National Aeronautics and Space Administration

Commercial Crew Program
John F. Kennedy Space Center

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Crew Transportation
Technical Management Processes

original signed by
Kathryn L. Lueders
Manager (acting), Commercial Crew Program

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Record of Revision/Changes

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C-2	Removed Export Control marking for STI	1/28/2015
C-1	Updated Appendix B per CCP CR 0119	1/28/2015
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1.0 Introduction

Under the guidance of processes provided by *Crew Transportation Plan* (CCT-PLN-1100), this document, with its sister documents, *International Space Station (ISS) Crew Transportation and Services Requirements Document* (CCT-REQ-1130), *Crew Transportation Technical Standards and Design Evaluation Criteria* (CCT-STD-1140), *Crew Transportation Operations Standards* (CCT STD-1150), and *ISS to Commercial Orbital Transportation Services Interface Requirements Document* (SSP 50808), provides the basis for a National Aeronautics and Space Administration (NASA) certification for services to the ISS for the Commercial Provider. When NASA Crew Transportation System (CTS) certification is achieved for ISS transportation, the Commercial Provider will be eligible to provide services to and from the ISS during the services phase.

1.1 Purpose

The purpose of this document is to provide Commercial Providers a summary of the technical management processes that support the design, development, test, evaluation, and certification effort and NASA's expectations of the processes and products that NASA considers crucial to a successful development effort.

1.2 Scope

This document and its supporting documents are applicable to the design, development, test, evaluation, certification, production and operation of the end-to-end CTS. The end-to-end CTS includes all assets and processes required to transport NASA crew to and from the ISS, including:

- An integrated space vehicle.
- Supporting systems for production, ground, flight, and recovery operations.
- Capabilities and processes for pre-flight planning and trajectory and abort analysis.
- Crew health and medical care.
- Capabilities and processes for manufacturing, ground processing, mission control, launch control, and post-landing recovery.
- Safety and mission assurance.
- Training processes for operations personnel and crew.

1.3 Precedence

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

1.4 Delegation of Authority

This document was jointly prepared by the CCP and the ISS Program and will be managed by the CCP. CCT-PLN-1120 will be maintained in accordance with standards for the CCP documentation. The CCP is responsible for assuring the definition, control, implementation, and verification of the CCP requirements identified in this document.

1.5 Verb Application

Throughout this document and its supporting documents, statements containing *shall* are used for binding requirements even in the absence of specific verifications. It is understood that after the plans

and processes are approved, they will be verified through surveillance; *will* is used as a statement of fact, declaration of purpose, or expected occurrence; and *should* denotes a statement of best practice.

2.0 Documents

2.1 Applicable Documents

Document Number	***Title*: Description**
AS9100	*Quality Management Systems: Aviation, Space, and Defense Organizations*
NASA-STD-8719.13	*NASA Software Safety Standard, Chapter 7*
NASA-STD-8739.8	*NASA Software Assurance Standard, Sections 6, 7.1, 7.2.4, 7.3,7.4*
SSP 30234	*Failure Modes and Effects Analysis and Critical Items List Requirements for ISS*
SSP 30309	*ISS Safety Analysis and Risk Assessment Requirements*
SSP 30599	*ISS Safety Review Process*
SSP 41170	*ISS Configuration Management Requirements*

2.2 Reference Documents

Document Number	***Title*: Description**
CCT-PLN-1010	*Mishap Preparedness and Contingency Plan (MPCP) for CCP*
CCT-REF-1121	*Probabilistic Safety Analysis Methodology Guide*
NPR 8715.3	*NASA General Safety Program Requirements*
SSP 50108	*ISS CoFR Process Document*

3.0 Program Management and System Engineering Elements

The Commercial Provider shall develop and implement program plans with sufficient detail to convey the approach for accomplishing program objectives. These plans are intended to span the CTS life-cycle.

3.1 Project Management

The Commercial Provider is responsible for the project management of the CTS, which includes developing, utilizing, and maintaining the tools to enable management of the CTS.

3.1.1 Project Management and System Engineering Data Products

In support of CTS certification, the products shall include, at a minimum, the following:

- A Project Management Plan (PMP) for the purpose of providing a roadmap for executing, monitoring, and controlling the project. Core components may be described with subsidiary plans or in the PMP. Subsequent sections cover topical expectations.
- Other plans not addressed by the PMP that capture the approach to the management of requirements, peer reviews/checks, handling of dissenting opinions, data (operational and non-operational), risk, cost, scope, schedule, change control, process control, quality assurance, performance reporting, and as applicable, maintenance, refurbishment, and disposal of the spacecraft and launch vehicle.

3.1.2 Project Management and System Engineering NASA Focus Areas

NASA will assess the PMP and supporting documentation for adequacy of the management approach and processes used. This includes the evaluation of the Commercial Provider's compliance with the contents noted above.

3.2 Configuration Management

The Commercial Provider will own and maintain configuration control over its requirements, specifications, flight products, numerical models, and drawings that govern the development and baseline configuration of the CTS. The Commercial Provider is responsible for integrated change control and tracking, and managing the actual changes when and as they occur. To this end, the Commercial Provider shall define the tools and techniques to manage and document the integrated, approved CTS configuration including systems, equipment, and operations products; control, record, and report changes; and audit the systems and items to verify conformance.

3.2.1 Configuration Management Data Products

In support of CTS certification, the products shall include, at a minimum, the following:

- A Configuration Management (CM) Plan, processes, procedures and data to include project-approved and controlled information, change packages, non-conformance reporting and disposition, audit results, requirement and verification traceability, associated performance data, and an overview of the tools utilized for configuration control.

3.2.2 Configuration Management NASA Focus Areas

NASA will assess the CM Plan for adequacy of the technical and management approach and processes used. This includes the evaluation of the Commercial Provider's compliance with the contents noted above as well as supporting documentation for the following:

- Adequacy of tracking.
- Incorporation of updates or modifications to include re-validation prior to use, as appropriate.
- Coordination across disciplines and functional areas and notification to stakeholders.
- Audit strategy and results.
- Corrective action.
- Lessons learned.

3.3 Risk Management

The Commercial Provider is responsible for the development and implementation of a risk management process.

3.3.1 Risk Management Data Products

In support of CTS certification, the products shall include, at a minimum, the following:

- A Risk Management Plan that documents the full life-cycle of a risk process together with approval, mitigating, acceptance, reporting, and integration mechanisms throughout the life-cycle of the CTS. The considerations for operations products and the management of operational risks are contained in the operational standards outlined in CCT-STD-1150.

3.3.2 Risk Management NASA Focus Areas

NASA will assess the Risk Management Plan for adequacy of the technical and management approach and processes used. This includes the evaluation of the Commercial Provider's compliance with the contents noted above as well as supporting documentation for the following:

- Adequacy of risk identification efforts.
- Risk characterization criteria, mitigation, and elevation.
- Risk control (ensure results can affect decisions throughout the CTS life-cycle).
- Risk response planning to include contingency and residual risk planning.

3.4 Requirements Management

The Commercial Provider is responsible for developing, implementing, and maintaining a closed-loop requirements management process to ensure hardware, software, support equipment, ground systems processing, and configuration requirements are accomplished for all configuration managed systems and equipment.

3.4.1 Requirements Management Data Products

In support of CTS certification, the products shall include, at a minimum, the following:

- Requirements Management Plan, processes, and supporting data.

3.4.2 Requirements Management NASA Focus Areas

NASA will assess the Requirements Management Plan for adequacy of the technical and management approach and processes used. This includes the evaluation of the Commercial Provider's compliance with the contents noted above as well as supporting documentation for the following:

- Requirements allocation and traceability (includes parent/child relationships and "meet the intent" requirements).

- Verification and Validation (V&V) planning and results with supporting data (any models and/or analysis data, test data, and results).
- Variance and constraint handling.

3.4.3 NASA Requirements Management

Where the evaluation of NASA requirements results in non-compliance, the Commercial Provider may request relief in the form of a variance. A variance may take one of several forms, as defined below:

- Variance: A formal request for relief from a requirement. Variances should be submitted as early in the life-cycle or workflow process as practical. A variance can be an exception, deviation or waiver.
- Exception: A variance that authorizes permanent relief from a specific requirement and may be requested at any time during the life-cycle of the program.
- Deviation: A variance that authorizes temporary relief in advance from a specific requirement and is requested during the formulation/planning/design stages of a program operation to address expected situations.
- Waiver: A variance that authorizes temporary relief from a specific requirement after the baseline system has been approved. Waivers are requested during the implementation of a program or operation to address situations that were unforeseen during design or advanced planning.

Requests for variance to CCP requirements shall include, at a minimum, the following:

a. Detailed rationale for the request.
b. Risk assessment with and without approval.
c. Risk mitigations and controls in place, if any.
d. Effectivity.

Variances will be reviewed and approved through the CCP board structure. Requests for variance to SSP 50808 shall be processed in accordance with SSP 41170.

3.5 Interface Management

The Commercial Provider is responsible for establishing procedures and practices to ensure proper interface definition, documentation, and compliance throughout the CTS life-cycle.

3.5.1 Interface Management Data Products

In support of CTS certification, the products shall include, at a minimum, the following:

- Interface requirements for the CTS elements, external interfaces including operational (e.g., spacecraft to ISS), and interface definition documentation.

3.5.2 Interface Management NASA Focus Areas

NASA will assess Interface Requirements and Control Documents for technical completeness and accuracy. This includes the evaluation of the Commercial Provider's compliance with the contents noted above.

3.6 Quality Assurance

The Commercial Provider is responsible for developing and implementing a quality management system that assures quality requirements are flowed down from design into the manufacturing and operational processes.

3.6.1 Quality Assurance Data Products

In support of CTS certification, the products shall include, at a minimum, the following:

- A Quality Management Plan (compliant with AS9100).
- Associated reports and products, including requirement traceability that describes the quality requirements; the requirement driver; and how, where, when, and by whom they are implemented and verified.

3.6.2 Quality Assurance NASA Focus Areas

NASA will assess the following:

- Adequacy, completeness, and effectiveness of the Quality Management Plan.
- Requirement traceability for completeness and accuracy.
- Nonconformance control reports for completeness, adequacy, and effectiveness of the engineering disposition.
- Corrective and preventative action reports for effectiveness of the root cause investigation and corrective actions.
- Government Industry Data Exchange Program (GIDEP) records for completeness, disposition, and closure.
- Calibration maintenance records for measuring and test equipment for completeness and adequacy.

3.7 Technical Reviews

The Commercial Provider shall hold Milestone Reviews to include, at a minimum, those shown in Table 3-1. The purpose of these reviews is to formally evaluate progress towards CTS certification. Descriptions of typical Milestone Reviews are shown in Appendix G, Table G-1.

