National Aeronautics and
Space Administration

HLS-IRD-010
REVISION C
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HUMAN LANDING SYSTEM (HLS) PROGRAM HUMAN-CLASS DELIVERY LANDER (HDL) SYSTEM TO CARGO INTERFACE REQUIREMENTS DOCUMENT (IRD) – SUSTAINED PHASE

REVISION AND HISTORY PAGE

Revision No.	Change No.	Description	Release Date
-	HLS-C0198	Initial Release (Reference HCB.03.23.2022)	03/24/2022
	HLS-MD-0010	Updating definitions for sustaining/App P/SLD. The intent is to be consistent between SOW, DRDs, SRDs, and IRDs.	04/28/2022
A	HLS-C0256	Revision A (Reference HCB.06.22.2022) Incorporation of industry provided feedback for App P RFP. Added Field Of View Requirement, Resolved TBSs and FWDs.	06/29/2022
B	HLS-C0392	Revision B (Reference HCB.09.27.2024) Updates to clarify HDL to cargo interface requirements.	11/08/2024
C	HLS-C0486	Revision C (Reference HCB.03.10.2026 OSB) Reformat Document to use HLS-PRT-006, HLS Program Document Control List, for applicable document revision control. Add HLS-RPT-006 to the Section 2.1 Applicable Documents the statement, "See HLS-RPT-006, HLS Program Document Control List, for the applicable document revision." Remove the "Document Revisions" column in the applicable documents table in Section 2.0 Documents. Remove all callouts to applicable document revisions (e.g. requirement statements & requirement rationales) throughout the document.	04/29/2026

TABLE OF CONTENTS

SECTION **PAGE**

APPENDIX

TABLE

FIGURE

1.0 INTRODUCTION

The Human-class Delivery Lander (HDL) is a lunar landing system element responsible for delivering cargo to the lunar surface. The HDL is managed by the Human Landing System Program Office within the Artemis Lunar Exploration Program. The HDL is developed in parallel with the Integrated Lander and will be delivered to support the Artemis Sustained Mission Phases beginning at Artemis VII.

The Human-Class Delivery Lander (HDL) will deliver two types of large cargo, Integrated Cargo and Offloaded Cargo, to the surface on the moon. The HDL cargo will be launched by the HDL Provider, and the HDL will be expected to perform full delivery. Providers may choose any approach to staging, multiple launches, or aggregation within the bounds of the HDL's and the cargo's operational and environmental limits. The Integrated Cargo (Lunar Surface Habitat) and Offloaded Cargo (Lunar Pressurized Rover) serve as pathfinders / use cases for the HDL delivery capability definition captured in the HDL System Requirements Document (SRD) and this IRD.

1.1 PURPOSE

This document provides a description of the accommodations provided by the HDL to deliver the Cargo to the Lunar Surface. The HDL utilities defined herein present the bounding cases for cargo mass, volume, and utilities, and are captured in the interface requirements between the HDL and the Cargo. The document requirement structure is as follows:

Section 2.0 includes the reference and applicable documents

Section 3.1 includes characteristics and functions at the interface

Section 3.2 – 3.9 contain interface requirements for the HDL side of the interface. In most cases corresponding interface requirements are included for Cargo.

Section 4 contains verification methodology, success criteria, and responsibility.

1.2 SCOPE

This document applies to cargo launched in the HDL. The current cargo use cases include the Lunar Surface Habitat (SH) and the Pressurized Rover (PR). This HLS-IRD-010 captures the standard accommodations, functions, and utilities available for cargo. The HLS-RQMT-007, HDL SRD Rev B will reference this IRD for interface requirements between the HDL and Cargo. A unique HDL to Cargo Interface Control Document (ICD) will be written for each unique Cargo launched on the HDL. While attached to the HDL, communication between the Cargo and Mission Systems will be delivered to Earth by the HDL in accordance with the HLS-IRD-004-01, HLS Program Integrated Lander to Mission Systems IRD – Sustained Phase, Rev C. See Figure 1-1 HDL Document Tree for a complete summary of the relationship between the HDL and Cargo related documentation.

