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Interface Definition Document (IDD) for International Space Station (ISS) Visiting Vehicles (VVs)

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CONCURRENCE
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Interface Definition Document (IDD) for International Space Station (ISS) Visiting Vehicles (VVs)

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1 Introduction

The International Space Station (ISS) is an international endeavor. Cooperating, in partnership, with National Aeronautics and Space Administration (NASA) are the Russian Space Agency, the National Space Development Agency of Japan, the Canadian Space Agency, and the participating member countries of the European Space Agency (ESA). The Station uses capabilities of different space vehicles to launch flight elements, systems for assembly, utilization and resupply items, and crew on orbit. Space vehicles of various designs are envisaged to be developed in support of these functions. These vehicles, which visit the on-orbit Space Station, are generally called visiting vehicles (VVs).

1.1 Scope

This document is applicable to the newly designed space vehicles that will interact with the ISS. This document is not applicable to Shuttle, Soyuz, Progress, and their modifications. This document is also not applicable to the ISS modules.

This document defines performance and interface requirements that are not part of the System Specification for the International Space Station, SSP 41000, and are specific to Visiting Vehicles. The requirements in this document are subordinate to the Concept of Operations and Utilization (COU) Principles, SSP 50011, VOL. 1.

The responsibility for developing space transportation systems and for making them technically and operationally compatible with the Space Station rests on the provider of the space transportation system. While attached to the ISS, or situated in a proximity of the station and requires ISS support, a VV is considered to be part of the on-orbit Space Station and shall be compatible with the requirements of the System Specification for the International Space Station, SSP 41000 and/or associated Segment Specifications. Functional decomposition and allocation of the requirements to the specific VV will be performed and approved by the ISS Program in the development of the VV specification.

1.1.1 Identification

An ISS Visiting Vehicle is defined as a spacecraft that has its own propulsion and control systems, is able to perform independent maneuvers in space, and will interact with the ISS.

Several examples of vehicles under development are the:

- Automated Transfer Vehicle (ATV) developed by ESA;
- H-II Transfer Vehicle (HTV) developed by National Space Development Agency of Japan (NASDA)
- Crew Return Vehicle (CRV)

1.2 Control and maintenance

This document is signed by the ISS Partners Program Managers. The document, and subsequent changes to this document, shall be controlled by the Space Station Control Board according to SSP 50123, ISS Configuration Management Handbook, including, if necessary, updates during ISS partners coordination process.

2 Applicable and Reference Documents

The following specifications, standards, and handbooks form a part of these requirements to the extent specified herein. If international agreements exist with requirements that meet or exceed the requirements of these documents, the multi- and/or bilaterally agreed requirements take precedence. Unless otherwise specified, the current revision and date of issue of a document should be considered applicable.

2.1 Applicable Documents

JSC-26626	*EVA Generic Design Requirements Document*
JSC-TBD	*Determination of Berthing Boxes for a Free-flying Vehicle at the ISS*
MIL-STD-1576	*Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems*
SSP 30237	*Space Station Electromagnetic Emission and Susceptibility Requirements for EMC*
SSP 30243	*Space Station Systems Requirements for Electromagnetic Capability*
SSP 30256	*EVA Standard ICD*
SSP 30425	*Space Station Program Natural Environment Definition for Design*
SSP 30426	*Space Station External Contamination Control Requirements*
SSP 30599	*Safety Review Process*
SSP 41163, Rev. D	*Russian Segment Specification*
SSP 41162	*United States On-orbit Segment Specification*
SSP 50005	*ISS Flight Crew Integration Standard*
SSP 50123	*ISS Configuration Management Handbook*
JSC-26938	*Procurement Specification for the Androgynous Peripheral Docking System for the ISS Missions*
MIL-STD-1553B	*Digital time Division Command/Response Multiplex Databus*
NSTS 07700	*System Description and Data Design*
NSTS 21000-IDD-ISS	*Interface Definition Document for the International Space Station*
NSTS 21000-IDD-MDK	*Shuttle Interface Definition Document for Middeck Payloads, Rev. A*
SSP 41167	*Mobile Servicing System Segment Specification for the International Space Station Program*
SSP 41149	*ISS Berthing Visual Cues System ICD*
SSP 42004, Rev. C	*Mobile Servicing System to User Interface Control Document*, Part 1
SSP 42007	*United States On-Orbit Segment to Italian Mini-pressurized Logistics Module ICD*

SSP 50021	*Space Station Safety Requirements*
SSP 50228	*Space Station Program Configuration and Assembly ICD*
SSP 52051	*User Electric Power Specifications and Standards*
SSP 57003	*Attached Payload Interface Requirements Document*
SSP 57004	*Attached Payload Hardware Interface Control Document Template*
JCX-95051	*Japanese Experiment Module Exposed Facility (JEM-EF) to Experiment Payload (generic) ICD*
530-SNUG	*Space Network User's Guide*

2.2 Reference Documents

SSP 50011	*Concept of Operations and Utilization (COU) Principles*, VOL. 1
SSP 41000	*System Specification for the International Space Station*
D684-10020-01	Program Master Integration and Verification Plan

2.3 Order of precedence

Unless specifically noted in the text of this document, in the event of a conflict this document and the references cited herein, the text of this document takes precedence. However, nothing in this document, supersedes applicable laws and regulations unless a specific exemption has been obtained.

If some of the requirements in the documents listed above were not agreed with an International Partner – developer of a VV, this agreement should be achieved in the process of the VV specification development.

In the event of a conflict between the text of this document and ISS Program-approved VV Specifications and/or Interface Requirement Documents (IRDs) or Interface Control Documents (ICDs), the text of Program-approved specifications and IRDs/ICDs takes precedence with respect to a VV design.

3 General

3.1 Major constraints

3.1.1 VV design

The VV design shall not cause a design change to the ISS.

3.1.2 VV attachment to ISS

The VV shall only mate at permissible ISS locations. An ISS port or attachment point will be assigned to the VV and shall be approved by the ISS Program. An analysis of geometric configuration of the vehicle shall be performed in the early stages of development to ensure compatibility with ISS configuration, traffic planning and operational scenarios.

3.1.2.1 Permissible mating locations

The following International Space Station ports provide possible mating locations for a VV:

Mating location on the United States On-orbit Segment (USOS)

1. Forward port of Node 2 with Pressurized Mating Adapter-2 (PMA-2);
2. Nadir port of Node 2;
3. Nadir port of Node 3 with PMA-3 installed or removed;
4. Node 3 Starboard;

Mating locations on the Russian Segment

1. Service Module Aft Port;
2. Universal Docking Module Nadir port;
3. Docking and Stowage Module Nadir port.
4. Docking module 1 (prior to UDM)
5. Nadir port of FGB (prior to DSM)
6. Port port of the UDM (via re-docking from the nadir port)

Notes:

1. VV of a Partner, approaching the RS of the ISS will only use specific allocated and approved RS locations. This requirement is applicable to all RS docking ports.
2. The forward port of Node 2 is currently used as the primary Shuttle docking port and is not intended for any other use.
3. It is necessary to note, that attachment of a VV to the USOS ports, if performed with the aid of VV jet firings and not SSRMS, shall be concurred with experts of the RS and other to perform an analysis of an allowable negative impact of VV jet firings on this segment's equipment and hardware during proximity operations.

4. Unpressurized VVs, science payloads, free-flyers or other close proximity vehicles may use not only ISS ports, but also truss locations, external facilities and surfaces of the ISS modules, on-orbit pallets and other ISS locations providing berthing capabilities. In each individual case, the location shall be identified by the ISS Program for each specific vehicle.

