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Human Landing System to Orion Interface Requirements Document

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1 SCOPE

1.1 Introduction

This Interface Requirements Document (IRD) defines the Human Landing System (HLS) requirements and verification approach for interfaces between the HLS and the Orion. The detailed design implementation of the HLS to Orion interfaces in response to this IRD will be defined in the HLS to Orion Interface Control Document (ICD).

1.2 Program Description

This document provides interface requirements between the HLS and the Orion. The document requirement structure is as follows:
A. Section 3.2 contains interface requirements for the HLS side of the interface.
B. Section 4 contains verification methodology, success criteria, and responsibility.

1.3 Roles and Responsibilities

Prior to baseline of this IRD, updates and changes will be managed by the Book Manager, controlled through the appropriate Working Group(s) and /or Cross Program Panel / Board. Issues are elevated to the Cross Program Integration Team (CPIT) and if need be Program Managers as necessary for resolution. The process to baseline the IRD and change control thereafter is documented in HLS-PLAN-004, HLS Configuration and Data Management Plan.

1.4 Interface Configuration Management

Each interface requirement in this document is uniquely numbered and identified by the presence of a tag of the form "[HLS-ORION-####]" at the beginning of the requirement statement. The "####" portion of the identifier is a unique number assigned by the Dynamic Object Oriented Requirements System (DOORS)requirements database. The complete identifier is tagged to the requirement and used to track changes to the requirement in the DOORS requirements database.
The convention used in this document for requirements is as follows:

> *Shall -- used to indicate a requirement which must be implemented and its implementation verified;*
> *Should -- used to indicate a goal which must be addressed by the design but is not formally verified;*
> *Will -- used to indicate a statement of fact and is not verified.*

In some cases the values of quantities included in a requirement have not been determined and are designated as "to be resolved" (TBR), "to be determined" (TBD) or "to be supplied" (TBS). Where approximate values of such quantities are known and provide useful guides for development, these are shown along with the TBR notation. Where no value is yet known, a TBD is included. Where a value is known, but has not been supplied to the IRD Book Manager, a TBS is included.

2 APPLICABLE DOCUMENTS

2.1 Government Documents

The documents listed in this section are referenced in content of the IRD. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited within the IRD whether or not they are listed here in Section 2.1.

Document #	**Document Title**
ESD10012	Exploration Systems Development Concept of Operations Document
MPCV 70080	Cross Program E3 Requirements Document
MPCV 72633	Orion Multi-Purpose Crew Vehicle Interface Definition Document
NASA-STD-4003A	Electrical Bonding For NASA Launch Vehicles, Spacecraft, Payloads, And Flight Equipment
SSP 51075	NASA Docking System Block 2 Interface Definition Document
TBD	HLS / Orion Loads Databook
TBD	HLS Electrical Power Quality Specification

2.2 Order of Precedence

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

3 INTERFACE DEFINITION AND DESCRIPTION

3.1 HLS to Orion Characteristics and Functions

HLS-Orion-0001 HLS to Orion External Interface
The HLS shall interface with the Orion.

Rationale: The HLS must be compatible with the Orion standard interface definition in accordance with the MPCV 72633, Orion Multi-Purpose Crew Vehicle (MPCV) Interface Definition Document (IDD).

3.1.1 Interface Description

The physical and functional interfaces described in this document are depicted at a summary level in Figure 3.1.1-1 - Human Landing System to Orion Interface Drawing. Each physical and functional interface between HLS and Orion is shown with an arrow indicating the direction of the interface. No direction or dependencies between system interfaces is implied.

