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SUSTAINED PHASE HUMAN LANDING SYSTEM (HLS) CONCEPT OF OPERATIONS

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REVISION AND HISTORY PAGE

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1 INTRODUCTION

The sustained phase Human Landing System (HLS) Concept of Operations (ConOps) describes the HLS integrated lander mission concepts that will enable a sustained human lunar presence. The HLS integrated lander is a vehicular system that first transports crew essential logistics and mission support equipment from Earth to near-rectilinear halo orbit (NRHO). The HLS integrated lander then transports crew from Gateway in NRHO to the lunar surface, enables the crew to perform multiple Extravehicular Activity (EVA) events and access surface assets, and then safely returns the crew to Gateway for return to Earth (RTE). The HLS integrated lander also returns lunar samples and other equipment to NRHO to enable sample Return-to-Earth (RTE) for further scientific study.

1.1 PURPOSE

NPR 7123.1C Appendix A states that a ConOps "stimulates the development of the requirements and architecture related to the user elements of the system. It serves as the basis for subsequent definition documents." NPR 7123.1C also illustrates in Figure 3-1 SE Engine that SE Process 1 Stakeholder Expectations Definition feeds into SE Process 2 Technical Requirements Definition. One of the outputs of SE Process 1 is a ConOps, whereas requirements documents and interface requirement documents (IRDs) are an output of SE Process 2.

The primary purpose of this document is to define the concept of operations for the sustained phase of the NASA Artemis effort to establish a sustained human presence on the Moon. This document captures the top-level operational concept for how the HLS sustained phase service providers will be expected to participate in the broader NASA effort. This document is also used to define HLS mission phases and is intended to inform the functional analysis that provides the basis for HLS Program requirements.

The Design Reference Missions (DRMs) are included to describe the current understanding of mission types to be used in the sustained phase of lunar exploration. The DRMs establish an operational context, descriptions of situations that will be encountered during the selected mission types, and top-level operational sequences with a focus on interactions between the HLS integrated lander, non-HLS systems, and NASA crew. Also, the DRMs are intended to capture capabilities, rather than a manifest or specific mission plan. The DRMs are representative of currently known bounding cases.

1.2 SCOPE

The NASA Artemis effort encompasses two exploration campaign segments, the Human Lunar Return (initial) and Sustained Lunar Presence (sustained). This document defines the mission concepts for the early portions of the sustained campaign missions. It also identifies the potential functional interactions of the HLS integrated lander with Orion, Gateway, Extravehicular Activity (EVA) system, lunar surface systems, and NASA crew. The specific architecture/vehicle implementation of this ConOps will be provided in future documentation, as this represents only provider-agnostic information.

1.3 CHANGE AUTHORITY AND 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. The appropriate NASA Office of Primary Responsibility (OPR) identified for this document is HLS Systems Engineering & Integration Office.

1.4 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 1.4-1 APPLICABLE DOCUMENTS

DOCUMENT NUMBER	DOCUMENT TITLE
AES-50007	AES Concept of Operations
GP 10027	Gateway Concept of Operations
HEOMD-003 (ANNEXES 1-8)	Crewed Deep Space Systems Human Rating Certification Requirements and Standards for NASA Missions
HEOMD-007	HEOMD SCOPE
HEOMD-404	Artemis Base Camp Reference Mission
HLS-CONOP-008	HLS Sustaining Phase RF Communications Concept of Operations
HLS-PLAN-004	HLS Configuration and Data Management Plan
LTV-CONOP-001	Lunar Terrain Vehicle Concept of Operations

1.5 REFERENCE DOCUMENTS

The following documents contain supplemental information to guide the user in the application of this document. Requirements and IRDs are listed within the ConOps as reference documents because NPR 7123.1C Appendix A states that a ConOps "stimulates the development of the requirements and architecture related to the user elements of the system. It serves as the basis for subsequent definition documents."

TABLE 1.5-1 REFERENCE DOCUMENTS

Document Number	Document Title
AES-50002	AES Artemis Lunar Exploration Requirements
ESD 10012	ESD CONOPS
EVA-EXP-0042	Exploration EVA System Concept of Operations
EVA-EXP-0067	HLS - xEVA Interface Requirement Control Document

TABLE 1.5-1 REFERENCE DOCUMENTS

Document Number	Document Title
EVA-EXP-0070	HLS EVA Compatibility Interface Requirements Document (IRD)
EVA-EXP-0070-ANX-02	HLS EVA Compatibility IRD Annex - Integrated Lunar Sustained Phase
GP 10031-01	Gateway to Visiting Vehicle IRD, Annex 1: HLS Program Integrated Lander Requirements
GP 10045-01	Gateway to Visiting Vehicle RF IRD, Annex 1: HLS Program Integrated Lander Requirements
GP 10046-01	Gateway to Lunar Systems RF IRD, Annex 1: HLS Program Integrated Lander Requirements
GP 10164	Artemis Specification for the Rendezvous, Proximity Operations and Docking/Undocking (RPODU) Targets
HEOMD-003-01-08	Crewed Deep Space Systems Human Rating Certification Requirements and Standards for NASA Missions
HEOMD-006	Human Exploration and Operations (HEO) Utilization Plan
HLS-IRD-004-01	HLS Program Integrated Lander to Mission Systems IRD – Sustained Phase
HLS-PAP-008	Human Landing System (HLS) Landing Site Considerations for Sustained Phase Missions
HLS-PAP-014	Lunar Surface Standby Operations
HLS-PAP-018	Initial Evaluation of Non-Polar Access
HLS-PLAN-016	HLS Technical Management Plan
HLS-RQMT-006	HLS Program Integrated Lander Requirements Document – Sustained Phase
SPD-1	Space Policy Directive-1 Reinvigorating America's Human Space Exploration Program

2 SUMMARY

The HLS integrated lander is a vehicular system that enables the transport of logistics and mission support equipment from Earth to an Earth-Moon L^2 NRHO, which is oriented over the southern pole with a 9:2 synodic resonance with the Moon's orbit around Earth. The HLS integrated lander transports crew and cargo from Gateway in NRHO to the lunar surface, provides crew habitation and EVA support on the surface, and then safely returns crew and cargo to the Gateway for return to Earth. After the initial mission phase, the lunar campaign will evolve to the sustained phase for more ambitious surface missions. In the sustained phase, the HLS integrated lander will require the capability to dock to Gateway, land up to four crew members on the lunar surface for transfer to habitable lunar surface assets, operate for extended durations near the lunar south pole, and support eight-hour EVAs for the advancement of surface goals. Also, the agency has a goal of being able to perform two-crew sorties to non-polar landing sites.

3 DESIGN REFERENCE MISSIONS (DRM)

The DRMs contained in this section are intended to serve as the bounding mission cases that describe the top-level operational sequence that drives HLS system and mission design during the sustained phase of the Artemis lunar exploration campaign. There are currently two primary DRMs and one variant; any DRM variants are intended to be a representation of using the primary DRM established capabilities in different operational contexts and external environments. The overall Artemis mission architecture is generically represented in Figure 3.0 from Space Launch System (SLS) launch through Orion's NRHO departure; the shown three-element architecture is for reference only and represents one possible approach.

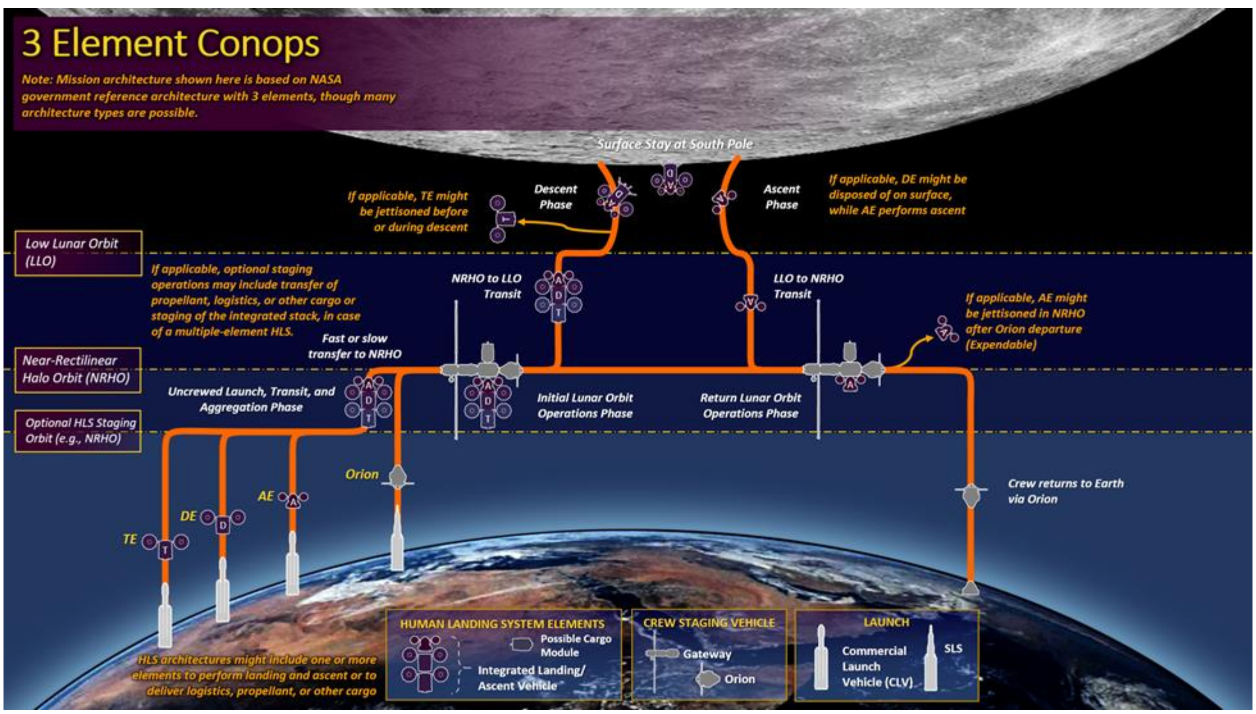

Figure 3-1 Sustained Phase Mission Architecture (Generic 3-Element Option)

The total set of capabilities needed for the campaign have been broken down into sets of capabilities, with each set being defined by a design reference mission. Table 3-1 provides a summary of the primary DRMs.