Table 3-1: Milestone Reviews

Review	Description
Certification Baseline Review (CBR)	The Commercial Partner shall co-chair with NASA a Certification Baseline Review (CBR) after award of contract(s) for the second phase of NASA's CTS Certification activities. The purpose of the CBR is to establish the CTS design baseline, the Commercial Partner's certification plan, life-cycle costs, and schedules for CTS certification.
Design Certification Review (DCR)	Prior to the first low Earth orbit (LEO) crewed test flight, the flight test readiness process will include a Design Certification Review of applicable elements from completed CTS Certification Milestones (for an interim CTS certification) and a Flight Test Readiness Review. The DCR formally documents the configuration baseline (hardware, software, and processes used in design, production, and operations) and the conditions under which the CTS is certified (performance, fabrication and operational environments,

	constraints). The DCR also presents the current state of the verification and validation effort, including the overall status of all verification closures and any changes to the V&V plan since CBR.
Flight Test Readiness Review (FTRR)	For crewed flight tests, the FTRR examines tests, demonstrations, analyses, and audits that determine the system's readiness for a safe and successful flight/launch and for subsequent flight test operations. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.
Operations Readiness Review (ORR)	Upon successful completion of the flight test phase of crewed flights, an Operational Readiness Review will be conducted. The ORR occurs once during the program life-cycle (or at the introduction of new or significantly modified systems/facilities). The ORR evaluates all project and support (flight and ground) hardware, software, personnel, plans, processes, and procedures to ensure flight and associated ground systems are in compliance with program requirements and constraints during the sustaining phase.
Certification Review	Upon successful completion of all flight tests, any delta DCRs, and the ORR, the Certification Review determines that the CTS meets the Design Reference Mission (DRM) for which it was developed.
Flight Readiness Review (FRR)	The FRR examines tests, demonstrations, analyses, and audits that determine the system's readiness for a safe and successful flight/launch and for subsequent flight operations. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.

3.7.1 Technical Review Data Products

In support of CTS certification, at a minimum, the Commercial Provider shall address at milestone reviews the types of data shown in Appendix F and H.

3.7.2 Technical Review NASA Focus Areas

NASA will review supporting documentation for successful entrance and exit criteria, such as:

- Provider risks and mitigation strategies identification.
- Compliance with requirements.
- Compliance to Provider plans and processes.
- Description of the systems and architecture (hardware, software, legacy, interfaces, and facilities).
- Constraints affecting system development.
- Credible con-ops and cost, schedule and investment review, and mission feasibility.
- Interfaces to other NASA Programs and Commercial Providers, as well as, external interfaces.
- Test and evaluation strategy and life-cycle support (logistics, manufacturing operations).
- Quality assurance, safety, reliability, and maintainability metrics meet acceptable risk level and adequate margins.
- V&V Plan status.
- Approved/configuration-controlled documentation for each subsystem (specifications, drawings), interface control documents and requirements flow down (verifiable), certification plans, and certification data packages.
- Test plans and procedures for fabrication, assembly and integration, test, and launch operations.

- Operational limits and constraints.
- Command and telemetry list.
- Production tools, materials, operations, processes, and methods are consistent with quality requirements and occupational safety, environmental, and energy conservation requirements.
- Production and support staff are qualified and trained.
- All integration plans and procedures are completed.
- All elements and/or components are available for integration and have been verified against all mechanical, electrical, functional, and safety interface requirements.
- Closure of actions and plans.
- Technical planning that is sufficient to proceed to next development phase.

3.8 Mishap Reporting and Investigation Process

The Commercial Provider shall provide, develop, and manage a Mishap Reporting and Investigation Plan and process that is compatible with 51 USC Section 70101 et seq (accommodates an Accident Investigation Board appointed by the President).

3.8.1 Mishap Reporting and Investigation Process Data

The mishap reporting and investigation process shall include, at a minimum:

- A data repository to document events, including investigation findings and corrective actions.
- Methods for trending mishap and close-call data over time to determine if there is a common root cause, an unidentified process escape, or an increase/decrease in overall events.
- Methods for communicating mishaps/close-call events, investigation findings, and recommendations to the Commercial Provider. This includes timeframes for initial reporting, investigation statuses, and investigation closures.
- Data and reports associated with non-CCP missions for similar systems.

3.8.2 Mishap Reporting and Investigation Process NASA Focus Areas

NASA will assess the mishap plans and processes for completeness.

4.0 Design and Development

The Commercial Provider will own, manage, and control the design and safety analysis approach and processes for producing a design that meets requirements, as well as identifying, understanding, eliminating, and controlling hazards and risks to safety. NASA will review and approve the safety analysis to assess the design and to evaluate the risk to crew health and safety.

4.1 Alternate Design and Manufacturing Standards

The Commercial Provider shall propose alternatives to satisfy "meet the intent of" requirements in CCT-REQ-1130 where the Commercial Provider opts not to utilize the NASA standard. Alternate Standards are defined as any change to the NASA prescribed standard. CCT-STD-1140 will be utilized by the CCP as the evaluation criteria for acceptable alternative standards. NASA will work with the Commercial Provider to agree on content.

Alternate standards will be reviewed and approved at the CCP Program Control Board (PCB). Once the alternate standards have been approved, they will be used in the Commercial Provider's CTS certification evaluation. The NASA standard will remain as the baseline requirement until an alternate standard is approved by NASA. Changes will be approved through the CCP board structure.

4.2 System Safety and Reliability

The Commercial Provider shall incorporate safety and reliability into the design process to identify and eliminate catastrophic hazards, and to control critical hazards for all mission phases. If elimination is not practical, the Commercial Provider shall put in place controls that reduce the risk to an acceptable level that ensures crew safety. These controls shall be verified.

The safety and reliability processes provide an integrated, systematic, and comprehensive approach, which can be used to determine the need for design changes and safety measures, such as failure tolerance, based on an understanding of the risk to the crew due to individual hazards, as well as the system as a whole. These methods are used to balance risks and trades by identifying hazards and developing hazard controls based on assessments of crew risk and rankings of risk scenarios. In this way, the level of failure tolerance and other safety measures can be selected commensurate with the risk posed to the crew. This includes the evaluation of hardware and software capabilities, limitations, and interdependence, as well as environmental and human factors relevant to safety.

The safety and reliability processes shall:

- Emphasize the use of industry standard safety and reliability analyses (e.g., hazard, failure modes and effects, criticality, etc.) throughout the life-cycle (i.e., design, manufacture, and operation) of the Commercial Provider's CTS, as well as during any changes to the approved design and/or operation.
- Provide detailed plans for the communication and acceptance of risk to stakeholders and/or the appropriate control boards to ensure residual risk is appropriately managed.
- Include methodologies for performing qualitative assessments of the probability of occurrence and the severity of hazards, including detailed definitions for likelihood and severity categories that will be used by the Commercial Provider to ensure a uniform method of assessing hazards.
- Provide for closed-loop tracking and verification of hazard controls to include operations controls (e.g., Launch Commit Criteria (LCC), flight rules, procedures, or other means).

- Include a plan for communication and approval of safety and reliability analyses.

The safety analysis shall include an assessment of crew survival strategies for all mission phases and the system capabilities required to execute each strategy. The scenarios should include system failures and emergencies (such as fire, collision, toxic atmosphere, decreasing atmospheric pressure, and medical emergencies) with specific capabilities or proposed capabilities (such as abort, safe haven, rescue, emergency egress, emergency systems, and emergency medical equipment or access to emergency medical care) identified to protect the crew. The results will be used to verify and validate the capabilities provided by the design of the system and make crew survival an integrated element of the design process.

4.2.1 System Safety and Reliability Data Products

The Commercial Provider shall provide a Safety and Reliability Plan, which describes how safety and reliability analytical methodologies are integrated into the design process and used to identify and eliminate or control catastrophic or critical hazards and balance risks and trades. This shall include, at a minimum, the processes for hazards analysis, failure modes and effects analysis, and Probabilistic Safety Analysis (PSA). To the extent that it applies, the Commercial Provider shall leverage off historical performance data to guide the implementation of the approaches, and shall describe the process for utilization of historical information.

NASA recognizes software Independent Verification and Validation (IV&V) as a valuable risk reduction technique. For all flight and ground software for which NASA requires insight, the plan shall address the process of software IV&V in accordance with CCT-REQ-1130, software engineering requirements. The IV&V Agent shall independently select the segments of the software, hardware and system to analyze and test, choose the IV&V techniques, define the schedule of IV&V activities, and select the specific technical issues and problems to act on and will document this. The IV&V Agent shall provide its findings in a timely fashion to both the software development organization and to the Commercial Provider’s management. The IV&V effort is intended to identify gaps and deficiencies in the software developer's processes to include areas such as requirements, software designs, development and testing which might be corrected or be subsequently documented as a formal Program risk. Closed-Loop tracking of the IV&V Agent’s findings shall be maintained and tracked to closure to include the Commercial Provider’s disposition of these comments. The findings of the IV&V Agent, along with the corresponding Commercial Partner’s disposition shall be shared with NASA at pre-determined intervals.

For software and safety items where ISS is identified as being an affected party and/or stakeholder, the plan shall address:

- The process for complying with SSP 30234; SSP 30309; NASA-STD-8739.8 Sections 6, 7.1, 7.2.4, 7.3 and 7.4; and NASA-STD-8719.13 Chapter 7.
- The process of software independent verification and validation.

The Commercial Provider shall make available the results of the associated analyses, such as hazard analysis, failure modes and effects analysis reports, which support design decisions. This documentation shall provide sufficient detail to clearly identify potential hazards, causes, likelihood and consequence, the design changes made, and the controls put in place to mitigate the hazards, along with rationale supporting these decisions.

Hazard reports shall mature during the design development process as additional details are generated consistent with the CTS design maturation and established milestones. By the end of the development process, the hazard reports shall include, at a minimum, the following:

- Summary of hazard analysis results.
- Hazard description and effect, including upstream and downstream effects.
- A risk assessment for each hazard cause.
- A risk matrix that captures a snapshot of the total risk of the hazard.
- Failure modes that can lead to a hazard (cross-referenced to failure modes and effects analysis, if available).
- Failure modes and how the failure can affect interfacing subsystem operations.
- The system component or mission phase that the analysis is concerned with.
- The configuration or phase of the mission that the system is in when the hazard is encountered (e.g., maintenance, during flight, ground processing, etc.).
- Recommended design or actions necessary to eliminate or control the hazard.
- Description of the design and operational controls.
- Verification for the hazard controls (e.g., design features, inspections or tests, procedures in operations and maintenance manuals, LCC, flight rules, or other means).

Each hazard report shall stand alone. Data required to understand the hazard, the hazard controls, and the safety/engineering verification methods shall be attached to the report. Examples of such data include logic diagrams; description of the applicable flight/support system and its operation; a listing of the sequence of events; a list of critical procedures/processes that require special verification; lists of mechanisms; lists of connections made or broken; lists of penetrations to space and associated seals; and summaries of proposed tests or test results.