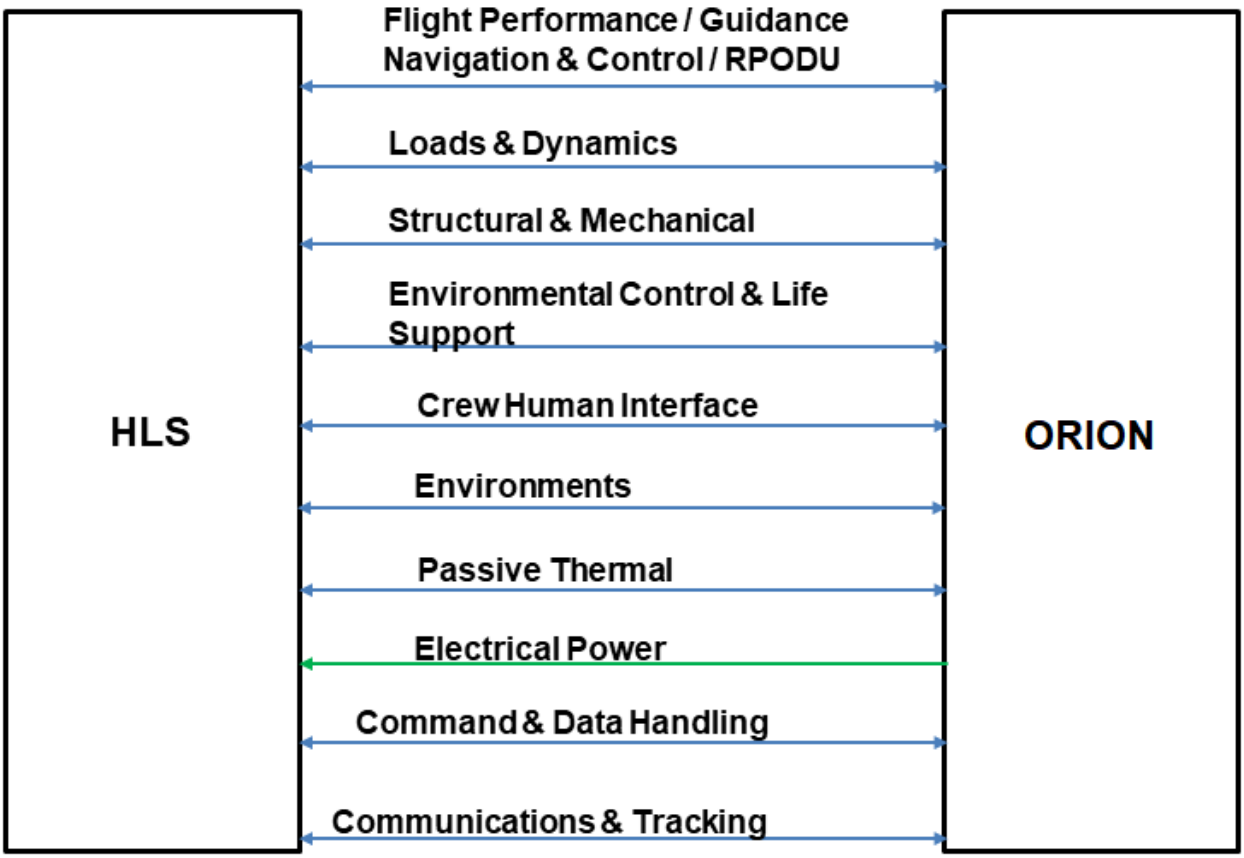

Figure 3.1.1-1 - HLS to Orion Interface Drawing

3.1.1.1 Human Landing System Description

The HLS is a human rated space craft system with the capability to sustainably ferry astronauts and technology demonstrators to and from the surface, yielding new science and material resources – and leveraging the Moon as a proving ground for future Mars missions.

3.1.1.2 Orion Description

Orion is the spacecraft used to transfer flight crews, cargo, and support equipment from Earth to Lower Earth Orbit or lunar orbit and subsequently return the crew to Earth's surface. The Orion System consists of a Launch Abort System, Crew Module, Service Module, and Spacecraft Adapter. Orion will be used in all phases Exploration Systems to transport crew and cargo to orbit and back. Exploration Systems Development Concept of Operations Document (ESD 10012) establishes the Design Reference Mission that include Orion crew transport capability to and from a lunar orbit, to and from Earth-Moon Lagrange Point and to and from Deep Space Habitat for Near Earth Asteroid or Mars exploration missions.

3.1.1.3 Human Landing System to Orion Interface Plane Description

3.1.1.4 Human Landing System Interface Functions

HLS will support the following functions at the interface to Orion:
a. Mechanical Attachment
b. Exchange Data
c. Exchange Commands
d. Provide Passageway/Access
e. Provide Docking/Mating Aids
f. Capability to Recieve Power
g. Crew Transfer
h. Exchange Atmosphere
i. Equalize Pressure
j. Provide Attitude Control
k. Communication and Tracking Information Exchange

3.1.1.5 Orion Interface Functions

Orion will support the following functions at the interface to HLS:
a. Mechanical Attachment
b. Exchange Data
c. Exchange Commands
d. Provide Passageway/Access
e. Capability to Provide Power
f. Crew Transfer
g. Exchange Atmosphere
h. Communication and Tracking Information Exchange

3.1.2 Interface Responsibilities

The HLS Program carries the responsibility for design of the interface requirements imposed on the HLS portion of this interface and the Orion Program, through the HLS to Orion IRD, carries the responsibility for designing to the interface requirements imposed on the Orion portion of this interface.

