National Aeronautics and Space Administration

Commercial Crew Program
John F. Kennedy Space Center

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# Crew Transportation System Design Reference Missions

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## Record of Revision/Changes

| Revision | Description | Date |
|---|---|---|
| **Basic-3** | Removed Export Control marking for STI | 1/28/2015 |
| **Basic-2** | Updates to Appendix B per CCP CR 0119 and editorial change to Figure 1-1 | 1/28/2015 |
| **Basic-1** | Updated Appendix A | 07/19/2013 |
| **Basic** | Baselines *Crew Transportation System Design Reference Missions*. | 12/8/2011 |

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# 1.0 Introduction

The United States (U.S.) Government, through the National Aeronautics and Space Administration (NASA), is investing in the development of a U.S. commercial crew space transportation capability with the goal of achieving safe, reliable, and cost effective access to and return from the International Space Station (ISS). NASA's primary objective for the Commercial Crew Program (CCP) is transporting crew to and from the ISS. Additional commercial mission scenarios can potentially enhance the Commercial Provider's customer base and aid in achieving increasingly safe, reliable, and cost effective crew transportation, thereby, benefiting NASA missions to the ISS.

## 1.1 Purpose

The purpose of this document is to describe Design Reference Missions (DRMs) representative of the end-to-end Crew Transportation System (CTS) framework envisioned to successfully execute commercial crew transportation to orbital destinations. The initial CTS architecture will likely be optimized to support NASA crew and NASA-sponsored crew rotation missions to the ISS, but consideration may be given in this design phase to allow for modifications in order to accomplish other commercial missions in the future. With the exception of NASA's mission to the ISS, the remaining commercial DRMs are notional. Any decision to design or scar the CTS for these additional non-NASA missions is completely up to the Commercial Provider. As NASA's mission needs evolve over time, this document will be periodically updated to reflect those needs.

## 1.2 Scope

The sample DRMs contained in this document are top-level mission scenarios applicable to potential missions to low Earth orbit (LEO) destinations. As described in the parent certification document, CCTSCR-12.10, *Commercial Crew Transportation System Certification Requirement for NASA Low Earth Orbit Missions*, "NASA plans to purchase commercial crew space transportation services to LEO and the ISS as part of NASA's exploration plans and policies."

This document describes concept DRMs and is not a requirements document. For the ISS DRM, this document works in conjunction with the processes defined in *Crew Transportation Plan* (CCT-PLN-1100) and *Crew Transportation Technical Management Processes* (CCT-PLN-1120), the requirements defined in *ISS Crew Transportation and Services Requirements Document* (CCT-REQ-1130), the additional requirements defined in *ISS to Commercial Orbital Transportation Services Interface Requirements Document* (SSP 50808), and the standards found in *Crew Transportation Technical Standards and Design Evaluation Criteria* (CCT-STD-1140) and *Crew Transportation Operations Standards* (CCT-STD-1150).

## 1.3 Precedence

In the event of a conflict between the text of this document and applicable compliance requirements, the applicable compliance requirements take precedence.

## 1.4 Delegation of Authority

This document was prepared by and will be managed by NASA's CCP. CCT-DRM-1110 will be maintained in accordance with standards for the CCP documentation.

# 2.0 Design Reference Missions

The Commercial Provider is responsible for the design, development, production, operation, management, and integration of the end-to-end CTS. The CTS is comprised of flight system and ground system elements needed to support the execution of all phases of a mission. The flight system consists of a launch vehicle, crewed spacecraft, cargo to be transferred to the orbital destination, and flight crew equipment. The ground systems consist of the equipment, infrastructure, facilities, and personnel that support mission design, production, assembly, integration, test, launch preparation, launch operations, flight operations, and recovery activities.

The DRMs can influence the systems architecture and operational concepts for the end-to-end CTS.