TABLE 3-1 OVERVIEW OF PRIMARY DRMS

	DRM-H-001 POLAR SORTIE	DRM-H-002 POLAR EXCURSION
CREW STAGING VEHICLE	Gateway	Gateway
SURFACE CREW SIZE	2	4
SURFACE STAY (DAYS)	6.25	33
LANDING LOCATION	South Pole	Artemis Base Camp
DARKNESS (HOURS)	0-40	120-230 (per period) 240-460 (total duration)
SURFACE HABITATION	HLS Integrated Lander	HLS Integrated Lander and Artemis Base Camp Elements
NUMBER OF EVAS	5 total: • 4 planned • 1 unplanned	2 total: • 1 full round-trip transfer by EVA • 1 unplanned

3.1 DRM-H-001 POLAR SORTIE MISSION

Figure 3-2 DRM-H-001 Polar Sortie Mission

DRM-H-001 is a sortie to the lunar south pole region with two crew members and a surface stay of up to 6.25 days. The HLS integrated lander element(s) will launch and be delivered uncrewed into NRHO. Once the HLS integrated lander element(s) are integrated in NRHO, the first part of the Lunar Orbit Checkout Review (LOCR) will be conducted, and the HLS integrated lander will dock to Gateway after a “GO” call is made. After docking, the second part of LOCR will be conducted to ensure the HLS integrated lander is healthy prior to crew launch on Orion. Once an "GO" call is made from LOCR, the Initial Uncrewed Docked Operations Phase begins. During this phase, the HLS integrated lander may remain docked to Gateway or undock and loiter separately to manage vehicle consumable constraints but must be successfully redocked prior to Orion arrival in NRHO.

Once Orion has arrived, it will deliver a co-manifested payload to Gateway as part of its arrival and Gateway docking activities. Co-manifested payload delivery and operations will be payload specific. Some of the payloads will be new Gateway modules that require some initial activation before preparation for the surface mission may begin. Also, some deliveries may require Orion to relocate to a different Gateway port upon successful co-manifested payload docking. These delivery operations could require an additional revolution in NRHO prior to beginning the surface mission, for a total initial docked operations time of approximately 1.5 revolutions, or 9-10 days. The HLS integrated lander will remain docked to Gateway during these operations.

The Initial Docked Operations (IDOPS) phase will begin when Orion has successfully docked to the port where it will be located for the remainder of the crewed NRHO mission, the hatches are opened to connect the two environments, and the crew has successfully ingressed into Gateway. IDOPS is focused on ensuring that the crew, HLS integrated lander, and EVA and intravehicular activity (IVA) suits are ready to perform the surface operations mission phase. The preparation activities will occur at Gateway, and Gateway will be responsible for delivery of some of the surface mission equipment via Deep Space Logistics (DSL). This equipment will then need to be transferred to the HLS integrated lander. The items delivered by DSL and the HLS integrated lander will be determined on a mission specific basis.

Once the crew, spacesuits, and any additional mass to be delivered to the surface (such as defined by HLS-RQMT-006) are in the HLS integrated lander and ready for the surface operations phase, then the HLS integrated lander will undock and back away from Gateway and descend to the lunar south pole. The total HLS integrated lander habitation capability for two crew members for DRM-H-001 and variants is required to be at least eight days from staging vehicle undocked to staging vehicle docked. The HLS integrated lander surface habitation (SH) duration will be driven by the mission-specific duration spent in descent and ascent, but this duration is expected to be approximately six days. While on the surface, the crew will perform multiple EVAs that begin and end in the HLS integrated lander to support utilization and exploration goals. The sustained phase HLS integrated lander design will have the capability to support up to five (four planned and one unplanned) EVAs per sortie with EVA durations lasting up to eight hours, as defined by HLS-RQMT-006, and the capability for an additional hour of contingency. The total number of conducted EVAs will be a function of achievable surface stay time and other operational considerations (to be determined by or negotiated with NASA). When the approximately six-day surface operations are completed, the HLS integrated lander will perform ascent to return the crew, samples, and selected equipment (such as defined by HLS-RQMT-006) to Gateway in NRHO.

Once in NRHO, the HLS integrated lander will rendezvous and dock to Gateway. The crew and lunar samples will be transferred to Orion for RTE. Excess trash will be transferred out of Orion to ensure that Orion does not exceed its Earth re-entry mass limit. At the end of the crewed phase of the mission, the hatches between Gateway and the HLS integrated lander will be closed. The HLS integrated lander will remain docked to Gateway until after Orion undocks and begins the RTE. If the provider chooses to dispose of the HLS integrated lander, this must be done safely after Orion has begun RTE and should be done in a way as to not interfere with the Gateway NRHO Reference Trajectory. The disposal must also meet all planetary protection requirements.

Alternatively, the provider may begin preparations for future HLS missions with the HLS integrated lander after Orion has begun RTE.

3.1.1 DRM-H-001B NON-POLAR SORTIE MISSION VARIANT

DRM-H-001b is a variant of DRM-H-001 and outlined in Figure 3-3 and Table 3-2 below. It is a two-crew surface sortie mission that will use the non-polar sortie capability to target a lunar landing at a location of scientific interest other than the lunar south pole. The Non-Polar Sortie missions could land at sites within a wide range of latitudes and are not restricted to solely the Earth-facing side, which requires the HLS integrated lander to be capable of operating in a wide range of surface thermal and solar angle environments.

Figure 3-3 DRM-H-001B Non-Polar Sortie Mission

TABLE 3-2 DRM-H-001 VARIANT

	DRM-H-001B NON-POLAR SORTIE
CREW STAGING VEHICLE	Gateway
SURFACE CREW SIZE	2
SURFACE STAY (DAYS)	2 (threshold) 6 (goal)
LANDING LOCATION	Non-Polar
DARKNESS (HOURS)	0-40
SURFACE HABITATION	HLS Integrated Lander
NUMBER OF EVAS	2 (threshold): • 1 planned • 1 unplanned 5 (goal): • 4 planned • 1 unplanned

Similar to DRM-H-001, this variant includes the HLS provider delivering manifested logistics and equipment from Earth to NRHO and using DSL to deliver some of the surface mission equipment. This equipment will need to be transferred to the HLS integrated lander. The items delivered by DSL will be determined on a mission-specific basis.

Because the overall capability of the vehicle should be determined by the primary DRM-H-001, transit and surface stay times for non-polar sorties will vary based on landing location. More detail on NRHO-based non-polar flight profile considerations may be found in HLS-PAP-018 Initial Evaluation of Non-Polar Access. While the overall HLS crewed mission duration is similar to DRM-H-001, the split between in-space operations time and surface operations time should be tailored to the orbital mechanics specific to the selected landing site and mission date. This tailoring will allow mission planners to balance surface exploration goals with HLS operational requirements. The surface stay duration will be no longer than six days but may be shorter (e.g., approximately two days as shown in Figure 3-3) if the HLS integrated lander spends more time in transit from NRHO or in low lunar orbit (LLO) loiter.

Like other sortie DRMs, the crew of two will live and work out of the HLS integrated lander during their surface stay and will perform multiple EVAs to support utilization and exploration goals. The total number of conducted EVAs will be a function of achievable surface stay time and other operational considerations (to be determined by or negotiated with NASA). Once the surface operations are complete, the HLS integrated lander will perform ascent to return the crew, selected equipment, samples, and any additional return mass (as defined by HLS-RQMT-006) to Gateway in NRHO.

Once in NRHO, the HLS integrated lander will rendezvous and dock to Gateway. The crew and lunar samples will be transferred to Orion for RTE. Excess trash will be transferred out of Orion to ensure that Orion does not exceed its Earth re-entry mass limit. Prior to Orion departure, the hatches between Gateway and the HLS integrated lander will be closed. If the provider chooses to dispose of the HLS integrated lander, this must be done safely after Orion has begun RTE and should be done in a way as to not interfere with Gateway. Alternatively, the provider may begin preparations for future HLS missions with the HLS integrated lander after Orion has begun RTE.

3.2 DRM-H-002 POLAR EXCURSION MISSION

Figure 3-4 DRM-H-002 Extended Surface Excursion Mission

DRM-H-002 is an extended surface excursion mission that will leverage pre-placed assets at the lunar south pole to support four crew for a longer duration surface mission of up to 33 days. The HLS integrated lander will deliver mass from Earth to NRHO that includes all or part of the total manifested mission logistics and equipment, as defined by HLS-RQMT-006.