3.1.3 Engineering Units, Tolerances, and Conversions

Numerical data entered in shall be in International System of Units (SI) (metric) units with applicable tolerances. The equivalent value shall be added in English (inch–pound–second) Parenthesis. Conversions between English and SI units shall be in accordance with ASTM E–380, standard procedure for use of the SI.

3.2 Structural and Mechanical Interface Requirements

This section covers structural and mechanical interfaces including envelopes, coordinate systems, mounting/installation, stowage provisions, handling, purge-vent-drain, umbilicals and appendages, docking attachment mechanisms, structural design requirements and utility mechanical connections/fittings.

HLS-Orion-0003 Provide Structural / Mechanical Attachment
The HLS shall be compatible with an active NASA Docking System Block 2 (NDSB2) docking mechanism.

Rationale: The Orion will have an active NDS Block 2 docking mechanism. The HLS must have a compatible docking mechanism for the Orion to perform Rendezvous, Proximity Operations, Docking, and Undocking (RPODU) with the HLS and to safely open the hatch and transfer crew and supplies between the ascent element and the Orion.

HLS-Orion-0004 Provide Passageway between Elements
The HLS shall have a passageway providing for the transfer of crew and cargo to and from Orion.

Rationale: The HLS and the Orion require a passageway with hatches that maintain a habitable environment during transit, after both hatches are opened, crew and cargo can transfer between modules. This requires a non-obstructed passage way with a passage opening per SSP 51075, NDS Block 2 IDD (Figure 3.7.1.3.1-2: NDSB2 Static Envelope). The static passage clearance is 800.00 mm.

3.3 Loads and Dynamics Interface Requirements

This section covers on-orbit induced structural loads (load spectra, pressure loads, pressure spectra, thermally induced structural loads, acceleration environment, docking loads, and plume impingement loads) and associated dynamics.

HLS-Orion-0019 Integrated Loads
The HLS shall withstand the loads defined in the HLS / Orion Loads Databook (TBS).

Rationale: The HLS / Orion Loads Databook will include on-orbit induced loads and loads spectra, on orbit pressure loads and loads spectra, on-orbit acceleration loads, plume impingement pressure normal & shear. Design of the Docking Mechanism will influence the Loads and Dynamics. System Architecture and module designs will influence Loads and Dynamics

HLS-Orion-0020 Docking and Undocking Loads
The HLS shall limit loads imparted at the docking and undocking interface to be within the values specified in the Orion IDD, Section 6.0.

Rationale: The Orion MPCV IDD, Section 6.0 defines the docking mechanism soft capture system, hard capture system, and undocking maximum allowable interface loads.

HLS-Orion-0021 Mating Interface Heat Flux
During docked operations, the HLS shall have a maximum heat flux of TBD at physically mated surfaces.

Rationale: This is a passive thermal limitation on the HLS regarding what heat load it can induce on the Orion.

3.4 Environmental Control and Life Support Interface Requirements

This section covers environmental interfaces including thermal, contamination, humidity, air pressure, atmosphere, and life support.

HLS-Orion-0005 Exchange Atmosphere
During open hatch operations, the HLS shall exchange air with the Orion through the open vestibule.

Rationale: The circulation can be augmented with Inter-Module Ventilation (IMV) ducting and / or fans, if the integrated analysis shows this function is required. If required, this functionality introduces a mass risk to the HLS Program.

HLS-Orion-0022 Docking Vestibule Pressurization/Depressurization
The HLS shall have the capability to pressurize and depressurize the docking vestibule.

Rationale: Orion has the capability to pressurize and depressurize the docking vestibule, but is limited on overall mission consumables. HLS capability to perform the pressurization/depressurization function provides both redundancy for this critical function and flexibility for consumables management.

HLS-Orion-0007 Pressure Equalization
Prior to open hatch operations, the HLS and Orion shall both have the capability to equalize cabin pressure.

Rationale: Pressures on both sides of the docking hatches must be equalized to enable hatch opening. Capability for both vehicles to perform this function provides both redundancy for this critical function and flexibility for consumables management.

HLS-Orion-0006 Pressure Control
The HLS and Orion shall both be capable of maintaining pressure control for the integrated HLS / Orion configuration.