Hazard report format shall contain, as a minimum, the above bulleted list, as well as, the content specified in accordance with SSP 30599, Appendix D.

4.2.2 System Safety and Reliability NASA Focus Areas

NASA will review and approve the safety and reliability products through a phased safety review process, assess the Commercial Provider's determination of risk likelihood and consequence, and evaluate whether the design decisions and hazard controls put in place by the Commercial Provider are sufficient to ensure crew safety. In addition, for operations controls, NASA will verify the Commercial Provider meets the intent of CCT-STD-1150, Section 4.

4.3 Probabilistic Safety Analysis

The Commercial Provider shall conduct a probabilistic safety analysis (PSA).The PSA is a structured probabilistic treatment of scenarios, likelihood, and consequences. It consists of the application of probabilistic methods and related processes to evaluate safety. The CCP utilizes the PSA to evaluate the risks of Loss of Crew (LOC) and Loss of Mission (LOM). The PSA is applied throughout design development, as well as during the operational phase, in order to verify through analysis that a Commercial Provider's CTS meets established LOC and LOM requirements. During the design phase, it is expected that the PSA will be utilized to assist design decisions to minimize risk.

An overview of the PSA process guidelines and NASA's expectations for the performance of a PSA are provided in *Probabilistic Safety Analysis Methodology Guide* (CCT-REF-1121).

4.3.1 Probabilistic Safety Analysis Data Products

The results of the PSA, with supporting data, shall include, at a minimum, the following:

- Estimates of the LOC/LOM probability, including associated Bayesian uncertainties for the entire mission, as well as for any system, function, or mission phase for which the Agency or Program has established safety goals, thresholds, or requirements, or for which the Commercial Provider has established an allocation.
- A risk profile (distribution of the total LOC or LOM probability) consisting of LOC or LOM estimates for individual risk contributors that jointly equal the mission-level LOC or LOM probability estimate.

4.3.2 Probabilistic Safety Analysis NASA Focus Areas

Assessment of the PSA process will be measured upon the thoroughness of individual technical products, together with an integrated analysis, where applicable. Emphasis will be placed on the incorporation of a systematic and comprehensive PSA approach applicable to the criteria that includes the definition of objectives, scenario development, quantification and uncertainty analysis, interpretation of results, and documentation. The purpose of the technical evaluation is to confirm that the PSA model properly identifies the LOC/LOM estimates for the Commercial Provider's CTS.

4.4 Software Safety and Assurance

In addition to the software qualification/acceptance activity, the Commercial Provider shall be responsible for the management of software safety throughout the CTS life-cycle. To this end, the Commercial Provider shall define a Software Safety Plan to document safety-critical software determination processes, management, software development and analysis methods (including support of hazard analyses and production of hazard reports), implementation and test, and operational use.

4.4.1 Software Safety Data Products

In support of CTS certification, the products shall include, at a minimum, the following:

- Software Safety Plan, processes, and data.
- Software safety-criticality evaluation results.
- Analysis results that identified hazards associated with a specific requirement, design concept, or operation have been evaluated for software's contribution to the hazard cause and verification that controls or mitigations have been incorporated.
- Commercial Provider software acquisition documentation.

4.4.2 Software Safety NASA Focus Areas

NASA's review of software safety will focus on the following:

- Review of the Software Safety Plan for adequacy and completeness.
- Validation of models or simulations used to make critical decisions that impact human safety.
- Methods and procedures used for verification, validation, and uncertainty assessments.
- Review of analysis results that identify software as a contributor to a hazard cause and the controls or mitigations that have been incorporated.

4.5 Integrated Safety Review Process

Safety is the responsibility of the Commercial Provider for systems and operations developed as part of the CTS. The compliance with safety requirements is formally executed as a subset of CTS certification.

This will be done in conjunction with the development review processes established in Section 3.7 of this document. The review of certification for safety requires that a unique perspective be applied to the development of the systems very early in the development process. NASA accomplishes this through a phased review and approval process anchored to major milestones and through insight into the decisions affecting safety and engagement of the engineering community in decisions affecting risk.

The foundation for safety certification is a comprehensive integrated risk analysis utilizing tools, such as hazard analysis, failure mode effects analysis, and PSA. These tools work together to influence the decisions surrounding risk. NASA must understand what methodologies are applied within a Commercial Provider's development and operational programs to ensure the foundation is consistent with expectations for identification and resolution of safety risk.

The Commercial Provider's integrated safety analysis shall be an integral part of the CTS certification. The hazard analysis is a critical piece of the safety analysis. NASA gains a significant amount of insight through the incremental review of the Commercial Provider's hazard analysis and shall have the Commercial Provider conduct, submit and present its hazard analysis and reports to NASA for review and approval. NASA will utilize a phased safety review process to assess the design and operations of the CTS through incremental reviews anchored to major CCP milestones. This process evaluates the associated hazards and the controls implemented by the Commercial Provider in its CTS design to ensure all hazards and causes have been identified and adequately controlled (reference SSP 30599 and SSP 30309). In the timeframe of the Milestone Reviews, the associated hazard reports shall be presented to a NASA board and board member participation will be determined by the content in the safety analysis defined by one of the two following stakeholder areas:

a. Occupant safety throughout all mission phases, including docked operations as it relates to hazards created by the CTS vehicle (stakeholder: CCP; CCP Review).
b. Integrated hazards created by the combined operations during the Rendezvous, Proximity Operations, Docking and Undocking (RPODU) phase (stakeholders: CCP/ISS; CCP/ISS joint review).

The phased safety review process is meant to ensure the completeness of the Commercial Provider's hazard analysis and to provide opportunities for NASA and the Commercial Provider to participate in real-time value-added risk discussions that are beneficial to both NASA and the Commercial Provider. NASA will look to the Commercial Provider to present its analysis at these incremental milestone reviews. The Commercial Provider shall provide the assurance that all hazards and hazard causes inherent in the design and operations are identified; adequate control strategies have been employed to control each of the hazards and causes; and to detail the methods utilized to verify all hazard controls. Significant risks identified as a result of the hazard analysis and discussions will be forwarded to CCP and ISS Program Management.

The board responsible for conducting the phased safety reviews of the Commercial Provider's hazard analysis is chartered to meet the following goals:

a. Determine compliance to relevant requirements.
b. Evaluate the residual safety risk from meeting established requirements.
c. Identify unique safety risk not otherwise captured by the requirements.
d. Evaluate the derived safety requirements from the hazard analysis.
e. Establish the overall risk of the system.
f. Foster value-added risk discussion with the Commercial Provider

The CCP phased safety reviews shall be conducted in three phases per SSP 30599. Phase I will be conducted in a timeframe that is consistent with a Preliminary Design Review (PDR) level of maturity. Phase II will be conducted in a timeframe that is consistent with a Critical Design Review (CDR) level of maturity. Phase III will be conducted in a timeframe that is consistent with a DCR level of maturity. Phase III includes the incremental closure of all the verification activities identified in the hazard reports post DCR. The Commercial Provider shall closeout all verifications deemed required for crewed flight test prior to the FTRR and all remaining verifications prior to the the ORR milestone. At the closeout of all verifications, the hazard report will be approved by the board and a letter certifying completion of the Phase III review will be signed and recorded.

The scope of the safety reviews is to determine, given a Commercial Provider's solution, that analysis was conducted to the appropriate level to surface key risks in the design and whether risks exist beyond the requirements established for certification. The results of the safety reviews are intended to inform the design and program reviews and establish the level of acceptable risk for the system. Any requirement non-compliances or accepted risk discussions outside the delegated authority of the NASA board responsible for reviewing the provider's safety analysis will be forwarded to the CCP/ISS Program Boards for acceptance.

4.6 Radioactive Material Usage

The Commercial Provider shall be responsible for characterizing and reporting potential risks associated with a planned launch of radioactive materials into space on launch vehicles and spacecraft, during normal or abnormal flight conditions. Procedures and levels of review and analysis required for nuclear launch safety approval vary with the quantity of radioactive material planned for use and potential risk to the general public and the environment. Details of the nuclear launch safety approval process can be found in NPR 8715.3, Chapter 6.

4.7 Human Error Analysis

The Commercial Provider shall conduct a human error analysis for all mission phases to include nominal operations and those operations planned for response to system failures. The results will be incorporated into design and operational procedures to minimize the likelihood and negative effects of human error.

4.7.1 Human Error Analysis Data Products

The Commercial Provider shall develop a summary of how the human error analysis (to date) was used to:

- Understand and manage potential catastrophic hazards which could be caused by human errors.
- Understand the relative risks and uncertainties within the system design.
- Influence decisions related to the system design, operational use, and application of testing.

4.7.2 Human Error Analysis NASA Focus Areas

NASA will evaluate the Human Error Analysis (HEA) to ensure it identifies potential human actions, human errors, hazards, and process failure modes; models human performance, and qualitatively characterizes how human error affects the system. The HEA should be used iteratively to make design trades and decisions for all mission phases, including operations both within the space system and control centers. For all nominal operations, including responses to system failures and abort scenarios,

the HEA will 1) identify inadvertent operator actions which would cause a catastrophic event and determine the appropriate level of tolerance; 2) identify other types of human error that would result in a catastrophic event; and 3) ensure application of the appropriate error management.

4.8 Human Systems Integration

The Commercial Provider shall establish a Human Systems Integration (HSI) strategy to ensure that humans and their needs, as well as their capabilities and limitations, are considered during the design and operation of the system.

4.8.1 Human Systems Integration Data Products

The HSI products shall include, at a minimum, the following:

- A master task list including identification of nominal and critical tasks necessary for established mission objectives and concepts of operation.
- Task analyses in support of the CCT-REQ-1130 requirements that include evaluations of functional allocation for manual and automated crew and system tasks; expected utilization of operator capabilities to execute the mission, prevent aborts, and prevent catastrophic events; and evaluations of the crew's ability to accomplish mission critical and volume driving tasks.
- A summary of crew workload and usability evaluations that demonstrates the impact of crew interface designs on human error and total human-system performance.
- Human-in-the-loop testing strategy in support of planned human test and demonstration activities.

4.8.2 Human Systems Integration NASA Focus Areas

Supporting documentation will be assessed to ensure that human capabilities and limitations have been adequately considered. Focus areas include:

- Evidence of human capability and limitations considerations as part of trade studies/analysis activities.
- Human-in-the-loop test planning and results.
- Task analysis to identify sequencing (e.g., parallel, serial, multiple crew/systems, individual crew/systems) of tasks, time related data (e.g., duration, frequency, limits), task priority, and volume or architecture drivers.
- Evaluation of how crew interface workload and usability impacts human error and total human-system performance.
- Evaluation of the crew's ability to effectively accomplish mission critical and physical accommodation driving tasks.