3.1.3 VV performance

An analysis of the vehicle capabilities shall be performed in the early stages of development to ensure compatibility with ISS configuration, traffic planning and operational scenarios.

3.1.4 Flight control functions and responsibilities

Functions and responsibilities of the Mission Control Center-Houston (MCC-H), MCC-Moscow (MCC-M), Visiting Vehicle Control Center (VVCC), VV crew (if the VV is manned), and ISS crew related to flight control during VV insertion, rendezvous, approach, docking, ISS-mated flight, separation, breakout, and the subsequent descent to Earth shall be determined and allocated.

3.1.5 ISS parameters, resources and services

3.1.5.1 ISS altitude and inclination

The VV shall be compatible with the ISS altitude profile from 278 to 460 km [150 to 250 n. mi.] at an inclination of 51.6 deg.

3.1.5.2 ISS resources available

For ISS utility resources allocated to the VV, system-specific analyses will be performed to determine what the ISS can provide. The ISS resources include, but are not limited to: electrical power, temperature and humidity control, and command and data handling (C&DH). The detailed allocation will be documented in the VV specification or a VV to ISS IRD (or ICD). Under no circumstances shall a VV require resources in excess of those allocated at a specific interface.

3.1.5.3 Free-Flyer Servicing

The scope of maintenance performed on free-flyer vehicles docked to the ISS is defined by ISS capabilities and depends significantly on the ISS docking port used. ISS ports for free flyers and the scope of service for a specific vehicle of this type shall be defined and approved by the ISS Program.

3.1.6 VV requirements implementation

Implementation of the requirements for newly designed VVs, as specified in this document, will be monitored by the ISSP.

3.1.7 VV Flight Program

Flight Program for a VV shall be developed together with ISS and approved by a VV developer and ISS Program in the joint document.

3.2 Visiting Vehicles overview

There are several types of Visiting Vehicles:

a. Manned visiting vehicles for crew and cargo transport–support the delivery and return of cosmonauts/astronauts and a load of cargo to the ISS and back to Earth.

b. Manned vehicles for crew transport only –are crew rescue vehicles that travel to or are delivered to the ISS and support long-term crew rescue functionality when docked to the ISS. They also provide for quick separation from the ISS in off-nominal situations, when necessary, with the cosmonauts/astronauts and a safe return to Earth.

c. Unmanned cargo vehicles –deliver cargo to the ISS (dry, wet, and gaseous). This cargo may be located either in a pressurized compartment of the vehicle or in unpressurized compartments. When the cargo vehicles depart from the ISS, they will carry waste (destructive reentry) or returnable cargo (recoverable reentry). [These vehicles may also perform burns for ISS reboost and attitude control.]

d. Free-flyer vehicles – are vehicles which operate independently in accordance with their programs, and attach (dock or berth) to the ISS in order to obtain assistance for maintenance, planned or emergency repair or replenishment of consumables for the extension of an autonomous space flight.

e. Close-proximity free flyers – Free-flying vehicles which are normally stowed on the ISS and deployed around the ISS for viewing, special sensing, and other activities. These free-flyers will be remotely operated from the ISS.

3.2.1 Crew transport and transfer

Manned visiting vehicles for crew and cargo transport will deliver to the ISS and return to Earth cosmonaut/astronaut crews, and also a certain amount of cargo in the crew compartment—including personal items, cargo subject to immediate return to Earth, the results of investigations and experiments, etc.

These VVs will provide all the necessary conditions for crew life support during autonomous flight and support ISS life support functions during mated operations. They will also provide the capability for cosmonaut/astronaut crew transfer to and from the ISS through a pressurized tunnel docking mechanism.

3.2.2 Crew return

The ISS Crew Return (or Crew Rescue) Vehicles will provide return of the entire permanent resident international crew in off-nominal ISS situations, and also for a planned crew rotation.

There are special requirements to Crew Return Vehicles that depend on crew rotation schedules. Resources of a Crew Return Vehicle will have to ensure VV to the ISS attached flight for at least a duration of on-orbit crew rotation period, but usually no less than 6 months.

3.2.3 Cargo Transport

A VV carrying cargo will provide resupply and return (for returnable cargo VV) capability for the ISS.

3.2.3.1 Cargo accommodations

The VV should be designed to provide conditions for storage, attachment, and transfer of delivered, returned, and removable cargo (pressurized and unpressurized). Storage conditions and mechanical accommodations for this cargo should be compatible with the cargo accommodation approach employed by the ISS. For pressurized cargo, the ISS approach is specified in SSP 50467, ISS Stowage Accommodation Handbook: Pressurized Volumes.

3.2.3.2 Cargo VV launch and return manifest

The cargo manifest for all VVs will be defined by the ISS Program. Specific cargo content for a VV and a correlation of its mass, dimensions and volume will be defined by ISS Program based on the capabilities of the vehicles, determined by the vehicle developer, and ISS needs.

3.2.3.3 Types of ISS cargo items

A VV carrying cargo will be able to transport some or all types of the following cargo in pressurized or unpressurized compartments, and also on the external surfaces of the vehicle:

- system spares for planned maintenance or for replacement of failed units and systems, supplies, tools, and support equipment;
- consumables and flight crew equipment , including life support consumables and equipment;
- user payloads and experiment products;
- propellants for orbital maneuvers, such as reboost and attitude control, and to create and replenish propellant reserves in the ISS tanks;
- water and/or a coolant agent for ISS systems, units and components thermal conditioning
- high pressure oxygen and nitrogen;
- waste products

3.2.3.3.1 Small pressurized payloads

A number of experiments and resupply items are designed to fly in the Orbiter middeck lockers. It is desirable for a returnable cargo VV to be capable of transporting ISS experiments designed to be carried in middeck lockers according to NSTS 21000-IDD-MDK Shuttle Interface Definition Document for Middeck Payloads. There are different requirements for Progress-delivered cargo.

3.2.3.4 ISS program-provided cargo elements

A Cargo Visiting Vehicle may be required to transport ISS-provided Cargo Elements to the on-orbit Space Station.

Several examples of such cargo elements include:

- Mini-pressurized logistics module (MPLM);
- ISS Pallets, such as: SpaceLab Pallet, Express Pallet, unpressurized logistics carriers (such as ULC or UCP), integrated with cargo;
- Crew Return Vehicle CRV.

3.2.3.5 Propellant resupply

If a VV is delivering propellant to the Russian Segment (RS) of the ISS, the VV propellant systems and assemblies and the delivered propellant shall satisfy the requirements indicated in SSP 41163, Russian Segment Specification.

3.2.3.6 Crew access

During mated flight with the ISS, the pressurized VV carrying cargo will provide the ISS crew access to the pressurized cargo compartment for cargo transfer. The VV itself, or through a functional combination of the VV and ISS, will provide all necessary crew life support functions to perform planned operations.

4 VV proximity operations requirements

4.1 General requirements

4.1.1 VV performance

The VV performing rendezvous, proximity operations, docking, and departure shall be the active vehicle that is capable of performing required maneuvers with the on-orbit ISS at its predefined attitude.

4 1.2 Lighting conditions

The VV shall be able to perform rendezvous and proximity operations and docking regardless of natural light conditions.

4.2 Visiting vehicle navigation, guidance and trajectory

4.2.1 VV navigation capability

4.2.1.1 VV current state vector

a) During separated phase of its flight, a VV shall be capable of determining, maintaining, and monitoring its absolute state independent of the ISS.

b) The VV shall monitor its relative state with respect to defined limits during all phases of approach after AI and during nominal separation.

c) When attached to the ISS, a VV shall be capable of receiving the current state vector from the ISS, a ground control center or provide its own state vector determination capability.

