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Human Landing System to Mission Systems Interface Requirements Document

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1 SCOPE

1.1 Introduction

This Interface Requirements Document (IRD) defines the interface requirements and verification approach for the Human Landing System (HLS) and Mission Systems (MS) interface. There is no physical interface between the HLS and MS. The detailed design implementation of the HLS to MS interfaces in response to this IRD will be controlled in appropriate Interface Control Documents (ICD).

The HLS to MS IRD defines the detailed functional requirements, associated rationale, and related verification requirements (TBR) for all aspects of the interface between the HLS and MS. The interface requirements cover the necessary communication, data, and information capabilities and data exchange layers that apply any time data exchange occurs between the HLS and Mission Systems. This document does not define operational requirements or processes, nor does it contain requirements regarding reliability, maintainability, and workmanship. Those requirements and processes are flowed down to each system independently through the System Requirements Documents (SRDs) and other documentation owned at the project level.

Note: This document does not differentiate between crewed and uncrewed operations except where specified in a requirement (section 3.6.2, L2-HLS-MS-0053). The Broad Agency Announcement (BAA) statement of work (SOW) is the authoritative source with respect to the responsibilities for crewed and uncrewed operations and missions.

1.2 Program Description

This document provides interface requirements between the HLS and the MS. The document requirement structure is as follows:

A. Section 3.2 contains interface requirements for both sides 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 "[L2-HLS-MS-####]" at the beginning of the requirement statement. The "####" portion of the identifier is a unique number assigned by the 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), 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 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 following documents are referenced in the requirements set below and should be followed within the extent of the requirement.

Document Number	Title
IETF-STD-0005	Internet Engineering Task Force Standard for Internet Protocol
RFC 8200	Internet Protocol, Version 6 (IPv6) 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 MS Interface Characteristics and Functions

3.1.1 Interface Description

The physical and functional interfaces described in this document are depicted at a summary level in the figure entitled Human Landing System to Mission Systems Interface Drawing. Each physical and functional interface between HLS and Mission Systems is shown with an arrow indicating the direction of the interface. No direction or dependencies between system interfaces is implied. Only Direct with Earth (DWE) interfaces are defined in this IRD. Communications, Data and Information sent through another interface as a pass through are defined in the interface document for which that interface applies. The HLS to Mission Systems interface design may be influenced by other HLS interfaces which may have more restrictive requirements than those in this document.

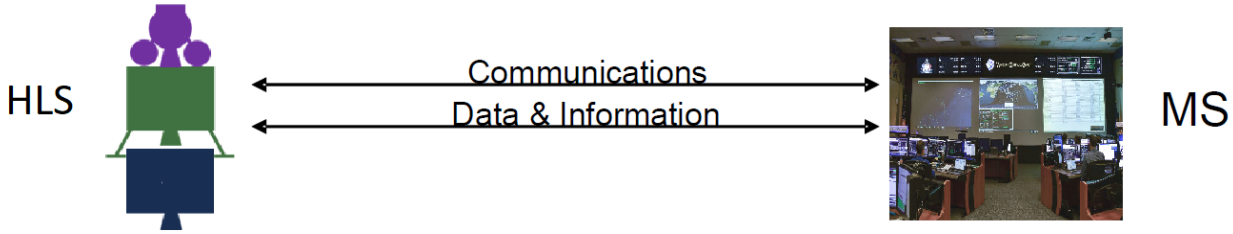

Figure 1- HLS to Mission Systems Interface Drawing

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 Mission Systems Description

Mission Systems in the context of this IRD refers to all systems on Earth with which the HLS will interface or systems necessary to provide the functions associated with the systems on Earth. Bi-directional communications between HLS and Mission Systems is via the Deep Space Network (DSN) and any other appropriate communications and tracking networks. The DSN Operations Interface Control Document (OICD) supplies the core RF to Earth ground ICD components, Earth ground to ground, scheduling services and other information. Use of additional networks will be controlled in their respective ICDs.

