 reliability analysis,

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		Call to Station" and ending at close of day-of-launch window.		maintainability planning, and the level 3 Logistics Support Plan (LSP). Verification shall be considered successful when analysis verifies the CEV launch availability of no less than 98% at a 50% confidence exclusive of weather and range safety.
3.2.12	CV0632	The CEV shall provide launch opportunities for at least four consecutive days per TLI opportunity for the Lunar Sortie and Lunar Outpost Crew missions.	Analysis	Verification shall be by analysis. An analysis of CEV engineering data and associated drawings shall prove that vehicle has the capability to launch for a minimum of four consecutive days per TLI opportunity. Verification shall be successful when the analysis proves that the CEV is launch capable for a minimum of four consecutive days.
3.2.12	CV0633	The CEV shall provide crew launch opportunities for at least four consecutive days per launch attempt for ISS missions.	Analysis	Verification shall be by analysis. An analysis of CEV engineering data and associated drawings shall prove that vehicle has the capability to launch for a minimum of four consecutive days per ISS opportunity. Verification shall be successful when the analysis proves that the CEV is launch capable for a minimum of four consecutive days.
3.2.12	CV0770	The CEV shall be prepared, after a missed launch opportunity for a lunar mission, to launch again within 26 days (the beginning of the next TLI opportunity) using the same spacecraft elements.	Analysis	Verification shall be by Analysis. Analysis shall be performed on the CEV systems for capability to support subsequent flight operations following a missed opportunity. Subsystem servicing requirements, timeframes involved with launch processing turnarounds, infrastructure capability to support the flight readiness, and subsystem robustness will be analyzed to verify CEV ability to maintain launch readiness. Verification shall be considered successful when review of CEV systems and capabilities support 26 days launch readiness capability.
3.2.12	CV0771	The CEV shall not require additional servicing or reconfiguration and remain in a launch ready state, exclusive of CEV system failures, for a minimum 2 hour period of time beginning with the Terminal Count through the end of the launch	Analysis	Verification shall be by Analysis. Analysis shall be performed on the CEV systems for capability to support launch ready conditions continuously for at least 2 hours post launch configuration. Analysis will include CEV subsystem operational flight configuration stability and the subsystem capabilities for continuous flight ready

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		window.		sustainment. Verification shall be considered successful when review of CEV systems, sub-systems, and capabilities support sustained launch ready state of at least 2 hours.
3.2.13	CV0023	The CEV shall limit ground processing to less than 45 workdays, to include operations from arrival at Assembly, Integration & Production facility through integration with the launch vehicle.	Analysis	Verification shall be by an analysis of CEV manufacturing and production planning and launch site processing planning to demonstrate that the required ground processing turnaround time can be attained. The verification shall be considered successful when the analysis shows that the production rate of CEV spacecraft with associated shipping, transportation and ground processing (including any refurbishment time for reusable equipment and integration and checkout with other elements) can provide sufficient assets to attain the 45-day turnaround rate.
3.2.13	CV0032	The CEV shall provide for non-time critical nominal cargo loading at the spacecraft processing facility.	Demonstration	Verification shall be by demonstration. During CEV processing activities ground processing personnel shall demonstrate the ability to load nominal (non-time critical) cargo into the CEV during routine process operations activities.
3.2.13	CV0192	The CEV and associated support hardware shall be transportable from the manufacturer's site to the launch site per CxP 70028, Ground Systems Element to Crew Exploration Vehicle Interface Requirements Document.	Analysis	Verification shall be by an analysis of CEV manufacturing, production, and transportation planning and launch site processing planning to demonstrate that the CEV and its associated hardware can be transferred from the site of manufacture to the launch site. The verification shall be considered successful when the analysis shows that the transportability of the CEV spacecraft and its support hardware with associated shipping, transportation and ground processing (including any refurbishment time for reusable equipment and integration and checkout with other elements) can be performed.
3.2.13	CV0193	The CEV shall be transportable from its recovery location per CxP 70028, Ground Systems Element to Crew Exploration	Analysis	Verification shall be by an analysis of CEV manufacturing, production, and transportation planning to that the CEV and its associated hardware can be transported from the

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		Vehicle Interface Requirements Document.		recovery site (land or water). The verification shall be considered successful when the analysis shows that the transportability of the CEV spacecraft and its support hardware with associated shipping, transportation and ground processing can be performed.
3.2.13	CV0723	The CEV shall provide all IVA tools required for CEV on-orbit maintenance and reconfiguration.	Analysis	Verification shall be by analysis. Analysis shall be performed on CEV released engineering drawings and schematics to ensure that the CEV design has provided the necessary infrastructure to develop and deliver the tools needed for maintenance activities. Verification shall be declared successful when the analysis proves that the planned maintenance tasks can be performed with the tools.
3.2.13	CV0778	The CEV shall be mated to the CLV at the Launch Site without requiring demating of elements and subsystems.	Analysis	Verification shall be by Analysis. Analysis shall be conducted of CEV systems. Manufacturing and production documents will be examined to verify the CEV systems are designed for independent integration and do not call for deintegration of any module or element to facilitate the integration of a subsequent system or module. Integration plans pertaining to the assembly of CEV modules will be analyzed focusing on system buildup. A review of CEV integration plans with CLV and GS will be analyzed for indicated presence of a positive building block approach. Analysis to support the verification of this requirement will require the review of developed integration documents for CEV, CLV, and GS. Verification shall be considered successful when analysis provides evidence and supporting documents for positive CEV incremental integration of CEV modules and complete CEV integration with CLV and GS without deintegration.
3.2.13	CV0779	The CEV shall provide access for integration of time-critical cargo components no later than 12 hours prior to a scheduled launch.	Analysis	Verification of the late stow cargo on the CEV shall be by analysis. An timeline analysis of pre-launch mission activities shall reveal a allocated time for stowing cargo no later than L - 12 hours. In addition, an analysis of engineering drawings shall reveal the means the CEV shall

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				provide access to an area designated for late stow cargo and the availability of this area no later than L - 12 hours. Verification will be complete when the analysis proves that the CEV has provided access to a late stow area in the vehicle and that it is accessible at a point no later than L - 12 hours.
3.2.13	CV0835	The CEV shall provide CEV hardware and CEV GSE infrastructure to maintain systems through their operational life cycles.	Test	Internal voice quality testing shall be performed per the Conversation Opinion Test specified in ITU-T-P.800.
3.2.13	CV0845	The CEV shall provide for non-time critical nominal cargo destow at the spacecraft processing facility.	Demonstration	Verification shall be by demonstration. During CEV processing activities ground processing personnel shall demonstrate the ability to load nominal (non-time critical) cargo into the CEV during routine process operations activities. This requirement seems redundant to CV0032
3.2.13	CV0847	The CEV shall provide the capability for ground facility test equipment to command, monitor, and stimulate the CEV.	Test	Verification shall be by Test. The test shall verify the capability for ground facility test equipment to command, monitor, and stimulate the CEV. The verification shall be considered successful when the ground facility is able to command, monitor and stimulate the CEV.
3.2.13	CA5495-PO	The CEV shall sustain in-space operations using only onboard equipment and spares without resupply or support from personnel other than the crew.	Analysis, Test	The ability of CEV to sustain operations as defined in the DRM using only onboard equipment and spares without resupply or support from personnel other than the crew shall be verified by analysis. Analysis shall verify CEV conformance with CxP 70132, Constellation Program Commonality Plan, CxP 70087, Constellation Reliability and Maintenance (R&M) Plan, the CEV Logistics Support Plan (LSP), and the related Logistics Support Analysis Records (LSAR). Analysis shall be updated based upon ground testing. Verification shall be considered successful when analysis shows that CEV provides infrastructure to maintain systems through their operational life cycles to achieve mission success.