4.2.1.2 Visiting vehicle relative navigation capability

a) The VV shall determine its position and velocity relative to the ISS during all phases of approach after Approach Initiation (AI) and during nominal separation.

b) Independetly of the ISS, the VV shall determine its position and velocity relative to the ISS and its attitude and attitude rate (either with respect to ISS or with respect to an orbital reference frame) with sufficient accuracy to complete a Collision Avoidance Maneuver (CAM).

4.2.2 Trajectory requirements

4.2.2.1 Predefined trajectory

The VV shall approach/depart from the ISS following a predefined trajectory. This predefined trajectory must be followed starting 90 minutes before AI; while within the AE, and during departure.

4.2.2.1.1 Hold-point opportunities

The VV approach trajectory shall include predefined hold-points where the VV can receive “go/no-go” commands from the associated MCC, ISS crew or the VVCC. The VV shall be able to maintain hold-points within proximity of the ISS, as required by safety considerations, operational needs and constraints (see 4.6.8.2.1). Specific formats for these commands as well as location of hold points will be included and documented in the VV ICD.

4.2.2.1.2 Berthing capture operations

The VV, which requires SSRMS grapple for berthing operations, shall maintain its attitude and relative position with its grapple fixture in a defined grapple box for SSRMS capture for a minimum of 5 minutes. The berthing box parameters shall be determined in accordance with JSC TBD, Determination of Berthing Boxes for a Free-flying Vehicle at the ISS.

4.2.2.2 Arrival at Keep out sphere (KOS)

The VV, considering all dispersions, shall arrive at the opening of the approach corridor outside of the ISS Keep Out Sphere (KOS).

4.2.2.3 Visiting Vehicle approach targeting

From outside the Approach Ellipsoid (AE), a VV approach shall employ an offset targeting scheme which places the vehicle’s dispersed (3-sigma dispersions) trajectory outside the KOS.

4.2.2.4 Keep out sphere penetration

The VV shall penetrate the KOS in the assigned approach corridor, but only after all safety-critical functions are verified operational.

4.2.2.5 Trajectories prior to approach initiation

Prior to AI, all VV coast trajectories (including the 3-sigma dispersions) shall not intercept the ISS AE for a minimum of 24 hours.

4.2.2.6 Approach and departure corridor

The VV shall accomplish approach to and departure from the ISS within the corridor specified for the particular VV in the specific VV Interface Control Document (ICD).

4.2.2.7 Dynamic clearance envelope

Minimum clearance between each specific VV and the ISS dynamic envelope shall be defined and agreed upon. This minimum clearance between the ISS and the VV shall be verified via modeling and analysis of the interface areas taking into consideration dynamic behavior of both vehicles.

4.2.2.8 Off nominal separation trajectory

In the event of an off-nominal separation in which a secondary separation method has been used, the VV shall still maintain attitude and trajectory control limits set for the nominal separation.

4.2.2.9 Safe retreat

The VV shall be able to perform a safe retreat to hold-points (inside or outside the ISS AE) during approach on command from the ground or from the ISS crew.

4.2.2.10 Nominal separation attitude

A VV shall be able to separate from the ISS at the predefined attitude, documented in the VV ICD.

4.2.2.11 Depature envelope

During the departure of a VV from the ISS, the separating vehicle shall maintain a positive opening rate until the vehicle is outside the AE. After it has exited the AE, the VV shall not reenter the ISS AE unless it is commencing a re-rendezvous.

This requirement is not applicable to certain specifically agreed operations for ISS inspection, photography, etc.

4.3 Off nominal operations

4.3.1 Collision avoidance maneuvers (CAM)

a) The approaching VV shall have an automated CAM capability that places the vehicle on a trajectory that will not intercept the ISS AE in fewer than 24 hours.

b) VV projected CAM trajectory at any point of VV trajectory after AI, shall be defined prior to AI.

c) The VV projected CAM relative trajectory shall be available to the ISS crew and associated MCC via predefined visual images.

4.3.1.1 Collision avoidance maneuver outside the keep out sphere (KOS)

A VV CAM that is initiated outside of the KOS shall not allow the vehicle to enter the KOS.

4.3.1.2 Collision avoidance maneuver inside the keep out sphere

A VV CAM that is initiated inside the KOS shall begin by establishing a positive opening rate.

4.3.1.4 Off nominal separation attitude

A manned VV shall be capable of separating from the Station tumbling at a rate of up to 2°/sec RSS.

4.3.1.5 Failed docking capture

In the event of failed capture, the VV shall:

a) be able to determine that failed capture has occurred and begin an active recovery within 10 sec (TBC);

b) provide recovery from a failed capture which begins with maneuvers that create and maintain positive clearance and assure that there will be no clearance violation with the ISS;

4.4 VV monitoring requirements

4.4.1 VV data monitoring

a) During Integrated Trajectory Operations of its flight the VV shall acquire system performance, configuration and status data, and out-of-tolerance conditions for VV allocated functions, including hazards data, system inhibits and jet firing status.

b) A VV shall be capable of storing and retransmitting 30 min (TBC) of onboard status data collected during a communications outage.

c) During Integrated Trajectory Operations the VV shall monitor all systems, subsystems, and operations which could produce a force or a torque on the VV.

4.4.2 Visual Monitoring

a) The VV shall be directly, or indirectly, visible to the on-orbit ISS crew from 1, 000 m [3,280 ft] to capture.

b) If an acquisition light is used to support proximity operations, the VV shall provide a remote capability for the ISS crew to switch the acquisition light on and off when within 60 meters of the ISS.

c) The VV gross attitude shall be visually recognizable to the ISS crew from 500 m (TBC) distance to capture.

d) The VV shall provide visual target references for monitoring capture.

4.5 VV communications, commands and data transfer

All parameters of the VV and ISS necessary to implement functions described in this section have to be defined and documented in a joint ISS/VV document.

4.5.1 VV-ISS communication coverage

a) The VV shall provide omni-directional space-to-space communications to the ISS within a range of 3 km in orbital plane, and within a range of 1.5 km out of plane.

b) Omni-directional communications coverage shall provide 100% visibility for all nominal planned trajectories (including 3-sigma dispersed), from AI to attachment during approach, and from attachment to 3 km during separation.

c) Omni-directional communication coverage shall provide 90% visibility of contingency trajectories, which are not covered by the nominal coverage.

4.5.2 Secondary Range and Range Rate measuring capability

a) The VV shall provide an alternate (secondary) means of measuring its state (range and range rate) relative to the ISS for Integrated Trajectory Operations within 3 km (TBC) of the Station.

b) This secondary capability shall be independent from the primary range and range rate measuring capability;

c) This secondary measuring capability shall be independent of VV attitude and lighting conditions.

4.5.3 VV telemetry information transfer

The VV shall transmit acquired VV data (per 4.4.1.a and c) to the ISS crew and to MCC-H and/or MCC-M. The composition and format of the telemetric information transmission will be defined in the appropriate VV to ISS and VV to Ground ICDs.

4.5.4 Commands transfer

A VV shall establish communication and data links to receive commands from the on-orbit ISS crew, from the corresponding MCC and flight director prior to AI and while in the AE. The composition and format of the command information transmission will be defined in the appropriate VV to ISS and VV to Ground ICDs.