Mission Systems is a subset of Flight Operations (FO) containing the facilities, infrastructure, trainers, workstations, servers, networks, and software. Exploration Systems generate goals, objectives, and the flight schedule which drives operations. Exploration Systems supply vehicle configuration data, system capabilities, and constraints which are important drivers to the mission planning process. The Flight Operations Directorate (FOD) performs tactical planning based on this information to ensure that the FOD appropriate resources, tools, and schedules are assigned to the task. Flight Dynamics acquires the initial data set required for subsequent mission planning definition. Based on the initial trajectory profile, timeline, and requirements generated in Flight Dynamics, the iterative planning process begins. Crew activity planning, system resource planning, crew procedures development, flight controller procedures development, and inventory planning are done for each mission phase to ensure an integrated mission operations plan is developed. The appropriate reconfiguration data is built for the vehicle(s) configuration. The plan is simulated, along with error cases for training, by the Training Systems (TS21), User Apps (UA21) and Mission Control Center (MCC21) in order to train the crew and flight controllers, gain experience on the mission, and to gain shelf life on the hardware and software needed to support the mission. Finally, the mission is executed from the Mission Control Center

- Houston (MCC-H) utilizing Mission Systems (MS) along with MCC-H core capabilities and external interfaces with HLS engineering and ESD elements.

3.1.1.3 Human Landing System to Mission Systems Plane Description

Not Applicable.

3.1.1.4 Human Landing System Interface Functions

The HLS will be providing the following interface functions:
a. Provide and Receive Data and Information
b. Provide and Receive Communication

3.1.1.5 Mission Systems Interface Functions

MS will be providing the following interface functions:
a. Provide and Receive Data and Information
b. Provide and Receive Communication

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 NASA Mission Systems carries the responsibility for designing to the interface requirements imposed on the Mission Systems portion of this interface.

3.1.3 Coordinate Systems

Define the coordinate system used for interface requirements on each side of the interface.

3.1.4 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 S1 units shall be in accordance with ASTM E–380, standard procedure for use of the SI.

3.2 Mechanical Interface Requirements

Not Applicable.

3.3 Structural Interface Requirements

Not Applicable.

3.4 Environmental Interface Requirements

Not Applicable.

3.5 Electrical Interface Requirements

Not Applicable.

3.6 Communications and Tracking Interface Requirements

This section should cover communications interfaces including various data standards, message timing, protocols, error detection/correction, functions, status, etc. While Mission Systems capabilities are flexible, HLS communications may be influenced or limited by other interfaces.

Note: In addition to these HLS-to-Mission Systems Communication Interface Requirements, there will be simultaneous HLS-to-Orion, and HLS-to-Gateway communication Interface Requirements that mandate that simultaneous Radio Frequency Communication take place from HLS-to-Mission Systems, HLS-to-Orion, and HLS-to-Gateway. 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-to-Earth communications with Mission Systems at certain times, while Orion or Gateway's phasing orbit has the potential to cause communication outages when Orion or Gateway is occulted by the moon as it travels over the lunar North Pole. Having simultaneous dissimilar Radio Frequency communication paths helps ensure that continuous radio frequency communication coverage is available to the Mission and the Crew.

L2-HLS-MS-0012 Default Receive Mode

The HLS shall be able to receive communications and commands from Mission Systems during all modes of operation.

Rationale: The system needs to be able to receive on its links at all times.

L2-HLS-MS-0014 Full-Duplex Channel

The HLS shall receive the uplink and transmit the downlink simultaneously with Mission Systems.

Rationale: Each link will have the ability to transmit and receive simultaneously using techniques such as frequency separation, etc. Ka-band is transmit only for links with Mission Systems.

3.6.1 RF Communications

For Operational Point to Point links one end of the link will perform the point A role and the other end of the link will perform the point B role. Point A – requirements generally apply to the HLS flight system or transponder end of the link. Point B – requirements apply to the opposite end of Point A links, generally the infrastructure end of the link (Space Network (SN), Near Earth Network (NEN), DSN, etc.). In the case of proximity communications links, the Point B side of the link originates the forward link signal and forms radiometric measurements. For the HLS to Mission Systems communication

links, the HLS performs the point A role while Mission Systems performs the point B role.

L2-HLS-MS-0005 IP Packet Formulation
The HLS shall use IP as specified in IPv4 (IETF-STD-0005, Internet Protocol) or IPv6 (RFC 8200, Internet Protocol, Version 6 (IPv6) Specification) <TBR> as a network layer with Mission Systems.