4.9 Margin Management

The Commercial Provider shall develop an integrated vehicle performance and design margin allocation strategy, and implement it through a detailed set of vehicle stage, system, subsystem, and component performance requirements and specifications. The Commercial Provider's strategy, backed up by an assessment of its integrated design approach, will identify and define the appropriate levels of design or performance margin needed at the vehicle stage, system, subsystem, and/or component level, and address uncertainties and the expected variations in vehicle manufacturing, operational performance, and/or operational environments. Consistent with this approach, as the Commercial Provider decomposes and flows down higher-level CTS requirements, the Commercial Provider will implement its strategy by clearly identifying and allocating the appropriate amount of margin into its approved

stage, system, subsystem, and/or component requirements for the respective hardware and software designs.

4.9.1 Margin Management Data Products

The Margin Management Plan shall include, at a minimum, the following:

- A set of critical system resources (e.g., mass, propellant, power) that need to be managed in order for the design to meet its requirements.
- A definition of how margin is calculated for each resource.
- An assessment of operating margin, growth allowance, and program manager's reserve for each parameter.
- A margin specification at each development milestone.
- A Margin Management Report at each development milestone that consists of the current basic resource estimate and margin of each resource.

4.9.2 Margin Management NASA Focus Areas

Supporting documentation will be assessed to ensure that a comprehensive margin management strategy is being employed. Focus areas include:

- Closed-loop process between spacecraft and launch vehicle performance analysis with adequate margins to protect for production and operation variability and evidence of margin's utilization in the design analysis.
- Traceability of managed performance parameters to the system measures of effectiveness (e.g., payload mass, consumable reserves) and design standards.
- Integration of margin management with the risk process to implement correction when limits are exceeded.

5.0 Test and Verification

This section includes hardware and software qualification and acceptance test programs, integrated and end-to-end test of flight hardware and software, ground systems test planning, vehicle performance management planning, and flight test planning. This may be accomplished through a series of demonstrations and joint reviews. More information on V&V as part of certification can be found in Section 7.

5.1 Qualification and Acceptance Test Planning

5.1.1 Qualification and Acceptance Test Data Products

In support of CTS certification, the products shall include, at a minimum, the following:

- Qualification and acceptance documentation and supporting data.
  - Test plans, test reports, and requirements traceability/management.
  - Test configurations and deviations.
  - Qualification margins and derivations.
  - Environments specified and data used in development (e.g., acoustic, shock, etc.).
- Software Development Plan, verification results, and peer review signoff.

5.1.2 Qualification and Acceptance Test NASA Focus Areas

NASA will assess documentation in support of qualification and acceptance testing. NASA will focus on the following:

- Qualification and acceptance documentation and associated reports.
- Test fidelity and completeness.
- Validated models and/or analysis used.
- Requirements traceability/management.
- Performance requirements and margin analysis.
- Software development environment, tools, and adherence to the development process.
- Mapping of system, Computer Software Component (CSC), and interface requirements to software design and test.

5.2 End-to-End Test

The Commercial Provider is responsible for performing, tracking, and recording CTS flight hardware and software integration, test, and checkout. This includes facility integration for hardware and software.

5.2.1 End-to-End Test Data Products

In support of CTS certification, products shall include, at a minimum, the following:

- Test procedures, non-conformance, and failure analysis.

5.2.2 End-to-End Test NASA Focus Areas

NASA will perform assessments to determine if documentation, evaluation, and anomaly resolution during integration, test, and checkout is adequate. Detailed expectations for facility integration standards are found in CCT-STD-1150.

5.3 Flight Test

The Commercial Provider shall develop and implement a flight test program as part of the V&V effort. This includes vehicle performance management and margin. Flight test objectives address risk reduction and validation needs. As flight hardware and software continues to mature throughout development, flight test objectives and the associated strategy will be updated.

Decision criteria for legitimate flight test objectives satisfy at least one of the following:

a. Ground testing is not sufficient to adequately test the objective.
b. Significant risk exists after all ground testing and analysis is complete.
c. Flight test is the only method to achieve validation of the objective.

The flight test program shall include a crewed flight to the ISS. This minimally crewed flight shall include a NASA crew, dock with the ISS, remain docked for a sufficient duration to check-out ISS interfaces, and then return to a supported landing site.

A contractor-led Joint Test Team (JTT) (reference CCT-PLN-1100) shall conduct crewed test flights.

5.3.1 Flight Test Data Products

In support of CTS certification, the flight test program shall address the test objectives in Table 7-1 that meet the criteria for flight test.

5.3.2 Flight Test NASA Focus Areas

NASA will review the flight test program objectives and detailed test results for certification.

5.4 Joint ISS Visiting Vehicle Integration, Verification, and Test Planning

The ISS Program and the CCP will work with the Commercial Provider to negotiate an ISS Visiting Vehicle Joint Integration, Verification, and Test Plan (JIVTP). This test plan will define the steps, planning agreements, and products to be completed for joint ISS Visiting Vehicle requirement verification, execution, and closure. It also identifies organizational roles, responsibilities, and verification ownership.

6.0 Production and Operations Validation and Verification

The Commercial Provider shall develop and implement an approach for the management and control of processes for production, assembly, integration, launch and mission planning, execution and recovery. Production and operations can and do generally overlap. Production requirements still apply to those final vehicle assembly steps, just as operational requirements apply to any operational activities.

The Commercial Provider shall define, manage, validate, and implement an end-to-end flight and test readiness process to include processing and operating plans to execute launch, mission, and recovery activities.

6.1 Production Control

The Commercial Provider shall establish and maintain an approach to adequately verify production hardware/software.

6.1.1 Production Control Data Products

In support of CTS certification, documents and data records describing or developed during the associated processes shall include, at a minimum, the following:

- Manufacturing, fabrication, storage, and transportation processes which comply with design.
- Provide documentation to clearly show how production related hazard controls, identified through the safety review process, have been flowed down into production requirements and can be traced to implementation.
- Inventory acceptance process and records to verify that incoming parts and materials comply with all design drawings and specifications and include required materials certification data.
- Inventory control processes and records that ensure parts and materials are properly warehoused in accordance with materials control and storage requirements, and that shelf life requirements are properly observed.
- Inventory assignment/distribution process and records which provide adequate control and traceability of critical parts and materials from the source to the final “as built” configuration.
- Implementation of non-conformance identification, tracking, and corrective action with verification that issues are returned to print or accepted as a design change through the FRR process.
- Provide documentation to clearly show how tooling and equipment used in the manufacture and test of flight hardware is verified to meet all production requirements and tolerances.
- Production support processes for metrology and other critical production support activities and related production records to verify production processes and equipment are maintained within established limits.
- Assembly/integration and test plans for subsystem, system, stage, and vehicle.
- Periodic audits to verify compliance.

6.1.2 Production Control NASA Focus Areas

NASA will perform assessments to determine if the processes provide adequate documentation and completeness, which includes the evaluation of the Commercial Provider’s compliance with these processes. In addition to certification, NASA will verify that key performance parameters are trended, evaluated, and understood flight-to-flight.

6.2 Operations Planning

6.2.1 Operations Planning Data Products

Operations products shall include, at a minimum, the following:

- The Commercial Provider shall develop operations processes and products consistent with CTS design limitations. Operations processes shall define methods to develop, validate, and certify the operations products and facilities. Operations products shall include: mission manifesting; flight design; ground operations procedures supporting nominal and off-nominal operations, mission controller/flight crew procedures supporting nominal and off-nominal scenarios while in-flight, nomenclature definition, vehicle and crew timelines, ground monitoring/control systems, and flight rules.

6.2.2 Operations Planning NASA Focus Areas

NASA will verify the Commercial Provider meets the intent of CCT-STD-1150, Section 3.

6.3 Operations Training

6.3.1 Operations Training Data Products

Operations products shall include, at a minimum, the following:

- The Commercial Provider shall develop a training program for personnel having safety critical or mission critical roles. This training program shall include simulation training for flight crew and mission controller personnel that closely mimics the conditions that will be seen during flight and address nominal and off-nominal scenarios. The training program shall also define standards for non-critical roles, including instructors and lessons. Personnel with safety or mission critical roles include mission designers, assembly/integration/testing and launch engineers, technicians and quality control personnel, mission and ground controllers, all flight crew, and recovery personnel.

6.3.2 Operations Training NASA Focus Areas

- NASA will verify the Commercial Provider meets the intent of CCT-STD-1150, Section 5.

6.4 Operations Execution

6.4.1 Operations Execution Data Products

Operations products shall include, at a minimum, the following:

- The Commercial Provider shall develop a mission execution process addressing operational communication plans, operational management plans, realtime analyses, and contingency action plans. This includes defining mission authority (provider led, interfaces to NASA led, and joint decision making), which allows for informed decision-making and risk management. The associated CTS Mission Management Process is addressed in CCT-PLN-1100.

6.4.2 Operations Execution NASA Focus Areas

NASA will verify the Commercial Provider meets the intent of CCT-STD-1150, Section 6.

6.5 Operations Review Process

6.5.1 Operations Review Process Data Products

Operations products shall include, at a minimum, the following:

- The Commercial Provider shall develop a ground processing, real-time, and post-flight review process to validate the CTS is performing as predicted and operating within design limitations. Ground processing review shall include a process that tracks and resolves anomalies, captures potential process improvements, and lessons learned to improve and inform future ground operations and CTS design changes. Real-time review process shall analyze and assess in-flight anomalies and CTS performance such that mission execution can continue safely. The post-flight review process shall include debriefing the flight crew and operations personnel.

6.5.2 Operations Review Process NASA Focus Areas

NASA will verify the Commercial Provider meets the intent of CCT-STD-1150, Section 7.

7.0 Certification Plan Overview

The Commercial Provider, with CCP approval, shall define, control, and execute an end-to-end Certification Plan per Appendix C. The provided Certification Plan defines an integrated strategy for certification of the complete CTS and defines a structured and organized approach for implementing the strategy. Since certification is a progressive process and is highly sensitive to the order of execution, the certification strategy will clearly define the order of execution, with a schedule and critical path clearly outlined. The Certification Plan will define the V&V methods for all CTS technical requirements, including the requirements which result from the necessary decomposition and flow down of higher level CTS requirements to the appropriate level. CTS requirements V&V includes those requirements established to control critical hazards. The Commercial Provider shall deliver a V&V plan per Appendix D. NASA will approve the V&V Plan which includes all NASA technical requirements in CCP-REQ-1130 and SSP 50808, and all Commercial Provider decomposed or derived requirements. Although NASA will only verify compliance of the NASA technical requirements in CCP-REQ-1130 and SSP 50808, NASA will review data supporting these lower level requirement closures. All "meets the intent" requirements are applied to the CTS, as described in Section 4.1 of this document for alternate standards and CCT-REQ-1130, Section 3.10 for human health, medical, and performance. Complete execution of the Certification Plan will ultimately provide the objective evidence necessary to verify compliance with all design and performance requirements governing the capability and performance of all critical systems, subsystems, and the integrated CTS. Where the Certification Plan includes validation, verification, or demonstration of design requirements, system performance, or accuracy of analytical models through test (including test flights), the Commercial Provider shall develop a test plan. The plan would document test objectives with linkage to specific requirements that are verified by the test. For flight tests, the test plan shall require NASA approval.