4.5.5 Voice communication

A manned VV in the ISS AE shall provide two-way voice communications with the ISS and also with the MCC responsible for flight control. The formats for the voice radio link and capabilities of the ground stations will be defined in the appropriate VV to ISS and VV to Ground ICDs.

4.5.6 Television images

The type of VV-produced television image (i.e., color or black-and-white) and transmission format shall be compatible with ISS formats and telemetry and will be identified in the appropriate VV to ISS and VV to Ground ICDs.

4.6 VV commands and control

All parameters of the VV and ISS necessary to implement functions described in this section have to be defined and documented in a joint ISS/VV document.

4.6.1 Critical commands

A VV shall accept, acknowledge and execute critical commands issued by the ISS crew, associated MCC or VV Control Center. The list of critical commands and their timing will be identified in the VV ICD.

4.6.1.1 Emergency termination commands

The VV shall be able to receive commands for emergency termination of approach and mating operations (abort) generated by the ISS crew, by MCC-H, MCC-M, or VVCC. The VV shall acknowledge the receipt of an emergency termination command by sending a notification message to the associated MCC, VV CC and the ISS crew.

4.6.2 Propulsion commands

a) Vehicles using SSRMS for berthing shall be capable of receiving and executing propulsion commands (such as ‘enable’) while in free-drift prior to SSRMS capture and after SSRMS release at departure.

b) An abort or CAM command issued by the ground or the ISS crew shall automatically remove all propulsion inhibits.

4.6.3 Attitude and translational control inhibits

The VV shall inhibit attitude and translational control upon command from the ISS prior to Space Station Remote Manipulator System (SSRMS) grapple, or upon docking contact detection with allowable predefined post-contact thrust.

4.6.4 Commands security

A VV communication system shall provide protection for all command links to the VV to prevent unauthorized third-party control of the VV.

4.6.5 Automatic abort commands

The VV shall generate an automatic abort command upon the following conditions:

- if there is an unresolvable anomaly;
- if the VV has executed AI and the space-to-space communication link has lost lock for a time exceeding either the command timing (paragraph 4.6.8.3) or telemetry/monitoring timing requirements (paragraph 4.6.8.4).
- in case of other predefined off-nominal situations requiring abort.

4.6.6 Automatic abort execution and scenario

a) The VV shall be able to execute abort commands issued automatically by its onboard systems.

b) The abort scenario shall be predefined for each failure, predefined limit exceeded, and type of anomaly. These defined instances will be listed in the VV interface control document (ICD).

4.6.7 Separation initiation and control

a) Nominal separation of the VV from the ISS shall be initiated by commands from either the VV, the ISS, or an associated MCC.

b) All separation methods shall be operable or commandable by the ISS crew and the ground.

4.6.8 Timing requirements

4.6.8.1 Time for exiting the approach ellipsoid

The departing vehicle shall be outside the bounds of the AE within 90 minutes.

4.6.8.2 Proximity operations timing

4.6.8.2.1 VV outside the International Space Station approach ellipsoid:

The VV shall be capable of performing re-rendezvous and stationkeeping in hold points, if necessary, sustaining up to 34 cumulative hours (24 hours + 1 crew shift) outside the ISS AE.

4.6.8.2.2 Integrated operations duration:

Operations inside the ISS AE (including hold-points) shall nominally last fewer than 10 hours up to docking/berthing capture.

4.6.8.3 Command execution timing

During proximity operations the VV systems shall be able to execute commands to abort or hold issued by the ISS crew and the ground within predefined time limits as specified below:

a) with sufficient time for the VV to provide a safe trajectory;

b) with sufficient time for the crew to identify that the VV has executed the command and make decision on necessity of contingency operations. This time shall be 10 sec (TBC) within the KOS and 2 min (TBC) after the AI has been executed, but outside the KOS;

c) in time for the VV to stop its approach to the ISS (and begin an opening rate, in case of abort) within half the distance of the vehicle to ISS, when the distance from VV to ISS is no less than TBD m.

   Note: this distance is measured from the point at which the command was issued by the crew/ground to the final mating point.

4.6.8.4 Monitoring and telemetry timing

The VV shall provide telemetry data to the ISS crew with adequate time for the crew to identify, evaluate, and react to safety critical items.

4.6.8.5 Maximum free-drift time for berthing

For SSRMS capture operations, the VV shall remain within the berthing box (see paragraph 4.2.2.1.2) for up to 90 sec of free drift.

5 Interface Requirements

The requirements in this chapter are intended for VV developer information and do not superceed the requirements of the SSP 41000, System Specification for the ISS, and Segment Specifications for ISS Segments.

5.1 General Interface Requirements

This section contains general requirements for a VV compatibility with ISS hardware, software, and operations. Interface requirements provided in sections 5.2, VV to United States On-orbit Segment interfaces, section 5.3, VV to RS interfaces, and section 5.4, VV to the Japanese Experiment Module (JEM)-External Facility (EF) interfaces, represent additional or more detailed interface requirements specific to the applicable segments.

5.1.2 VV compatibility with ISS operations and configuration

a) The VV operational scenarios, geometric dimensions and configuration shall allow the vehicle to perform safe maneuvers in specified areas when it is in close proximity to the ISS.

b) When attached to an ISS segment, a VV shall not interfere with crew working conditions on the ISS, nominal onboard systems and assembly operations, conditions for conducting science investigations and experiments, extravehicular robotics (EVR) operations and extravehicular activity (EVA), as described in the appropriate segment specification and the specification for the VV.

c) The following shall be provided by the VV:

- compatibility of VV environmental control and life support system (ECLSS) with that of the ISS;
- pressurization for VV pressurized areas and compliance with associated allocated atmospheric leak rate;
- compatibility of the thermal modes of the VV and ISS operational systems, assemblies, and structures;
- compatibility of electrical operational modes and characteristics of the VV and ISS, including electrical power parameters, methods of commutation, and electric circuit protection;
- compatibility of the VV and the ISS C&DH systems software and hardware;
- compatibility with the radio frequency (RF), telemetry and commands formats of existing ISS communication systems. The VV shall meet the coverage requirements of specified ranges to ensure safety during the rendezvous process;
- electromagnetic compatibility of the VV and ISS equipment, as specified in SSP 30237, Space Station Electromagnetic Emission and Susceptibility Requirements for Electromagnetic Compatibility (EMC), and SSP 30243, Space Station Systems Requirements for EMC.

- the VV shall satisfy the quiescent and nonquiescent requirements for ISS external contamination and control inputs in accordance with SSP 30426, Space Station External Contamination Control Requirements, with the specific allocations to be agreed by the ISSP and the VV.

5.1.3 Natural environments compatibility

A VV shall meet specified performance when exposed to the on-orbit natural environments shown in the SSP 30425, Space Station Natural Environments Definition for Design. Technical measures which protect the VV from accidents due to the natural space environment during space flight—such as from cosmic vacuum, micrometeoroids and orbital debris, exposure to radiation, ionizing radiation, etc. —shall be developed and implemented.

5.1.4 Extravehicular activities interfaces

The VV shall provide necessary access to the ISS elements to perform EVR and EVA operations.

The capability of conducting EVA, the technical devices for EVA (cosmonaut/astronaut translation paths, work sites for performing operations, and necessary tools), and access to the external surfaces shall be provided on the VV to support necessary tasks.

5.1.5 Mating Hardware interfaces

A VV shall always use a common attachment mechanism. VV mating hardware shall be compatible with the corresponding mating hardware of the assigned ISS port, and with the ISS systems necessary to perform proximity operations. There are two types of mating: docking and berthing.