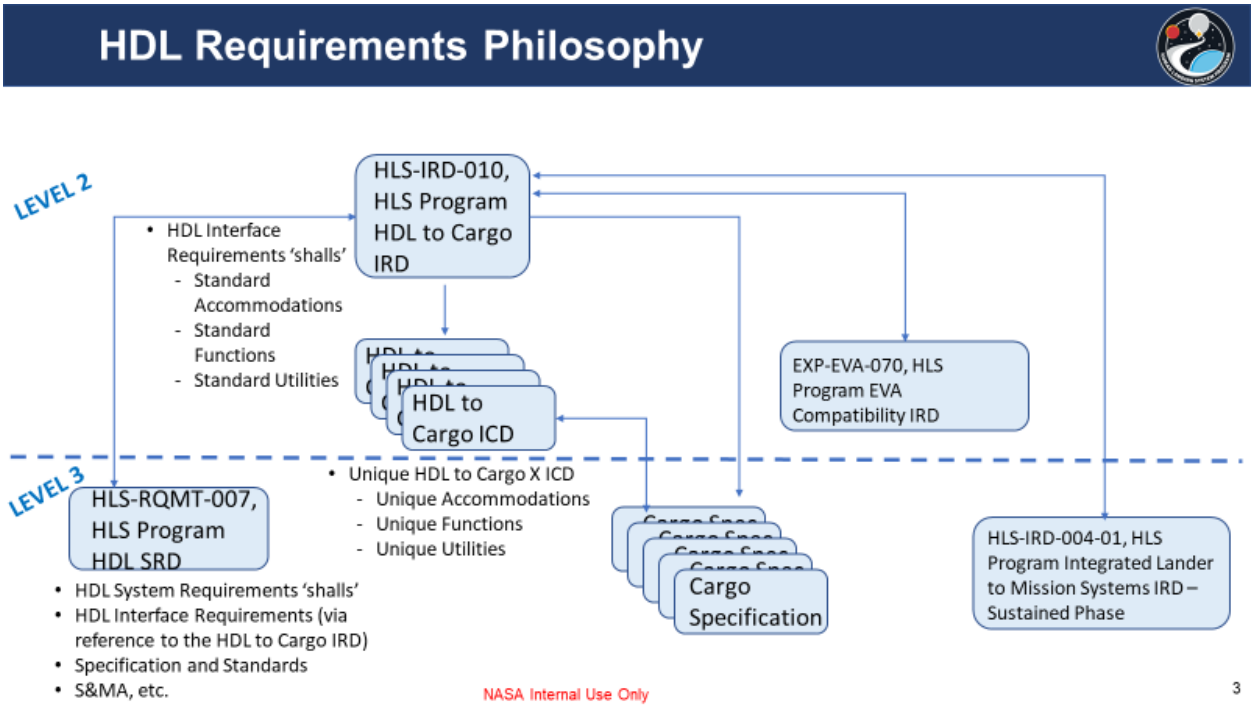

Figure 1-1 HDL Document Tree

1.3 CHANGE AUTHORITY/RESPONSIBILITY

Proposed changes to this document shall be submitted via a Change Request (CR) to the appropriate Human Landing System Control Board for consideration and disposition.

All such requests will adhere to the Human Landing System Configuration and Data Management Plan, documented in HLS-PLAN-004, Rev B.

The appropriate NASA Office of Primary Responsibility (OPR) identified for this document is the HLS Systems Engineering and Integration (SE&I) Office.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein.

TABLE 2-1 APPLICABLE DOCUMENTS

Document Number	Document Revision	Document Title
HEOMD-003-04	A	International Space Power Systems Interoperability Standard (ISPSIS)
HLS-STD-004	Rev A	HLS Electromagnetic Environmental Effects (E3) Requirements Document
IETF-STD-0005	7/29/2020	Internet Engineering Task Force Standard for Internet Protocol

2.2 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document.

TABLE 2-2 REFERENCE DOCUMENTS

Document Number	Document Revision	Document Title
HLS-IRD-004-01	C	Human Landing System (HLS) Program Integrated Lander to Mission Systems IRD – Sustained Phase
HLS-PLAN-003	Rev D	Human Landing System (HLS) Program Safety and Mission Assurance (SMA) Plan
HLS-RQMT-007	Rev B	Human Landing System (HLS) Program Human-class Delivery Lander (HDL) Requirements Document – Sustained Phase
NIST SP811	3/2008	Guide for the Use of the International System of Units
NPR 2810.1	F	Security of Information Technology

3.0 INTERFACE DEFINITION AND DESCRIPTION

3.1 HDL TO CARGO 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 Figure 3-1 HDL to Cargo Interface Drawing. Each physical and functional interface between HDL and Cargo is shown with an arrow indicating the direction of the interface. No dependencies between system interfaces are implied. A detailed list of interface functions once the Cargo and HDL are mated is provided in paragraphs 3.1.1.4 and 3.1.1.5.