The HLS integrated lander element(s) will launch and be delivered uncrewed into NRHO. Once the HLS integrated lander element(s) are integrated in NRHO, the first part of the Lunar Orbit Checkout Review (LOCR) will be conducted, and the HLS integrated lander will dock to Gateway after a “GO” call is made. After docking, the second part of LOCR will be conducted to ensure the HLS lander is healthy prior to crew launch on Orion. Once an “GO” call is made from LOCR, the Initial Uncrewed Docked Operations Phase begins. During this phase, the HLS integrated lander may remain docked to Gateway or undock and loiter separately to manage vehicle consumable constraints but must be successfully redocked prior to Orion arrival in NRHO.

After Orion inserts into NRHO, it will dock to Gateway for preparation for the extended lunar surface operations phase. During some missions, Orion will be delivering a co-manifested payload to Gateway as part of its arrival activities. Each co-manifested payload will have module-specific delivery and initial operations that need to occur prior to beginning preparation for the surface mission. Delivery of some co-manifested payloads may require Orion relocating to a different Gateway port upon successful co-manifested payload docking. The HLS integrated lander will remain docked to Gateway during these operations.

The IDOPS phase will begin when Orion has successfully docked to the port where it will be located for the remainder of the crewed NRHO mission, the hatches are opened to connect the two environments, and the crew has successfully ingressed into Gateway. IDOPS is focused on ensuring that the crew, HLS integrated lander, and EVA and IVA suits are ready to perform the surface operations mission phase. Part of the preparation activities for DRM-H-002 are preparing Gateway to be uncrewed for approximately 35 days. Gateway is responsible for delivery of the surface mission equipment via the DSL. The items delivered by DSL will be determined on a mission-specific basis. DSL cargo might be transferred to the HLS integrated lander. These additional operations may require an additional NRHO revolution of integrated stack operations prior to the surface excursion.

Once all vehicles have been properly prepared and crew and supplies are ready for the surface operations, the HLS integrated lander will undock from Gateway and descend to the Artemis Base Camp at the lunar south pole with four crew on board. The total HLS integrated lander habitation capability for four crew for DRM-H-002 is required to be at least eight days.

Once on the lunar surface, the crew will prepare to perform transfers to other pre-placed habitable elements at the Artemis Base Camp (ABC) to live in for the duration of their surface stay. The HLS integrated lander will need the capability to provide 5 days of crewed surface habitation time for this DRM, split between pre- and post-transfer activities. The crew will then transfer from the HLS integrated lander to the habitable surface element(s) where they will live and work for the remainder of the excursion. The sustained missions will have the capability to perform EVAs for a max duration of eight hours, plus an additional hour allocated as contingency. This will facilitate the transfer to surface elements and advancement of surface goals.

Once the crew has transferred to the surface elements, the HLS provider may choose to operate their vehicles in standby mode. Standby mode is a state in which the HLS integrated lander is not the source of crew life support and is not in the critical path for dynamic surface activities such as EVA, rover expeditions, etc., but it remains the crew's lifeboat in some off-nominal and early mission termination scenarios. The HLS integrated lander standby mode may be leveraged to reduce power use, consumables use, etc., and the minimum vehicle functions that should still be present are defined in HLS-PAP-014 Lunar Surface Standby Operations. The HLS integrated lander will be capable of maintaining communication with prepositioned surface assets. During any part of the surface operations phase, the HLS integrated lander will be required to survive periods of both prolonged, continuous, and intermittent darkness due to surface feature shadowing. Additionally, due to the length of the surface stay, the sun may travel 360 degrees around the HLS integrated lander, changing solar angles and shadowing. At the end of the surface operations phase, the crew will transfer to the HLS integrated lander and prepare the HLS integrated lander for departure from the lunar surface.

Once the surface operations phase has been completed, the HLS integrated lander will perform ascent to return the crew, utilization equipment, Government-Furnished Property (GFP), and samples to Gateway in NRHO. Once in NRHO, the HLS integrated lander will rendezvous and return docked operations will begin. When the vehicle has safely docked, lunar samples, any return cargo, and crew will be transferred to Orion for RTE. Excess trash will be transferred out of Orion to ensure that Orion does not exceed its Earth re-entry mass limit. At the end of the crewed portion of the HLS mission, the hatches between Gateway and the HLS integrated lander will be closed. The HLS integrated lander will remain docked until after Orion undocks and departs for Earth. The HLS integrated lander may then undock or remain docked to Gateway and prepare for future missions with the HLS integrated lander or dispose of itself as necessary.

4 MISSION PHASES

This section describes and defines each HLS mission phase when utilizing Gateway and serves as the program reference for mission phase nomenclature. For purposes of simplification, this document will refer to DRM-H-001 and DRM-H-001b as the sortie missions, and DRM-H-002 as the surface excursion missions. This section will indicate where the mission types differ.

HLS DRMs are decomposed into the following mission phases, that are defined further in subsequent subsections:

- Uncrewed Launch, Transit, and Aggregation
- Initial Lunar Orbit Operations
- Descent
- Surface Operations
- Ascent
- Return Lunar Orbit Operations
- Post-Mission Operations

4.1 UNCREWED LAUNCH, TRANSIT, AND AGGREGATION

4.1.1 HLS LAUNCH TO NRHO INSERTION

For each HLS mission, the HLS provider will safely deliver a fully certified HLS integrated lander along with mission logistics and supplies to NRHO. The transit profile from Earth to NRHO will be selected by the HLS provider.

The HLS integrated lander, logistics, and supplies may be launched in any configuration that safely delivers the vehicle, equipment, and supplies to NRHO. For instance, the HLS integrated lander may be launched using a distributed launch concept with separate elements launched individually or using a single integrated launch. Definition of specific launch concepts will be provided in the HLS provider's ConOps document.

There are multiple trajectory options for delivery to the lunar vicinity. Ballistic lunar transfers, which may range up to 120 days or longer, reduce the delta-V required for insertion into NRHO. Fast transits can reach lunar orbit in a few days but require a higher delta-V insertion to the final orbit. Ultimately, the trajectory selected must balance the design considerations for the HLS integrated lander with the mission requirements and must support the overall Artemis Mission Schedule as defined by the AES manifest. Definition of specific transit concepts will be provided in the HLS provider's ConOps document.

4.2 INITIAL LUNAR ORBIT OPERATIONS

Initial Lunar Orbit Operations are defined as the phase of the mission during which the HLS integrated lander is in NRHO, prior to the NRHO departure burn (NRD) that begins descent. The primary focus of this mission phase is to prepare for execution of a sortie or excursion prior to crewed descent to the surface. The amount of time that is required between Orion insertion into NRHO and crew departure to the surface is constrained by the end-to-end mission design and crew preparation activities and has a direct effect on mission availability. Therefore, the duration of initial lunar orbit operations will be constrained by the need to minimize the duration of this phase to enable maximum mission availability, and the need to have sufficient time to complete all lunar mission preparation activities.

Initial Lunar Orbit Operations consists of the following mission phases:

- Initial Loiter (ILTR)
- Initial Rendezvous, Proximity Operations, and Docking (IRPOD)
- Initial Docked Operations (IDOPS)
- HLS Undock and Backaway (HU&B)

4.2.1 INITIAL LOITER

The ILTR mission phase begins when the HLS integrated lander is inserted into NRHO, and it ends with the successful completion of the LOCR (both parts) when the integrated lander is docked to Gateway. The purpose of the LOCR is to ensure that the HLS integrated lander is fully assembled, loaded with consumables, and has completed a successful functional checkout and docking prior to crew launch onboard Orion via the SLS. For distributed launch architectures, the HLS integrated lander assembly will be completed prior to initiation of the LOCR and crew launch. If significant launch slips occur, HLS provider may choose to undock from Gateway, loiter nearby, and then redock to Gateway prior to Orion arrival. If the HLS integrated lander undocks from Gateway during this phase, the mission will revert to ILTR mode of operation and flight rules. After LOCR (both parts), the HLS integrated lander is expected to be able to remain docked to Gateway or loiter undocked for up to 90 days to enable multiple crewed launch opportunities for a given mission. This duration includes the transit duration of Orion from Earth to the Moon.

During uncrewed operations, any HLS integrated lander element operating in the lunar vicinity will do so using ground-based command and control and/or a combination of automation and/or autonomy. The design must consider communications latency when Mission Control is in the operational command and control and/or decision loop in order to support planned and unplanned operation scenarios. This does not imply any requirements on ground-based control versus autonomous operations.

4.2.2 INITIAL RENDEZVOUS, PROXIMITY OPERATIONS, & DOCKING (IRPOD)

Information on the RPOD sequences will be vehicle specific, and therefore provided in the HLS provider ConOps documents.

IRPOD will follow a standard RPOD sequence for the HLS integrated lander, serving as the chaser vehicle, and Gateway, serving as the target vehicle. IRPOD begins with a rendezvous phase, followed by proximity operations, soft capture, and hard capture. Proximity operations begin when the HLS integrated lander acquires the Gateway docking axis. For Gateway missions, the HLS integrated lander docking approach procedures will be governed by GP 10031-01 Gateway to Visiting Vehicle Interface Requirement Document Annex 1: Human Landing System Requirements. This procedure will be a remote or autonomous docking operation of an uncrewed HLS integrated lander with an uncrewed Gateway for DRM-H-001, DRM-H-001b, and DRM-H-002.

Using the Gateway visiting vehicle (VV) link, the Gateway transceiver operates in Point B mode and provides range and range rate data to the approaching HLS integrated lander transceiver operating in Point A. If the HLS provider implements a Point B transceiver, then the HLS integrated lander will generate its own solution.