Figure 1-1 depicts a general DRM to an orbital destination. The launch vehicle inserts the spacecraft into orbit and multiple orbital maneuvers are subsequently executed to rendezvous in the destination orbit with the satellite. After mission objectives at the destination are complete, the spacecraft departs and returns to Earth.

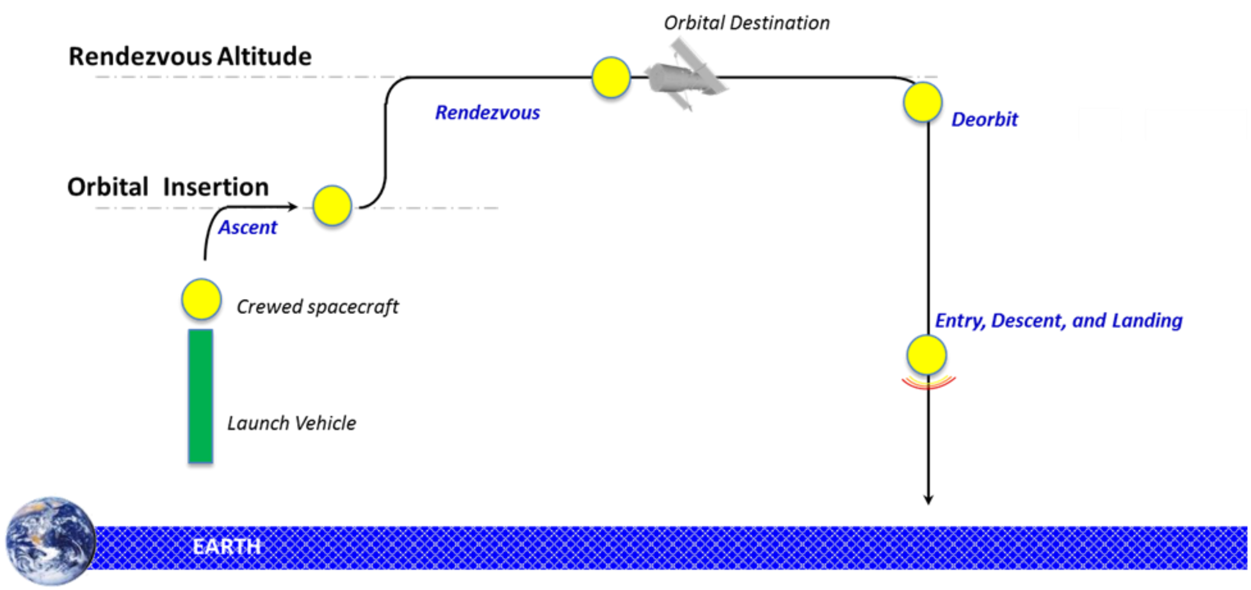


**Figure 1-1: General DRM to Orbital Destination**

Common to all DRMs in this document are the following mission and system capabilities[1]:

a. Support multiple back-to-back launch opportunities in a 2-week period in order to accomplish a single mission.
b. Transport crew and cargo to the orbital destination.
c. Transport flight crew equipment, including items such as food, water, clothing, hygiene supplies, sleep accommodations, trash volumes, and medical equipment, to support the crew during orbital free-flight operations.
d. Provide one extra day of orbital flight operations prior to mated operations in order to support a contingency re-rendezvous activity, plus an additional 12 hours for deorbit waveoff due to system anomalies or unanticipated weather issues.
e. Provide contingency early mission termination and safe return of the crew throughout the mission. This includes anytime aborts during ascent, as well as expedited return during the orbital phase.
f. Support crew rescue for off-nominal, contingency landings, following expedited coordination with the Commercial Vehicle Control Center (CVCC). When possible, additional personnel (e.g., flight surgeon) will also be deployed to the contingency site.
g. Ensure orbital collision avoidance notifications are received, and provide any necessary mitigation during real-time operations during the pre-launch and free-flight mission phases.
h. Provide safing and disposition of all landed vehicle hardware, including any required environmental cleanup (e.g., toxic propellants, maritime hazards, etc.).