5.1.5.1 Separation implementation

Implementation of separation commands shall not damage the mating mechanism.

5.1.6 Docking interfaces

5.1.6.1 Docking mechanism

During approach and docking a VV is always an active element, and the ISS is passive. For docking to the ISS RS, the active part of a “cone and drogue” type docking mechanism shall be installed on the VV. For docking to the US Segment the active part of an androgynous peripheral docking system (APDS) shall be used.

The VV docking system shall meet the physical interface for a particular port, as defined in sections 5.2 and 5.3 of this document.

5.1.6.2 Docking contact

The VV shall provide a capability to detect docking contact.

5.1.6.3 Docking force limits

The VV shall meet all docking force limit requirements (constraints for the dynamic parameters) for the particular port to which the vehicle is planned to dock at a specific ISS configuration. These limits shall be finalized upon completion of the analysis of the VV dynamic docking loads.

5.1.6.4 Redundant separation method for the docking interface

VVs shall have a backup separation interface equipped with the simplest and most reliable separation device (e.g., pyrobolts, pyrolocks, pushers, etc.) to counter off-nominal situations caused by failing nominal docking/berthing system components during separation of the VV from the ISS. All separation methods shall be remotely operable or commandable by the ISS crew and the ground.

5.1.7 Berthing interfaces

Berthing of a VV to ISS is performed using the Mobile Servicing System (MSS) SSRMS, described in SSP 41167, MSS Segment Specification for the International Space Station Program.

5.1.7.1 Truss accommodations

If the VV attaches to the truss, it shall fully comply with SSP 57003, Attached Payload Interface Requirements Document, and SSP 57004, Attached Payload Hardware Interface Control Document Template, using the passive side of an associated attachment mechanism.

5.1.7.2 Pressurized berthing attachment mechanism

The VV shall use the passive side of a Common Berthing Mechanism (CBM) for berthing with the USOS. The active part of the CBM is always installed on the ISS.

5.1.7.2.2 Common berthing mechanism

Docking shall not be performed at a CBM interface because CBM interfaces are designed only for berthing. Any VV that is to be berthed with a CBM will be grappled by the SSRMS and placed within the capture envelope with the proper capture velocity conditions for that particular CBM interface. CBM capture envelopes and conditions are unique to each VV configuration and ISS stage at the time of berthing. Envelopes and conditions will be determined for a given VV through use of dynamic loads analysis cycles during the VV development process.

5.1.7.2.3 Redundant separation method for the berthing interface (CBM) and robotics capture and release interface

a) The VVs berthing interface (CBM) to the United States on-orbit segment (USOS) side of the ISS does not provide for a backup separation method. If a VV is unable to separate from the CBM interface and is determined to create a catastrophic hazard condition, the VV shall include a backup separation method in its design to separate from the CBM interface.

b) VVs captured and berthed by the MSS shall provide a one failure tolerant backup separation method between the SSRMS and the vehicle body.

5.1.7.3 Extravehicular robotic requirements—payload handling

Any VV that is to be berthed to the ISS with the SSRMS shall comply with the payload handling requirements in SSP 41167, Mobile Servicing System Segment Specification for the International Space Station Program and SSP 42004, MSS to User ICD (Generic).

5.1.7.3.1 Grapple fixtures

A VV shall be equipped with the SSRMS-compatible Grapple Fixture (GF) to permit robotics operations.

a) <u>Flight-releasable grapple fixture (FRGF) and Electrical Flight Grapple Fixture (EFGF)</u>: The VV design shall comply with the requirements in NSTS 21000-IDD-ISS, Section 14 and NSTS 07700, System Description and Data Design, VOL. XIX, Appendix 8, if an FRGF or EFGF is used on the VV.

b) <u>Power data grapple fixture (PDGF)</u>: VV design shall comply with requirements in SSP 42004, Rev. C, Mobile Servicing System to User Interface Control Document (Generic), Part 1 and SSP 42003, SSMB to MSS ICD, if a PDGF is used.

5.1.7.3.2 Special-purpose dexterous manipulator accommodations

If the VV is to use the fine arm for operations, requirements for the robotics interface shall comply with SSP 42004 and SSP 42003.

5.1.7.3.3 Electrostatic Discharge (ESD)

Structures isolated from Space Station electrical ground and intended to be gripped and re-located using the local end-effector (LEE) of the SSRMS, shall have provisions to bond at first contact through a resistance of 10,000 ohm +/- 20% tolerance to limit the electrostatic discharge current between the end-effector and the structure.

5.1.7.3.4 Space Vision System (SVS) interfaces

5.1.7.3.4.1 SVS Targets

To support SSRMS operations, the VV shall be configured with SVS targets according to SSP 50228, Space Station Program Configuration and Assembly ICD. Specific location for the targets on the VV surface will be identified by the ISS Program and provided in the VV to SVS targets ICD.

5.1.7.3.4.2 ISS Targets

The ISS has existing targets (e.g., visual, reflectors) on docking ports for approach and docking. These targets shall be used to the maximum extent by the VV, as applicable. The ISS targets are defined in TBD.

5.1.7.3.4.3 Berthing visual cue interfaces

To support SSRMS operations the VV shall use the ISS Berthing Visual Cues System in accordance with SSP 41149, ISS Berthing Visual Cue System ICD.

5.1.8 Utility interfaces

The VV mated with the ISS shall be designed so that all necessary interfaces can be passed through the attachment mechanism or EVA established connections, if available at the port. After mating, additional interfaces between the VV and the ISS which block the closing of hatches are not allowed. The specific composition of interfaces at the VV-ISS interface plane depends on the ISS port assigned.

The VV utilities shall be capable of being disconnected prior to, or at separation without damage to the VV or the ISS.

5.1.9 Crew interfaces

All VV hardware and software which will have a crew interface shall be designed in accordance with SSP 50005, Space Station Crew Integration Standard. All VV acoustic emissions shall be in accordance with NC-50 and shall be verified by test.

5.1.10 C&DH interface

A VV C&DH system shall be compatible with MIL-STD-1553B, *Digital Time Division Command/Response Multiplex Databus*.

5.1.11 Tracking and Data Relay Satellite (TDRS) interface

A VV using TDRS to communicate to the ground centers shall comply with the requirements of Space Network User's Guide, 530-SNUG. [The VV interface with the NASA Space Network shall be designed in accordance with the specific VV Radio Frequency Interface Control Document between the VV project and the Goddard Space Flight Center Network and Mission Services Office/Code 450].

5.2 United States On-orbit Segment Interface Requirements

When attached to the USOS, the VV shall be compatible with the USOS requirements in SSP 41162, USOS Specification.

5.2.1 Docking

On the U.S. segment, a VV shall only dock at the:

- autonomous peripheral docking system (APDS) at the PMA-2 on the Node 2 forward port;
- APDS designated at PMA-3 on the nadir port of Node 3.

The interfaces for these ports are described in NSTS 21000-IDD-ISS, Interface Definition Document for the International Space Station.

5.2.1.1 Androgynous peripheral attach system (APAS)

Specific docking contact conditions shall be developed for any given VV via dynamic loads analysis cycles.

Detailed information about the APAS configuration, which the Space Shuttle Orbiter uses for ISS missions, can be found in JSC-26938, Procurement Specification for the Androgynous Peripheral Docking System for the ISS Missions. In particular, FIGURE 20-D of that document shall be used to develop the VV interface for the APAS.

5.2.1.2 Androgynous peripheral attach system undocking operations

For backup release of the interface, both the active and the passive structural hooks on the VV-mounted active APAS shall have pyrotechnic release. The ISS APAS has no pyrotechnics.