The HLS integrated lander will provide a docking mechanism, either integrated with the vehicle or as part of an Active-Active Docking Adapter (AADA) which will be compatible with Gateway's passive docking mechanism. In addition, for Gateway missions, the HLS integrated lander must have the ability to dock to Orion in a contingency case for in-flight crew rescue, which requires a docking mechanism compatible with Orion's active docking mechanism. The HLS integrated lander may require an Active-Active Docking Adapter (AADA) or an androgynous docking adapter for docking to Gateway. This docking adapter may be disposed of at end of mission if a subsequent HLS mission does not require its use (this will be a NASA decision).

4.2.3 INITIAL UNCREWED DOCKED OPERATIONS

The primary objective of the Initial Uncrewed Docked Operations mission phase is the completion of LOCR (second part) and prepare for the crewed Orion launch. During this phase, the HLS integrated lander will send vehicle health and status data to the Gateway vehicle and ground personnel. This phase begins when the HLS integrated lander successfully docks to Gateway. The phase ends either when the HLS integrated lander undocks and backs away from the Gateway, or when Orion successfully docks to Gateway, where it will remain for the crewed mission.

4.2.4 INITIAL CREWED DOCKED OPERATIONS (IDOPS)

The primary objective of the IDOPS mission phase is to enable the crew to depart for the lunar surface safely and efficiently. All HLS integrated lander operations that occur during this time should be designed to expedite the departure process.

The IDOPS phase will begin when Orion has successfully docked to the port where it will be located for the remainder of the crewed NRHO mission, the hatches are opened to connect the two environments, and the crew has successfully ingressed into Gateway. IDOPS ends at the HLS integrated lander undocking for descent to the lunar surface. Prior to the hatch opening, Orion will adjust its pressure to match shared atmospheric standards. If the Orion has excess gas, it may be used to assist in vestibule pressurization, but Gateway has the primary function. Similarly, the HLS-Gateway vestibule will be pressurized by the Gateway. The Gateway Vehicle System Manager (VSM) will command Gateway modules to set the proper cabin conditions/set-point. The HLS integrated lander will be commanded by Gateway VSM or ground personnel to set the proper cabin conditions/set-point. If the Gateway pressure is higher than the HLS integrated lander maximum design pressure (MDP), the HLS integrated lander must provide its own automatic pressure relief system. Once pressure equalization has been achieved, the hatches can be opened, and the crew will begin the initial ingress into Gateway. The crew will also open the hatch to the HLS integrated lander after sufficient local and remote checkouts have been performed. This includes the cabin atmosphere and constituents. Intermodule Ventilation (IMV) ducting will be installed to establish the shared environment. HLS integrated lander will provide the IMV ducting hardware that will be installed across the hatch interface (i.e., a drag-through duct) and Gateway will provide the fan/circulation through the ducting.

When docked to Gateway, Orion will require a tail-to-Sun orientation to maintain proper thermal and power profiles and this, in addition to port assignment, will determine the attitude of the integrated vehicle stack (Gateway, HLS, and Orion) during IDOPS. When the HLS integrated lander is docked to Gateway, if the HLS integrated lander mass is under 45 metric tons, Gateway will provide stack control. If the HLS integrated lander mass is above 45 metric tons, the HLS integrated lander will provide attitude control and orbital maintenance; Gateway will be responsible for position determination and will send an impulse request to the HLS integrated lander which will then perform the appropriate burn or maneuver needed. Gateway will provide atmosphere control during open hatch operations including pressure control and air revitalization. Stack control constraints are covered in GP 10031-01 Gateway to Visiting Vehicle Interface Requirements Document Annex 1: Human Landing System Integrated Lander Requirements.

The IDOPS phase may require multiple crew days, and thus the crew will require exercise, nutrition, and sleep during this mission phase. Exercise, nutrition, and waste management system functions will be provided by Gateway during IDOPS.

4.2.4.1 SHARED HABITABLE ENVIRONMENT

When the HLS integrated lander is docked directly to Gateway in an open-hatch configuration, Gateway will provide air revitalization and pressure control (consumables, air scrubbing) for the Gateway and HLS integrated lander habitable volumes. However, the HLS integrated lander is still responsible for performing air circulation within the HLS integrated lander volume. All Environmental Control and Life Support System (ECLSS) functionality between Gateway and HLS integrated lander is covered in the GP 10031-01 Gateway to Visiting Vehicle Interface Requirement Document Annex 1: Human Landing System Integrated Lander Requirements. A joint strategy between HLS, Gateway, and Orion programs will be developed and implemented to ensure low lunar dust levels in the combined habitable volume. Exercise and Waste Management System functions will be provided by Gateway during IDOPS.

4.2.4.2 SORTIE AND EXCURSION DEPARTURE PREPARATIONS

Before the crew can depart the NRHO for the lunar surface, a series of preparation activities must occur. These activities include, but are not limited to, those described in the following sections.

4.2.4.3 INITIAL INGRESS

Gateway initial ingress will be the first time the crew will enter the Gateway after either Gateway's initial deployment or after a long uninhabited period. The initial ingress for Gateway will be conducted according to preestablished protocols that ensure the safety of the crew and will allow the crew to perform a checkout prior to proceeding to other operations. The checkout and procedures will follow GP-10027 Gateway ConOps. For some missions, ingress into a co-manifested payload located between Orion and Gateway may have to occur prior to ingress into the pre-deployed portions of Gateway.

HLS integrated lander initial ingress will be the first time the crew will enter the HLS integrated lander after successful completion of Orion's RPOD with Gateway. The initial ingress into the HLS integrated lander will be conducted according to preestablished protocols that ensure the safety of the crew and will allow the crew to perform a checkout prior to proceeding to other operations.

4.2.4.4 SUIT PREPARATION AND CHECKOUT

An important part of the mission preparation process will be ensuring that suits are ready for a sortie or excursion, and any suit to be used will undergo a thorough checkout and preparation process. Suit assembly, fit check, and suit checkout will occur on the HLS integrated lander prior to departure. All vehicle interfaces required for suit checkout will need to be accessible and active during this portion of the IDOPS. Once checkouts are completed, the EVA suits will need to be stowed for descent to the surface, and IVA suits will need to be ready for use during the descent and ascent phases.

4.2.4.5 HLS LOGISTICS AND SUPPLY PREPARATION

The HLS integrated lander may require crew activity to transition between on-orbit mode and surface mission mode. The scope of this activity will be unique to each vehicle architecture. This may include activities such as preliminary vehicle checkout (separate from the final pre-departure checkout) activation of cabin and crew support equipment, or cabin reconfiguration. All such activities must be completed prior to vehicle departure, and the total time required for such activities should be minimized to help enable overall Artemis mission availability.

Depending on vehicle design, some items may need to be reconfigured or relocated from their launch configuration to an IDOPS and/or the sortie/excursion configuration prior to departure. Some utilization equipment may be launched on DSL and will need to be transferred to the HLS integrated lander. To keep track of this inventory, a NASA and/or provider Inventory Management System will be utilized. The use of this system will help ensure that inventory will remain in the appropriate vehicle or be transferred to the appropriate vehicle.

The EVA suits to be used on the mission may be launched hard-mounted to the HLS integrated lander or in government-provided launch enclosures (soft-stowed). The launch enclosures may be stowed in the Gateway prior to departure for the lunar surface.

A small amount of individual crew supplies might be launched with the crew on Orion and then transferred to the HLS integrated lander, such as the individual crew HLS Medical Accessories Kit (HMAK).

4.2.4.6 FINAL INGRESS AND DEPARTURE CHECKOUT

The specific sequence of final ingress and departure checkout activities will depend on the architecture and design provided by each HLS provider and will be worked into the final ingress timeline and procedures. The HLS integrated lander and the Gateway will be prepared for undock by removing hatch impediments, such as the IMV, and hardware located in the vestibule. For all architectures, prior to ending IDOPS and initiating undock and backaway, the crew must be fully suited in their IVA suits that will be used for lunar descent and landing, and the vehicle must pass all checkouts as required by flight rules.

Once the HLS integrated lander lunar surface crew are fully suited in IVA suits and in the HLS integrated lander with the hatch closed, a final system checkout will be performed in conjunction with Mission Control to ensure that the HLS integrated lander is ready for departure and initiation of a sortie or excursion. The crew in IVA suits must have their umbilical connections fully mated and checked out prior to departure, as required. Crew not participating in the lunar sortie or excursion will remain aboard the Gateway.

Lunar saturation operations at reduced pressure environment will be used to reduce prebreathe duration prior to EVA. The crew may have to begin their desaturation operations prior to departing for the lunar surface to achieve the shortest prebreathe duration. If a certain assumed desaturation time is not achieved prior to the first EVA, then prebreathe duration for the first EVA will be somewhat longer.

4.2.5 INITIAL UNDOCK & BACKAWAY (IU&B)

IU&B begins after successful departure checkout and ends at NRHO departure burn. Once final checkout has been completed, an Authority to Proceed (ATP) decision to begin IU&B, based on mission criteria to be established in flight rules, will be made by Mission Control. Upon a “Go” call for the HLS integrated lander departure, initial separation and backaway will be performed. The crew onboard the HLS Integrated lander will be suited in pressure suits during this phase through completion of the HLS integrated lander’s NRHO departure burn using restraints as required to operate the HLS integrated lander.

The integrated Gateway and HLS integrated lander stack will maneuver to the specified undock attitude, Gateway will inhibit reaction control system (RCS) firings while maintaining attitude control, and the S-Band Proximity Communications Link (for Orion) or the S-band Gateway to Visiting Vehicle (VV) Link (for Gateway) will be re-established.