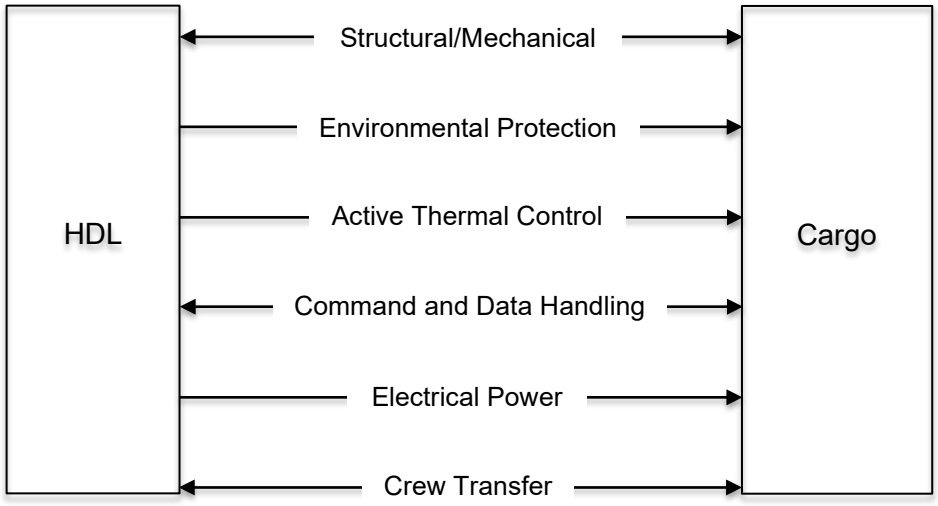

Figure 3-1 HDL to Cargo Interface Drawing

3.1.1.1 HDL Description

The HDL is a spacecraft system with the capability to transfer cargo from the Earth and land the Cargo on the Lunar Surface.

3.1.1.2 Cargo Description

The Cargo in this context is any element transferred by the HDL from the Earth and landed on the Lunar surface.

3.1.1.3 HDL to Cargo Interface Plane Description

The HDL to Cargo physical interface plane will be defined in the HDL to Cargo unique ICD. Standard utility interfaces will be located at a utility interface panel and will be defined in the HDL to Cargo ICD. The HDL to Cargo unique ICD will be developed as illustrated in Figure 1-1 HDL Document Tree.

3.1.1.4 HDL Interface Functions

The HDL will support the following functions at the physical interface to the Cargo:

A. Support Structural/Mechanical Attachment (in some cases disconnection)

B. Provide Active Thermal Control

C. Support Command and Data Handling

D. Supply Electrical Power

E. Provide Crew Access to Cargo

F. Provide Environmental Protection to Cargo

3.1.1.5 Cargo Interface Functions

The Cargo will support the following functions at the physical interface to the HDL:

A. Support Structural/Mechanical Attachment (in some cases disconnection)

B. Receive Active Thermal Control

C. Support Command and Data Handling

D. Receive Electrical Power

E. Provide Crew Access to Cargo

3.1.2 Interface Responsibilities

The HDL has the responsibility for designing to the interface functions described in Section 3.1.1.4 and to the requirements levied within this IRD. The Cargo has the responsibility for designing to the interface functions described in Section 3.1.1.5 and to the requirements levied within this IRD.

3.1.3 Engineering Units, Tolerances, and Conversions

Numerical data in these requirements and numerical data exchanged in response to these requirements is in International System of Units (SI) (metric) units with applicable tolerances. The equivalent value will be added in English (inch–pound–second) in parenthesis. Conversions between English and SI units is in accordance with NIST SP811, (3/2008 revision) Guide for the Use of the International system of Units (SI) for standardization and conversion of the units of measure.

3.2 GENERAL OPERATIONAL INTERFACE REQUIREMENTS

A wide variety of options are available for the integrated HDL/Cargo Configuration. The illustration below in Figure 3-2 Cargo Orientation Options provides three potential options: deck mounted cargo, underslung mounted cargo, and nose mounted cargo. In each of these configurations, the

cargo's field of view to deep space would be obstructed in different ways. These obstructions can hamper the cargo's ability to independently generate power, reject heat, communicate with Earth, and perform other necessary activities. Due to these potential obstructions, as well as the nominal stowed physical and operational configurations of the Cargo, the HDL will provide for some basic minimal services to the cargo.

Figure 3-2 Cargo Orientation Options

[HDL-CP-020] HDL-Cargo Physical Interfaces Disconnect
The HDL shall have physical interfaces with Cargo which are capable of being disconnected/severed from each other. If the HDL performs the active disconnect, the Cargo will accommodate it. If the Cargo performs the active disconnect, the HDL will accommodate it.

Rationale: The HDL, Cargo, or both HDL and Cargo will perform actions that enable offloading, e.g., crane or hoist, to allow for Cargo offloading and deployment. Offloaded Cargo will be limited by defined specific volume, total mass, and associated mass properties (i.e., center of gravity).

HDL-CP-102] Cargo-HDL Physical Interfaces Disconnect
The Cargo shall have physical interfaces with HDL which are capable of being disconnected/severed from each other. If the HDL performs the active disconnect, the Cargo will accommodate it. If the Cargo performs the active disconnect, the HDL will accommodate it.

Rationale: The HDL, Cargo, or both HDL and Cargo will perform actions that enable offloading, e.g., crane or hoist, to allow for Cargo offloading and deployment. Offloaded Cargo will be limited by defined specific volume, total mass, and associated mass properties (i.e., center of gravity).

[HDL-CP-021] Cargo Offloading - HDL
The HDL shall be capable of transferring Offloaded Cargo to the lunar surface.