5.2.2 Berthing locations

If the VV brings a pressurized module (PM), the VV shall be berthed at:

- the nadir port on the Node 2,
  the interfaces for this port are described in SSP 42007, United States On-Orbit Segment to Italian Mini-pressurized Logistics Module ICD;
- the nadir port on the Node 3 (with PMA-3 removed);

If the VV requires unpressurized berthing locationthe berthing location will be allocated by NASA for each specific vehicle.

5.2.4 Electrical Power System interface

Electrical systems of a VV interfacing with USOS shall be compatible with 120 Vdc power, according to SSP 52051, User Electric Power Specifications and Standards.

VV’s EPS return wire shall be grounded to the vehicle chassis with the isolation of at least 1 Mom to minimize electrostatic discharge between VV and USOS.

5.2.6 EVA interfaces

5.2.6.1 Extravehicular activity tools

VV shall use the standard EVA tool set available on board the ISS as defined in SSP 30256, EVA Standard ICD.

5.2.6.2 Extravehicular activity unique tools

Unique EVA tools shall be designed in accordance with JSC-26626, EVA Generic Design Requirements Document. All VV unique EVA tools shall be launched and stored on the VV.

5.2.6.3 EVA worksites

VV shall design EVA work sites according to requirements established in SSP 30256.

5.3 Russian Segment Interface Requirements

When attached to the Russian Segment (RS), the VV shall be compatible with the RS requirements in SSP 41163, RS Specification.

5.3.1 Designated approach zones

A VV approaching the ISS RS shall use only approved and Russian Space Agency (RSA)-concurred ISS RS ports for docking. The VV shall use only specially designated zones of the ISS RS for approach.

5.3.2 Permissible docking locations

Allowable docking locations of the RS ISS are listed in the paragraph 3.1.2.1 of this document.

5.3.3 Communications

All VVs, during rendezvous and proximity operations, and mated flight to the RS shall have compatible communications systems. During integrated operations (see paragraph 4.5.1) the VV shall)maintain constant two-way radio communication between the VV, MCC-M and the ISS RS. Allowable intervals of loss of communication shall be agreed between the VV and ISS RS in the joint ICD.

5.3.4 Visiting vehicle propulsion system

The transport cargo VV for docking to the ISS RS at the aft port of the SM shall be be capable of using its own propulsion system to control motion of the ISS center of gravity (c.g.) and around the c.g., including ISS reboost, ISS attitude control, and ISS stabilization per the ISS mission plan requirements, gyrodynes desaturation, and debris avoidance maneuvers. The tasks to be performed by the VV propulsion system shall be reviewed and approved by the ISSP.

5.3.5 Visiting vehicle control system

The cargo transport VV docked to the ISS RS shall be designed so that the ISS RS control system can control its propulsion system for attitude control and reboost burns during docked flight. The specific control scheme shall be concurred on by the ISSP.

5.3.6 Automatic and Manual Control Modes

The VV, docking to the ISS RS, shall have an automatic control mode and a manual mode (for manned VV), during the final approach, berthing, docking, undocking, and initial separation phases.

5.3.7 Body coordinate systems

The VV as a whole and the docking mechanism shall use right-hand orthogonal body coordinate systems.

5.3.8 Visiting vehicle docking mechanism

The VV shall use the active side of a P&C-type docking mechanism for docking with the RS.

5.3.9 Visiting vehicle free flight

A VV shall provide the capability for freeing up the corresponding port on the ISS and conducting autonomous flight with subsequent docking to the ISS. The duration of the VV's free flight is up to eight weeks.

5.4 General Interface Requirements for a VV to the JEM-EF

A VV which utilizes the Japanese Experiment Module (JEM)-exposed facility (EF) shall comply with the requirements in JCX-95051, Japanese Experiment Module Exposed Facility (JEM-EF) to Experiment Payload (generic) ICD.

6 Safety

6.1 General requirements

Visiting vehicle flight safety refers to the combined features of the VV and technical devices interacting with it, and also to special measures providing for the prevention or relatively low possibility of illness, injury, or death of even one of the VV or ISS crew members, the failure to complete the planned ISS flight program, and loss of functionality. These safety requirements apply 90 minutes prior to execution of an AI maneuver and remain in effect until the VV physically exits the bounds of the AE.

All VVs shall comply with all safety requirements per SSP 50021, Space Station Safety Requirements.

6.2 Human Engineering Safety

A VV shall meet the Human Engineering safety requirements contained in the SSP 50005, Flight Crew Integration Standard.

6.3 Safety analysis and process

6.3.1 International Space Station safety review process

VVs shall be subject to the safety review process detailed in SSP 30599, Safety Review Process, which defines the phased safety review process for ISS elements. Safety reviews are conducted to review and assess safety hazards for all mission phases related to the design, operations, and functional capabilities of ISS elements and support equipment, and to the integration of all ISS elements.

6.3.2 Safety analysis

It is highly desirable to implement any VV design process taking into consideration preliminary planning for measures that will facilitate resolution of off-nominal situations. These measures include redundant paths for critical systems, development of alternate operational scenarios, etc.

All off nominal situations should be identified by a VV developer and reviewed by the ISS Safety, Reliability and Mission Assurance and Mission Operations Directorate organizations, and the Safety Review Panel along with other appropriate disciplines. When the list of all credible off nominal situations is agreed by all applicable ISS organizations and a VV developer, an analysis of all possible off-nominal situations and hazards shall be performed for each VV relative to the planned flight programs, accompanied by the release of appropriate documents. The analytic procedure and documents describing this analysis shall be concurred by the ISSP.

As part of this analysis, a VV developer shall demonstrate the safety of the vehicle and associated engineering measures such as: failure detection, isolation and recovery (FDIR) procedures, redundant functional paths, back-up operational scenarios, etc.

Basic principles of the safety analysis for a Visisting Vehicle are based on the analysis of possible off-nominal situations and actions to counteract their effect relative to the planned flight programs and the VV performance. The following is usually taken into consideration to ensure the safety of the design and completeness of the safety analysis:

6.3.2.1 Risk management

VV functional systems have to be designed to the following principles:

- no single failure or single operator error can result in a critical hazard event;
- no combination of two separate failures or two operator errors, including failures in the same functional chain, can result in a catastrophic hazard event;
- design for minimum risk, i.e. reasonable engineering measures should be applied in the areas which failures cannot invalidate the safety of the design, or where redundancy methods are not possible or not reasonable. The measures such as higher safety factors, extended tests and analysis programs should be considered.

6.3.2.2 Off-nominal situation identification

It is recommended to provide each VV with a system (means) of failure detection, isolation and recovery, which will provide for automatic or manual, with the help of a crew and/or VVCC personnel, detection of off-nominal situations and issue necessary commands for their isolation and recovery. Off-nominal even information will be provided to the VV crew (for manned VV), ISS crew, and VVCC personnel in real time for assessment and resolution.

6.3.2.3 Off nominal situations analysis

While performing hazard analyses for a VV, a VV designer should consider off-nominal situations which may happen to a vehicle (or have occured in the past to other space vehicles). Examples of such situations include, but are not limited to:

- off-nominal parameters for VV motion relative to the Station during Integrated Trajectory Operations;
- off-nominal parameters of communications between the VV and ISS before capture;
- off-nominal position and motion of the VV relative to the ISS during stationkeeping before manipulator capture;
- failed manipulator capture or capture with failed mating;
- hatch failing open after mating or failing to close before demating;
- failed separation of the VV from the station;
- depressurization of the VV to the Station interface or pressurized VV compartments;
- explosion or fire hazards in the VV;
- impermissible changes in the VV atmosphere;
- systems failure;
- inadvertent operator actions or operator errors;
- software incompatibility or bugs;
- loss of ISS resources while mated.