Rationale: IP provides for network layer services over interfaces that have low delay (under 5 sec (TBR) and an expectation of real time end-to-end connectivity. Use of IP allows for maximum leverage of terrestrial networking developments under appropriate circumstances. IPv4-based technology is widely available in the commercial market. IPv6-only stack provides advantages such as increased security and more efficient routing. IPv6 technology is not as readily available.

L2-HLS-MS-0013 Security
The HLS shall provide link layer encryption and decryption on links with Mission Systems.

Rationale: The system needs to protect the information carried on its links.

L2-HLS-MS-0030 Encryption Control
The HLS shall be able to enable or disable encryption on uplinks and/or downlinks to support contingency operations with Mission Systems.

Rationale: The system needs to be able to turn off encryption to support spacecraft recovery, contingency modes, etc. Nominally we encrypt both uplink and downlink.

3.6.2 Telemetry

Telemetry is any data that flows from HLS to Mission Systems, and could consist of any combinations of voice, data, video, etc. Telemetry could be sent to Mission Systems over X-Band link, S-Band link, and/or Ka-Band link. HLS doesn't always have to be transmitting to Mission Systems 100% of this time, but it does have to be listening to Mission Systems 100% of the time, and have the capability to transmit telemetry to Mission Systems at any time necessary.

L2-HLS-MS-0001 Launch Pad Operations
The HLS shall provide telemetry to Mission Systems via the ground system / launch pad interface.

Rationale: Health & status data to Mission Control is needed during the launch pad operations phase, and will be provided via hardline umbilical connections, not via any type of Radio Frequency link.

L2-HLS-MS-0002 Cruise Phase, RPODU, Lunar Descent, Lunar Surface Operations, and Ascent to Orion or the Gateway.
The HLS shall provide 2-way telemetry to Mission Systems after launch vehicle separation, including the cruise phase to Orion or Gateway, RPODU with Orion or

Gateway, descent to the lunar surface, lunar surface operations, and ascent to Orion or Gateway.

Rationale: Health & status telemetry is needed during the HLS cruise phase, RPODU, lunar descent, lunar surface operations and ascent to Orion or Gateway*. Command and telemetry may be used by itself (without ranging) during the majority of cruise phase, and radiometric tracking (ranging) will also be needed occasionally to assist with trajectory correction maneuver planning, execution, and analyses. Considerations need to be made for real time and non-real time video telemetry: Non-real time video on flyby as the HLS/Element passes near the Lunar North Pole on its Halo Orbit, real time video of proximity operations and docking (particularly when no crew is present), real time video of descent and landing on the lunar surface, real time video of extravehicular activities on the lunar surface, and real time video of the ascent to Orion* or Gateway *from the ascent vehicle viewing the lunar surface and the lunar surface viewing the ascent vehicle.*

L2-HLS-MS-0052 Ascent Video

During ascent, the HLS shall provide video from the lunar surface to Mission Systems.

Rationale: From the HLS RF Communications ConOps: During ascent from the lunar surface/return to Orion or Gateway*, as the vehicle ascends away from the lunar surface, the HLS will transmit live video of the departure DWE.*

L2-HLS-MS-0053 Simultaneous Audio/Video Streams

The HLS shall be capable of providing at least two simultaneous audio and two simultaneous video streams of the crewed system to Mission Systems.

Rationale: Two audio and video streams are needed to support all required operations and flight phases (except ascent) for the vehicle, while also being able to conduct medical conferences, private family conferences, and nominal and off-nominal operations. During ascent, only one conversation will be conducted and the second audio stream provides no redundancy. Use of one audio stream during ascent and entry yields extra bandwidth for the transmission of real-time critical telemetry.

3.6.3 Tracking

Tracking includes interface requirements for radiometric ranging.

L2-HLS-MS-0006 Ranging

The HLS shall use coherent tracking services with Mission Systems.

Rationale: Radiometric tracking/ranging is needed to support Guidance, Navigation, & Control (GN&C) since there are currently no "Global Positioning System" like capabilities. The ranging mode selected provides for simultaneous data with ranging.

L2-HLS-MS-0037 Non-coherent Mode

The HLS shall provide a non-coherent mode of operation in Point A mode with Mission Systems.

Rationale: Non-coherent operation is required in order that system can deliver telemetry when tracking is not required. When two-way radiometric measurements are not required, a non-coherent mode of operation is preferred since signal acquisition and tracking is easier, faster, and requires a lower Eb/No.