Rationale: The HDL may perform actions that enable offloading, e.g., crane or hoist. Offloaded Cargo is limited by defined specific volume, total mass, and associated mass properties (i.e., center of gravity). NASA is responsible for determining landing zone for each mission and it is expected that mission specific considerations will be factored into that selection.

[HDL-CP-022] Cargo Offloading
If applicable, the Cargo shall be capable of being offloaded to the lunar surface.

Rationale: The Cargo may perform actions that enable offloading, e.g., driving down a ramp. Offloaded Cargo is limited by defined specific volume, total mass, and associated mass properties (i.e., center of gravity).

[HDL-CP-023] Cargo Transfer Time
The HDL shall limit cargo transit time from Earth launch through lunar touchdown to no greater than 210 days.

Rationale: Bound transit duration for lunar delivery. Allow for low energy transfer (~120-180 days) and refueling/aggregation ops/phasing loiter (~30 days).

3.3 STRUCTURAL/MECHANICAL INTERFACE REQUIREMENTS

[HDL-CP-032] Dynamic Launch and Landing Volumetric Envelope
The Cargo shall be contained within a dynamic volumetric envelope of either

1) a 6.35-meter (250 inch) diameter cylinder with an 8.8-meter (346.4 inch) height

   or

2) a 4.57-meter (179.9 inch) diameter cylinder with a 7.8-meter (307 inch) height.

Rationale: These envelopes dimensions represent ranges of expected cargo for the HDL delivery. This is inclusive of any cargo-unique adapters.

[HDL-CP-056] Launch and Landing Center of Mass
During launch and landing operations the HDL shall accommodate Cargo with a center of mass height located between 0 to 4.5 meters (0 to 177.1 inch) from the reference plane and +/- 0.25 meters (9.8 inch) off the centerline of the Volumetric Envelopes stated in HDL-CP-032.

Rationale: This bounds the design for the 15 t (33069.3 lbm) mass capability. The reference plane is between the HDL standard payload interface and the Cargo or Cargo specific interface adapter (if needed).

[HDL-CP-033] Cargo Mass
The Cargo shall not exceed 15 t, inclusive of any cargo-unique adapters.

Rationale: Cargo cannot exceed HDL performance capabilities.

[HDL-CP-034] Mechanical Mating
The HDL shall mechanically mate with the Cargo.

Rationale: The HDL will provide for standard physical attachment interfaces to Cargo throughout the life of the mission to the Lunar Surface. Mechanical mating ensures the Cargo remains stationary with no movement during launch, transit, and landing.

[HDL-CP-035] Cargo Mechanical Mating
The Cargo shall mechanically mate with the HDL.

Rationale: The Cargo will provide for standard physical attachment interfaces to HDL throughout the life of the mission to the Lunar Surface. Mechanical mating ensures the Cargo remains stationary with no movement during launch, transit, and landing.

[HDL-CP-036] MMOD Protection
The HDL provider shall limit Micrometeoroid and Orbital Debris (MMOD) risk to the cargo to a Probability of No Penetration (PNP) limit specified in the Cargo-specific ICD for the applicable mission environment.

Rationale: The Cargo has been designed to a mission profile launching directly from Earth to NRHO and is sized to an MMOD requirement corresponding to that profile. If alternate mission profiles (specifically those aggregating in higher MMOD risk areas like LEO) are chosen, additional integration with cargo providers will be necessary to find a solution addressing potential mass or operations impacts beyond those used to derive cargo targets [see HDL-S-R-0030].

[HDL-CP-037] Loaded Mass Accommodation
For Cargo that remains attached to the HDL post landing, the HDL shall maintain a stable configuration for a Cargo loaded mass up to 22 metric tons (48501.7 lbm).

Rationale: The HDL is responsible for structurally and mechanically supporting the Cargo + Cargo lander stack for the service life of the Lander. The loaded mass includes any additional mass added to the launched and landed Cargo.

3.4 ELECTRICAL INTERFACE REQUIREMENTS

[HDL-CP-040] HDL Electrical Power Interface
The HDL shall have the capability to provide the Cargo with at least 2 kW continuous power from launch to at least 2 days (48 hrs) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

Rationale: The cargo will need power from Earth launch to becoming self-sufficient on the lunar surface. Once the cargo is offloaded, the 2 days (48 hrs) gives the cargo some time to deploy and perform checkouts before becoming power independent. For mobile Cargo not offloaded directly to the lunar surface (i.e., offloaded while attached to a cargo adapter):

Demating from the cargo adapter may be conducted, either 1) after offloading before the 48 hours begins, or 2) after HDL is ready for Cargo to conduct post-offloading checkouts and prior to Cargo egress, if HDL design allows, per constraints identified in the HDL Integrated Analysis Document. Umbilical(s) providing power, thermal, and data support may be disconnected either 1) prior to Cargo egress or 2) after limited Cargo egress, if HDL design allows, per constraints identified in the HDL Integrated Analysis Document.