This separation will occur at the AADA and HLS integrated lander interface or the direct HLS integrated lander interface with Gateway. After the separation, the Gateway will re-establish attitude control when the HLS integrated lander reaches a distance that provides adequate structural separation and limits HLS integrated lander plume-impingement loads on the Gateway. A series of small backaway burns to increase the separation between the two vehicles to a safe distance will then be performed.

4.3 DESCENT

The descent segment of the mission begins with the HLS integrated lander NRD and ends with the HLS integrated lander safely touching down on the lunar surface. The descent phase consists of NRD, descent transit to LLO, descent phasing orbit loiter, and final descent. The HLS provider is responsible for determining the descent profile specific to their HLS integrated lander. DRM-H-001b may require the HLS integrated lander to start descent operations earlier in the NRHO to get the proper alignment for the descent trajectory. Regardless of profile, the crew onboard the HLS integrated lander will remain suited until NRD is complete and will don suits again for the final descent. Other suited periods may be required during descent based on the energy and risk level of the specific dynamic event. Crew are not required to nominally don or doff suits simultaneously, but the capability for unassisted simultaneous don/doff is required for contingency scenarios where crew need protection from a compromised cabin.

4.3.1 NRHO DEPARTURE BURN (NRD)

The HLS integrated lander will perform a propulsive maneuver(s) (the NRD) to initiate departure of NRHO at the end of backaway. The timing and magnitude of this maneuver will depend on the architecture provided by each HLS provider and the intended surface destination.

4.3.2 DESCENT TRANSIT

Transits from the NRHO to either a phasing orbit or the initiation of the final descent trajectory vary in both duration and energy required. Transits between NRHO and a phasing orbit or final descent for all variations of the surface mission are expected to be at least 12 hours in duration. The length of this transit means that the crew will likely require a rest period during the transit to have adequate performance capability to execute final descent. Nominally, the transit rest period would include nutrition, sleep, and biological waste elimination, and therefore vehicle intervention from the crew during this period should be minimal.

4.3.3 DESCENT PHASING ORBIT LOITER

A loiter in LLO may be needed for crew preparation for descent and/or navigation state updates to reduce error after the descent lunar orbit insertion (DLOI) burn. At this time the crew is expected to don IVA suits and perform final vehicle checkouts prior to initiating final descent. The provider may choose both the profile of and time spent in a phasing orbit based on the needs of their specific HLS integrated lander architecture. One possible solution to reach non-polar landing sites is to loiter longer in LLO. This may require additional delta-V for station keeping and will be provider design-specific.

4.3.4 FINAL DESCENT

For final descent, the crew will wear an IVA suit using restraints as required to operate the HLS integrated lander. The descent from the phasing orbit to the lunar surface will typically consist of four distinct sub-phases. A descent orbit insertion (DOI) burn will place the HLS integrated lander in an orbit with a perilune sufficiently low to perform powered descent initiation (PDI). The PDI and braking phase will slow the HLS integrated lander into a surface-intercepting trajectory and arrest the HLS integrated lander to a sufficiently low altitude to begin the approach phase. The approach segment typically consists of a pitch maneuver to allow for crew viewing of the landing site. The terminal descent and touchdown segment consists of the final vertical descent to the surface, achieving the desired velocity/attitude state for touchdown. The duration and profile of these phases will vary with descent trajectory design. The HLS integrated lander will perform precision navigation to achieve a safe landing within a 50-meter radius of the target site. Details of hazard detection operations will be vehicle specific.

The HLS integrated lander will have the capability to land automatically without crew on board. For crewed landings that capability remains but will also provide capability for manual control. In instances where the crew takes over the landing function, the HLS integrated lander may still use automated functions such as embedded stabilization and feedback loops. These will reduce crew workload and improve handling qualities. Crew manual control does not imply direct control of individual thrusters, etc. Manual control represents a blended control mode between the crewmember making the needed adjustments while the vehicle continues to support with some, if not most, of its automated functions. These capabilities will be defined as part of the operationally pre-determined flight scenarios governed by flight rules.

For DRM-H-002, several HLS integrated landers will be delivered to the same base camp location. Cargo elements will be delivered prior to crewed missions. Flight trajectories for the Approach, Terminal Descent, and Touchdown Phase will avoid overflight/damage to preplaced assets.

4.3.5 DESCENT ABORT

If an abort is required as a response to a problem experienced during any portion of descent per flight rules and abort region definitions pre-determined by NASA, the HLS integrated lander will safely return the crew to Gateway.

4.4 SURFACE OPERATIONS

For both sortie and excursion missions, immediately following lunar surface touchdown, the HLS integrated lander and crew, in coordination with Mission Control, will determine ATP with the surface operations phase. This includes identifying the health and status of the lunar surface systems and, if necessary, commanding the lunar surface systems transition to operational modes. Following ATP, the HLS integrated lander and crew will begin surface stay preparations. This phase includes vehicle safing and cabin reconfiguration. Vehicle safing is the process that transitions the HLS integrated lander from descent mode to a safe surface mode. Cabin reconfiguration will consist of transitioning the vehicle between microgravity and lunar gravity configurations, stowage reconfiguration, and any other activities required to create lunar gravity living and working arrangements. The crew will doff and store the IVA suits used for descent at this time. Surface stay preparations will ensure that the HLS integrated lander will be ready to perform ascent operations at the end of the surface stay, whether that is for a planned ascent or an unplanned early mission termination. Please refer to EVA-EXP-0042 Exploration EVA System Concept of Operations for more details about EVA surface operations and dust mitigation.

The DRM surface stay times are based off the 6.5-day NRHO orbit. The timelines will vary depending on transit and/or LLO loiter durations and the provider's delta-V capability. For example, the DRM-H-001b Non-Polar Sortie surface stay time may vary depending on if extra time is spent in transit and/or LLO loiter to align with landing site trajectory and will be provider design-specific.

The HLS integrated lander will provide crew support functions while the crew live in, and operate out of, the HLS integrated lander. This includes providing life support, consumables, enabling surface access for EVA, supporting EVAs, and transfer to the surface assets. The HLS integrated lander will also provide functions to support utilization in the cabin environment, including but not limited to human research, biological research, and physical sciences research. Utilization support functions include power, stowage, laptop/tablet computing, and network access for payloads. In establishing a surface stay time for any mission profile, the priority is optimizing the number, productivity, and duration of EVAs. The HLS integrated lander will be power independent and provide communication functionality during all portions of the surface mission.

The lunar landing site may be reused; the HLS integrated lander should not impede future potential landing missions. HLS-PAP-008 addresses traffic management considerations.

4.4.1 SORTIE MISSIONS

For the sortie missions, two crew members will be transported to the lunar surface by the HLS integrated lander, and two will remain aboard Gateway in NRHO. These lander-based EVAs will allow EVA crew to return to the HLS integrated lander at any time during an EVA to stow samples or EVA hardware. Crew should also be able to return and reconnect to their umbilical at any time.

4.4.2 EXTENDED SURFACE EXCURSION MISSIONS

For the excursion missions, all four crew will be transported to the lunar surface by the HLS integrated lander, and Gateway will be left in the uncrewed state. After landing on the surface and all required checks and preparations are completed, the HLS integrated lander will be left in an uninhabited state for approximately 30 days while the crew performs most surface operations using lunar surface assets such as the Lunar Terrain Vehicle (LTV), Pressurized Rover (PR), and Surface Habitat (SH).

4.4.3 EVA

The purpose of the HLS lunar surface missions is to conduct utilization activities and exploration of the Moon’s surface through EVA. A standard EVA operation will consist of pre-EVA preparations, EVA, and post-EVA operations. The number and duration of EVAs performed on a single mission are dependent upon vehicle capabilities, surface stay duration, and the activities that occur outside of EVA such as pre/post EVA operations, nutrition, hygiene, and sleep. As one of the main objectives of any sortie or excursion is to perform surface science, these activities and operations will be tightly integrated both in development and in implementation to maximize the amount of time available during the crew day to perform an EVA.

4.4.3.1 PRE-EVA PREPARATIONS

Preparation for surface EVAs will include procedure review, suit checkout, suit donning, and any other activities required to maximize crew safety while operating outside of the HLS integrated lander vehicle. During pre-EVA preparations, the vehicle will provide power, audio/data communications, suit loop ventilation, vacuum access (carbon dioxide removal), high-pressure oxygen, and cooling water to the suit. An oxygen-rich prebreathe is required to achieve further body tissue nitrogen desaturation for operating in the atmosphere provided by the suit and to reduce the likelihood of decompression sickness. The duration of prebreathe is determined by many factors, including the atmospheric pressure and gas composition chosen for the HLS integrated lander crew cabin. The crew may have to begin their desaturation operations prior to departing for the lunar surface to achieve the shortest prebreathe duration. After donning the EVA suits, the gas within the suit will be purged to remove nitrogen from the internal suit volume. Final prebreathe will follow purge and following prebreathe, nominal EVA tasks will be performed.

Once prebreathe has finished, the depress/repress volume of the HLS integrated lander will be depressurized. The depress/repress volume is defined as the volume within the HLS integrated lander that is depressurized and repressurized, respectively, to allow the crew to exit and enter the HLS integrated lander. This volume may be a separate volume such as an airlock or may be the crew cabin itself. Once the depress/repress volume has been fully depressurized, the crew will open the exterior hatch, unhook from umbilicals, and proceed to the lunar surface, bringing with them any necessary tools/hardware to the surface.