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3.2.13	CV0776	The CEV shall accept software updates without requiring LRU removal.	Analysis, Test	Verification shall be by test and analysis. The test shall show that the CEV accepts software updates without requiring LRU removal. The analysis shall be performed using engineering drawings and documentation of the CEV C&DH system. Verification shall be considered successful when the test and supporting analysis prove that the CEV can accept all valid software updates without requiring LRU removal..
3.2.14	CV0718	The vehicle shall provide 1.5 cubic feet of "ready-access" stowage volume allowing for suited crew access with one hand, without the use of tools and without removing panels.	Analysis, Demonstration	Verification shall be by Analysis and Demonstration. The Analysis shall be performed using NASA validated engineering drawings and models to show that the 1.5 (TBR) cubic feet stowage volume is accessible. The demonstration shall be performed by a gloved crew member to show that the 1.5 (TBR) cubic feet is accessible by the a suited crew member. The verification shall be considered successful when the analysis and demonstration prove that the 1.5 (TBR) stowage volume can be accessed by a suited crew member with one hand, without the use of tools or the removal of panels.
3.2.14	CV0727	The CEV shall limit the maximum A-weighted overall Sound Pressure Level (SPL), at the crewmember's head position, to 135 dBA or less, during cabin depressurization valve operations.	Test	Verification shall be by test. The test shall be performed using flight like valves during depressurization to show that the SPL is equal to or less than 105 dBA. The test shall be deemed successful when the test data shows that the SPL is equal to or less than 105 dBA.
3.2.14	CV0836	The CEV shall limit the time following suit donning to crewmember egress of the vehicle to 30 minutes, not inclusive of pre-breathe time in the event of an EVA.	Demonstration	A demonstration shall be performed to show that communications between the 6 crew member audio positions and Mission Systems via CTN occurs without disruption or degradation.
3.2.14	CV0548	The CEV shall control cabin temperature per HSIR 3054 except during suited operations, while docked to the ISS with hatches open, lunar quiescent phase and post-landing.	Analysis	Verification shall be by analysis of the atmosphere control hardware. Test data of the equipment at the subsystem level should be provided as validation of the analytical model. The verification will be considered successful when the model has been validated, and the resulting analysis

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				shows the hardware can control the cabin temperature within +/-2 deg F.
3.2.14	CA0426-PO	The CEV Net Habitable Volume shall be no less than 10.76 m3 (380 ft3).	Analysis	Net habitable volume shall be verified by analysis. The analysis shall review the design of the CEV and shall assess the net habitable volume using JSC 63557 (TBR-001-960), Net Habitable Volume Verification Method, which defines analytical processes to calculate net habitable volume. The verification shall be considered successful when the analysis shows the CEV net habitable volume is no less than 10.76 m3 (380 ft3).
3.2.14	CA0288-PO	The CEV shall control cabin pressure to a selectable setpoint between 103 (TBR-001-923) kPa (14.9 psia) to 58 (TBR-001-501) kPa (8.4 psia) with 0.7 (TBR-001-500) kPa (0.1 psia) increments.	Test	The control of cabin atmospheric pressure shall be verified by test. The test shall be performed using a test article with flight-like cabin volume to show that the atmospheric pressure control hardware will maintain cabin pressure within the specified range over the maximum mission duration. The verification shall be considered successful when the test shows that pressure is successfully controlled by the CEV over the range of 103 (TBR-001-923) to 58 (TBR-001-501) kPa (14.9 to 8.4 psia), in 0.7 (TBR-001-500) kPa (0.1 psia) increments.
3.2.14	CV0084	The CEV shall provide negative pressure relief to maintain the differential pressure at less than 1 psid crush pressure.	Analysis, Demonstration	Verification shall be by analysis and demonstration. Analysis shall be performed on CEV released engineering drawings and components (i.e. relief valves) to ensure proper pressure equalization between the CEV internal volume and the Earth's atmosphere prior to landing. A demonstration on a qualification CEV unit shall be performed to prove this capability. Verification will be successful when analysis shows and demonstration proves that the CEV is capable of maintaining equalized pressure during entry.
3.2.14	CV0545	The CEV shall not automatically relieve cabin pressure volume overboard at a	Analysis, Test	Verification shall be by Analysis and Test. Analysis shall be performed on engineering data to verify design of ECLSS

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		pressure lower than 15.15 psia.		provides for the prevention of CM over pressurization. Examination of circuit design and redundancy shall be analyzed for completeness. Physical test of the pressure relief system using flight software shall be incorporated into verification activities at the subsystem and/or element level. Verification shall be considered successful when the analysis of engineering data from drawings and test results sufficiently document redundant control of CEV over pressurization.
3.2.14	CA3105-PO	The CEV shall maintain the cabin environment at a pressure of no less than 55 kPa (8.0 psia) from an initial nominal cabin pressure with an equivalent cabin hole diameter of 0.64 (TBR-001-106) cm (0.25 in) to allow the crew time to don suits per CA3058-PO.	Analysis, Test	The CEV cabin pressure preservation for suit donning during an external pressure leak shall be verified by analysis and test. The analysis shall use a modeled leak of an equivalent 0.64 (TBR-001-106) cm (0.25 inch) diameter hole in the cabin to show that the available gas resources and atmosphere control will maintain the crew environment at 55 kPa (8.0 psia) for the time defined to don suits in CA3058-PO. A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA suit donning and pre-breathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained during suit donning. A test in the CEV flight test article utilizing flight qualified software shall show that the vehicle responds to a simulated rapid decompression event by activating the pressure control components required to maintain pressure and oxygen concentration. The verification shall be considered successful when the analysis and tests show that the CEV can maintain cabin pressure at 55 kPa (8.0 psia) for the time defined to don suits in CA3058-PO.
3.2.14	CV0793	The CEV shall maintain the cabin environment at a pressure per CA3105-PO to allow the crew time to don suits	Test	Verification shall be by test. The test shall be conducted using flight like hardware to prove that the CEV pressure can be maintained for at least 1 hour, to allow the crew to

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		and complete connections to life support in 1 (TBR-001-113) hour.		don suits. The verification shall be considered successful when the test data proves that the CEV pressure can be maintained for at least 1 hour, to allow the crew to don suits in the event of an emergency.
3.2.14	CA3133-PO	The CEV shall control cabin oxygen partial pressure to a selectable setpoint between 18 (TBR-001-124) kPa (2.6 psia) ppO2 and 21 (TBR-001-911) kPa (3.1 psia) ppO2 with 0.7 (TBR-001-912) kPa (0.1 psia) increments.	Test	The control of oxygen partial pressure shall be verified by test. The test shall be performed using a test article with flight-like cabin volume to show that the oxygen partial pressure control hardware will maintain oxygen pressure within the specified range over the maximum mission duration. The verification shall be considered successful when the test shows that oxygen partial pressure is successfully controlled by the CEV over the range of 18 (TBR-001-124) to 21 (TBR-001-911) kPa (2.6 to 3.1 psia), in 0.7 (TBR-001-912) kPa (0.1 psia) increments.
3.2.14	CA3061-PO	The CEV shall limit the maximum oxygen concentration within the pressurized cabin to 30% (TBR-001-109) by volume.	Analysis, Test	The oxygen concentration within the pressurized cabin shall be verified by test and analysis. The test shall be performed using a test article with flight-like cabin volume to show that the atmosphere control system can detect when the oxygen concentration reaches 30% (TBR-001-109). The test shall be performed using a test article with flight-like cabin volume to show that the atmosphere control system can adjust the constituents to maintain the oxygen concentration to 30% (TBR-001-109) maximum. The analysis shall show that the materials selection is certified to meet the 30% (TBR-001-109) oxygen environment. The verification shall be considered successful when the tests show that the CEV atmosphere control system limits the maximum oxygen concentration within the pressurized cabin to 30% (TBR-001-109) by volume and the analysis of materials shows the materials selection meets the 30% (TBR-001-109) oxygen environment.
3.2.14	CA5711-PO	The CEV shall return the CEV	Analysis	Returning the CEV pressurized volume to a habitable