For cargo that is not offloaded from the HDL, the 2 days (48 hrs) begins after landing and post-landing reconfiguration is complete and the cargo can begin performing activations and checkout. Some checkouts and deployments may occur prior to offloading or landing complete. Those checkouts and deployments will be cargo specific and addressed in cargo specific Interface Control Documents.

[HDL-CP-041] Cargo Electrical Power Interface
The Cargo shall draw a maximum of 2 kW of continuous power from the HDL from launch to a maximum of 2 days (48 hrs) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

Rationale: The cargo will need power from Earth launch to becoming self-sufficient on the lunar surface. Once the cargo is offloaded, the 2 days (48 hrs) gives the cargo some time to deploy and perform checkouts before becoming power independent. For mobile Cargo not offloaded directly to the lunar surface (i.e., offloaded while attached to a payload adapter), readiness for post-offloading checkouts includes demating from the payload adapter after offloading before the 48 hours begins, and either 1) allowing Cargo egress to lunar surface while providing the 48 hours of support or 2) allowing all Cargo checkouts to be conducted prior to egress, including any required Cargo deployments (e.g., solar arrays, communications antenna) or 3) both 1 and 2. For cargo that is not offloaded from the HDL, the 2 days (48 hrs) begins after landing and post-landing reconfiguration is complete and the cargo can begin performing activations and checkout. Some checkouts and deployments may occur prior to offloading or landing complete. Those checkouts and deployments will be cargo specific and addressed in cargo specific Interface Control Documents.

[HDL-CP-042] HDL Power Quality
The HDL shall conform to the power interface defined in HEOMD-003-04, *International Space Power Systems Interoperability Standard (ISPSIS)*, Rev A for power provided at the HDL to Cargo Interface.

Rationale: The HDL Power System requires integrated criteria for compatibility with the Cargo.

[HDL-CP-043] Cargo Power Quality
The Cargo shall conform to the power interface defined in HEOMD-003-04, Rev A, for power provided at the HDL to Cargo Interface.

Rationale: The Power System requires integrated criteria for compatibility with the HDL Electrical Power System.

3.5 COMMAND AND DATA HANDLING INTERFACE REQUIREMENTS

[HDL-CP-052] HDL Data Interface
The HDL shall exchange data with Cargo via bi-directional communication link(s) from launch to at least 2 days (48 hrs) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

Rationale: The architecture supports direct data transfers between the HDL and the Cargo (including sending and receiving health & status and sending commands). For mobile Cargo

not offloaded directly to the lunar surface (i.e., offloaded while attached to a payload adapter), readiness for post-offloading checkouts includes demating from the payload adapter after offloading before the 48 hours begins, and either 1) allowing Cargo egress to lunar surface while providing the 48 hours of support or 2) allowing all Cargo checkouts to be conducted prior to egress, including any required Cargo deployments (e.g., solar arrays, communications antenna) or 3) both 1 and 2. This data interface may be via hardline, RF communication (low-rate and/or high-rate), Wi-Fi, and/or other.

[HDL-CP-053] Cargo Data Interface
The Cargo shall exchange data with HDL via bi-directional communication link(s).

Rationale: The architecture supports direct data transfer between the HDL and the Cargo (including sending and receiving health & status and receiving commands). This data interface may be via hardline, RF communication (low-rate and/or high-rate), Wi-Fi, and/or other.

[HDL-CP-054] HDL Command and Data Relay
Upon receipt from Mission Systems, the HDL shall have the capability to relay commands and data to the Cargo from launch to at least 2 days (48 hrs) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

Rationale: For mobile Cargo not offloaded directly to the lunar surface (i.e., offloaded while attached to a payload adapter), readiness for post-offloading checkouts includes demating from the payload adapter after offloading before the 48 hours begins, and either 1) allowing Cargo egress to lunar surface while providing the 48 hours of support or 2) allowing all Cargo checkouts to be conducted prior to egress, including any required Cargo deployments (e.g., solar arrays, communications antenna) or 3) both 1 and 2.

Based on the Applicability Matrix located in HLS-IRD-004-001 HLS Integrated Lander to Mission Systems IRD, HLS-MS-0002 is applicable to HDL and "Integrated Lander" and includes the Cargo and associated data and commands. The combination of HDL-CP-053 in HLS-IRD-010 and HLS-MS-0002 located in the HLS-IRD-004-001 HLS Integrated Lander to Mission Systems IRD requirements ensures the required HDL capability that, upon receipt of data from Cargo, the HDL will relay data from Cargo to the Earth, either Direct-with-Earth (DWE) or Relayed-with-Earth (RWE), from launch to at least 2 days (48 hours) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

[HDL-CP-055] Cargo Command and Data Relay
Upon receipt from Mission Systems to the HDL, the Cargo shall have the capability to receive relayed commands and data from the HDL.