[1] Note that these are expected capabilities. As noted in Section 1.2, specific requirements derived from each DRM are provided in separate documents (e.g., CCT-REQ-1130 and SSP 50808).

# 3.0 NASA Design Reference Missions

## 3.1 ISS Design Reference Mission[2]

The CTS has two top-level objectives in support of the NASA mission of providing services to the ISS. The primary objectives are to provide for crew rotation capability for four NASA or NASA-sponsored crewmembers, henceforth called NASA crew, and to provide an emergency crew return capability for these crewmembers at any time while the commercial spacecraft is docked to the ISS. Secondary objectives include transporting a limited amount of ISS Program-specified pressurized cargo to the ISS, returning pressurized cargo from the ISS, and providing for a crew safe haven capability when the spacecraft is docked to the ISS.

The spacecraft will be capable of transporting NASA crew to the ISS and docking 24 hours after launch. Mission launch opportunities must be accomplished within NASA-specified timeframes to accommodate ongoing ISS science operations and to minimize ISS traffic model impacts associated with other visiting vehicles. Prior to launch, the CTS supports a NASA-provided pre-launch health stabilitization program for NASA crew. The CTS also assures comparable health stabilization for any other crewmembers. Within a few hours of launch, NASA completes their crew medical assessments and baseline data collection process in NASA-provided facilities and hands the crew over to the CTS provider for transportation to the launch site. The NASA flight surgeons will serve as the physicians for the NASA crew during all phases of flight.

Lift-off occurs when the launch site passes through the ISS's orbital plane. Daily launch opportunities then depend on the resulting phasing; an everyday launch opportunity is desirable, but not required. Launch and ascent into the 51.6 degree inclination must meet Range Safety constraints associated with the launch site. Following ascent, an orbital insertion maneuver is executed and becomes the first of several orbital rendezvous maneuvers to be performed. These maneuvers bring the spacecraft closer towards the ISS. ISS standard communications are used when the spacecraft closes to within tens of kilometers to the ISS and ship-to-ship voice communications are established. Relative navigation is performed by the spacecraft using available cooperative and non-cooperative assets on the ISS. Communication and telemetry monitoring will be shared between the CVCC and the ISS mission control facilities, Mission Control Center - Houston (MCC-H). MCC-H Mission Authority will be established to ensure ISS, spacecraft, and crew safety. When in close proximity to the ISS, after receiving approval from both the spacecraft and MCC-H, the spacecraft begins a final approach to a NASA-specified docking port on the ISS. After docking, the vestibule between the ISS and the spacecraft is pressurized and verified not to be leaking. The spacecraft hatches are opened and the crew transfers into the ISS, placing the newly arrived spacecraft in a semi-quiescent state.

If the nominal docking attempt is not successful, or if an anomaly occurs near docking which would prevent docking at the nominal opportunity, the spacecraft backs out to a short safe distance and performs necessary reconfigurations, followed by a second approach and docking attempt. If that docking is also unsuccessful, the spacecraft will separate from the ISS vicinity on a collision-free safe trajectory and the spacecraft will prepare for a final re-rendezvous and docking attempt on the following crew day. If this final docking attempt is unsuccessful, the mission will be terminated, and the crew will return to Earth.

[2] The ISS DRM is documented here and in CCT-REQ-1130. In case of conflict, 1130 takes precedence

Because of the short time duration from launch to docking, internal maintenance of the spacecraft should not be necessary, nor should the crew require certain complex habitability items for food and waste management that can be found on longer duration vehicles, like the Space Shuttle or the ISS.

Extravehicular Activity (EVA) will not occur because the complexity of preparing for and executing an EVA is precluded due to the short time in the spacecraft early in the mission. Similarly, EVA will not be performed during the short free-flight duration from undocking to landing.