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		pressurized volume to a habitable environment following the contamination of the cabin atmosphere following a fire, toxic release, and docking with another vehicle that has suffered such an event.		environment following a contamination event shall be verified by analysis. The analysis shall verify that the CEV can remove constituents of the contamination to reduced levels below the maximum exposure limits. The analysis model shall incorporate the cabin volume, ventilation system, contaminant removal method and its time-dependent performance. The verification shall be considered successful when the analysis shows that the CEV returns the CEV pressurized volume to a habitable environment by reducing starting concentrations of 200 mg CO/m3, 30 mg HCl/m3, and 1,000 mg dichloromethane/m3 by 95% following a contamination event.
3.2.14	CA0886-PO	The CEV shall provide not less than two vestibule pressurization cycles per mission.	Analysis, Test	The vestibule pressurization shall be verified by analysis supported by test. The analysis shall determine that gas resources for two vestibule pressurization cycles are available for each mission. Analysis of the CEV Gas Storage and vestibule pressurization shall show that the CEV can store the consumables necessary for and execute two vestibule pressurization cycles. The verification shall be considered successful when the analysis, supported by a qualification test of the pressurization operation show that the CEV can execute at least two vestibule pressurization cycles per mission.
3.2.14	CV0064	The CEV shall measure pressure within the mated vestibule volume within (TBD-002-030) pressure range and with (TBD-002-039) measurement accuracy when the CEV docking hatch is closed.	Analysis, Test	Verification shall be by test and analysis. A test shall be performed on CEV pressure sensors to verify that they are capable of accurately monitoring the mated vestibule volume pressure when the CEV hatch is closed. Verification shall be successful when analysis of the CEV data and independent calibrated pressure sensors show a CEV sensor accuracy of no worse than TBD.
3.2.14	CV0068	The CEV shall de-pressurize the vestibule to less than 0.1 psia within 4 min prior to	Test	Verification shall be by test. A test shall be performed on CEV pressurized volumes to verify that they are capable of

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		demating.		depressurizing the vestibule prior to CEV demating. A successful verification will include testing of the electronic and/or manual components responsible for performing de-pressurization. The test must include pressure measurements on both the test element and the CEV prior to and after de-pressurization.
3.2.14	CV0493	The CEV shall provide a CEV-to-transfer vestibule differential pressure of 0.1 psi within 5 minutes of the command to equalize pressure for a vestibule of (TBD-002-233) cubic feet.	Analysis	Verification shall be by analysis supported by test. An analysis of the CEV integrated vehicle system, should provide data to build a model to simulate CEV ability provide a CEV-to-transfer vestibule differential pressure of 0.1 psi with in 5 minutes of receiving command to equalize pressure. Verification shall be successful when analysis shows that the vehicle can equalize . A pressure test shall be performed on the CEV integrated vehicle to test ability of the vehicle to meet this requirement. Verification shall be considered successful when CEV provides a CEV-to-transfer vestibule of 0.1 psi within 5 minutes of receiving command.
3.2.14	CA3106-PO	The CEV shall maintain the cabin environment at a pressure to support pre-breathe as defined in CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), Section (TBD-001-962), with an equivalent cabin hole diameter of 0.64 (TBR-001-106) cm (0.25 in) and a suit pressure per CA5659-PO.	Analysis, Test	The CEV cabin pressure preservation for pre-breathe during an external pressure leak shall be verified by analysis and test. The analysis shall use a modeled leak of an equivalent 0.64 (TBR-001-106) cm (0.25 inch) hole in the cabin to show that the available gas resources and atmosphere control will maintain the crew environment at a sufficient pressure based on suit pressure and HSIR requirements for pre-breathe pressure and time. A test in a test article with flight-like cabin and suit loop volumes and components and integrated with EVA suit donning and pre-breathe operations shall show that the cabin pressure and oxygen partial pressure can be maintained to support pre-breathe. A test in the CEV flight test article utilizing flight qualified software shall show that the vehicle responds to a simulated

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				rapid decompression event by activating the pressure control components required to maintain pressure and oxygen concentration. The verification shall be considered successful when the analysis and tests show that the CEV can maintain cabin pressure to allow crew pre-breathe.
3.2.14	CV0794	The CEV shall maintain the cabin environment at a pressure per CA3106-PO, with a temporary contingency suit pressure of 8 <TBR-002-216> psid positive for up to (TBD-002-217) minutes.	Analysis, Demonstration	Verification shall be by Analysis and Demonstration. An analysis will be conducted on CEV cabin pressurization system, utilizing as build drawings, specifications, interim test data, etc. to determine the capability to support a CEV pressurized environment for TBD minutes with a leak as specified in CA3106-PO. Capability to maintain CEV cabin pressure may be demonstrated in an accredited high fidelity CEV mockup, if available. Verification shall be successful when analysis and demonstration provide sufficient prove that the pressurization system can maintain the cabin pressure with the leaks as specified in CA3106-PO.
3.2.14	CA3140-PO	The CEV shall provide oxygen and nitrogen storage to survive from the largest gas consumable combination of two pressure events. (EVA, contaminated atmosphere, and unrecoverable cabin leak).	Analysis	The quantity of consumables required for 2 pressure events shall be verified by analysis. The analysis shall determine the quantity of consumables resources required for the following cases: EVA (for lunar missions only) which includes gas for suit donning, suit purge, pre-breathe, cabin depress and cabin repress to 70 (TBR-001-127) kPa (10.2 psia); contaminated atmosphere event which includes gas for emergency breathing apparatus if applicable, and cabin depress/repress to initial pressure if applicable; unrecoverable cabin leak which includes gas required to maintain cabin at 55 kPa (8 psia) while crew dons suits, purges suit loop, and performs pre-breathe. The analysis shall determine which combination of 2 cases requires the greatest resources, considering that there can be only one unrecoverable cabin leak event per mission. The analysis shall then determine that those consumables resources are provided by the vehicle

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				consumable gas stowage design. The verification shall be considered successful when the analysis shows that the CEV can provide consumables for 2 pressure events.
3.2.15	CA5555-PO	The CEV shall meet its requirements during and after exposure to the induced environments for each Design Reference Mission as specified in CxP 70143, Constellation Program Induced Environment Design Specification.	Analysis, Inspection	CEV function and performance during and after exposure to induced environments shall be verified by analysis and inspection. The inspection shall consist of two primary parts: - Review of the induced environmental verifications submitted against all of the CEV/System IRD requirements. - Review of the induced environment verifications submitted against CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element requirements for DRM total induced environments. The analysis shall be an integrated systems analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification. The verification shall be considered successful when the analysis shows that the CEV function and performance requirements are met during and after exposure to CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.
3.2.15	CA5560-PO	The CEV shall limit its induced environment contributions for each Design Reference Mission to within the limits specified in CxP 70143, Constellation Program Induced Environment Design Specification.	Analysis, Inspection	CEV induced environment contributions shall be verified by analysis and inspection. The inspection shall consist of two primary parts: - Review of the induced environmental verifications submitted against all of the CEV/System IRD requirements. - Review of the induced environment verifications submitted against CxP 72000, System Requirements for the Crew Exploration Vehicle (CEV) Element requirements for DRM total induced environments. The analysis shall be an integrated systems

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				analysis addressing the scope of issues described in Section 4 of CxP 70143, Constellation Program Induced Environment Design Specification (IEDS). The verification shall be considered successful when the analysis shows that the CEV peak and cumulative induced environments will not exceed CxP 70143, Constellation Program Induced Environment Design Specification induced environments for each DRM.
3.2.15	CA0374-PO	The CEV shall meet its requirements during and after exposure to the environments defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), Sections 3.1, 3.2, 3.3, 3.5, 3.6 and 3.7.	Analysis, Inspection	Compliance of the CEV with its functional and performance requirements during and after exposure to the DSNE environments shall be verified by inspection and analysis. The analysis shall consist of an integrated analysis that includes the following: 1) Development of a Natural Environment Requirements Sensitivity and Applicability Matrices (NERSAMs), defined in section 4 of the DSNE, and 2) Allocation of the natural environments requirements to the lower tier elements and their verification methods and details. The analysis shall include the following integrated configurations: CEV/LSAM, CEV/LSAM/CaLV-EDS, CEV/CLV, CEV/CLV/GS, CEV/ISS. The inspection will consist of a review of the lower tier verification closure data. The closure analysis shall utilize lower tier verification closure data and address interactions of each lower tier system on other systems to address integrated environment effects. The verification shall be considered successful when the inspection and integrated analyses show: 1) The NERSAM has been completed in accordance with section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), 2) The natural environment requirements and verification have been allocated to the lower tier systems in accordance with Section 4 of CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE), 3) Lower tier verifications have been completed and 4) The CEV