Rationale: This communication link can be used as a relay between the Cargo and Earth to enable the cargo team to operate the cargo. The HDL transfers data to Earth, either Direct-with-Earth (DWE) or Relayed-with-Earth (RWE), as defined in the HLS-IRD-004-01, HLS to Mission Systems IRD – Sustaining Rev C.

[HDL-CP-103] IP Packet Formulation
The HDL shall use IP as specified in IPv4 (IETF-STD-0005, Internet Protocol, 7/29/2020) as a network layer on hardline connections with Cargo.

Rationale: IP provides for network layer services over interfaces that have a low delay (under 5 sec) and an expectation of real-time end-to-end connectivity. The use of IP allows for maximum leverage of terrestrial networking developments under appropriate circumstances. IPv4-based technology is widely available in the commercial market.

[HDL-CP-104] Cyber Security - Cargo
The Cargo shall be compatible with the cybersecurity of the HDL.

Rationale: The Cargo side of the interface needs to implement cybersecurity architecture that is compatible with HDL cybersecurity implementations.

[HDL-CP-105] Cyber Security - HDL
The HDL will provide a level of Information Technology (IT) security risk management to mitigate threats, vulnerabilities, and/or exposures consistent with the confidentiality, integrity, and availability of those resources.

Rationale: Rationale: Security must be managed to NASA expectations and industry standards to minimize risk to all mission systems facilities, HDL vehicle systems, and mission success. The HLS Program employs an NPR 2810.1, Rev F risk management approach to its information security. The HLS Program leverages NIST (800 series) and Federal Information Processing Standards-related standards (via HLS Contract Data Requirement Description (DRD), MA-011) as enumerated applicable documents within NPR 2810.1, Rev F. A unified approach to cyber security for the integrated system will be used by both programs. The HDL SRD, HLS-RQMT-007 Rev B, requirement HDL-S-R-0005 captures this requirement at the HDL level.

3.6 THERMAL CONTROL INTERFACE REQUIREMENTS

[HDL-CP-060] HDL Active Thermal Control
The HDL shall have the capability to provide the Cargo with active thermal control heat transport of at least 2 kW continuous power from launch to at least 2 days (48 hrs) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

Rationale: The Cargo may not be fully deployed or be capable of independently managing Cargo thermal conditions. Therefore, the HDL may be required to provide the Cargo with heat transport and rejection capability from Earth launch to becoming self-sufficient on the lunar surface. Once the cargo is offloaded, the 2 days (48 hrs) gives the cargo some time to deploy and perform checkouts before becoming thermal independent. For mobile Cargo not offloaded directly to the lunar surface (i.e., offloaded while attached to a payload adapter), readiness for post-offloading checkouts includes demating from the payload adapter after offloading before the 48 hours begins, and either 1) allowing Cargo egress to lunar surface while providing the 48 hours of support or 2) allowing all Cargo checkouts to be conducted prior to egress, including any required Cargo deployments (e.g., solar arrays, communications antenna) or 3) both 1 and 2. For cargo that is not offloaded from the HDL, the 2 days (48 hrs) begins after landing and post-landing reconfiguration is complete and the cargo can begin performing activations and checkout. This capability allows heat to be either provided to or received from the Cargo through the HDL active thermal interface.

Note: The active thermal control will be designed to dissipate at least 2 kw of heat from the cargo. Heat will be available through the active thermal control system to be provided to the cargo based on HDL design availability but is not required at a given heat rate.

[HDL-CP-061] Cargo Active Thermal Control
If applicable, the Cargo shall have the capability to receive active thermal control heat transport from the HDL of at least 2 kW continuous power from launch to a maximum of 2 days (48 hrs) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

Rationale: The Cargo may not be fully deployed or be capable of independently managing Cargo thermal conditions. Therefore, the HDL may be required to provide the Cargo with heat transport and rejection capability from Earth launch to becoming self-sufficient on the lunar surface. Once the cargo is offloaded, the 2 days (48 hrs) gives the cargo some time to deploy and perform checkouts before becoming thermal independent. For mobile Cargo not offloaded directly to the lunar surface (i.e., offloaded while attached to a payload adapter), readiness for post-offloading checkouts includes demating from the payload adapter after offloading before the 48 hours begins, and either 1) allowing Cargo egress to lunar surface while providing the 48 hours of support or 2) allowing all Cargo checkouts to be conducted prior to egress, including any required Cargo deployments (e.g., solar arrays, communications antenna) or 3) both 1 and 2. For cargo that is not offloaded from the HDL, the 2 days (48 hrs) begins after landing and post-landing reconfiguration is complete and the cargo can begin performing activations and checkout. This capability allows heat to be either provided to or received from the Cargo through the HDL active thermal interface.