4.4.3.2 PERFORMING AN EVA

The crew will translate to and from the surface by a mechanism such as a ladder, mechanically lowered platform, or any other design that is compatible with the crew safety, EVA suit, HLS integrated lander design, and mission objectives.

The science and utilization plan for EVA are in formulation and will increase in maturity over time. Those plans are expected to include general scouting and exploration enhanced by introduction of surface mobility rovers (such as Lunar Terrain Vehicle); surveying and reconnaissance; geologic observations, descriptions, imagery, and corresponding communications with science support teams; sampling including rocks, regolith, volatiles, and subsurface drilling; possible deployment of handheld and surface deployable payloads; etc. For DRM-H-001, assuming no rover, EVA crew are currently planned to stay within a 2 km radius from HLS integrated lander, depending on the terrain and surface environment.

At the end of any lander-based EVA, the crew will ingress back into the vehicle using the depress/repress volume. During ingress, the crew must work to minimize the amount of lunar dust introduced into the crew cabin, physically ingress into the vehicle, and the atmosphere must be repressurized prior to crew doffing any portion of the EVA suit. During repressurization, the crew will visually inspect the hatch seal to ensure its integrity. The vehicle will be brought back to the previous atmospheric set point to enable consistency of prebreathe protocol for following EVA days.

4.4.3.3 POST-EVA ACTIVITIES

Once repressurization has been completed, the crew will doff the EVA suit, perform any remaining dust mitigation activities, and complete the activities needed to prepare for the next EVA on the following crew day (if applicable), including the stowage of any samples and equipment from the EVA, EVA suit maintenance, consumables recharge, and download of suit data. The crew will also have a Private Medical Conference (PMC), work with the Flight Operations team on Earth to resolve any issues encountered during that day’s EVA, and prepare for the next EVA, including science planning.

The EVA system, surface assets, and the HLS integrated lander will share responsibility for maintaining dust exposure within permissible limits. Operationally, the crew will perform dust mitigation activities external and internal to the HLS integrated lander and surface asset volumes. The ECLSS and Crew Systems will help to remove dust from the EVA suits and cabin volume so it is collected and does not cause crew or vehicle harm, especially in the microgravity environment where more dust liberation may occur than would be experienced in lunar gravity. Specific dust mitigation processes are still under development and will be influenced by specific vehicle architectures.

4.4.3.4 SURFACE TRANSFER EVA ACTIVITIES (DRM-H-002)

In DRM-H-002, the crew performs most surface operations using lunar surface assets such as the Lunar Terrain Vehicle (LTV), Pressurized Rover (PR), and Surface Habitat (SH). For these missions, the crew will transfer from the HLS integrated lander to the surface assets soon after landing.

4.4.3.4.1 Pre-Transfer Surface Ops

Like in DRM-H-001, immediately following landing the crew will safe the vehicle and perform any required vehicle reconfiguration to prepare for the surface stay. The following day, the crew will prepare for the transfer by EVA to surface assets and transitioning the vehicle for standby mode.

4.4.3.4.2 Initial Surface Transfer

To transition into the surface asset-based portion of the surface mission, the crew will perform an EVA transfer to the surface assets. While the crew is operating out of the surface assets, the HLS integrated lander will be uninhabited. In addition to the operations that are performed prior to any lander-based EVA, before the transfer is initiated the crew will perform any activities required to enable the HLS integrated lander to remain uninhabited during the approximately 30-day surface asset-based portion of the mission. When these activities are complete, the four crew members will egress the HLS integrated lander, leaving the hatch in a configuration such that no single failure prevents crew ingress. (Note: Egress processes are determined by the HLS integrated lander design and will be partner specific. Each HLS integrated lander design will enable the crew to access the surface safely from the crew cabin.)

At this point, the four crew members will split into two-person crews. The Pressurized Rover crew will walk to the rover and perform a visual inspection. Upon completion of the inspection, the crew will ingress into the Pressurized Rover. The Foundation Surface Habitat (FSH) crew will walk to the LTV, which will have been pre-deployed via ground command at a location accessible by the crew. The FSH crew will reconfigure the LTV for crewed operations and perform any checkout procedures needed before traveling to the basecamp via the LTV prior to ingress into the habitat. All LTV ConOps will be defined in the LTV-CONOP-001 Lunar Terrain Vehicle Concept of Operations.

When the surface crew has safely ingressed into the surface assets and the HLS integrated lander is uninhabited, the HLS integrated lander will have the option of transitioning to a standby mode to preserve consumables, power, fuel, etc., while still protecting the HLS integrated lander, EVA, and GFP hardware from harsh lunar environments. The initial transition to standby mode, once the crew is deemed safe in their respective assets, can be performed either remotely from Earth or remotely by the crew from surface assets. Any crew intervention for the transition to standby should remain within the currently planned HLS integrated lander surface habitation times. The full transfer process will be constrained to a single crew day.

4.4.3.4.3 Return Surface Transfer

Return transfers are the transfers from the surface assets back to the HLS integrated lander. The operations preceding return transfer will be specific to each surface asset and will be defined in the concept of operations for each asset <**TBS-CONOPS-006-001**>. The HLS integrated lander will need to return to the fully operational, habitable mode prior to the initiation of any return transfers back to the HLS integrated lander. Part of the return to operational mode will be automated system checkouts to ensure that all crew support functions are in good working order. The return to operational mode command will need to be initiated by either the crew in a surface asset or by Mission Systems.

Before the crew begins the transfer back to the HLS integrated lander, the HLS integrated lander will be commanded from its standby mode to its full operational mode. All automated checkouts will be successfully completed prior to the PR and SH crews beginning transfer EVA preparation activities. Once both crews have egressed their respective surface asset and have traveled back to the HLS integrated lander, the crew will don any fall protection and ingress the HLS integrated lander.

4.4.4 ASCENT PREPARATIONS

Once the crew has ingressed from the return transfer, the focus will turn to ascent preparations. The transfer will occur approximately two days prior to ascent. The transfer day is expected to be physically demanding, so a full crew day has been allocated for crew recovery and ascent preparations.

For the sustained missions, it is a goal to be capable of returning EVA suits to Gateway. The provider may choose to discard EVA hardware, trash, and other items to save upmass for ascent. Lastly, the crew will perform any required vehicle reconfiguration and vehicle systems will be checked out prior to ascent. Like egress and ingress, the details of these operations will be captured in vehicle-specific concepts of operation. Vehicle checkout may be initiated onboard or from Earth, depending on vehicle design, mission planning, and flight rules.

4.4.5 SURFACE EARLY MISSION TERMINATION

In the event of a problem on the surface that requires early mission termination of a surface mission per pre-defined flight rules and abort region definitions, the HLS integrated lander will safely return the crew to the Gateway. In the event the cabin is compromised, the HLS integrated lander will provide a capability that preserves crew health and performance until the crew can resolve the issue or return to the Gateway. An early mission termination may require the crew to shelter in place until the Gateway is in the correct orbital position for an ascent. Depending on the contingency, the crew may shelter in the SH, PR, or the HLS integrated lander. The duration and location will be dependent on where the Gateway is in NRHO, available consumables, and the nature of the contingency.

4.5 ASCENT

Upon completion of the surface mission, the crew will use the HLS integrated lander to ascend to the Gateway. The ascent phase begins with the start of cabin reconfiguration prior to ascent element checkout. This includes liftoff, LLO loiter and phasing if applicable, and orbit transfer to Gateway rendezvous. The ascent phase ends with insertion burn into NRHO.

4.5.1 POWERED ASCENT

Powered ascent is the phase during which the HLS integrated lander performs a propulsive maneuver to propel the HLS integrated lander off the surface of the Moon to either a phasing orbit or a direct return to NRHO trajectory. The powered ascent profile is vehicle architecture-dependent and will vary based upon the design provided by each HLS provider. The HLS integrated lander ascent capabilities may include automated ascent, as well as the capability for the crew to pilot the vehicle, with the nominal use of these capabilities to be defined as part of operationally pre-determined flight scenarios governed by flight rules. During powered ascent, the crew will be suited in an IVA and restrained as required to enable the crew to safely operate the vehicle while being protected from ascent loads.

4.5.2 ASCENT PHASING ORBIT LOITER

A loiter in LLO may be needed for navigation state updates to reduce error after the LLO insertion (LLOI) burn. The ascent phasing orbit loiter begins at LOI and ends at the LLO departure (LLOD) burn. At this time, the crew will doff their suits at the completion of insertion into the phasing orbit, if a phasing orbit is required. The HLS provider may choose both the profile of and time spent in a phasing orbit based on the needs of their specific HLS integrated lander architecture.

4.5.3 ASCENT TRANSIT

The ascent transit phase begins at either insertion into a direct return to NRHO trajectory at the end of powered ascent or at the completion of the LLOD burn. The crew will be suited for the LLOD burn. The ascent transit duration and energy required will depend on the architecture provided by each HLS provider. Transits for all variations of sorties or excursions between a phasing orbit or powered ascent and NRHO are expected to be at least 12 hours in duration and will therefore require a crew rest period during the transit to enable adequate crew performance capability for subsequent operations. Nominally, the transit rest period would include nutrition, sleep, and biological waste elimination, and therefore planned vehicle intervention from the crew during this period should be minimized. For the non-polar sortie (DRM-H-001b) the transit time may be longer, this will be site-specific and provider architecture-dependent.

4.5.4 NRHO INSERTION BURN

The HLS integrated lander will perform a propulsive maneuver to insert into the NRHO at the end of the ascent transit. The timing and magnitude of this maneuver will depend on the HLS integrated lander design.