6.3.2.4 Counteractions to off-nominal situations

When possible off-nominal situations are identified, measures to counteract their effect relative to the planned flight programs and VV performance should be identified. Those measures could be either automatic or include crew or MCC personnel involvement. Examples of such measures are:

- localization and elimination of hazards that arise during off-nominal situation;
- transfer of a function to redundant channels of the functional architecture for critical systems;
- switch to backup software;
- use backup operational solutions under the flight program, such as:
  - VV stationkeeping relative to ISS;
  - VV departure from the AE to a safe area;
  - emergency termination of approach and mating operations (see paragraphs 4.6.1.1 and 4.6.5).

7 Verification

7.1 General

The VV provider is responsible for the performance of verification activities as will be specified in applicable specifications and IRD/ICDs and shall produce verification evidence for compliance with all VV applicable requirements.

The VV verification shall consist of, but not be limited to:

a. Data for the reliability analysis collected and recorded during qualification.

b. Engineering (development) evaluation and tests may be required for analyzing design approaches to ensure that requirements encompassing material selection, tolerances, and operational characteristics are satisfied. If development test data is intended to be used to qualify hardware, its intent shall be previously declared.

c. A qualification program encompass the entire range of activity to verify that the design conforms to requirements when subjected to environmental life cycle conditions including those required for environmental workmanship screening during the acceptance phase. Flight fidelity dedicated qualification test articles shall be used for the qualification program.

Environmental models shall be used to represent environments that cannot be achieved under the conditions of ground testing. Simulators, used for verifying requirements, shall be validated such that the item undergoing qualification can not distinguish between the simulator and actual operation hardware/software.

d. Integration testing and checkout shall be conducted during VV buildup. Activities such as continuity checking and interface mating shall be performed. Activities such as major component operation in the installed environment, support equipment compatibility, and documentation verification shall be proven during qualification.

e. Validation of VV ground facilities shall be performed in support of analyses, ground testing and other verification activities. Validation of facilities can be performed by comparison to real-world results or to another validated facility.

Formal verification of performance characteristics for the full range of performance requirements shall be accomplished during qualification.

7.2 Element test phase

The basic objectives of the ground tests shall include, but not be limited to:

- strength verification (static, dynamic, acoustic, impact, and vibration tests);
- validation of hardware layout modeling, installation, and assembly;
- joint operation of the VV systems and assemblies, including the required interaction with ISS systems and facilities;

- testing of life support systems;
- thermal conditions of systems and structures, including those in a flight-like environment;
- testing VV communications systems (including RF blockage and multipath characterization);
- ISS mating/demating;
- firing tests (engine burns) and gas dynamics tasks;
- testing and verification of the operability of the emergency rescue system (for manned vehicles);
- integrated electrical tests, including avionics tests;
- integrated software tests, including testing the ground debugging facility (RSA) or Software Verification Facility (NASA);
- integrated guidance, navigation, and control (GN&C) tests.

7.3 Integrated test phase

The VV testing program phase shall conclude with an integrated phase where testing of the entire VV system, including the vehicle itself, ground and support elements, will be performed under conditions as close to the flight conditions as possible. VV integrated tests shall be performed using full scale items or their simulators, including flight versions of components and systems and flight-qualified software. Test objectives shall include, but not be limited to:

- compatibility of onboard systems that are part of the ISS-VV orbital complex (after VV docking to the ISS);
- software in terms of control of systems, assemblies, and mechanisms located on the VV and ISS, but connected via the main electrical and data interfaces;
- joint functionality of systems, assemblies, and mechanisms of the orbital complex in nominal and off-nominal situations;
- compatibility of ISS and VV systems that work together during rendezvous, prox ops, and separation.

7.4 Proximity operations verification

7.4.1 Rendezvous and proximity operations analysis

The VV provider shall perform an analysis to confirm the performance of VV approach, mating, demating, and separation operations with the ISS.

7.4.2 Abort analysis

The VV provider shall perform analyses to confirm VV performance during approach and mating abort failures.

8 Demonstration flight

All VV requirements shall be verified on the ground prior to VV launch. However, there are some functions and conditions that are extremely difficult to simulate on the ground. To increase the level of confidence of a VV to perform its mission safely and successfully, a demonstration flight shall be included in the VV program.

8.1 Flight test program

The VV flight test program shall demonstrate and verify readiness of the VV and its flight-support facilities to perform the functions needed to perform VV mission to the ISS. The VV demonstration flight program shall be documented in the flight operations plan developed jointly by a VV developer and the agency providing the mating location. The demonstration flight operations plan shall require approval of the ISS Program.

All safety-critical functions shall be flight demonstrated in a region that is not hazardous to the ISS. There are two approaches to the demonstration flight scenario:

a) to mate a VV with an independent spacecraft with identical mechanisms as the ISS;

b) to perform demonstration during an actual approach to the ISS, provided each step of the demonstration flight will lead to increasing capabilities and confidence that safety is assured for the ISS.

The technique used by the VV shall be defined and approved by the ISSP depending on a spectrum of different considerations, such as: experience of VV personnel, adequate ground-based verification of the VV functionality, availability and fidelity of an independent spacecraft, and financial impacts to the Program.

8.2 Demonstration of safety-critical functions

The functions that shall be demonstrated, as a minimum, during demonstration flight include:

- the VV approach to the ISS or the ISS-simulating spacecraft, including maintaining the required approach corridor and stationkeeping;
- rendezvous and mating within predetermined kinematic parameters;
- mechanical capture and establishment of required functional interfaces between the VV and the ISS or the ISS-simulating spacecraft;
- unmating and back off from the ISS or the ISS-simulating spacecraft;
- verification of VV Guidance Navigation and Control (GN&C) systems functionality by ground personnel;
- testing of the emergency termination of the VV approach to demonstrate functional capabilities in an off-nominal situation including collision avoidance and abort capability;
- check of a VV TORU for the RS ISS, if installed. TORU use for proximity operations is to be discussed by a specific developer and RSA and RSC-E.
- command/data telemetry transfer;
- establishment of the communications link;

- collision avoidance maneuver;
- efficiency and reliability of the VVCC ground support personnel and equipment.

9.0 Interaction of the Visiting Vehicle Designer with the International Space Station Program

9.1 Joint Development

The ISSP and the VV developer shall jointly concur on the development of the VV in terms of the following.

- ♦ concurrence of detailed requirements (specification, IRD/ICDs, flight rules, etc.) for a specific VV;
- ♦ concurrence of the off-nominal situations of the VV, which might affect the ISS;
- ♦ investigating the off-nominal situations of the ISS, which might affect the VV;
- ♦ integration of the VV within the ISSP, including joint tests;
- ♦ concurrence of the joint requirements for the demonstration flight and for analysis of the results;
- ♦ concurrence of the joint verification plan

Executors of the above-mentioned work shall be determined per joint ISSP/VV decision.

ISS Program participation is ensured by providing visibility into a VV program via bilateral or multilateral reviews and development of bilateral and multilateral documentation.

9.2 Verification documentation

Verification requirements for USOS, United States Ground Segment and all U.S. End Items are defined in their respective specifications Section 4, Quality Assurance Provisions. The NASA verification process for ISS is identified in the Program Master Integration and Verification Plan (PMIVP), D684-10020-01.