The spacecraft will be designed to be attached to the ISS for 210 days, although nominal crew rotations will occur at approximately 180-day intervals. The spacecraft remains quiescent and requires minimal maintenance during docked operations. The CVCC will provide routine, periodic support for these docked operations, in association with MCC-H. The ISS will provide power and environmental resources to the spacecraft in order to maintain the vehicle in a return-to-Earth ready state.

Due to limitations in the number of docking ports on the ISS, the spacecraft may need to be relocated from one docking port to another during ISS increment operations to provide operational flexibility. To accomplish this relocation, the spacecraft's full crew complement will ingress the spacecraft and close the hatch, and the spacecraft will be relocated from one port to the other port. The crew needs to be in the spacecraft to protect from the potential failure to re-mate with a docking port and preserve assured return for the crew.

When docked to the ISS, the spacecraft also provides a contingency "safe haven" capability allowing the crew to retreat to the spacecraft, close the hatch, and remain in a safe environment for up to 24 hours. If necessary, the spacecraft atmosphere will be purged during this activity. The ISS will provide attitude control during this 24-hour period. After the ISS returns to a habitable environment state, the crew will open the hatch and re-enter the ISS. If the ISS cannot achieve a habitable state during this period, the crew will return to Earth.

While docked to the ISS, the spacecraft will also serve as an emergency return vehicle for contingencies requiring the return of the crew brought to the ISS. Emergencies could result from ISS system failures, an uninhabitable crew environment, or a medical event requiring the return of the crewmembers. The crew will return to Earth within 24 hours of a declaration of an intention to return early. The crew will be fully trained to execute these contingency return-to-Earth operations, landing at a location where rescue is likely to be most expedient.

Due to the limited size and power available, the spacecraft is expected to have basic first aid and life support capability to respond to immediate medical conditions in the free-flight mode.

The launch of the next rotation mission will occur prior to the departure of the current increment crew working on the ISS, resulting in a handover period where two commercial spacecraft would be docked to the ISS for approximately 7 to 10 days. If the Commercial Provider has received NASA approval to fly non-NASA crew to the ISS, the spacecraft will need to provide food, water, clothing, Environmental Control and Life Support System (ECLSS) consumables, and other logistics for these crewmembers for the docked timeframe, since NASA does not generally pre-position these supplies on the ISS.

After handover is complete, the current increment crew will return in the spacecraft. They will enter the spacecraft, perform a vehicle health check, close hatches, depress the vestibule, perform a hatch leak check to verify seal integrity, and depart from the ISS. When available consumables permit, the spacecraft will potentially circumnavigate the ISS while in proximity to assess the external configuration of the ISS prior to final departure. During this circumnavigation, the crew will capture imagery to allow post-flight analysis of the ISS configuration.

The timeframe from undocking through landing is envisioned to be a short 4 to 8 hour free-flight duration. Landing will occur on the continental U.S. land mass or waters directly extending from the coast for nominal landing. This reduces risk by minimizing rescue force assets, increasing proximity to U.S. medical facilities, increasing security, and ensuring a prepared landing site free of hazards. If the nominal deorbit maneuver is waived-off after separation from the ISS, a subsequent landing at an alternate landing site, with nearby recovery forces, will be possible. The spacecraft may also perform orbital maneuvers in LEO to better accommodate alternate landing sites. Returning crew will be deconditioned and potentially have impaired musculoskeletal, cardiopulmonary, and neurovestibular capabilities as a result of long duration exposure to the micro-gravity and space environment, resulting in degraded crewmember performance in the post-landing timeframe. Because of the deconditioned state of the crew, special considerations need to be provided for crew recovery, medical care, and other post-landing care activities.

Upon arrival at the landing location, the NASA crew will be met with a recovery crew that will assist the astronauts in egress operations and removal of time critical cargo. NASA personnel will begin post-flight medical and science evaluations soon after egress is complete in a temporary facility at the landing location. Subsequently, the NASA crew, NASA support personnel, and time critical cargo will be transported by a CTS element to a staging location where handover will be completed and the NASA crew and cargo will be flown back to Houston using NASA assets.