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				meets its functional and performance requirements during and after exposure to CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) environments in all integrated configurations.
3.2.15	CV0247	The CEV shall provide a Probability of No Penetration (PNP) of 0.993 or greater over 5 years exposure to the Micrometeoroid and Orbital Debris (MMOD) environments as defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) section 3.3.6.	Analysis	Verification shall be by Analysis supported by Test. Analysis shall be performed to determine if the CEV design as documented in engineering released drawings and other pertinent documentation will meet the functional and performance requirements of a Probability of No Penetration (PNP) of 0.993 (TBR-002-092) or greater over a 5 years exposure to the MMOD environments as defined in CXP-00102, Constellation Program Design Specification for Natural Environments (DSNE), section 3.3.6. The Bumper code shall be used for the PNP analysis. Penetrations are defined as MMOD damage to the CEV that lead to loss-of-vehicle or loss-of-crew either on-orbit or during reentry. Hypervelocity impact tests shall be performed to verify the ballistic limit equations used in the PNP analysis. The PNP assessment shall be conducted for the time durations the CEV is attached to a particular ISS port (with total duration equal to 5 years for purposes of the PNP analysis). Verification shall be considered successful when analysis provides confirmation that the CEV design meets or exceeds the 0.993 over 5year PNP requirement.
3.2.15	CV0248	The CEV shall provide a PNP of 0.999 or greater for the maximum lunar mission duration with exposure to the MMOD environments as defined in the CxP 70023, Constellation Program Design Specification for Natural Environments (DSNE) section 3.3.6.	Analysis	Verification shall be by Analysis supported by Test. Analysis shall be performed to determine if the CEV design as documented in engineering released drawings and other pertinent documentation will meet the functional and performance requirements of a Probability of No Penetration (PNP) of 0.999 (TBR-002-038) or greater for the lunar sortie and lunar outpost mission duration with exposure to the MMOD environments as defined in CXP-00102, Constellation Program Design Specification for Natural Environments (DSNE), section 3.3.7. The Bumper code

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				shall be used for the PNP analysis. Penetrations are defined as MMOD damage to the CEV that lead to loss-of-vehicle or loss-of-crew either on-orbit or during reentry. Hypervelocity impact tests shall be performed to verify the ballistic limit equations used in the PNP analysis. Verification shall be considered successful when analysis provides confirmation that the CEV design meets or exceeds the 0.999 (TBR-002-038) per mission PNP requirement.
3.3	CV0268	The CEV shall use nameplates and product markings using operational nomenclature registered in accordance with CXP-72019, Constellation Nomenclature Plan.	Inspection	Verification shall be by Inspection. Inspection shall be made of all CEV engineering released drawing to check that the use nameplates and product markings composed using operational nomenclature are registered in accordance with CXP-02007, Constellation Nomenclature Plan. Verification shall be considered successful when all released drawings show visual evidence of appropriate nameplates and markings for tracking purposes.
3.3	CV0479	The CEV shall meet the < 0.01% Collected Volatile Condensable Material (CVCM) limit per NASA STD 6016 section 4.2.3.6 for materials directly exposed to the external environment used in large quantity (> 1 Kg total mass or > 1 square meter total surface).	Analysis	Verification shall be by an analysis of selected CEV materials. A complete list of all materials utilized outside the pressurized volume and physical samples of large area or large mass utilization materials will be provided for testing needed to support ISS integration requirements. The verification shall be considered successful when the analysis shows that CEV is fully in compliance with the requirements in NASA-STD-6016.
3.3	CV0480	The CEV shall vent gases and vapors aft and away from ISS and other Constellation systems to which CEV is mated.	Analysis	Verification shall be by an analysis of CEV environmental systems. The verification shall be considered successful when the orientation analysis shows that CEV can limit materials (molecular and particulate) contamination deposits resulting from fluid dumping and venting. The following data shall be provided to assist in the evaluation: a) Location and orientation of any active vents b) Location and orientation of inter-hull vacuum venting pathways
3.3	CV0649	The CEV GSE shall comply with the	Inspection	Verification of Human-System Integration requirements shall

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		provisions of NASA-STD-5005 Revision B Ground Support Equipment.		be by inspection. The inspection shall determine if each requirement within the HSIR allocated to CEV has been verified either via the original verification requirement in the HSIR Level 2 document or an approved alternate verification requirement in a CEV Level 3 SRD or IRD. Verification shall be considered successful when the inspection indicates that all CEV human-system integration verification requirements have been closed.
3.3	CV0822	The identification and marking of CEV equipment shall be in accordance with MIL-STD-130M, Identification and Marking of U.S. Military Property.	Inspection	Verification shall be by Inspection. Inspection shall be made of all CEV engineering released drawing to check that the use nameplates and product markings composed using nomenclature in accordance with MIL-STD-130M, Identification and Marking of U.S. Military Property. Verification shall be considered successful when all baselined drawings show visual evidence of appropriate nameplates and markings for tracking purposes.
3.3	CV0858	The CEV shall meet the < 0.1% Collected Volatile Condensable Material (CVCM) limit per NASA STD 6016 section 4.2.3.6 for materials internal to the outer shell of the spacecraft used in large quantity (> 1 Kg total mass or > 1 square meter total surface).	Test	Verification shall be by an analysis of selected CEV materials. A complete list of all materials utilized outside the pressurized volume and physical samples of large area or large mass utilization materials will be provided for testing needed to support ISS integration requirements. The verification shall be considered successful when the analysis shows that CEV is fully in compliance with the requirements in NASA-STD-6016.
3.3.1	CV0855	The CEV shall meet the electrical bonding requirements of NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, and Flight Equipment.	Test	Verification shall be by test. The test shall be performed on flight like equipment to ensure the electrical bonding requirements can be met. The verification shall be considered successful when the electrical bonding requirements of NASA-STD-4003, Electrical Bonding for NASA Launch Vehicles, Spacecraft, and Flight Equipment has been met.
3.3.1	CV0856	The CEV shall comply with CxP 70050-01, Constellation Program Electrical	Analysis, Test	Verification shall be by Analysis and Test. The Analysis and Tests shall be performed on flight like equipment to show

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		Power System Specification, Volume 1: Electrical Power Quality Performance for 28 VDC and CxP 70050-02, Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28 VDC.		compliance with the Power Quality Specification. The verification shall be considered successful when the analysis and test comply with the CxP 70050-01, Constellation Program Electrical Power System Specification, Volume 1: Electrical Power Quality Performance for 28 VDC and CxP 70050-02, Constellation Program Electrical Power System Specification, Volume 2: User Electrical Power Quality Performance for 28 VDC requirements.
3.3.1.1	CV0661	The CEV shall meet the requirements of CxP 70080, Constellation Program Electromagnetic Environmental Effects (E3) Requirements Document.	Analysis, Test	Verification shall be by test and analysis. The test shall verify that electromagnetic compatibility has been achieved successfully for all planned simultaneous subsystem operations, and can be maintained at certification levels over the design life cycle. Analysis shall verify that electromagnetic compatibility has been achieved successfully, and can be maintained at certification levels over the design life cycle, for operational conditions that are impractical to test on the ground. Verification is considered successful when analyses and tests show that the CEV successfully complies with design, functional and operational performance requirements.
3.3.2	CV0043	The CEV shall withstand a maximum blast overpressure of 15 psid over ambient conditions without catastrophic failure	Analysis	Verification shall be by analysis. Analysis by similation of blast scenarios will be performed to support verification A ground test shall be performed on the CEV at the WSTF as per NASA/TM--2003212059, Guide for Hydrogen Hazards Analysis on Components and Systems. The verification shall be considered successful when the analysis and test shows that the CEV can withstand a blast overpressure of up to 20 PSID over ambient conditions in order to ensure crew survival. Tests results will also be used to augment models.
3.3.2	CV0255	All safety-critical CEV mechanisms and all mission-critical CEV mechanisms shall comply with Sections 1-4 of NASA-STD-	Analysis, Inspection, Test	Verification that all safety-critical CEV mechanisms and all mission-critical CEV mechanisms comply with Sections 1-4 ofNASA-STD-5017, "Design and Development