4.6 RETURN LUNAR ORBIT OPERATIONS

Return Lunar Orbit Operations begin once the HLS integrated lander has performed the NRHO insertion burn. Return Lunar Orbit Operations are defined as the portion of the mission beginning when the HLS integrated lander is in the NRHO after lunar surface ascent, through docking with Gateway, but prior to the Orion NRHO departure burn, subsequently referred to as Orion RTE, with all four crew members. The primary focus of this mission phase is to prepare for Orion RTE with both the crew and lunar samples, as well as prepare the HLS integrated lander for either disposal or loiter in a lunar orbit to await the next mission. The Return Lunar Orbit Phase consists of the following mission phases:

- Return Loiter (RLTR)
- Return Rendezvous, Proximity Operations and Docking (RRPOD)
- Return Docked Operations (RDOPS)

- Return Undock & Backaway (RU&B)

4.6.1 RETURN LOITER (RLTR)

After NRHO insertion, it is anticipated that a full crew sleep period will be required prior to initiation of RRPOD. The need for this sleep period is dependent on ascent duration and will be evaluated for each specific mission profile. If a sleep period is required, the HLS integrated lander may loiter in the NRHO for that duration.

4.6.2 RETURN RENDEZVOUS, PROXIMITY, OPERATIONS AND DOCKING (RRPOD)

Prior to RPOD, the crew will don their IVA suits in support of this mission phase. Once the HLS integrated lander has returned to NRHO and after any required loiter period, the HLS integrated lander will rendezvous with the integrated Gateway/Orion stack. This portion of RRPOD, the HLS integrated lander performs the active portion of the rendezvous as the active chaser vehicle while Gateway serves as the passive target vehicle. RRPOD begins with a rendezvous phase, followed by proximity operations, soft dock, and hard dock. For Gateway missions, the HLS integrated lander must have the ability to dock to Orion in a contingency case for in-flight crew rescue. Proximity operations begin when the HLS integrated lander acquires the Gateway docking axis. All docking is governed by the HLS-RQMT-006 Sustained Phase HLS Program Integrated Lander Requirements Document or GP 10031-01 Gateway to HLS Visiting Vehicle Interface Requirements Document Annex 1: Human Landing System Integrated Lander Requirements. For either mission type, it is currently assumed that the crew will require a sleep period prior to initiation of RRPOD.

4.6.3 RETURN DOCKED OPERATIONS (RDOPS)

Following hard dock, the Gateway and the HLS integrated lander will each adjust their individual cabin conditions to an agreed upon set-point prior to vestibule pressurization. After pressure equalization has been achieved, the Gateway and HLS integrated lander hatches are opened, the crew doffs their suits, installs IMV, and the crew begins RTE preparations. As with IDOPS, Orion will require a tail-to-Sun orientation. The HLS integrated lander will remain docked to the Gateway with the hatch open until the Orion is ready to return to Earth. Excess trash will be transferred out of Orion to ensure that Orion does not exceed its Earth re-entry mass limit.

4.6.4 SHARED ENVIRONMENT

As with IDOPS, prior to crew opening of the HLS integrated lander docking hatch, the integrated lander will modulate its cabin pressure to a pressure compatible with shared atmosphere standards.

When the HLS integrated lander is docked directly to Gateway in an open-hatch configuration, Gateway will provide air revitalization and pressure control (consumables, air scrubbing) for the Gateway and HLS integrated lander habitable volumes. The Gateway IMV pulls air from the HLS integrated lander and filters the air flow before mixing with the Gateway volume. Air flows back through the open hatch into the integrated lander to assist with dust mitigation. The HLS integrated lander will ensure low lunar dust levels to remain within Gateway/Orion stack limits prior to hatch opening. A joint strategy between HLS, Gateway, and Orion programs will be developed and implemented to ensure low lunar dust levels in the combined habitable volume. All ECLSS functionality between Gateway and the HLS integrated lander is covered in GP 10031-01 Gateway to Visiting Vehicle Interface Requirement Document Annex 1: Human Landing System Requirements.

The RDOPS phase may require multiple crew days, and thus the crew will require exercise, nutrition, and sleep during this mission phase. Exercise, nutrition, and waste management system functions will be provided by Gateway during RDOPS.

4.6.5 RTE PREPARATIONS

RTE departure preparations include but are not limited to the following.

4.6.5.1 SAMPLE AND RETURN CARGO TRANSFER

The lunar surface samples brought back by the crew and any return cargo will need to be transferred to and safely stowed in Orion for RTE.

4.6.5.2 UNCREWED OPERATIONS MODE

Prior to the targeted Orion RTE time, the crew will prepare Gateway for an uncrewed operations mode. The vestibule between Habitation and Logistics Outpost (HALO) and the HLS integrated lander will be configured for the undock of the HLS integrated lander and/or the uncrewed period, and the HALO hatch will be closed. The HALO element will begin its nominal uncrewed operations. The Vehicle System Manager will oversee the vehicle, with periodic intervention from ground controllers, while the Gateway is uncrewed. Functions to be performed by the Vehicle System Manager include mission management and timeline execution, resource management, fault management, and vehicle control and operation.

4.6.5.3 FINAL ORION INGRESS AND DEPARTURE CHECKOUT

Prior to the targeted Orion RTE time, the crew will perform hatch seal inspections and cleanings, and will enter Orion and perform a vehicle checkout before closing the HLS integrated lander and Gateway hatches and the Orion hatches.

The total duration of RDOPS will be determined by the specific mission profile, including the relative positions of the NRHO arrival burn and NRHO departure locations in NRHO.

4.6.6 RETURN UNDOCK & BACKAWAY

The crew may be donned in their IVA suits for this mission phase. Prior to the targeted Orion RTE time, Orion will undock from Gateway, perform backaway, and transit to the NRHO departure burn location. During undock and the initial portion of backaway, the integrated Gateway and HLS integrated lander stack will inhibit RCS firings and maintain attitude hold until Orion reaches a predetermined distance from the integrated Gateway and HLS integrated lander stack. At that time, Gateway will receive a command and the integrated Gateway and HLS integrated lander stack will return to its nominal stack control mode. RU&B will end when Orion performs the NRD. Vehicle departure procedures will be governed by GP 10031-01 Gateway to Visiting Vehicle Interface Requirement Document Annex 1: Human Landing System Requirements.

4.7 POST-CREWED MISSION OPERATIONS

Once Orion performs the NRD, the HLS integrated lander can begin operations to enter a loiter phase for future mission use, or it can begin disposal operations. If the providers choose to dispose of any element/equipment/waste of the HLS integrated lander after the mission, these items must be disposed of in locations that will pose no harm to or interfere with NASA lunar orbit missions or vehicles or assets of historical value and comply with applicable planetary protection regulations to ensure a safe disposal of the vehicle. If the provider decides to perform disposal operations, the provider must discuss with the NASA Office of Primary Responsibility (OPR) for post-mission trajectory confirmation to identify alternate disposal strategies, including opportunistic science that may address NASA goals and objectives.

5 OFF NOMINAL AND CONTINGENCY OPERATIONS

This section references the overarching contingency capability required (per HLS-RQMT-006) for the HLS integrated lander to abort to the Gateway and safely return the crew at any time during the mission. The ConOps also references aborts during the descent and early mission termination during the surface mission phases. Surface early mission termination covers an extended surface phase, due to a missed nominal ascent, requiring the HLS integrated lander to provide a crew "safe haven" on the surface for an additional period of time and return the crew to the Gateway in time for a nominal Orion return to Earth. This section introduces a broader set of contingencies which drive design and operations. In addition, the HLS integrated lander will have the capability to dock with Orion if there are issues with a return to the Gateway.

For any human spaceflight mission, the crew, Flight Control Team, and vehicle must be prepared and ready to react to failures and contingency situations. Some contingencies are critical with respect to their consequences, time-to-effect, and/or mission phase in which the event occurred. Significant failures and contingencies may result in mission abort (loss of mission) and/or loss of crew. The HLS integrated lander human rating certification will be achieved via design standards, failure tolerance, reliability, and LOC/LOM analysis as well as explicit crew survival capabilities. From an operations perspective, contingencies will be included in the flight rules, flight procedures, and flight training.

The following sections describe various contingency scenarios and the HLS integrated lander capabilities necessary to respond and recover from the event. This is a high-level overview and crew/vehicle responses vary depending on flight phase (e.g., HLS integrated lander docked to Gateway, HLS integrated lander in transit, or HLS integrated lander on the lunar surface). In general, the explicit capabilities and responses below do not cover resources provided by other Artemis vehicles and assets.

5.1 EMERGENCIES

Scenario: **HLS Integrated Lander Fire, Leak/Depress, and Toxic Atmosphere**

Description: Emergencies are the highest threat to the crew and habitable environment and require immediate vehicle and operator responses to detect, isolate, and recover.

- Fire - Events can originate in the open cabin as well as behind panels and avionics bays. Fire events behave differently in micro-gravity and partial-gravity environments.
- Leak - Depress events can arise due structural compromise, hatch/seal failure, valve failure exposed to vacuum, inability to repress cabin after EVA, and micrometeoroids and orbital debris (MMOD) strike with varying impacts depending on hole size and flight phase in which event occurred.
- Toxic Release - Event resulting from a toxic spill/release into the cabin.