After recovery operations are complete, the spacecraft will be safed and transported to a location for subsequent post-flight evaluation.

## 3.2 Additional NASA Design Reference Missions

Currently, no other NASA DRMs have been defined. As NASA's mission needs evolve over time, this document will be periodically updated to reflect those needs.

# 4.0 Potential Commercial Design Reference Missions

The following potential commercial DRMs are presented to provide insight into how additional missions beyond those acquired by NASA may influence early design decisions for the CTS architecture.

## 4.1 Commercial Space Station Design Reference Mission

The CTS top-level objectives for this DRM are to provide crew access, and potentially cargo transfer, to a commercially sponsored space station (CSS)[3] in LEO. Note that NASA currently has no plans to fly NASA astronauts to any space station other than the ISS.

Depending on the chosen launch site and CSS inclination, launch and ascent may require different ground and flight assets to meet Range Safety constraints than those used to support ISS missions. Similarly, additional ground tracking and communications infrastructure may be required for mission operations. To support ascent aborts, rescue forces must be properly postured and consistent with the spacecraft ascent ground track in order to assure expedited rescue of the crew.

Once in orbit, rendezvous maneuvers are performed to bring the spacecraft closer to the CSS. CSS-compatible relative navigation and communications systems are used to complete the rendezvous with the spacecraft, subsequently docking to the CSS at an available docking port.

Once docked, the attached phase mission duration is expected to be on the order of 1 to 2 weeks. During attached operations, the spacecraft also provides a contingency "safe haven" capability allowing the crew to retreat to the spacecraft, close the hatch, and remain in a safe environment for up to 24 hours. The spacecraft will also serve as an emergency return vehicle for contingencies requiring expedited return of the crew.

Upon completion of mission objectives, the spacecraft will separate from the CSS, deorbit, and land at appropriately chosen landing sites consistent with the CSS inclination.

## 4.2 Satellite Servicing Design Reference Missions

The top-level objective for this series of DRMs is to provide servicing of commercial satellites.

In general, each satellite servicing mission will have a unique inclination and altitude, along with unique servicing needs. Depending on the satellite's orbit, launches from different launch sites may be necessary. Cargo carrying capability for these servicing missions must include all hardware and tools necessary to perform the servicing and the return of any items required for post-flight analysis.

Potential servicing may include planned change-out of orbit-replaceable units (ORUs), unique unplanned hardware servicing tasks, or refueling. The satellite to be serviced is not expected to have a standard crew transfer docking mechanism and potentially has no cooperative features to aid in rendezvous. The satellite may be disabled and not capable of maintaining a stable nominal attitude (the Space Shuttle has a rich history of repair to such satellites).

[3] This DRM does not propose an architecture. The limited descriptions here are only provided to set the context for the reference mission needs.

Mission duration for these servicing missions is expected to be on the order of 1 to 2 weeks. After rendezvous, the servicing timeframe itself may be several days. As such, the spacecraft should support human habitability of crewmembers for timeframes consistent with the mission duration. Human habitability includes the ability to sustain the crew with sufficient food, water, clothing, hygiene supplies, sleep accommodations, trash volumes, medical equipment, etc., for the full mission duration, plus any extension days.

To optimize cost effectiveness, the spacecraft should generally have the performance and mission duration capability required to conduct the mission with a single launch. The spacecraft should be configurable to provide all necessary human habitation capabilities, mission performance capabilities, rendezvous aids, docking mechanisms, and servicing mechanisms to execute the mission. The spacecraft could be potentially designed in a dual-payload launch configuration, where a separate servicing module is co-manifested on the same launch vehicle as the spacecraft[4]. In the latter case, once on orbit, the spacecraft will reconfigure and dock with the servicing module before beginning orbital rendezvous maneuvers.