International Partners' VV verification requirements will be documented in associated specifications and IRD/ICDs based on the VV/ISSP agreements. Verification agreements between ISS Program and International Partners will be documented in Bilateral Integration and Verification Plans (BIVPs).

Ground centers facilities verification will be performed in accordance with associated ground-to-orbit ICDs and SSP 54500, International Ground System Specification. Verification planning for ground systems will be documented in SSP 54501, International Ground System Test and Verification Management Plan.

10.0 Definitions and Acronyms and Abbreviations

10.1 Definitions

abort A specific action or sequence of actions taken by the crew or ground control, that terminates a flight process. Replaces term "emergency termination".

approach The action of a free-flying space object as it nears the ISS. The "final approach" is usually the straight-line approach along the vector directly to the ISS mating mechanism or SSRMS grapple position.

approach ellipsoid a 4x2x2 km ellipsoid, centered at the Station center of mass, with the long axis aligned with the V-Bar.

approach initiation the point in the trajectory plan at which the approaching vehicle executes a maneuver that will cause the resulting dispersed (3-sigma) trajectory to penetrate the ISS AE.

automated an apparatus, process, or system manufactured to operate without human observation, effort, or decision.

autonomous having the right or the power of self government; undertaken or carried on without outside control. This term addresses operational usage.

berth Mating of a space object, whose motion is controlled by a grappling RMS, to another space object.

breakout The process in which an approaching vehicle separates from the vicinity of the ISS with no intention of resuming approach operations that day.

capture The state when the mating mechanisms of the approaching vehicle and the ISS have achieved physical connection. Many mating mechanisms first achieve a "soft docking" state in which the two vehicles are captured at an extendible interface, then a "hard docking" when the extendible mechanism is retracted and relative motion is fully constrained.

coast trajectory the trajectory a vehicle would take if all translational maneuvers are inhibited.

collision avoidance maneuver (CAM) A specific propulsive maneuver or sequence of maneuvers taken by an approaching vehicle so that its subsequent trajectory does not contact the target space object.

command authority the right or responsibiliity to make operational decisions.

control authority the ability to send commands.

contact Physical touching of two space objects.

corridor During final approach, a cone-shaped region extending from a desired approach end point, within which an approaching vehicle must stay due to plume constraints. It is formed by allowing an angular error from the center line vector which extends out from the desired end point. This may also apply to separation, if the separating vehicle must fire its maneuvering jets. The allowable angular deviation from the center line may also be range dependent, resulting in a series of 'steps' in the conical corridor.

***critical commands* –** all the commands that can modify the trajectory of the vehicle, modify the limits placed on the vehicle, which are monitored by the ISS crew of the Ground, and change in the fault tolerance of the vehicle.

departure The mission phase which includes reconfiguration, undocking, and separation of two space objects.

deploy Deliberate release of a space object intended for free flight.

dock Mating of one space object, under its own flight control, to another.

go/no-go point A relative location in the target-centered frame where positive permission must be granted to proceed with the approach, based on defined criteria. Without such permission, the approaching vehicle can either perform a breakout or can perform stationkeeping.

grapple Mating of the 'end effector' of an RMS to a grapple fixture on a spacecraft.

***free flight* –** a state when the motion of the VV is structurally independent of the ISS and the VV is not attached to station structure.

hold point The specific relative location where an approaching or separating vehicle may perform stationkeeping.

jettison Deliberate release of a space vehicle's structural element in a contingency. For example, the STS can jettison the Ku-band radar or the RMS or a payload solar array if they cannot be properly stowed for entry.

***integrated operations* –** the timeframe in the VV's timeline for which the ISS Flight Director has command authority. This timeframe starts 90 min prior to AI and ends when the VV departs the AE.

***integrated trajectory operations* –** the portion of integrated operations for which the VV is in free flight.

Keep Out Sphere a sphere centered at the Space Station center of mass with a radius of 200 m. Approach and departure corridor are defined within the KOS.

mate To bring two pieces of hardware together so that they mechanically latch to each other.

off-nominal situation A VV ***off-nominal situation*** is a technical condition of the VV and facilities interacting with it during space flight that was not envisaged by the nominal operating program; it is also unforeseen flight conditions and VV crew health deviation from the norm.

proximity operations Activities of a space vehicle within close range (< ~1 km) and with small relative velocity (< tenths of m/sec) with respect to a target vehicle. Includes final approach, stationkeeping, flyaround, and initial separation.

rendezvous Activities to bring a space vehicle close to another (the "target") at low or zero relative velocity. This involves navigation, guidance (both from the ground and from on board the vehicle), and control.

re-rendezvous Return of a vehicle to a space object from which it previously had separated, from a range at which maneuver targeting for orbital mechanics effects is necessary.

separation The motion of one space object away from another. It may be initiated by propulsive forces, by spring forces, or even by orbital mechanics effects.

stationkeeping Proximity operations intended to maintain a given close-range position relative to a target vehicle.

undock Open the mechanical latches connecting two mated space objects. Same as "release"

9.2 Acronyms and Abbreviations

AE	approach ellipsoid
AI	approach initiation
APAS	androgynous peripheral attach system
APDS	androgynous peripheral docking system
ATV	automated transfer vehicle
BIVP	Bilateral Integration and Verification Plan
°C	degrees Celsius
c.g.	center of gravity
C&DH	command and data handling
CAM	collision avoidance maneuver
CBM	common berthing mechanism
cm	centimeters
COU	concept of operations and utilization

CRV	crew return vehicle
dB	decibels
deg	degrees
DSM	docking and stowage module
ECLSS	environmental control and life support system
EF	external facility
EMC	electromagnetic compatibility
EPS	electrical power system
ERA	European robotic arm
ESA	European Space Agency
ESD	Electrostatic Discharge
EVA	extravehicular activity
EVR	extravehicular robotics
°F	degrees Fahrenheit
FDIR	failure detection, isolation and recovery
FRGF	flight-releasable grapple fixture
ft	feet
GF	grapple fixture
CN&C	guidance, navigation and control
HTV	H-II transfer vehicle
ICD	interface control document
IDD	interface definition document
in.	inches
IRD	interface requirements document
ISS	International Space Station
ISSP	International Space Station Program

JEM	Japanese Experiment Module
km	kilometers
KOS	keep out sphere
LEE	local end-effector
m	meters
MCC	Mission Control Center
MCC-H	Mission Control Center-Houston
MCC-M	Mission Control Center-Moscow
MPLM	mini-pressurized logistics module
MSS	Mobile Servicing System
n. mi.	nautical miles
NASDA	National Space Development Agency of Japan
P&C	probe and cone
PAS	payload attach system
PDGF	power data grapple fixture
PM	pressurized module
PMA	pressurized mating adapter
PMIVP	Program Master Integration and Verification Plan
prox ops	proximity operations
RF	radio frequency
RS	Russian Segment
RSA	Russian Space Agency
RSGF	rigidized sensing grapple fixture
RSS	Root Sum Square

sec	seconds
SEC.	Section
SM	Service Module
SSRMS	space station remote manipulator system
SVS	space vision system
TBC	to be confirmed
TBD	to be determined
TBS	to be supplied
TDRS	tracking and data relay satellite
TORU	teleoperator (remote) control mode
UDM	universal docking module
ULC	unpressurized logistics carrier
USOS	United States on-orbit segment
Vdc	volts, direct current
VOL.	volume
VV	visiting vehicle
VVCC	visiting vehicle control center