[HDL-CP-062] HDL Passive Thermal Interface
The HDL shall be designed to provide an adiabatic attachment interface plane(s) between the HDL and Cargo from launch to at least 2 days (48 hrs) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

Rationale: Heat flux across the passive thermal interfaces (conductive and radiative) must be minimized to reduce impacts on both HDL and Cargo. For mobile Cargo not offloaded directly to the lunar surface (i.e., offloaded while attached to a payload adapter), readiness for post-offloading checkouts includes demating from the payload adapter after offloading before the 48 hours begins, and either 1) allowing Cargo egress to lunar surface while providing the 48 hours of support or 2) allowing all Cargo checkouts to be conducted prior to egress, including any required Cargo deployments (e.g., solar arrays, communications antenna) or 3) both 1 and 2.

[HDL-CP-063] Cargo Passive Thermal Interface
The Cargo shall be designed to provide an adiabatic interface plane(s) between the HDL and Cargo from launch to a maximum of 2 days (48 hrs) after HDL is in a state ready for Cargo to conduct its post-offloading (if applicable) checkouts.

Rationale: Heat flux across the passive thermal interfaces (conductive and radiative) must be minimized to reduce impacts on both HDL and Cargo. For mobile Cargo not offloaded directly to the lunar surface (i.e., offloaded while attached to a payload adapter), readiness for post-offloading checkouts includes demating from the payload adapter after offloading before the 48 hours begins, and either 1) allowing Cargo egress to lunar surface while providing the 48 hours of support or 2) allowing all Cargo checkouts to be conducted prior to egress, including

any required Cargo deployments (e.g., solar arrays, communications antenna) or 3) both 1 and 2.

3.7 ENVIRONMENTAL INTERFACE REQUIREMENTS

[HDL-CP-070] HDL Electromagnetic Compatibility
The HDL shall be electromagnetically compatible with Cargo at the interface as defined in HLS-STD-004 HLS Electromagnetic Environmental Effects (E3) Requirements Document, Rev A.

Rationale: To meet mission and performance requirements, the integrated HDL/Cargo configuration must be electromagnetically compatible. Alternate standards and specifications that are equivalent are acceptable.

[HDL-CP-071] Cargo Electromagnetic Compatibility
The Cargo shall be electromagnetically compatible with HDL at the interface as defined in HLS-STD-004, Rev A.

Rationale: To meet mission and performance requirements, the integrated HDL/Cargo configuration must be electromagnetically compatible. Alternate standards and specifications that are equivalent are acceptable.

[HDL-CP-072] Induced Environments
The Cargo shall operate nominally after exposure to induced environments.

Rationale: The induced environments will be characterized by the induced loads and heat flux at the interface, as well as debris on the Cargo during landing, and dust contamination on the Cargo sensitive surfaces such as seals, radiators, solar arrays, etc., during and after landing.

3.8 FIRE PROTECTION INTERFACE REQUIREMENTS

Not Applicable

3.9 HUMAN FACTORS INTERFACE REQUIREMENTS

[HDL-CP-090] HDL Crew Access
The HDL shall be capable of facilitating access for crew to cargo on or near the lander during crewed operations, as necessary.

Rationale: It is necessary to provide conditions where EVA crew will be able to access cargo, both physically and visually (e.g., lighting for illuminator and indication), either by the HDL providing the functions or enabling those functions to be performed by the cargo.

[HDL-CP-091] Cargo Crew Access
The Cargo shall be capable of facilitating access for crew to cargo on or near the lander during crewed operations, as necessary.

Rationale: It is necessary to provide conditions where EVA crew will be able to access cargo, both physically and visually (e.g., lighting for illuminator and indication), either by the Cargo providing the functions or enabling those functions to be performed by the HDL.

3.10 SAFETY REQUIREMENTS

[HDL-CP-100] Catastrophic Hazards
During mated operations between the HDL and the Cargo, the integrated configuration shall be a minimum of single fault tolerant to catastrophic hazards without the use of emergency operations or emergency systems.

Rationale: Neither HDL nor Cargo will diminish the other system's failure tolerance to catastrophic hazards. The integrated hazard analysis for these cases will be led by HDL and assessed jointly to identify and document the distribution of the hazard controls and verifications. Proposed exceptions from the failure tolerance requirements may be approved via the integrated hazard analysis review process.

[HDL-CP-101] Failure Propagation
During mated operations between HDL and the Cargo, a single failure of a component in a functional path shall not induce any other failures external to the failed component.

Rationale: The analysis of a component whose failure may propagate across an interface will not end at the interface with other systems/subsystems but will be analyzed across the interface to determine effects on the interfacing element and ultimately on the spacecraft. To address impacts to the integrated system, spacecraft, launch vehicle, etc., a safety analysis (ex: FMEA/CILs, hazard analysis) will be conducted to identify failure effects that could propagate to interfacing flight subsystems or elements spacecraft. See A2.0 Glossary of Terms for where to find Catastrophic and Critical Hazard definitions.

4.0 INTERFACE REQUIREMENTS VERIFICATION

Each interface requirement defined in Section 3 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 organization responsible for the design of the hardware 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 Organizations 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 Systems 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.