Rendezvous operations are more complex depending on how cooperative the target satellite is, and whether or not a servicing module is being hauled by the spacecraft. When in close proximity to the target, remote manipulator subsystems may be used to mate with the satellite while minimizing plume impingement from spacecraft thrusters. If refueling is required, a small specialized docking mechanism interface might be used to complete the mating and to transfer the fuels. After mating, subsequent satellite servicing of hardware will be accomplished by a combination of remote manipulator operations and/or multiple EVAs.

For these servicing missions, the orbiting satellite is not a safe haven location where long duration and medical support accommodations are available.

Upon completion of the orbital servicing operations, the repaired satellite is deployed and the spacecraft will depart from the vicinity. Deorbit subsequently occurs within a few hours with landing at a location consistent with the servicing inclination.

[4] This DRM does not propose an architecture or set of possible architectures. The limited descriptions here are only provided to set the context for the reference mission needs.

# Appendix A: Acronyms

| Acronyms | Phrase |
|---|---|
| **CCP** | Commercial Crew Program |
| **CSS** | Commercial Space Station |
| **CTS** | Crew Transportation System |
| **CVCC** | Commercial Vehicle Control Center |
| **DRM** | Design Reference Mission |
| **ECLSS** | Environmental Control and Life Support System |
| **EVA** | Extravehicular Activity |
| **ISS** | International Space Station |
| **LEO** | Low Earth Orbit |
| **MCC-H** | Mission Control Center - Houston |
| **NASA** | National Aeronautics and Space Administration |
| **ORU** | Orbit-Replaceable Unit |
| **U.S.** | United States |

# 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. |

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| **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 |

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| | 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. |

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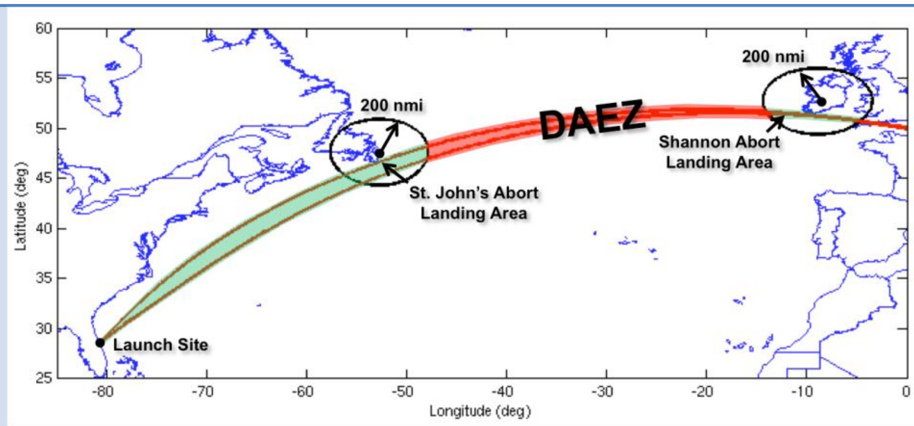
| **Downrange Abort Exclusion Zone Figure** |   **Figure B-1 Ascent Downrange Abort Exclusion Zone** |
| **Emergency** | An unexpected event or events during a mission that requires immediate action to keep the crew alive or serious injury from occurring. |
| **Emergency Egress** | Capability for a crew 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. |

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| **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.<br><br>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. |

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| **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:<br>• Tools designed for general use and not specifically for use on flight hardware.<br>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 |

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| | 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.<br>Designated Primary Landing Site – A supported landing site-intended for landing at the time of spacecraft undock.<br>Alternate Landing Site – A supported landing site to which the spacecraft landing can be diverted in the event the deorbit burn is delayed.<br>**Unsupported Landing Sites:**<br>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. |

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| **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).<br>• 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.<br>• 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.<br>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:<br>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 |

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| | 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 |

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| | 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 |

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| | 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. |