Prior to the first LEO crewed test flight, the flight test readiness process will include a DCR of applicable elements from completed CTS Certification Milestones (for an interim CTS certification) and an FTRR. The DCR will formally document the configuration baseline (hardware, software, and processes used in design, production, and operations) and the conditions under which the CTS is certified (performance, fabrication and operational environments, constraints). Following the CCP's concurrence with the Commercial Partner's determination of flight readiness, the CCP will develop a recommendation for flight readiness to be presented at the NASA FTRR. The purpose of this review is request approval to proceed to launch countdown for a mission that transports NASA crew and to document the formal acceptance of risk by NASA and the Commercial Partner. Upon successful completion of each FTRR and closure of open work, NASA will grant CTS Certification of Flight Test Readiness (CoFTR) for the flight test mission.

Milestone Reviews will be utilized to gain CCP concurrence of the progress toward CTS certification. The form of the CTS Certification Data Package is a compilation of pertinent documents. The package collectively illustrates, with supporting evidence, that the system has met the technical requirements and is safe to carry NASA crew to and from the ISS. The CTS Certification Data Package will be configuration managed (includes referenced/linked material) to clearly track changes made between milestones.

The CTS Certification Data Package Content is summarized in the Table 7-1. Supporting data necessary to satisfy the certification elements is shown in the Data Products sections throughout this document; data is not limited to that shown. A listing of NASA focus-areas for review, examination, or analysis

show those that NASA plans to perform for satisfaction of certification. Implementation of NASA assessments may identify additional focus areas or in-house analysis necessitating additional provided data.

Table 7-1: CTS Certification Data Package Content

CTS Certification Data Package content includes:
Summary level CTS configuration for certification, with further access to all relevant detailed design and manufacturing data, which influences the final as-designed or as-built configuration. This includes access to configuration definition products, such as CAD models, design drawings, production records, waivers, or deviations.
A description of each reference mission and operations plans for which CTS certification is being requested.
Management systems and the related implementation and control process.
System Safety to include hazard analysis and control process, human error analysis, software safety analysis, and crew survival strategy assessment.
Quality management system, implementation, and controls.
Integrated risk management and analysis.
Manufacturing and Operations V&V Plan, including plans for verification of specific hazard controls implemented.
Summary level flight hardware and software qualification and acceptance data, with further access to detailed relevant test plans and reports, analysis, analytical models, and inspection/demonstration related data.
A combined ground and flight test program, with objectives linked to program development/validation needs. The test program, which may include a combination of component tests, subsystem tests, system tests, stage tests, vehicle tests, vehicle suborbital flight tests, vehicle orbital flight tests, landing, and abort system tests, must be robust enough to provide confidence in the aspects of the system design, and reduce uncertainties to adequately operate within its established design envelop, not adequately verified by any other method. The following test objectives will be addressed with detailed test results before NASA will certify the vehicle: • Verify all design and performance requirements not previously verified by another method. • Validate the nominal performance of the system. • Validate the dynamic response characteristics of the system. • Validate the structural integrity of the system. • Demonstrate the critical separation systems performance. • Demonstrate the entry, landing, and recovery systems. • Validate the critical system environments. • Bound critical performance uncertainties. • Demonstrate the abort system performance during critical phases of flight. • For ISS, demonstrate manual/automatic rendezvous, proximity operations, and docking systems (including abort and hold). • Demonstrate the critical ground and mission support systems.
A summary of the end-to-end design certification process, with further access provided to the detailed design Certification Plan. The summary will identify V&V methods employed, general implementation approach, and summary results for the following (with links to the detailed results): • Certification of detailed CTS operational and design technical requirements. • Certification of CTS performance. • Certification of integrated human-system performance.

Appendix A: Acronyms

Acronyms	Phrase
CBR	Certification Baseline Review
CCP	Commercial Crew Program
CDR	Critical Design Review
CERR	Critical Event Readiness Review
CM	Configuration Management
CoFTR	Certification of Flight Test Readiness
CSC	Computer Software Component
CTS	Crew Transportation System
DCR	Design Certification Review
DR	Decommissioning Review
DRM	Design Reference Mission
FRR	Flight Readiness Review
FTRR	Flight Test Readiness Review
GIDEP	Government Industry Data Exchange Program
HEA	Human Error Analysis
HSI	Human Systems Integration
ICDR	Integrated Critical Design Review
IPDR	Integrated Preliminary Design Review
ISS	International Space Station
JIVTP	Joint Integration, Verification, and Test Plan
JTT	Joint Test Team
LCC	Launch Commit Criteria
LEO	Low Earth Orbit
LOC	Loss of Crew
LOM	Loss of Mission
MMT	Mission Management Team
MPCP	Mishap Preparedness and Contingency Plan
MRB	Material Review Board
MUA	Material Usage Agreement
NASA	National Aeronautics and Space Administration
ORR	Operations Readiness Review
PCB	Program Control Board
PDR	Preliminary Design Review
PFAR	Post-Flight Assessment Review
PLAR	Post-Launch Assessment Review
PMP	Project Management Plan
PSA	Probabilistic Safety Analysis
RPODU	Rendezvous, Proximity Operations, Docking and Undocking
SAR	System Acceptance Review
SDR	System Definition Review
SIR	System Integration Review

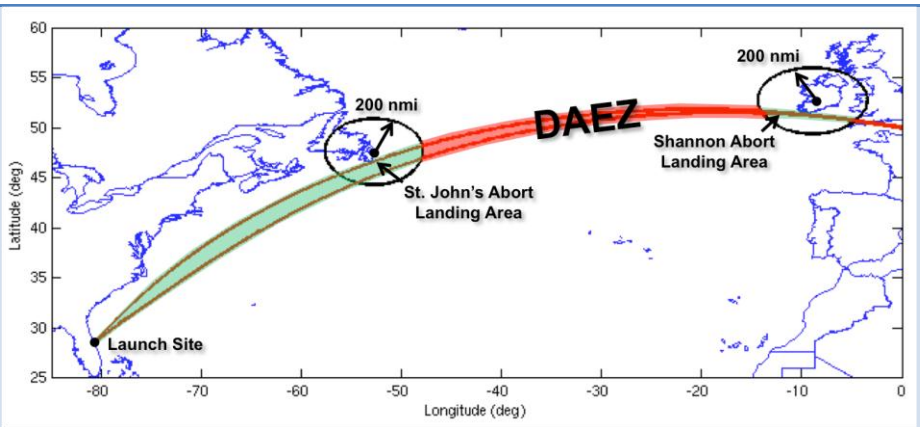
SORR	Stage Operational Readiness Review
SRR	System Requirements Review
TBD	To Be Determined
V&V	Verification and Validation

Appendix B: 1100 Series Definitions

Term	Definition
Abort	The forced early return of the crew when failures or the existence of uncontrolled catastrophic hazards prevent continuation of the mission profile and a return is required for crew survival.
Ambient Light	Any surrounding light source (existing lighting conditions). This could be a combination of natural lighting (e.g., sunlight, moonlight) and any artificial light source provided. For example, in an office there would be ambient light sources of both the natural sunlight and the fluorescent lights above (general office lighting).
Analysis	A verification method utilizing techniques and tools, such as math models, prior test data, simulations, analytical assessments, etc. Analysis may be used in lieu of, or in addition to, other methods to ensure compliance to specification requirements. The selected techniques may include, but not be limited to, task analysis, engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and analog modeling. Analysis may be used when it can be determined that rigorous and accurate analysis is possible, test is not cost effective, and verification by inspection is not adequate.
Annunciate	To provide a visual, tactile, or audible indication.
Approach Ellipsoid	A 4 x 2 x 2 km ellipsoid, centered at the ISS center of mass, with the long axis aligned with the V-Bar.
Approach Initiation	The approach initiation is the first rendezvous maneuver during a nominal approach that is targeted to bring the vehicle inside the ISS approach ellipsoid (AE).
Ascent	The period of time from initial motion away from the launch pad until orbit insertion during a nominal flight or ascent abort initiation during an abort.
Ascent Abort	An abort performed during ascent, where the crewed spacecraft is separated from the launch vehicle without the capability to achieve the desired orbit. The crew is safely returned to a landing site in a portion of the spacecraft nominally used for entry and landing/touchdown.
Automated	Automatic (as opposed to human) control of a system or operation.
Autonomous	Ability of a space system to perform operations independent from any ground-based systems. This includes no communication with, or real-time support from, mission control or other ground systems.
Backout	During mission execution, the coordinated cessation of a current activity or procedure and careful return to a known, safe state.
Breakout	Any action that interrupts the nominally planned free flight operations that are intended to place the spacecraft outside of a threatening location to the cooperative vehicle. This may be an automated or manually executed action. For the ISS, the area within which a vehicle poses a threat to ISS is called the Approach Ellipse.
Cargo	An item (or items) required to maintain the operability of the ISS and/or the health of its crew, and that must be launched and/or returned.