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		5017, Design and Development Requirements for Mechanisms.		Requirements for Mechanisms," shall be by the methods specified in the verification sections ofNASA-STD-5017 for the applicable requirements. Where the verifications not specified in NASA-STD-5017, the verification shall be by analysis, inspection and test as agreed upon in the Mechanical Systems Verification Plan (MSVP) for the applicable requirements. The MSVP contains a customized list of all the inspections, analyses and tests that will be performed to meet the agreed-to requirements of Sections 1 through 4 of NASA-STD-5017. The MSVP shall be prepared byte hardware developer and presented to the appropriate technical authority for approval. Verification shall be considered successful when the Project has submitted a Certificate of Compliance for the applicable requirements of Sections 1 through 4 of NASA-STD-5017.
3.3.2	CV0256	The CEV pressure vessels, pressurized structures, and pressure components shall comply with ANSI/AIAA S-80-1998, Space Systems - Metallic Pressure Vessels, Pressurized Structures, and Pressure Components as tailored by CxP 70135 (SDVR)	Analysis, Inspection, Test	Verification shall be by Analysis, Inspection, and Test. Analysis, inspection and test shall be performed to determine if the CEV design as documented in engineering released drawings and other pertinent documentation will meet the safety and performance requirements for pressure vessels, structures and components as defined in ANSI/AIAA S-80-1998, Space Systems - Metallic Pressure Vessels, Pressurized Structures, and Pressure Components as tailored by CxP 70135 (SDVR) . Verification shall be considered successful when analysis, inspection and test provide confirmation that CEV pressure vessels, pressurized structures, and pressure components comply with their specified requirements.
3.3.2	CV0257	The CEV composite overwrapped pressure vessels shall comply with ANSI/AIAA S-081-2000, Space Systems - Composite Overwrapped Pressure Vessels (COPVs) as tailored by CxP 70135 (SDVR).	Analysis, Inspection, Test	Verification shall be by Analysis, Inspection and Test. Analysis, inspection and test shall be performed to determine if the CEV design as documented in engineering released drawings and other pertinent documentation will meet the safety and performance requirements for composite overwrapped pressure vessels as defined in

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				ANSI/AIAA S-081-2000, Space Systems - Composite Overwrapped Pressure Vessels as tailored by CxP 70135 (SDVR).. Verification shall be considered successful when analysis, inspection and test provide confirmation that CEV pressure vessels, pressurized structures, and pressure components comply with their specified requirements.
3.3.2	CV0259	The CEV shall be designed for the loading conditions defined per Table 5.	Analysis	Verification shall be by Analysis. Analysis shall be performed to determine if the CEV design as documented in engineering released drawings and other pertinent documentation will meet the functional and performance requirements during and after exposure to the loads environment as defined in Document TBD, CEV Loads Data Book. Verification shall be considered successful when analysis provides confirmation that CEV designs are able to withstand the loads environment conditions as defined. Modeling and simulation should provide the required data once the CEV design is determined.
3.3.2	CV0307	The CEV pyrotechnics, associated electrical circuits and electronics shall conform to JSC 62809 Constellation Spacecraft Pyrotechnics Specification and JPR 8080.5 Pyrotechnics standards P-1 through P-7.	Test	Verification shall be primarily by test. In some cases select requirements may be met by Analysis or Inspection. Each pyrotechnic device shall be tested and reviewed to ensure strict compliance to JSC 62809. Verification shall be considered successful when all the test data is reviewed and a Flight Certification for each device is approved and signed.
3.3.2	CV0640	The CEV shall comply with NASA-STD-(I)-6016, Standard Material & Process Requirements for Spacecraft.	Analysis	Compliance with NASA-STD-(I)-6016, Standard Material & Process Requirements for Spacecraft shall be verified by analysis. The analysis shall consist of a review of the contractor developed Materials and Processes Selection, Control, and Implementation Plan. Verification is considered successful when the Materials and Processes Selection, Control, and Implementation Plan is approved by NASA.
3.3.2	CV0641	The CEV shall comply with CxP 70135,	Analysis, Test	Verification shall be by test and analysis. The structural

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		Structural Design and Verification Requirements.		tests and analysis shall be performed to show that adequate margins exist and that the requirements in CxP 70135 are met. The verification shall be considered successful when the structural tests and supporting analysis prove that the defined margins have been met.
3.3.2	CV0642	The CEV shall comply with NASA-STD-(I)-5019, Fracture Control Requirements for Spaceflight Hardware.	Analysis, Inspection, Test	Verification shall be by test, inspection, and analysis. The test, inspection, and analysis shall be performed to show that the fracture control requirements in NASA-STD-(I)-5019 are met. The verification shall be considered successful when the tests, inspections, and supporting analysis prove that the CEV meets the requirements called out in NASA-STD-5019.
3.3.2	CV0643	The CEV shall comply with JSC 62550, Structural Design and Verification Criteria For Glass, Ceramics and Windows in Human Space Flight Applications.	Analysis, Inspection, Test	Verification shall be by test, analysis and inspection. The tests, analyses and inspections shall be performed to meet the intent of the requirements in JSC 62550. Verification shall be considered successful when all criteria has been met per the requirements in JSC 62550.
3.3.3	CV0453	The CEV shall interchange major elements (SM, CM, LAS, SA) from one assembled configuration to another without requiring rework or repair.	Analysis, Inspection, Test	Verification shall be by Analysis, Inspection, and Test. Fit checks on hardware (by physical tooling mate, or by digital measurement) shall be used with analysis, which shall be performed on CEV released engineering drawings and electrical schematics to ensure that CEV has interchangeable major elements (SM, CM, LAS) to create interchangeable assembly configurations. Verification shall be successful when model and simulation analyses, inspections, and tests prove that the CEV is capable of interchanging major elements to meet various mission needs (TBD).
3.3.4	CV0142	The CEV shall provide redundant crew workstations to control and monitor CEV functions.	Analysis, Demonstration, Inspection, Test	Verification shall be by Inspection, Analysis, and Test or Demonstration. Inspections will be performed on CEV engineering released drawings to verify there are multiple locations where crew can perform all system functions. Test or Demonstration on qual systems shall be performed by a

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				crew rep or other qualified inspector to show that redundant workstations perform all CEV functions. (A test is highly recommended once this requirement is matured and "all" functions are defined.) Analysis shall be performed on Test or Demonstration results to evaluate effectiveness of multiple crew workstation. Verification will be successful when inspection of drawings and analysis of test show evidence of effective redundant crew workstations that will provide access to all CEV systems function. Inspection may also include review of released electrical schematics showing system redundancy at workstations.
3.3.4	CV0645	The CEV shall comply with the human system integration requirements defined in HSIR CxP 70024, Appendix J, Allocation Matrix with the exception of HSIR requirements HS3015A, HS3037, HS3061, HS3065, HS3065A, HS3070, HS3072, HS3073, HS3074, HS3082, HS3083, HS3105, HS3108, HS4008, HS4008B, HS4008C, HS4012, HS4022, HS5010, HS5012, HS6032, HS6059, HS6060, HS6091, HS6097, HS6099, HS6101 and HS10008 that will be met in conjunction with other systems as specified in the CEV SRD and CxP IRDs.	Analysis	Verification shall be by analysis. The analysis shall be performed to show that the CEV systems meet the intent of the requirements defined in the HSIR. The verification shall be considered successful when the analysis proves that the intent of the requirements have been met.
3.3.4	CV0795	The CEV shall prevent Toxic Hazard Level 4 chemicals from vehicle systems, as defined in Table C-1 in Appendix C of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR), from entering the habitable volume of the vehicle.	Analysis	Verification shall be by Analysis. Analysis shall be conducted on CEV fluid transport and storage systems utilizing as built drawings and manufacturing plans. The systems will be examined for adequate separation and containment devices and methods to maintain fluid isolation and prevention of hazard fluid release into the CEV habitation space. For gas, volatile liquid, or fumes that are not containable, use of the ARS will be examined for use to decontaminate. Analysis will include all CEV operational