Rationale: Ref Orion MPCV IDD, Section 9.8: After hatch opening, the Orion Air Revitalization System (ARS) is capable of maintaining the quality of the air for itself and a Docked Vehicle, as long as air circulation hardware for the docked pressurized volume is provided by the docked vehicle. The Orion Pressure Control System (PCS) is capable of controlling the pressure of both volumes, limited by its N2 and O2 consumables.

HLS-Orion-0008 Passive Thermal Independence
When docked to Orion, HLS shall be thermally independent.

Rationale: HLS will be responsible for its own thermal control, including but not limited to for passive thermal heat transfer, radiated heat load, metabolic heat load will, and will have the ability to manage its own heat loads during nominal operations.

3.5 Electrical Interface Requirements

This section covers electrical interfaces including power, switching, fusing, grounding, electro-explosive devices, electromagnetic interference and electromagnetic compatibility.

3.5.1 Electrical Power

HLS-Orion-0016 EPS Power Self-Sufficient
The HLS shall generate all power required for the HLS systems.

Rationale: The HLS will be power independent from the Orion power for all docked operations. During certain Orion operations where the Orion may be significantly shadowing the HLS arrays or brought the HLS into an attitude such that there is insufficient power generation, the HLS can receive power from the Orion EPS. The Orion has not allocated for power transfer to HLS and all transfer power will require power resource assessments by Orion prior to any power transfer.

HLS-Orion-0013 Power Transfer from Orion
The HLS shall have the capability to receive up to 1.8kW power via the interface with Orion.

Rationale: While docked, the HLS can receive power from the Orion. Power flows through the power connectors of the docking mechanism. The power control hardware will be located on the HLS.

HLS-Orion-0018 Power Quality
HLS shall be compatible with Orion electrical power system power quality at the interface.

Rationale: The HLS will be able to receive power from the Orion and will comply with Electrical Power Quality Specification Requirements for 120Vdc at the interface.

3.5.2 Electromagnetic Compatibility

HLS-Orion-0017 Electromagnetic Compatibility & Electromagnetic Interference (E3)
HLS shall be electromagnetically compatible with Orion.

Rationale: Electromagnetic Compatibility (EMC) is essential to the success of any vehicle design that incorporates a complex assortment of electronic, electrical, and electromechanical systems and sub-systems that is expected to meet operational and performance requirements while exposed to a changing set of electromagnetic environments composed of both man-made and naturally occurring threats. Orion system level requirements are found in MPCV 70080, Cross Program Electromagnetic Environmental Effects (E3) Requirements, a tailored version of MIL-STD-464 specifically tailored for the Orion Program. Orion EMI requirements are contained in a tailored version of MIL-STD-461 specifically tailored for the Orion Program.

HLS-Orion-0024 Bonding
The HLS shall meet the Electrical Bonding requirements of NASA-STD-4003A, NASA Technical Standard: Electrical Bonding For NASA Launch Vehicles, Spacecraft,

Payloads, and Flight Equipment for a Class R/H bond at the structural / mechanical interface to the Orion.

Rationale: Proper electrical bonding in accordance with bonding classifications and pertinent to the specific application is necessary to meet performance, safety, and EMC requirements.

3.6 Communications and Data Handling Interface Requirements

This section covers all communications, tracking, command and data handling requirements.

Note: In addition to these HLS to Orion Communication Interface Requirements, there will be simultaneous HLS to Mission Systems communication Interface Requirements that mandate that simultaneous Radio Frequency Communication take place from HLS to Orion and HLS to Mission Systems. Simultaneous Radio Frequency Communication paths are being used to mitigate the uncertainties associated with radio frequency communication at the lunar poles. Multipath degradation has the potential to cause intermittent or degraded direct-with-Earth (DWE) communications with Mission Systems at certain times, while Orion's phasing orbit has the potential to cause communication outages when Orion is occulted by the moon as it travels over the lunar North Pole in its Lunar Orbit. Having simultaneous dissimilar Radio Frequency communication paths helps ensure that continuous radio frequency communication coverage is available to the Mission and the Crew.

3.6.1 Communications and Tracking

HLS-Orion-0011 Maintain Docking Vehicle RF Communications Link

When within 400km of the Orion, the HLS shall establish and maintain S-Band bi-directional “Docking Vehicle” communication, telemetry, and radiometric ranging with Orion.