Catastrophic Event	An event resulting in the death or permanent disability of a ground closeout or flight crewmember, or an event resulting in the unplanned loss/destruction of a major element of the CTS or ISS during the mission that could potentially result in the death or permanent disability of a flight crewmember.
Catastrophic Hazard	A condition that could result in the death or permanent disability of a ground closeout or flight crewmember, or in the unplanned loss/destruction of a major element of the CTS during the mission that could potentially result in the death or permanent disability of a flight crewmember.
Command	Directive to a processor or system to perform a particular action or function.
Communications Coverage	Communication coverage is defined as successful link availability for nominal ascent and entry trajectories.
Communications Link	A communication link is established, whereas the received commands and voice from the CVCC to the spacecraft and the transmitted health and status data, crew health and medical related data, voice, telemetry, and transmitted launch vehicle and spacecraft engineering data are received.
Consumable	Resource that is consumed in the course of conducting a given mission. Examples include propellant, power, habitability items (e.g., gaseous oxygen), and crew supplies.
Continental U.S. Airport	An airport within the continental United States capable of accommodating executive jet aircraft similar to the Gulfstream series aircraft.
Contingency	Provisioning for an event or circumstance that is possible but cannot be predicted with certainty.
Contingency Spacecraft Crew Support (CSCS)	CSCS is declared when the spacecraft crew takes shelter on the ISS because the spacecraft has been determined to be unsafe for reentry. In this case, a rescue mission is required to return the spacecraft crew safely.
Crew	Any human onboard the spacecraft after the hatch is closed for flight or onboard the spacecraft during flight.
Crew Transportation System (CTS)	The collection of all space-based and ground-based systems (encompassing hardware and software) used to conduct space missions or support activity in space, including, but not limited to, the integrated space vehicle, space-based communication and navigation systems, launch systems, and mission/launch control.
Critical Decision	Those technical decisions related to design, development, manufacturing, ground, or flight operations that may impact human safety or mission success, as measured by defined criteria.
Critical Fault	Any identified fault of software whose effect would result in a catastrophic event or abort.
Critical Function	Mission capabilities or system functions that, if lost, would result in a catastrophic event or an abort.
Critical Hazard	A condition that may cause a severe injury or occupational illness.
Critical Software	Any software component whose behavior or performance could lead to a catastrophic event or abort. This includes the flight software, as well as ground-control software.
Critical Software/Firmware	Software/Firmware that resides in a safety-critical system that is a potential hazard cause or contributor, supports a hazard control or mitigation, controls

	safety-critical functions, or detects and reports 1) fault trends that indicate a potential hazard and/or 2) failures which lead to a hazardous condition.
Critical (sub)System	A (sub)system is assessed as critical if loss of overall (sub)system function, or improper performance of a (sub)system function, could result in a catastrophic event or abort.
CTS Certification	CTS certification is the documented authorization granted by the NASA Associate Administrator that allows the use of the CTS within its prescribed parameters for its defined reference missions. CTS certification is obtained prior to the first crewed flight (for flight elements) or operational use (for other systems).
CTS Element	One component part of the overall Crew Transportation System. For example, the spacecraft is an element of the CTS.
Deconditioned	"Deconditioned" defines a space crewmember whose physiological capabilities, including musculoskeletal, cardiopulmonary, and neurovestibular, have deteriorated as a result of exposure to micro-gravity and the space environment. It results in degraded crewmember performance for nominal and off-nominal mission tasks.
Definitive Medical Care	An inpatient medical care facility capable of comprehensive diagnosis and treatment of a crewmember's injuries or illness without outside assistance—capable of care of Category I, II, and III trauma patients. Usually a Level I trauma center, as defined by the American College of Surgeons.
Demonstration	A method of verification that consists of a qualitative determination of the properties of a test article. This qualitative determination is made through observation, with or without special test equipment or instrumentation, which verifies characteristics, such as human engineering features, services, access features, and transportability. Human-in-the-loop demonstration is performed for complex interfaces or operations that are difficult to verify through modeling analysis, such as physical accommodation for crew ingress and egress. Demonstration requirements are normally implemented within a test plan, operations plan, or test procedure.
Docking	Mating of two independently operating spacecraft or other systems in space using independent control of the two vehicles' flight paths and attitudes during contact and capture. Docking begins at the time of initial contact of the vehicles' docking mechanisms and concludes when full rigidization of the interface is achieved.
Downrange Abort Exclusion Zone	A geographical region of the North Atlantic Ocean to be avoided for water landings during ascent aborts for ISS missions due to rough seas and cold water temperatures. The region is depicted in Figure B-1. The St. John's abort landing area includes the waters within 200 nmi range to St John's International Airport (47° 37' N, 52° 45' W). The Shannon abort landing area includes the waters within 200 nmi range to Shannon International Airport (52° 42' N, 8° 55' W). Note: The northern and southern bounds of the DAEZ in the ISS Mission DAEZ figure are notional, as these bounds are limited only by steering and cross-range performance along the ascent trajectory and are not formally constrained.

Downrange Abort Exclusion Zone Figure	 **Figure B-1 Ascent Downrange Abort Exclusion Zone**
Emergency	An unexpected event or events during a mission that requires immediate action to keep the crew alive or serious injury from occurring.
Emergency Egress	Capability for a crew to exit the vehicle and leave the hazardous situation or catastrophic event within the specified time. Flight crew emergency egress can be unassisted or assisted by ground personnel.
Emergency Equipment and Systems	Systems (ground or flight) that exist solely to prevent loss of life in the presence of imminent catastrophic conditions. Examples include fire suppression systems and extinguishers, emergency breathing devices, Personal Protective Equipment (PPE) and crew escape systems. Emergency systems are not considered a leg of failure tolerance for the nominal, operational equipment and systems, and do not serve as a design control to prevent the occurrence of a catastrophic condition.
Emergency Medical Services	Services required to provide the crewmembers with immediate medical care to prevent loss of life or aggravated physical or psychological conditions.
End of Mission	The planned landing time for the entire mission, including the nominal pre-flight agreed to docked mission duration.
Entry	The period of time that begins with the final commitment to enter the atmosphere from orbit or from an ascent abort, and ending when the velocity of the spacecraft is zero relative to the landing surface.
Entry Interface	The point in the entry phase where the spacecraft contacts the atmosphere (typically at a geodetic altitude of 400,000 feet), resulting in increased heating to the thermal protection system and remainder of the spacecraft exterior surfaces.
External Launch Constraint	Conditions outside the CTS provider's control, such as range weather constraints or faults with range or ISS assets, or weather constraints affecting abort rescue forces capabilities. Range weather examples include ability to visually monitor the initial phases of the launch for range safety, etc. Non-weather range constraints include range safety radar and telemetry systems availability, flight termination systems readiness, clearance of air, land, sea, etc.
Failure	Inability of a system, subsystem, component, or part to perform its required function within specified limits.

Failure Tolerance	The ability to sustain a certain number of failures and still retain capability. A component, subsystem, or system that cannot sustain at least one failure is not considered to be failure tolerant.
Fault	An undesired system state and/or the immediate cause of failure (e.g., maladjustment, misalignment, defect, or other). The definition of the term "fault" envelopes the word "failure," since faults include other undesired events, such as software anomalies and operational anomalies. Faults at a lower level could lead to failures at the higher subsystem or system level.
Flight Configuration	The arrangement, orientation and operational state of system elements and cargo, vehicle cabin layout, flight software mode, and crew complement, clothing and equipment in the applicable mission or ground phase necessary in verification to evaluate the attributes called out in the requirement.
Flight Hardware	All components and systems that comprise the internal and external portions of the spacecraft, launch vehicle, launch abort system, and crew worn equipment.
Flight Operations	All operations of the integrated space vehicle and the crew and ground teams supporting the integrated space vehicle from liftoff until landing.
Flight Phase	A particular phase or timeframe during a mission is referred to as a flight phase. The term "all flight phases" is defined as the following flight phases: pre-launch, ascent, onorbit free-flight, docked operations, deorbit/entry, landing, and post-landing.
Flight Representative	Description of a test-article used in verifications in which the attributes under evaluation are equivalent to the flight article. Example: Human-in-the-loop tests for spacecraft egress must use an equivalent cabin layout, seats and restraints, and hatch configuration and masses. However, the propulsion system does not need to be functional, as it is not under evaluation.
Flight Rules	Established redline limits for critical flight parameters. Each has pre-planned troubleshooting procedures with pre-approved decisions for expected troubleshooting results.
Flight Systems	Any equipment, system, subsystem or component that is part of the integrated space system.
Flight Termination	An emergency action taken by range safety when a vehicle violates established safety criteria for the protection of life and property. This action circumvents the vehicles' normal control modes and ends its powered and/or controlled flight.
Free Flight Operations	Onorbit operations that occur when the spacecraft is not in contact with any part of the ISS.
Ground Crew	Operations personnel that assist the flight crew in entering the spacecraft, closing the hatch, performing leak checks, and working on the integrated space vehicle at the pad during launch operations.
Ground Hardware	All components and systems that reside on the ground in support of the mission, including the Commercial Vehicle Control Center, launch pad, ground support equipment, recovery equipment, facilities, and communications, network, and tracking equipment.

Ground Processing	• The work required to prepare the launch vehicle and spacecraft for mission from final assembly/integration/test through launch and resumes after landing for recovery of crew and cargo.
Ground Support Equipment	Any non-flight equipment, system(s), ground system(s), or devices specifically designed and developed for a direct physical or functional interface with flight hardware to support the execution of ground production or processing. The following are not considered to be GSE: • Tools designed for general use and not specifically for use on flight hardware. Ground Support Systems that interface with GSE Facilities.
Habitable	The environment that is necessary to sustain the life of the crew and to allow the crew to perform their functions in an efficient manner.
Hazard	A state or a set of conditions, internal or external to a system, that has the potential to cause harm.
Hazard Analysis	The process of identifying hazards and their potential causal factors.
Health and Status Data	Data, including emergency, caution, and warning data, that can be analyzed or monitored describing the ability of the system or system components to meet their performance requirements.
Human Error	Either an action that is not intended or desired by the human or a failure on the part of the human to perform a prescribed action within specified limits of accuracy, sequence, or time that fails to produce the expected result and has led or has the potential to lead to an unwanted consequence.
Human Error Analysis (HEA)	A systematic approach used to evaluate human actions, identify potential human error, model human performance, and qualitatively characterize how human error affects a system. HEA provides an evaluation of human actions and error in an effort to generate system improvements that reduce the frequency of error and minimize the negative effects on the system. HEA is the first step in Human Risk Assessment and is often referred to as qualitative Human Risk Assessment.
Human-in-the-Loop Evaluation	Human-in-the-loop evaluations involve having human subjects, which include NASA crewmembers as a subset of the test subject population, perform identified tasks in a representative mockup, prototype, engineering, or flight unit. The fidelity of mockups used for human-in-the-loop evaluations may range from low-fidelity, minimal representation, to high-fidelity, complete physical and/or functional representation, relevant to the evaluation. Ideally, the fidelity of human-in-the-loop mockups and tests increases as designs mature for more comprehensive evaluations. Further information on human-in-the-loop evaluations throughout system design can be found in JSC 65995 CHSIP.
Human-System Integration	The process of integrating human operations into the system design through analysis, testing, and modeling of human performance, interface controls/displays, and human-automation interaction to improve safety, efficiency, and mission success.
Ill or Injured	Refers to a crewmember whose physiological and/or psychological well-being and health has deteriorated as a result of an illness (e.g., appendicitis) or injury (e.g., trauma, toxic exposure) and requires medical capabilities exceeding