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				flight configurations, pre- and post-orbital considerations. Verification shall be considered successful when review provides evidence that the CEV prohibits Hazard Level 4 chemicals from entering the habitable volume of the CEV.
3.3.4	CV0796	The CEV shall induce upon the crew linear accelerations of no greater than (TBD-002-219) from launch to mission destination while the CEV has control authority.	Analysis, Test	Verification shall be verified by analysis and test. Analysis shall use a certified simulation to verify all nominal flight phase scenarios, as well as 3-sigma bounding Monte Carlo studies with dispersed GN&C, vehicle and environmental factors, when appropriate. Tests shall be used to validate the model, using data obtained from nominal flight tests, parachute tests, and/or other available flight and ground-based tests. The test data will provide continuous acceleration measures in order to compute the total linear acceleration that would be experienced by the crew directly by translation and indirectly by off-axis rotation (i.e. centrifugal force). Such testing will require on-board acquisition (or sampling) of 3D linear and 3D rotational acceleration (along and around the x, y, and z axes) on a millisecond timescale. The verification shall be considered successful when the analyses indicate with 99% confidence that simulated linear acceleration exposures of 500 msec or more during a nominal bounded trip are no greater than the limits depicted by the dashed blue lines in Figures 3.2-1 through 3.2-5 in CxP 70024, Human Systems Integration Requirements (HSIR).
3.3.4	CV0797	The CEV shall induce upon the crew sustained rotational accelerations of no greater than (TBD-002-220) degrees/s2 while the CEV has control authority.	Analysis	Verification shall be by analysis. Data collected from abort tests, parachute tests, and landing attenuation tests will provide acceleration measures to used in the analyses to evaluate vehicle rotational acceleration. The analysis shall use a certified simulation to verify all nominal flight phase scenarios. The verification shall be considered successful when the analyses indicate that the expected sustained rotational acceleration does not exceed 115 degrees/s2. 3D rotational acceleration (yaw, pitch, and roll) (on a

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				millisecond timescale) data collected from subsequent flight test will be used to validate the models and simulations conducted in the verification process.
3.3.4	CV0798	The CEV shall induce upon the crew transient rotational accelerations of no greater than (TBD-002-221) degrees/s2 while the CEV has control authority.	Analysis	The crew exposure to transient rotational acceleration shall be verified by analysis. Data collected from abort tests, parachute tests, and landing attenuation tests acceleration measures to be incorporated into the analysis models and simulations to evaluate vehicle rotational acceleration. The verification shall be considered successful when the analyses indicate that the expected rotational acceleration does not exceed TBR degrees/s2. 3D rotational acceleration (yaw, pitch, and roll) (on a millisecond timescale) data collected from subsequent flight test will be used to validate the models and simulations conducted in the verification process.
3.3.4	CV0799	The CEV shall induce upon the crew yaw, pitch, or roll rates of no greater than (TBD-002-222) from launch to mission destination while the CEV has control authority.	Analysis	Verification shall be by analysis . Data collected from abort tests, parachute tests, and landing attenuation tests will provide acceleration measures to evaluate vehicle rotational acceleration in the simulations. . The analysis shall use a certified simulation to verify all nominal flight phase scenarios, as well as 3-sigma bounding Monte Carlo studies with dispersed GN&C, vehicle and environmental factors. The verification shall be considered successful the analyses indicate with 99% confidence that the simulated rotation rate is no greater than the limits in those depicted in Figures 3.2-6 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR). 3D rotational acceleration (at least every 100 msec) data collected on subsequent flight test will be utilized to validate the analyses conducted in the verification process.
3.3.4	CV0802	The CEV spacecraft shall limit impulse noise at the crewmember's head position to less than 150 dB (TBR-002-249) peak overall SPL, during launch and entry	Analysis	Verification shall be by analysis. Data collected from prior flight testing will be used to determine the impulse noise level measured at the crewmember's ears. Analysis shall consist of estimating the impulse noise level at the crew-

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		phases including ascent abort.		member's ear by combining significant noise sources and including acoustic insertion losses of acoustic isolation and protective devices. The ignition noise should be determined by analyzing ground test data. Acoustic insertion losses of the pressure shell and other materials shall be determined by models and simulations. To be included in the CEV analysis, the effectiveness of hearing protection, headsets, and helmets shall be determined by modeling and simulation. Peak-hold sound pressure level measurements shall be made using a Type 1 sound level meter. The frequency response of the sound level meter shall extend to at least 6 Hz at its lower limit. The verification shall be considered successful when the results from the analyses indicate that the peak overall sound pressure level predicted at the crewmember's ears is less than 140 dB.
3.3.4	CV0804	The CEV shall limit vibration to the crew in any axis to less than (TBD-002-227) g rms integrated from 0.0167 to 80 Hz over any one-minute interval during dynamic phases of flight.	Analysis	Verification shall be by analysis. The analysis shall be performed using NASA accredited models, simulations, and engineering data to prove that the vibration levels are limited to less than (TBD-002-0226) integrated. The verification of the analysis shall be considered successful when the data proves that the vibration level to the crew is less than (TBD-002-0226) integrated.
3.3.4	CV0805	The CEV shall protect the crew from electrical hazards per Tables 3.3-2 and 3.3-3 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).	Analysis	Verification shall be by analysis. The analysis shall be performed using engineering data, schematics, and System Safety Hazard Analyses to ensure that the crew is protected from electrical hazards per CxP 70024. The analysis shall be deemed successful when the data proves that no electrical hazard to the crew exists or that the risk is properly mitigated (via a grounded wrist strap, etc.)
3.3.4	CV0806	The CEV shall limit the chassis leakage current for non-patient equipment to less than the values in Table 3.3-4 of CxP 70024, Constellation Program Human-Systems Integration Requirements	Analysis	Verification shall be by analysis. The analysis shall be performed using engineering data, schematics, and System Safety Hazard Analyses to ensure that the crew is protected from electrical hazards per CxP 70024. The analysis shall be deemed successful when the data proves that no

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		(HSIR).		electrical hazard to the crew exists or that the risk is properly mitigated (via a grounded wrist strap, etc.)
3.3.4	CV0807	The CEV shall limit the temperature of surfaces to which the bare skin of crew are exposed to the limits defined in Table 3.3-6 of CxP 70024, Constellation Program Human-Systems Integration Requirements (HSIR).	Analysis, Test	Verification shall be by analysis and test. The analysis shall be performed using NASA accredited models and engineering data to ensure that the touch temperature requirements are met per CxP70024. Where appropriate, testing of actual hardware temperatures shall be performed to ensure adherence to the limits specified in CxP 70024. The verification shall be considered successful when the analysis or test proves that the touch temperature requirements in CxP70024 Table 3.3 -6 are met or that the appropriate protection is in place (i.e. thermal blankets, etc).
3.3.4	CV0809	The CEV shall allow aerobic and resistive exercise training for 30 continuous minutes each day per crewmember for missions greater than 8 continuous days.	Analysis	Verification shall be by analysis. The analysis shall be performed using manifest and engineering data to determine if excersie equipment will be flown on any mission greater than 8 days. The analysis shall also verify that the crew timeline supports the use of exercise equipment during the mission. The verifications shall be considered successful when the analysis shows that exercise equipment will be flown and is planned for use on Lunar missions greater than 8 days.
3.3.4	CV0810	The CEV shall provide access to emergency equipment within the time to address the emergency.	Analysis, Demonstration	Verification shall be by demonstration and analysis. The demonstration and analysis shall be performed using flight-like hardware, NASA accredited models and simulators to prove that access to the CEV provided emergency equipment can be performed in (TBD) seconds to address the emergency. The demonstration and analysis shall be declared successful when the data proves that access to the CEV provided emergency equipment can be performed in (TBD) seconds to address the emergency.
3.3.4	CV0849	The CEV shall provide for thermal control of unsuited crewmembers such that heat stored remains within the range	Test	Verification shall be by test. The test shall be performed using flight hardware to simulate the thermal control of unsuited crewmembers such that heat stored remains within