Rationale: When the HLS is within 400 km of Orion, HLS establishes a docking vehicle communication link in Point A mode with the Orion (in Point B mode). Once HLS is docked with Orion, there is a hardline interface between the HLS and Orion for data exchange, and the Docking Vehicle radio frequency link is deactivated.

During HLS undocking, the Orion to HLS communication link is established; this link could be the Orion to docking vehicle link or the Orion to Lunar System link depending on the configuration and the data to be exchanged, communication range between Orion and HLS, etc. When Orion and HLS are in line-of-site, the Orion to HLS link is maintained all the way through descent, lunar surface ops, ascent and RPOD back with Orion.

HLS-Orion-0012 Maintain Lunar Systems RF Communications Link

The HLS shall establish and maintain S-Band bi-directional “Lunar Systems” communication, and telemetry, when at separation distances greater than 400 km, during lunar descent, surface operations and ascent to Orion.

Rationale: HLS communications with Orion allows for direct data transfer between the HLS and the Orion (including commands, telemetry, health & status, guidance, navigation, and control (GNC) data, audio, video, etc.) during lunar descent, surface ops and ascent.

3.6.2 Command and Data Handling

HLS-Orion-0009 Commanding
When attached to the Orion, the HLS shall have the capability to receive commands via the Orion interface, using an HLS device connected to the Orion C&DH network.

Rationale: The HLS avionics architecture needs to support an extensible capability in which critical commanding may be necessary from a vehicle docked to HLS. Since Orion will always be manned, there is no need for HLS to command Orion. Commanding from Orion to HLS will be done via a portable HLS device (i.e. laptop, tablet) which is independent from the Orion FSW. The HLS portable device will interface to HLS through an Ethernet port on Orion.

HLS-Orion-0010 Exchange Data
When attached to the Orion, the HLS shall have the capability to exchange data via the Orion 1Gb Ethernet interface.

Rationale: The HLS avionics architecture supports direct data transfer between the HLS and the Orion (including health & status, GNC data, audio, video, etc.) while attached, see Orion MPCV IDD, Section 7.1 for implementation details.

3.7 Performance Interface Requirements

HLS-Orion-0023 Performance Constraints and Interface Requirements
HLS mission design and performance shall be compatible with Orion's design properties and performance constraints as given in Table 3.7-1:

Table 3.7-1 - Orion Properties and Performance Constraints

Orion Properties

Parameter	Value
Orion Wet Mass Pre-TLI	59580 lbm | 27025 kg
Orion Wet Mass Post-TLI After Separation from Upper Stage	58,147 lbm | 26,375 kg
dV capability for major translational maneuvers (dV for trajectory corrections, attitude control, and flight performance uncertainties accounted for already)	3,445 ft/s | 1,050 m/s
Main Engine Isp	314.8 sec

Performance Constraints

Constraint	Description

Attitude Maintenance	· Orion's "baseline" power positive and thermally stable attitude is Tail-to-Sun (TtS) with a 20 deg dead band in pitch & yaw. · Excursions from TtS for up to three hours require thermal recovery of up to ten hours. (based on verification analysis)
Solar Eclipse Limitations	90 minutes in any single partial or total eclipse
Lunar Flyby Minimum Altitude	100 kilometers
Mission Availability to NRHO	On B1 SLS (with ICPS): Launch period of 8-12 consecutive days on average per lunar month, spaced evenly throughout the calendar year.

3.8 Operations Interface Requirements

This section covers operations interfaces including flight operations (docking/alignment, rendezvous, deployment/retrieval, and flight crew), ground operations (checkout, prelaunch, post landing, personnel), and command/control center (man-machine operations, personnel).

HLS-Orion-0002 Perform Rendezvous Proximity Operations, Docking and Undocking
The HLS shall be capable of performing RPODU as the target vehicle with Orion as the chaser vehicle.

Rationale: Rendezvous, proximity operations, docking, and undocking operations are critical functions required for crew survival and mission success. The HLS design will ensure that the HLS can function as the target vehicle while the Orion performs RPODU as the chaser vehicle. The HLS will maintain its attitude to an agreed to orientation within an envelope and provide Orion compatible sensor targets.

HLS-Orion-0015 Provide Orion-HLS (Integrated) Attitude Control
While docked to the Orion, the HLS shall provide attitude control for the integrated stack.

Rationale: While docked, the HLS will provide integrated, mated stack attitude control. The orientation of the HLS / Orion configuration will comply with the Orion MPCV IDD, Section 12.1.