L2-HLS-MS-0038 Loss of Signal
Upon unexpected/unintentional loss of signal with Mission Systems, the HLS shall automatically switch to a non-coherent mode of operation in Point A mode.
Rationale: Without automatic switching to non-coherent mode, loss of the signal could cause the system to stop transmitting as well. A good option is to "freeze" the current carrier frequency and Pseudo-Noise (PN) chip rate when the link is lost, and maintain the same modulation on transmission.

L2-HLS-MS-0015 FEC Control
The HLS shall be able to enable or disable forward error correction (FEC) with Mission Systems.
Rationale: The system needs to able to enable or disable FEC to support contingency and other operational scenarios. Downlink will nominally use FEC. Uplink will not.

L2-HLS-MS-0018 FEC Commanding
The HLS shall enable and disable communication link forward error correction (FEC) upon receipt of command from Mission Systems.
Rationale: The system needs to able to enable or disable FEC to support contingency and other operational scenarios. Downlink will nominally use FEC. Uplink will not.

L2-HLS-MS-0056 Ranging Accuracy
The HLS shall ensure radio latencies and turn-around-times of the HLS are characterized to fall within the range and range-rate accuracy and precision allocations for ranging with Mission Systems.
Rationale: The HLS is responsible for a portion of the range and range-rate accuracy and precision for the overall ranging with Mission Systems while the computation of the range and range-rate is the responsibility of Mission Systems. The specific allocations will be dependent upon the selected radios and networks/Earth ground systems for the HLS missions. It should be noted that for 2-way tracking services to function properly, the transmit clock needs to be derived from the receive clock, for continuity of timing on both communication paths. Also worth noting, the HLS Tx clock needs to be slaved to the HLS Rx clock for 2-way tracking services to work properly.

3.6.4 Relayed Commanding

Not applicable to the HLS to Mission System interface. While interfacing with, the Orion or Gateway has the ability to relay communications between the HLS and Mission Systems so that commands originating from Mission Systems reach the HLS when DWE communication is not available. DWE communication is preferred.

3.7 Command and Data Handling Interface Requirements

Command and Data Handling requirements address the way commands and data need to be formatted in order to provide a functional interface for the communications outlined in section 3.6.

L2-HLS-MS-0057 Process Commands
The HLS shall process commands received from Mission Systems.
Rationale: Processing of commands received from Mission Systems allows for control of the vehicle when needed.

L2-HLS-MS-0054 Telemetry Formats
The HLS shall use XML Telemetric and Command Exchange (XTCE) to exchange telemetry and command formats/databases during the development and operation phases.
Rationale: MCC recommends using the XTCE formats for commonality between programs.

3.8 Performance Interface Requirements

Not Applicable.

3.9 Operations Interface Requirements

Note: The launch conditions of the HLS elements are not defined in this document and will need to be negotiated with the Launch Vehicle provider.

3.10 Safety Interface Requirements

Not Applicable.

3.11 Reliability Interface Requirements

Not Applicable.

3.12 Maintainability Interface Requirements

Not Applicable.

3.13 Other

4 Interface 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. Table 4.1−1, Interface Verification Matrix, lists the responsibilities in verifying their own side of the interface as part of their independent (stand−alone) verification activities.
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.
e. Audit is a method that is satisfied at lower levels of organization by an accredited entity. The audit will simply confirm that the child requirements have been fully verified and that the verification of all lower level requirements fully satisfies the parent requirement. If the audit requires additional analysis to complete, it should be verified by analysis.

5 Acronyms

BAA	Broad Agency Announcement
BIVP	Bilateral Verification Plan
CPIT	Cross Program Integration Team
DSN	Deep Space Network
DWE	Direct with Earth
FEC	Forward Error Correction
HLS	Human Landing System
ICD	Interface Control Document
IP	Internet Protocol
IRD	Interface Requirements Document
MEIT	Multi-element Integration Test
MS	Mission Systems
NEN	Near Earth Network
PN	Pseudo-Noise
RF	Radio Frequency
RFC	Remote Function Call
RPODU	Rendevous, Proximity Operations, Docking, and Undocking
SBU	Sensitive But Unclassified
SIL	System Integration Laboratory
SN	Space Network
SOW	Statement of Work
SRD	System Requirements Document
TBR	To Be Resolved
TBS	To Be Supplied