4.3 VERIFICATION STRATEGY

The verification methods of the "shall" statements for both sides of the interface are captured in Appendix C. These verification methods are recommendations and may be negotiated by the individual program's providers in conjunction with the NASA program offices on both sides of the interface. Verification methods for "should" statements are not included as "should" statements are not mandatory requirements. If a provider chooses to implement a "should" statement, the subsequent verification methods may be negotiated by that provider and the NASA program offices on both sides of the interface. Verification methods for "will" statements are not included as "will" statements are informational for the interface taken from requirements in, and verified through, other documents such as a System Requirements Document.

APPENDIX A
ACRONYMS AND ABBREVIATIONS AND GLOSSARY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

TABLE A-1 ACRONYMS AND ABBREVIATIONS

BIVP	Bilateral Integration and Verification Plan
CR	Change Request
DWE	Direct-with-Earth
EVA	Extravehicular Activity
FWD	Forward Work
HCB	HLS Control Board
HDL	Human-class Delivery Lander
HLS	Human Landing System
ICD	Interface Control Document
IFHX	Interface Heat Exchanger
ISPSIS	International Space Power Systems Interoperability Standard
IRD	Interface Requirements Document
kW	Kilowatt
MEIT	Multi-element Integration Test
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
OPR	Office of Primary Responsibility
PR	Pressurized Rover
RF	Radio Frequency
RQMT	Requirement
RWE	Relayed-with-Earth
SE&I	Systems Engineering and Integration
SH	Lunar Surface Habitat
SI	International System of Units
SIL	Systems Integration Laboratory
SRD	System Requirements Document
TBS	To Be Supplied
xEVA	Exploration Extravehicular Activity

A2.0 GLOSSARY OF TERMS

TABLE A-2 GLOSSARY OF TERMS

Term	Description
Catastrophic Hazard	See HLS-PLAN-003, Rev D Table 5.10-2 Hazard Severity Definitions
Critical Hazard	See HLS-PLAN-003, Rev D Table 5.10-2 Hazard Severity Definitions
Demating	For mobile Cargo, demating is the mechanical release of connections between Cargo and HDL, with the exception of power, thermal, and data umbilical connections.
Deployed	This term is used to describe any Cargo that transitions to an operational phase that is different from the launch, transport, and landing phase.
Deployed Integrated	This term describes Cargo that remains attached to the HDL in an operational phase once the HDL has settled into a stable post landing configuration.
Direct-with-Earth (DWE)	This term describes the RF communications interface that occurs directly between the HDL and Mission Systems.
Mission Systems	The end-to-end terrestrial based hardware and software infrastructure, whether owned or operated by NASA or the contractor, supporting mission operations from the point of Radio Frequency (RF) receipt/transmit at RF communications ground sites, through associated data processing and distribution infrastructure, transport networks, mission control center systems and facilities, interfaces between operations facilities, to the end user display/control systems and support infrastructure. Mission Systems include all associated hardware and software infrastructure supporting crew and flight controller training for operations, including but not limited to simulations, networks, mockups, and interfaces to support infrastructure.
Offloaded	This term describes Cargo that is transferred from the HDL to the Lunar Surface. Here are the four different states that are bundled in “Offloaded”: • Cargo Offloaded • HDL ready for Cargo to conduct post-offloading checkouts • Mobile Cargo egress • Demating
Relayed	This term is defined for commands and data exchanged with Mission Systems on behalf of the HDL to Mission Systems Interface but are manifested in command and data exchanges between the HDL and Cargo.

TABLE A-2 GLOSSARY OF TERMS

Term	Description
Relayed-with-Earth (RWE)	This term describes the RF communications interface that occurs between the HDL and Mission Systems but is accomplished through a communications relay network.
Stable Integrated Configuration	This term describes a continuous timeline after the HDL has landed on the lunar surface and ceased providing Cargo services but remains physically attached to Cargo for its operational lifespan.

APPENDIX B
OPEN WORK

B1.0 TO BE SPECIFIED

The Table B-1 lists the specific To Be Specified (TBS) items in the document that are not yet known. The TBS is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBS item is numbered based on the document number (i.e., **<TBS-xxxx-00x-001>** is the first undetermined item assigned in the document). As each TBS is resolved, the updated text is inserted in each place that the TBS appears in the document and the item is removed from this table. As new TBS items are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original TBSs will not be renumbered.

TABLE B-1 TO BE SPECIFIED ITEMS

TBS	Section	Description
N/A		

B2.0 FORWARD WORK

The Table B-2 lists the specific Forward Work (FWD) issues in the document that are not yet known. The FWD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The FWD issue is numbered based on the document number (i.e., **<FWD-xxxx-00x-001>** is the first forward work assigned in the document). As each FWD is resolved, the updated text is inserted in each place that the FWD appears in the document and the issue is removed from this table. As new FWD issues are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original FWDs will not be renumbered.

TABLE B-2 FORWARD WORK ITEMS

FWD	Section	Description
N/A		