	those available on the ISS and transportation to ground-based definitive medical care. Ill or injured crewmember performance for nominal and off-nominal mission tasks will be degraded.
Inspection	A method of verification that determines conformance to requirements by the use of standard quality control methods to ensure compliance by review of drawings and data. This method is used wherever documents or data can be visually used to verify the physical characteristics of the product instead of the performance of the product.
Integrated Operations	All operations starting at 90 minutes prior to the ISS Approach Initiation and lasting until the vehicle leaves the ISS Approach Ellipsoid on a non-return trajectory.
Integrated Space Vehicle	The integrated space vehicle consists of all the system elements that are occupied by the crew during the space mission and provide life support functions for the crew. The integrated space vehicle also includes all elements physically attached to the spacecraft during the mission. The integrated space vehicle is part of the larger space system used to conduct the mission.
Landing	The final phase or region of flight consisting of transition from descent to an approach, touchdown, and coming to rest.
Landing Site	**Supported Landing Sites:** A fully supported site on a Continental U.S. land mass or waters directly extending from the coast with CTS recovery forces on station at the time of landing. The landing site zone extends through nominally expected dispersions from the landing site point. Designated Primary Landing Site – A supported landing site-intended for landing at the time of spacecraft undock. Alternate Landing Site – A supported landing site to which the spacecraft landing can be diverted in the event the deorbit burn is delayed. **Unsupported Landing Sites:** Emergency Landing – Any unsupported site (land or water) arrived at due to critical failures that force immediate return and preclude landing at a designated primary or alternate landing sites.
Launch Commit Criteria	Established redline limits for critical launch parameters. Each has pre-planned troubleshooting procedures with pre-approved decisions for expected troubleshooting results.
Launch Opportunity	The period of time during which the relative position of the launch site, the ISS orbital plane, and ISS phase angle permit the launch vehicle to insert the spacecraft into a rendezvous trajectory with the ISS (northerly launches only due to range constraints). The ISS is in-plane with the Eastern Range approximately every 23 hours and 36 minutes.
Launch Probability	The probability that the system will successfully complete a scheduled launch event. The launch opportunity will be considered scheduled at 24 hours prior to the opening of the launch window.
Launch Vehicle	The vehicle that contains the propulsion system necessary to deliver the energy required to insert the spacecraft into orbit.
Life-Cycle	The totality of a program or project extending from formulation through implementation, encompassing the elements of design, development, verification, production, operation, maintenance, support, and disposal.

Loss of Crew	Death or permanently debilitating injury to one or more crewmembers.
Loss of Mission	Loss of, or the inability to complete enough of, the primary mission objectives, such that a repeat mission must be flown.
Maintenance	The function of keeping items or equipment in, or restoring them to, a specified operational condition. It includes servicing, test, inspection, adjustment/alignment, removal, replacement, access, assembly/disassembly, lubrication, operation, decontamination, installation, fault location, calibration, condition determination, repair, modification, overhaul, rebuilding, and reclamation.
Manual Control	• The crew's ability to bypass automation in order to exert direct control over a space system or operation. For control of a spacecraft's flight path, manual control is the ability for the crew to affect any flight path within the capability of the flight control system. Similarly, for control of a spacecraft's attitude, manual control is the ability for the crew to affect any attitude within the capability of the flight/attitude control system.
MCC-H Mission Authority	• MCC-H has authority to make final decisions regarding spacecraft operations, including but not limited to Go/No-Go decisions and safety of flight and crew(s). • Beginning with either ISS integrated operations, or 30 minutes before the first required ISS configuration or crew activity in support of the spacecraft on rendezvous (e.g., ISS attitude maneuver, appendage configuration, USOS GPS configuration), whichever comes first. • Ending with either the end of ISS integrated operations, or when ISS is not required to maintain its configuration (e.g., ISS attitude, USOS GPS configuration, or appendages in a configuration) to support the spacecraft, whichever comes later. Applies anytime the spacecraft free-drift trajectory, including dispersions, is predicted to enter the ISS AE within the next 24 hours.
Mission	The mission begins with entry of the crew into the spacecraft, includes delivery of the crew to/from ISS, and ends with successful delivery of the crew to NASA after landing.
Mission Critical	Item or function that must retain its operational capability to assure no mission failure (i.e., for mission success).
Operations Personnel	All persons supporting ground operations or flight operations functions of the CTS. Examples of these personnel are listed below: Persons responsible for the production, assembly/integration/test, validation, and maintenance of flight hardware, production facilities, launch site facilities, operations facilities, or ground support equipment (GSE). Persons involved with supporting or managing the launch countdown, crew training, or mission during flight. Persons involved in post-flight recovery.
Orbit	This flight phase starts just after final orbit insertion and ends at the completion of the first deorbit burn.
Override	To take precedence over system control functions.
Pad Abort	An abort performed where the crewed spacecraft is separated from the launch vehicle while the launch vehicle remains on the launch pad. As a result, the

	crewed spacecraft is safely transported to an area which is not susceptible to the dangers associated with the hazardous environment at the launch pad.
Permanent Disability	A non-fatal occupational injury or illness resulting in permanent impairment through loss of, or compromised use of, a critical part of the body, to include major limbs (e.g., arm, leg), critical sensory organs (e.g., eye), critical life-supporting organs (e.g., heart, lungs, brain), and/or body parts controlling major motor functions (e.g., spine, neck). Therefore, permanent disability includes a non-fatal injury or occupational illness that permanently incapacitates a person to the extent that he or she cannot be rehabilitated to achieve gainful employment in their trained occupation and results in a medical discharge from duties or civilian equivalent.
Portable Fire Suppression System	A system comprised of one or more portable handheld fire extinguishers and access ports. These access ports allow the user to discharge fire suppressant into enclosed areas with potential ignition sources. See also 3.10.12.2 Use of Hazardous Chemicals.
Post-Landing	The mission phase beginning with the actual landing event when the vehicle has no horizontal or vertical motion relative to the surface and ending when the last crewmember is loaded on the aircraft for return to JSC.
Proximity Operations	The flight phase including all times during which the vehicle is in free flight beginning just prior to Approach Initiation (AI) execution and ending when the vehicle leaves the Approach Ellipsoid (AE).
Quiescent Docked Operations	The state of the CTS spacecraft while it is docked to the ISS with hatches open and ISS services, as called out in SSP 50808, connected and operational. From this state, the vehicle can support immediate ingress and transition into safe haven in the case of an emergency.
Recovery	The process of proceeding to a designated nominal landing site, and retrieving crew, flight crew equipment, cargo, and payloads after a planned nominal landing.
Reliability	The probability that a system of hardware, software, and human elements will function as intended over a specified period of time under specified environmental conditions.
Rendezvous	The flight phase of executing a series of onorbit maneuvers to move the spacecraft into the proximity of its target. This phase starts with orbit insertion and ends just prior to the approach initiation.
Safe Haven	A functional association of capabilities and environments that is initiated and activated in the event of a potentially life-threatening anomaly and allows human survival until rescue, the event ends, or repair can be affected. It is a location at a safe distance from or closed off from the life-threatening anomaly.
Safety	The absence from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment.
Safety Critical	A condition, event, operation, process, function, equipment or system (including software and firmware) with potential for personnel injury or loss, or with potential for loss or damage to vehicles, equipment or facilities, loss or

	excessive degradation of the function of critical equipment, or which is necessary to control a hazard.
Search and Rescue	The process of locating the crew, proceeding to their position, and providing assistance.
Software	Computer instructions or data stored electronically. Systems software includes the operating system and all the utilities that enable the computer to function. Applications software includes programs that do real work for users, such as word processors, spreadsheets, data management systems, and analysis tools. Software can be Commercial Off-The-Shelf (COTS), contractor developed, Government furnished, or combinations thereof.
Spacecraft	All system elements that are occupied by the crew during the space mission and provide life support functions for the crew. The crewed element includes all the subsystems that provide life support functions for the crew.
Space System	The collection of all space-based and ground-based systems (encompassing hardware and software) used to conduct space missions or support activity in space, including, but not limited to, the integrated space vehicle, space-based communication and navigation systems, launch systems, and mission/launch control.
Stowage	The accommodation of physical items in a safe and secure manner in the spacecraft. This does not imply that resources other than physical accommodations (e.g., power, thermal, etc.) are supplied.
Subsystem	A secondary or subordinate system within a system (such as the spacecraft) that performs a specific function or functions. Examples include electrical power, guidance and navigation, attitude control, telemetry, thermal control, propulsion, structures subsystems. A subsystem may consist of several components (hardware and software) and may include interconnection items such as cables or tubing and the support structure to which they are mounted.
System	The aggregate of the ground segment, flight segment, and workforce required for crew rescue and crew transport.
Task Analysis	Task analysis is an iterative human-centered design process through which user tasks are identified and analyzed. It involves 1) the identification of the tasks and subtasks involved in a process or system, and 2) analysis of those tasks (e.g., who performs them, what equipment is used, under what conditions, the priority of the task, dependence on other tasks). The focus is on the human and how they perform the task, rather than the system. Results can help determine the hardware or software that should be developed/used for a particular task, the ideal allocation of tasks to humans vs. automation, and the criticality of tasks, which drive design decisions. Further information on task analysis can be found in JSC 65995 CHSIP, Section 4.1.
Test	A method of verification in which technical means, such as the use of special equipment, instrumentation, simulation techniques, and the application of established principles and procedures, are used for the evaluation of components, subsystems, and systems to determine compliance with requirements. Test will be selected as the primary method when analytical techniques do not produce adequate results; failure modes exist, which could compromise personnel safety, adversely affect flight systems or payload operation, or result in a loss of mission objectives. The analysis of data

	derived from tests is an integral part of the test program and should not be confused with analysis as defined above. Tests will be used to determine quantitative compliance to requirements and produce quantitative results.
Validation	Proof that the product accomplishes the intended purpose. May be determined by a combination of test, analysis, and demonstration.

Appendix C: CTS Certification Plan

The Provider shall deliver to NASA an end-to-end certification plan. The Certification Plan will capture the processes to be utilized and the activities performed to demonstrate that the integrated CTS design and the associated production and operation capabilities will achieve a NASA Certification.

The Certification Plan will mature during the development process as additional details are generated consistent with the design maturation. By the end of the development process, the Certification Plan shall include, at a minimum, the following:

1) A summary of the CTS configuration (e.g. product breakdown structure) planned for certification.

2) A description of each reference mission and operations plans for which CTS certification is being requested (reference CCT-DRM-1110, Section entitled *NASA Design Reference Missions*).

3) A schedule of certification activities that includes the critical path and clearly defined certification milestones with NASA.

4) The strategy for certifying flight and ground hardware/software including: qualification of the design; acceptance of flight systems; mission operations capabilities; and management processes.

5) Identification of the physical resources (e.g. facilities, software, and simulators/mock-ups, and personnel for human-system performance testing) required to perform the V&V activities, as well as, the resource providers.

6) The plan to certify and maintain critical skills (e.g. welding, mission operators) and train the CTS crew.

7) A description of the deliverables that will be provided to NASA for verification and validation of manufacturing operations; for hardware and software qualification and acceptance test programs; environmental testing; and for the validation of models or simulations used to make critical decisions that may impact human safety and mission success.

8) A description of the process to understand and accept residual risk due to hazards, waivers, non-compliances, etc.

9) The list of products to be delivered for approval in the Certification Data Package as described in Table 7-1.