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		4.7 kJ/kg (2 BTU/lb) > heat stored > -4.1 kJ/kg (- 1.76 BTU/lb) during off-nominal situations.		the range 4.7 kJ/kg (2 BTU/lb) > heat stored > -4.1 kJ/kg (- 1.76 BTU/lb) during off-nominal situations. Verification shall be considered successful when test proves that the heat stored remains within the range 4.7 kJ/kg (2 BTU/lb) > heat stored > -4.1 kJ/kg (- 1.76 BTU/lb) during off-nominal situations.
3.3.4	CV0815	The CEV shall provide an in-space translation path for assisted ingress and egress of an incapacitated pressurized-suited crewmember.	Analysis, Demonstration	Verification shall be by Analysis and Demonstration. Analysis shall be performed on engineering data with respect to contingency EVA infrastructure to translation along pre-determined pathways. Mission plans, operating principles and EVA suit capability will be examined to support contingency EVA translation. Drawings and schematics will be inspected for inclusion of sufficient stability points of attachment for EVA crew members to utilize. Demonstration of flight crew ability to use the translate along mission prescribed pathways may be demonstrated in a NASA accredited simulator (NBL). Verification shall be considered successful when the analysis of engineering data and demonstration results sufficiently document CEV infrastructure to support contingency EVAs
3.3.4	CV0816	The CEV shall provide a translation path for assisted ground egress or extraction of an incapacitated suited crewmember.	Analysis, Demonstration	Verification shall be by Analysis and Demonstration. Analysis shall be performed on CEV released engineering drawings and schematics to ensure that the CEV design has provided a post landing egress path for an incapacitated, un-pressurized suited crewmember. Analysis on egress hatch configuration and CEV volume for suited crew maneuvering with aid of assistants will be completed. A demonstration shall be performed by an incapacitated, un-pressurized suited crewmember. Verification shall be considered successful when the analysis of engineering data and demonstration results sufficiently document CEV infrastructure to support crewmember egress.

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3.3.5	CV0749	The CEV shall protect systems and information as specified in the CxP 70070-ANX05, Book 1, Constellation Program Functional Security Requirements for Program Systems and Elements.	Analysis, Test	Verification shall be by analysis and test. The analysis and testing shall be performed per, lower level document CxP 70070-ANX05, Book 1, Constellation Program Management Plan, Annex 5: Security Management Plan. Verification shall be considered successful when the analysis and testing shows compliance with requirements specified in sections 3.3, 3.6, and 3.7 of CxP 70070-ANX05, Book 1, Constellation Program Management Plan, Annex 5.
3.3.5	CV0646	The CEV shall comply with CxP 70022, C3I Interoperability Standards Book, as specified in Volume 1, Appendix E, Applicability Matrix.	Analysis	Verification of CEV communication compliance with CxP7022, C3I Interoperability Specifications, Appendix E shall be by analysis. An analysis of the different facets of communication which include Command and Control, information exchange, data exchange, network communications, hard-line communications RF communications will show a clear interoperability between CEV and all other Constellation Systems. Verification will be considered successful when the analysis shows all CEV communication interfaces conform to CxP-70022, C3I Interoperability Specifications, Appendix E.
3.3.6	CV0647	The CEV shall comply with the requirements defined in CxP 70130 Extravehicular Activity (EVA) Design and Construction Specification, Appendix B.	Analysis	Verification shall be by analysis. The analysis shall be performed using engineering data to show that the CEV systems are EVA compatible per CxP 70130. Verification shall be considered successful when the analysis proves that the CEV systems are EVA compatible.
3.3.7				
3.3.9	CV0650	The CEV shall comply with CxP 70036 Constellation Environmental Qualification and Acceptance Testing Requirements (CEQATR).	Analysis, Test	Verification shall be by test and analysis. Testing and analysis shall be performed using NASA accredited models and engineering data to show that the CEV hardware meets the intent of the requirements in CxP 70036. Verification shall be considered successful when the test and analysis data prove that the intent of the requirements in CxP 70036 have been met.
3.4	CV0483	The CEV shall meet portable equipment	Analysis, Test	Verification shall be by Analysis and Testing. Analysis shall

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		interface requirements defined in the CxP 70035.		be performed on CEV released engineering drawings and specification and compared to applicable portable equipment interface requirements as defined in CXP-70035, Crew Exploration Vehicle (CEV) to Portable Equipments Interface Requirements Document (IRD). Verification shall be successful when analysis through modeling and testing of the interfaces shows that CEV can interface and appropriately interface with portable equipment as defined in CXP-70035.
3.4	CA0429-PO	The CEV shall interface with the CLV per CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document.	Analysis, Test	The CEV interfaces with the CLV shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CEV Project Office to demonstrate that the CEV-to-CLV interface requirements defined within CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew Launch Vehicle Interface Requirements Document, have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV and CLV flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalent) or across distributed SILs (or equivalent) prior to assembly of the integrated launch vehicle stack at the launch site. Testing shall also include a multi-system integrated test of the integrated CEV/CLV launch vehicle stack to demonstrate integrated functionality and interoperability between the flight systems and between the integrated launch vehicle stack and the ground support and mission control systems. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70026, Constellation Program Crew Exploration Vehicle - To - Crew

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				Launch Vehicle Interface Requirements Document, have been satisfied and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.
3.4	CA0800-PO	The CEV shall interface with the LSAM per CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD).	Analysis, Test	The CEV interfaces with the LSAM shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CEV Project Office to demonstrate that the CEV-to-LSAM interface requirements defined within the CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV and LSAM flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalents) or across distributed SILs (or equivalents) prior to first launch of the LSAM. Testing shall also include a multi-system integrated test of the integrated CEV/LSAM in-space vehicle stack (with and without EDS) prior to first human use of LSAM in space to demonstrate integrated functionality and interoperability between the flight systems and between the integrated in-space vehicle stack and the ground support and mission control systems. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70034, Constellation Program Crew Exploration Vehicle (CEV) to Lunar Surface Access Module (LSAM) Interface Requirements Document (IRD), have been satisfied, and (b) when the integrated avionics, software,

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				and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.
3.4	CV0720	The CEV shall deliver a LIDS/APAS adapter to ISS.	Analysis, Inspection, Test	Verification shall be by inspection, analysis and test. The inspection shall consist of a review of the approved manifest. The analysis shall consist of modeling and simulation of the CEV using conditions experienced during adapter delivery missions. The test shall consist of qualification and acceptance testing that encompasses the environments and performance requirements experienced during adapter delivery missions. The verification shall be considered successful when (a) a manifest indicating delivery of the adapter to the ISS is approved and (b) the analysis and testing indicates that the CEV is capable of delivering a LIDS/APAS adapter to the ISS without exceeding the certification of the ISS or LIDS/APAS adapter.
3.4	CV0721	The CEV shall launch an ISS LIDS/APAS adapter on top of the CM under the LAS-to-CM fairing.	Analysis, Test	Verification shall be by analysis and test. The analysis shall consist of modeling and simulation of the adapter mounted to the CEV under the LAS-to-CM fairing using conditions experienced during adapter delivery missions. The test shall consist of qualification and acceptance testing that encompasses the environments and performance requirements experienced by the CEV with an adapter mounted to the CEV under the LAS-to-CM fairing during adapter delivery missions. The verification shall be considered successful when the analysis and testing indicates that the CEV is capable of launching a LIDS/APAS adapter mounted to the CM under the LAS-to-CM fairing without exceeding the certification of the ISS or LIDS/APAS adapter.
3.4	CV0722	The CEV shall manually dock the ISS LIDS/APAS adapter to a PMA via the	Analysis	The docking of the ISS LIDS/APAS adapter to a PMA via the APAS by the CEV shall be verified by analysis. The