3.9 Safety Interface Requirements

3.9.1 Natural and Induced Environments

HLS-Orion-0014 Provide for Induced Environments
The HLS shall meet all safety, performance, utilization, and mission objectives during and after exposure to the induced environments.

Rationale: The HLS needs to operate through the induced environments imparted by Orion. Examples include EMI, loads, plume impingement, crew kick loads, crew

exercise, and contamination. In turn, HLS needs to constrain induced environments imparted to Orion such as plume loads, docking loads, and loads while docked.

3.9.2 Crew Human Interface

Forward Work.

3.10 Reliability Interface Requirements

Forward Work.

3.11 Maintainability Interface Requirements

Forward Work.

4 INTERFACE REQUIREMENTS VERIFICATION

Each interface requirement defined in Section 3.2 of this IRD shall be verified prior to the launch of the interfacing entities, unless otherwise specified, at the appropriate system/module level.
Section 4 defines the criteria for the sharing of responsibilities for the performance of the Verification Program, as well as the verification methods, procedures, and success criteria to be complied with during the verification process. It also assigns verification responsibilities, as appropriate, to each IRD Partner for the applicable portion of the Interface design.

4.1 Responsibilities

It is the responsibility of each interfacing element to establish and control the traceability between each of the Interface Requirements defined in this IRD and the corresponding design implementation data, as documented in the relevant ICD.
The Agency responsible for the design of the hardware or software which represents a mating side of the interface to be verified, is responsible for the verification that their own system/module is in compliance with the interface requirements established in the IRD, and that the “as built” status is in compliance with the associated ICD.
In the event stand−alone verification of each of the two mating parts of an interface is not sufficient and that active participation from the other Partner is necessary to fully verify the compliance with the IRD requirements, both Agencies are jointly responsible for the successful completion of interface verification. Joint participation activities are defined in the Bilateral Verification Plan (BIVP).

4.2 Terminology

The following methods are defined and shall be used to qualify the system:
a. Verification by inspection is the physical evaluation of equipment and/or documentation to verify design artifacts. Inspection is used to verify construction features, workmanship, and physical dimensions and condition (such as cleanliness, surface finish, and locking hardware). For example, “The Placard shall be Red.” can be verified by inspection.

b. Verification by analysis is a process used in lieu of (or in addition to) testing and inspection. Analysis techniques may include statistics and qualitative analysis, computer and hardware simulations, and computer modeling. Analysis should be used only when all of the following conditions apply: (1) rigorous and accurate analysis is possible, (2) verification by test is not feasible or cost effective, and (3) verification by inspection is not adequate. When conducting Verification by Analysis, the models, simulations, and analysis tools must be accredited by the Program and Element/Modules to certify appropriate fidelity and software development quality. The accreditation authority ensures that the tools have sufficient pedigree to provide usable information for decision-making, at the level of criticality required.
c. Verification by demonstration is the actual operation of flight or ground equipment or teams to evaluate its functional performance and/or its interfaces to other equipment or teams. The primary distinction between demonstration and test is that demonstrations provide qualitative results, whereas tests provide quantitative results.
d. Verification by test is the actual operation of flight, flight-like, and/or ground equipment with the necessary test support equipment and test environment. Test also applies to hardware or software verifications done on flight like systems in test facilities such as a System Integration Laboratory (SIL) and a Multi-element Integration Test (MEIT) lab.

5 APPENDIX A - ACRONYM LIST

ARS	Air Revitalization System
BIVP	Bilateral Verification Plan
CPIT	Cross Program Integration Team
DOORS	Dynamic Object Oriented Requirements System
DWE	Direct-with-Earth
E3	Electromagnetic Environment Effects
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPS	Electrical Power Supply
ESD	Exploration Systems Development
GNC	Guidance, Navigation & Control
HLS	Human Landing System
ICD	Interface Control Document
IDD	Interface Definition Document
IMV	Inter-Module Ventilation
IRD	Interface Requirements Document
ISS	International Space Station
MEIT	Multi-Element Integration Test
MPCV	Multi-Purpose Crew Vehicle
NDSB2	NASA Docking System Block 2
PCS	Pressure Control System
RF	Radio Frequency

RPODU	Rendezvous, Proximity Operations, Docking, and Undocking
SI	International System of Units
SIL	System Integration Laboratory
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Supplied

6 APPENDIX B - CROSS SECTION IMAGES OF HLS / ORION INTEGRATED CONFIGURATION

Forward Work