Appendix D: CTS Verification and Validation Plan

The Verification and Validation Plan shall identify the verification and validation activities, methods, deliverables, and processes that result in objective evidence that all elements of the CTS design, production, and operation meet the performance requirements and accomplish the intended design reference mission (reference CCT-DRM-1110, Section entitled *NASA Design Reference Missions*) when operated in the intended environment.

The V&V Plan will mature during the development process as additional details are generated consistent with the design maturation. By the end of the development process, the Verification and Validation Plan shall include, at a minimum, the following:

1) Provider's requirement statements and associated verifications.

2) Traceability from the Provider's requirement to the CCT-REQ-1130 and SSP 50808 requirement number.

3) Detailed descriptions of the verification activities to be performed to complete the verifications for all requirements traceable to CCT-REQ-1130, Section 3 requirements and in accordance with SSP 50808, Section 4. The details shall include the configuration of the activities relative to the planned flight configuration, the specific activities to be performed including the lifecycle verification, qualification and flight unit acceptance test activities, the measurable criteria for determining if the activities successfully verified the requirement, identification and validation of critical models and analyses, and joint verifications with the ISS Program as required in SSP 50808, Section 4.

4) Detailed descriptions of the activities to be performed to complete validation of the CTS. The details shall include the configuration of the activities relative to the planned flight configuration, the specific activities to be performed, and the measurable criteria for determining if the activities successfully validated the CTS.

5) Schedule of V&V activities and the products to be delivered and made available to NASA.

6) Manufacturing and operations V&V plans including those that implement hazard controls.

Appendix E: RESERVED

Appendix F: CTS FTRR/FRR Milestone Data

The following types of data support FTRR/FRR milestone assessments:

1. Mission/Flight Test Objectives.

2. Mission/Flight Test Risks
   a. All open risks or watch items.
   b. Tasks or activities during the flight that are required to mitigate a recurrent risk.
   c. Tasks or activities planned during the flight that significantly change the likelihood or consequence of a risk.
   d. Identify acceptance rationale for all risks.

3. CTS Design Modifications from the Certification Baseline.
   a. Modification requirements
      1) Waivers/exceptions to requirements or standards.
      2) Flight test specific modifications.
   b. Requirement implementation
      1) Trade studies and analyses that support design decisions.
      2) Assessment of the risk of LOC/LOM and associated level of uncertainty.
      3) Significant technical issues/anomalies and planned resolution.
      4) Significant risks, mitigation strategies, and expected residual risk.
   c. Requirement V&V strategies and results of tests, analyses, and evaluations.
      1) Implementation of capabilities identified for crew survivability.
      2) Implementation of hazard controls.
      3) Critical (sub)system performance.
      4) Integrated performance of critical (sub)systems.
      5) Critical software performance, security, and safety.

4. As-Built CTS Integrated Space Vehicle.
   a. Changes and waivers to requirements for refurbishment, production, assembly, and integration from established baseline (e.g. Material Review Boards (MRBs) and Material Usage Agreements (MUAs).)
   b. Implementation.
      1) Changes to plans and procedures for logistics, production, assembly, and integration.
      2) Compliance with configuration management and maintenance plans.
      3) Significant technical issues/anomalies and planned resolution.
   c. V&V results for the as-built CTS integrated space vehicle.
      1) Implementation of crew survivability hardware, software, and procedures.
      2) Implementation of hazard controls in hardware, software, and procedures.
      3) Critical (sub)system performance.
      4) Integrated performance of critical (sub)systems.
      5) Critical software performance, security, and safety.
      6) Human-system performance.

5. CTS Launch, Mission, and Recovery Operations.

a. Changes and waivers to requirements for launch, mission, and recovery (including flight test or flight unique changes).
b. Implementation.
    1) Changes to operational processes, plans, training, software, and facilities.
    2) Changes to operational controls for hazards.
    3) Significant technical issues/anomalies and planned resolution.
c. Verification results for changes to the operations system.
    1) Changes to operational processes, plans, training, software and facilities.
    2) Changes to operational controls for hazards.
    3) Waivers/Deviations/Exceptions applicable to operations products.
d. Verification that the CTS will be operated within the CTS certification during flight/flight test.
e. Readiness assessments for operations systems, personnel, crew, and procedures.
f. For ISS Stage Operational Readiness Reviews (SORR) preceding FRRs:
    1) Resources (hardware, software, data, analysis, or items in the manifest) being delivered, completed, or returned by each mission.
    2) All open risks or watch items that may potentially affect the crewmember(s) or commercial spacecraft's ability to complete their stay on-orbit.
    3) Tasks or activities during the flight and/or stage that are required to mitigate a recurrent risk.
    4) Tasks or activities planned during the flight and/or stage that significantly change the likelihood or consequence of a risk.
    5) Identify acceptance rationale for all risks.

6. Anomalies from the previous flight test/missions (including non-CTS flights) that affect the CTS certification and their resolution.

7. Closeout of actions from NASA-chaired Mission and Flight Test Readiness Reviews.

8. Assurance of compliance to Commercial Provider processes.
    a. Configuration and data management.
    b. Modification, production, and operation processes.
    c. Risk management.
    d. Safety analyses.
    e. Reliability analysis.
    f. Quality assurance management.

Appendix G: Typical Technical Milestone Reviews

Descriptions of typical Milestone Reviews are shown below:

Table G-1: Milestone Reviews

Review	Description
System Requirements Review (SRR)	The SRR examines the functional and performance requirements defined for the system and the preliminary Program or Project Plan, and ensures that the requirements and the selected concept will satisfy the mission.
System Definition Review (SDR)	The SDR examines the proposed requirements, the mission/system architecture, and the flow down to all functional elements of the system.
Preliminary Design Review (PDR) or Integrated PDR (IPDR)	The PDR demonstrates that the overall program preliminary design meets all requirements with acceptable risk and within the cost and schedule constraints, and establishes the basis for proceeding with detailed design. It shows that the correct design options have been selected, interfaces have been identified, and verification methods have been described. Full approved cost and schedules, as well as all risk assessment, management systems, and metrics, are presented.
Critical Design Review (CDR) or Integrated CDR (ICDR)	The CDR, or ICDR, demonstrates that the maturity of the program's design is appropriate to support proceeding full-scale fabrication, assembly, integration, and test, and that the technical effort is on track to complete the flight and ground system development and mission operations in order to meet overall performance requirements within the identified cost and schedule constraints. Progress against management plans, budget, and schedule, as well as risk assessment, are presented.
System Integration Review (SIR)	The SIR evaluates the readiness of the project to start flight system assembly, test, and launch operations. V&V plans, integration plans, and test plans are reviewed. Test articles (hardware/software), test facilities, support personnel, and test procedures are ready for testing and data acquisition, reduction, and control.
System Acceptance Review (SAR)	The SAR verifies the completeness of the specific end item with respect to the expected maturity level and to assess compliance to stakeholder expectations. The SAR examines the system, its end items and documentation, and test data and analyses that support verification.
Design Certification Review (DCR)	The DCR formally documents the configuration baseline (hardware, software, and processes used in design, production, and operations) and the conditions under which the CTS is certified (performance, fabrication and operational environments, constraints).
Operations Readiness Review (ORR)	The ORR examines the actual system characteristics and the procedures used in the system or product's operation, and ensures that all system and support hardware (flight and ground), software, personnel, and procedures are ready for operations and that user documentation accurately reflects the deployed state of the system.

Review	Description
Flight Readiness Review (FRR)	The FRR examines tests, demonstrations, analyses, and audits that determine the system's readiness for a safe and successful flight/launch and for subsequent flight operations. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.
Post-Launch Assessment Review (PLAR)	The PLAR is an assessment of system in-flight performance. For human space flight, the PLAR is performed by the CTS Mission Management Team (MMT).
Critical Event Readiness Review (CERR)	The CERR is a review to confirm readiness to execute a critical event during flight operations. For human space flight, the CERR is performed by the CTS MMT.
Post-Flight Assessment Review (PFAR)	The PFAR is a human space flight review that occurs after a flight mission in order to assess whether mission objectives were met and the status of the returned vehicle.
Decommissioning Review (DR)	The DR confirms the decision to terminate or decommission the system and assess the readiness for the safe decommissioning and disposal of system assets.

Appendix H: CCP Milestone Review Data

The following types of data support the CCP milestone reviews:

Data
1. Assessment of meeting the CTS Design Reference Mission (DRM) objectives
2. Operations Concept
3. CTS Integrated Space Vehicle (Launch Vehicle, Spacecraft) Architecture
a. Design requirements and standards (including variances to NASA requirements and standards)
b. Design baseline
c. External Interface Agreements
4. CTS Production Architecture
a. Design requirements and standards for facilities and systems to support production and assembly of the integrated space vehicle
b. Design baseline for production facilities and systems
c. External Interface Agreements
d. Plans and processes for production and assembly
e. Evidence of compliance with the plans and processes for production and assembly
5. CTS Operations Architecture
a. Design requirements and standards for facilities and systems to support integration, launch, flight, and recovery of the crew and vehicle
b. Design baseline for operations facilities and systems
c. External Interface agreements
d. Operations Plans for integration, launch, flight, and recovery
e. Operations Training Program for integration, launch, flight, and recovery
f. Operations Execution Process for integration, launch, flight, and recovery
g. Operations Review Process for integration, launch, flight, and recovery
h. Evidence of Compliance to the Operations Plans for integration, launch, flight, and recovery
i. Evidence of Compliance to the Operations Training Program for integration, launch, flight, and recovery
j. Evidence of Compliance to the Operations Execution Process for integration, launch, flight, and recovery
k. Evidence of Compliance to the Operations Review Process for integration, launch, flight, and recovery
6. Integrated design and safety analyses, especially those effecting:
a. Abort and catastrophic event prevention and crew survival strategy
b. Implementation of capabilities identified for crew survivability and crew survivability procedures
c. Failure tolerance levels
d. Hazard identification and control methods

Data
e. Implementation of procedural hazard controls
7. Assessment of the risk of LOC/LOM and associated level of uncertainty
8. Significant technical issues/anomalies and planned resolution
9. Significant risks, mitigation strategies, and expected residual risk (Technical and Programmatic)
10. Crew usability & human system performance, crew workload, and human error analyses
11. Verification & Validation (including Flight Test)
a. Verification and validation strategies and plans
1) Critical (sub)system performance
2) Integrated performance of critical (sub)systems
b. Verification and validation results
c. Flight Test Plan & Objectives
d. Flight Test Results
12. Certification Plan
13. Closeout of actions from NASA-chaired reviews
14. Management Plans
a. Program Management Plan
b. Configuration Management Plan
c. Risk Management Plan
d. Safety and Reliability Plan
e. Requirements Management Plan
f. Quality Management Plan
g. Software Safety Plan
h. Radioactive Materials Usage Report
i. Human System Integration Strategy
j. Software Development Plan
k. Margin Management Plan
15. Assurance of compliance to Commercial Provider processes.