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		APAS.		analysis shall be performed using a NASA-accredited, 6-DOF simulation (with primary flight software installed) that models the dynamics of the CEV and the ISS as individual vehicles in the LEO environment. The analysis shall also include a model of the LIDS/APAS systems, the adapter, and the ISS PMA to perform contact analysis. The analysis shall include both nominal and off-nominal docking conditions. The verification shall be considered successful when the analysis shows that the probability is at least 0.9987 (TBR) with 90% confidence that the CEV can successfully dock the ISS LIDS/APAS adapter to a PMA via the APAS. [A successful docking of the ISS LIDS/APAS is defined as the delivery of the mechanisms within the docking envelope and contact conditions as defined in lower-level documents, such as CEV-T-31000, CEV Spacecraft System Specification, or CEV-T-031, CEV Spacecraft GN&C Subsystem Specification.]
3.4	CV0814	The CEV shall interface with ISS per CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document.	Analysis, Test	Verification shall be by Analysis and Test. Analysis shall be performed on CEV released engineering drawings and specification and compared to applicable ISS interface requirements as defined in CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document. For the communication requirements, verification shall also be by test. Tests shall consist of integrated end-to-end testing in an accredited NASA test facility. Verification shall be considered successful when analysis and integrated tests through modeling show that the CEV can appropriately interface with ISS as defined in CxP 70031, Constellation Program Crew Exploration Vehicle - To - International Space Station Interface Requirements Document.
3.4	CA0361-PO	The CEV shall interface with CaLV per CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo	Analysis, Test	The CEV interfaces with the CaLV EDS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CEV Project

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		Launch Vehicle (CaLV) Interface Requirements Document (IRD).		Office to demonstrate that the CEV-to-CaLV EDS interface requirements defined within the CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV and CaLV EDS flight avionics and software at the appropriate Software Integration Laboratory (SIL) (or equivalents) or across distributed SILs (or equivalents) prior to first launch of the CaLV EDS. Testing shall also include a multi-system integrated test of the integrated CEV/LSAM/CaLV EDS in-space vehicle stack prior to first human use of the EDS/LSAM in space to demonstrate integrated functionality and interoperability between the flight systems and between the integrated in-space vehicle stack and the ground support and mission control systems. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70119, Constellation Program Crew Exploration Vehicle (CEV) to Cargo Launch Vehicle (CaLV) Interface Requirements Document (IRD), have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.
3.4	CA0894-PO	The CEV shall interface with Mission Systems per CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD).	Analysis, Test	The CEV interfaces with the MS shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CEV Project Office to demonstrate that the CEV-to-MS interface requirements defined within the CxP 70029, Constellation Program Crew

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				Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV avionics and software and the MS systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the MS to confirm interoperability and functionality between the CEV, GS, and MS. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70029, Constellation Program Crew Exploration Vehicle (CEV) to Mission Systems (MS) Interface Requirements Document (IRD), have been satisfied and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.
3.4	CA0893-PO	The CEV shall interface with Ground Systems per CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD).	Analysis, Test	The CEV interfaces with the Ground Systems shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CEV Project Office to demonstrate that the CEV-to-GS interface requirements defined within the CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD), have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV avionics and

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				software and the GS via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the GS to confirm interoperability and functionality between the CEV and GS. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70028, Constellation Program Ground Systems (GS) to Crew Exploration Vehicle (CEV) Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan, have been satisfied.
3.4	CV0098	The CEV shall provide interfaces to support recovery of the CEV by the recovery personnel per CxP 70028, Ground Systems Element to Crew Exploration Vehicle Interface Requirements Document.	Demonstration	Verification shall be by demonstration. Demonstration shall consist of recovery of the CEV from both land and water by recovery personnel utilizing CEV structures designed to facilitate vehicle recovery performed on CEV demonstration units. Verification shall be considered successful when both land and water demonstrations show that the CEV is capable of allowing ground recovery personnel to recover the vehicle.
3.4	CV0817	CEV shall provide post landing services, including power, resources and consumables for active cooling, air revitalization, fire detection, communication, lighting and critical avionics for at least 15 minutes (TBR-002-250) after landing.	Analysis, Test	Verification shall be by Analysis and Test. An analysis shall be performed on CEV engineering released drawings and habitable design documents to determine that the CEV has the infrastructure to support 15 minutes of post landing operations. This will include but not be limited to appropriate EPS, ECLSS, TCS, C&T, and C&DH systems. A test should be run on the CEV to perform post landing operations for 15 minutes. The verification shall be considered successful when test and analysis shows that the CEV has the infrastructure and resourses to provide post landing operations for 15 minutes without affecting

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				nominal operations of the CEV.
3.4	CA0896-PO	The CEV shall interface with the Communications and Tracking Network per CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV).	Analysis, Test	The CEV interfaces with the Communications and Tracking Networks shall be verified by Analysis and Test. The analysis shall consist of a CxP review of the verification data provided by the CEV Project Office to demonstrate that the CEV interface requirements defined within CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV) have been satisfied. Testing shall include those series of tests established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV avionics and software and the communications and networks systems via the appropriate SILs (or equivalents). Multi-system testing performed at the launch site for flight systems shall also incorporate the communications and tracking network systems to confirm interoperability and functionality between the systems. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70118-01, Constellation Program Systems to Communication and Tracking (C&T) Networks Interface Requirements Document (IRD), Volume 1: Crew Exploration Vehicle (CEV) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 70084, Constellation Program Integrated Test Plan and CxP 70086,Constellation Program Software Verification and Validation Plan have been satisfied.
3.4	CA0895-PO	The CEV shall interface with EVA Systems per CxP 70033, Constellation	Analysis, Test	The CEV interfaces with the EVA systems shall be verified by Analysis and Test. The analysis shall consist of a CxP

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		Program Crew Exploration Vehicle - To - Extravehicular Activity Systems Interface Requirements Document.		review of the verification data provided by the CEV Project Office to demonstrate that the CEV-to-EVA interface requirements defined within CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) have been satisfied. Testing shall include those series of tests established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan. Testing shall include integrated testing between the CEV avionics and software and the EVA systems at a SIL (or equivalent). Multi-system testing performed at the launch site for flight systems shall also incorporate the EVA systems to confirm interoperability and functionality between the CEV, GS, and EVA systems. Verification shall be considered successful when (a) Analysis confirms that all of the CEV interface verification requirements defined within CxP 70033, Constellation Program Crew Exploration Vehicle (CEV) - To - Extravehicular Activity Systems Interface Requirements Document (IRD) have been satisfied, and (b) when the integrated avionics, software, and multi-system test objectives established by CxP 77084, Constellation Program Integrated Test Plan and CxP 70086, Constellation Program Software Verification and Validation Plan have been satisfied.
3.5	CA5933-PO	The CEV shall (TBD-001-1019) include a Service Module (SM) that is configurable as a standalone Element.	Analysis	The ability of the CEV SM to be configured as a standalone Element shall be verified by analysis. The analysis shall consist of a review of the avionics, power, thermal, GN&C, C&T, structural and mass/volume capabilities of the CEV SM to show that it has the performance available for robotic missions. The analysis shall review the CEV SM design in a standalone configuration for compatibility with mission specific avionics kits, the addition of a fairing, and Architecture capabilities (e.g., communications, ground

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				operations). The verification shall be considered successful when the analysis shows that the SM can be configured to meet independent mission needs.
3.5	CA0386-HQ	The CEV shall have an outer mold-line that is derived from the Apollo Command Module (CM) design as defined in CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line.	Inspection	The outer mold-line of the CEV shall be verified by inspection. The inspection shall consist of the review of CEV configuration drawings for compliance with CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line. The verification shall be considered successful when the inspection shows that the outer mold-line of the CEV is in compliance with CxP 72085, Crew Exploration Vehicle (CEV) Spacecraft Outer Mold Line.