HLS Capabilities: Crew survival capabilities protect the crew in a compromised atmosphere, provide a breathing apparatus, provide an IVA suit, provide gases to replenish the atmosphere, and restore the atmosphere within limits.

5.2 SYSTEM CONTINGENCIES

Scenario: Inability to Return to Gateway

Description: This scenario covers any reason it is not possible to return to Gateway, notably docking mechanism failure, inability for Gateway attitude control (or free drift), and inhospitable Gateway environment.

- HLS Integrated Lander Docking Failure to Gateway
- Gateway loss of Guidance, Navigation, and Control (GN&C) or attitude/translational control
- Uninhabitable Gateway

HLS Capabilities: Explicit capability to dock directly with Orion.

Scenario: Loss of Software/Automation

Description: Automation failure can occur in any flight phase and in various systems. Some scenarios to consider include failures in emergency responses, GN&C failures in dynamics automation (RPOD/DDL/Ascent), and failures in automation which create hazards.

HLS Capabilities: In addition to design standards, failure tolerance, and reliability, HLS integrated lander provides sufficient manual capabilities including crew ability to shut down or override automated/robotic systems. In addition, crew manual control augments the automation in nominal and off-nominal dynamic mission phases.

Scenario: Loss of Communication

Description: This scenario is a total loss of communication between the crew onboard the HLS integrated lander and Earth, Gateway, and lunar surface assets.

HLS Capabilities: HLS integrated lander capability for concurrent RF communication with Earth, orbital, and surface crew. Potential for lunar comm/nav relay services in the lunar architecture may provide additional mitigation.

Scenario: Surface Mission Extension

Description: In the event of a missed nominal ascent, the crew and vehicle will stay for an extended duration on the lunar surface.

HLS Capabilities: HLS integrated lander systems and consumables to support the additional time required on the lunar surface and in transit to the Gateway within the time to meet the nominal Orion return to Earth.

5.3 HLS CREW CONTINGENCIES

Scenario: Incapacitated Crew, including Decompression Sickness

Description: This scenario may occur due to injury/trauma, decompression sickness, environmental, and crew exposure to toxic

HLS Capabilities: Explicit capabilities include crew mobility aids, surface operations (cabin) vertical orientation, hatch design, and single crew capability to operate and fly the vehicle. The decompression sickness (DCS) risk is mitigated through cabin pressure management and IVA suit capabilities.

Scenario: Backup Crew

Description: This contingency allows a backup crewmember to replace the prime crewmember, either pre-launch or inflight, to continue the lunar surface mission. Strategy includes vehicle/logistics capabilities and operations/training to account for a backup crewmember capable of supporting the lunar sortie mission.

HLS Capabilities: Explicit capabilities for HLS integrated lander logistics (EVA ancillary hardware, IVA suits and other individual equipment like hygiene, food, clothing, medical).

APPENDIX A
ACRONYMS AND ABBREVIATIONS
AND GLOSSARY OF TERMS

A1.0 ACRONYMS AND ABBREVIATIONS

TABLE A1-1 ACRONYMS AND ABBREVIATIONS

AADA	Active-Active Docking Adapter
ABC	Artemis Base Camp
AOS	Acquisition of Signal
ATP	Authority to Proceed
ConOps	Concept of Operations
CR	Change Request
DCS	Decompression Sickness
DLOI	Descent Lunar Orbit Insertion
DOI	Descent Orbit Insertion
DRM	Design Reference Mission
DSL	Deep Space Logistics
DWE	Direct with Earth
DTE	Direct to Earth
ECLSS	Environmental Control & Life Support Systems
EVA	Extravehicular Activity
GFP	Government Furnished Property
GN&C	Guidance, Navigation, and Control
HALO	Habitation and Logistics Outpost
HLS	Human Landing System
HEO	Human Exploration and Operations
HMAK	HLS Medical Accessories Kit
HUD	Heads-Up Display
IDOPS	Initial Docked Operations
ILTR	Initial Loiter
IU&B	Initial Undock & Backaway
IMV	Intermodule Ventilation
INFO	Informatics
IRD	Interface Requirements Document
IRPOD	Initial RPOD
IVA	Intravehicular Activity
LLO	Low Lunar Orbit
LLOD	Low Lunar Orbit Departure
LLOI	Low Lunar Orbit Insertion
LOCR	Lunar Orbit Checkout Review
LOS	Loss of Signal
LTV	Lunar Terrain Vehicle
MMOD	Micrometeroids and Orbital Debris

TABLE A1-1 ACRONYMS AND ABBREVIATIONS

MPCV	Multi-Purpose Crew Vehicle
NASA	National Aeronautics and Space Administration
NRD	NRHO Departure Burn
NRHO	Near-Rectilinear Halo Orbit
OPR	Office of Primary Responsibility
OPSCON	Operations Concept
PDI	Powered Descent Initiation
PMC	Private Medical Conference
PR	Pressurized Rover
RCS	Reaction Control System
RDOPS	Return Docked Operations
RLTR	Return Loiter
RPOD	Rendezvous, Proximity Operations and Docking
RRPOD	Return RPOD
RTE	Return to Earth
RU&B	Return Undock & Backaway
SH	Surface Habitat
SLS	Space Launch System
STI	Scientific and Technical Information
TBS	To Be Specified
UHF	Ultra-High Frequency
VSM	Vehicle System Manager
VV	Visiting Vehicle
WBS	Work Breakdown Structure
xEVA	Exploration Extravehicular Activities

A2.0 GLOSSARY OF TERMS

TABLE A2-1 GLOSSARY OF TERMS

Term	Description
Crew Staging Vehicle	The vehicle that serves as the crew transfer conduit to and from the HLS integrated lander; Gateway will fill this role for sustaining missions. Orion will transport the crew to NRHO, then enables transfer of crew between Orion and Gateway. Gateway then enables transfer of crew between Gateway and the HLS integrated lander.
Direct with Earth (DWE) Link	An RF link with geometric line-of-sight capability with Earth. Can be uni- or bi-directional (should always be specified). Direct to Earth (DTE) is sometimes used interchangeably.
Excursion Mission	A mission type that includes delivering four crew from NRHO to the lunar surface and returning to NRHO, which does involve pre-emplaced surface assets for achieving mission objectives. Excursion Missions include a generally longer surface duration than Surface Sortie Missions, e.g., approximately 33 days.
Initial	General modifier term that is applied to activities that need to occur after HLS integrated lander launch but prior to the primary surface mission, e.g.: • Initial Rendezvous, Proximity Operations and Docking • Initial Docked Operations • Initial ingresses • Initial Surface Transfer
Logistics	The goods and equipment that are manifested on the spacecraft to complete the mission, such as consumables, portable equipment, utilization, etc.
Mission	A sequence of activities or operations that are required to achieve one (or more) Agency goal(s). A mission can be broken down into "Mission Phases" (which group the sequence of activities or operations based on major mission milestones) for the purposes of communicating aspects of the operations, timeline, or performance. Each mission or mission phase can have its own set of elements and modules that are used to pursue the Agency goal(s). The duration of a mission or mission phase is defined by the activities or operations within it; additionally, the duration of a mission phase can be indirectly defined by the adjacent mission phases.

TABLE A2-1 GLOSSARY OF TERMS

Term	Description
Mission Availability	The number of mission opportunities based on the compendium of the overall mission planning constraints. These constraints may vary from mission to mission and will account for architecture elements and operations needed to perform a successful mission.
Mission Phase	A distinct period or stage in a series of events that comprise a Design Reference Mission (DRM). *Disambiguation note: The terms mission segment and mission phase co-exist within the Program and are sometimes used interchangeably by the Program itself or external organizations. The HLS Program has opted to not settle upon one term or another because the linguistic differences were deemed insignificant and not meaningful regarding the Program's overall technical context and its dialog with external organizations.*
Mission Segment	Each of the parts into which a DRM or one of its mission phases is or may be divided. The role title "Mission Segment Lead" has been formally adopted by the Program, as described within HLS-PLAN-016 Technical Management Plan §5.2.3 Mission Segment Leads and Discipline Lead. *Disambiguation note: The terms mission segment and mission phase co-exist within the Program and are sometimes used interchangeably by the Program itself or external organizations. The HLS Program has opted to not settle upon one term or another because the linguistic differences were deemed insignificant and not meaningful regarding the Program's overall technical context and its dialog with external organizations.*
Non-Polar	Term meaning that all latitudes are available, but not necessarily that all latitude/longitude combinations are available. Some areas at low latitudes and longitudes near zero degrees may not be reachable.
Primary	Modifier term that is applied to DRM-H-001 and DRM-H-002 in HLS-CONOP-006. Primary DRMs describe the current understanding of mission types to be used in the sustained phase of lunar exploration.

TABLE A2-1 GLOSSARY OF TERMS

Term	Description
Return	General modifier term that is applied to activities that need to occur after the primary surface mission, but preceding crew return to Earth, e.g.: • Return Rendezvous, Proximity Operations and Docking • Return Docked Operations • Return ingresses • Return Surface Transfer
Surface Sortie Mission	A mission type that includes delivering two crew members from NRHO to the lunar surface and returning to NRHO, which does not rely on pre-emplaced surface assets for achieving mission objectives. Surface Sortie Missions include a generally short surface duration, e.g., six days or less.
Transfer	A transfer is the process of moving from one asset to another; transfers cross an interface management boundary between assets that are controlled by different Work Breakdown Structure (WBS) organizations. For the transfer of crew members between assets, the responsible Program(s) or Project(s) need to make sure the destination habitat (surface habitat, pressurized rover, etc.) is ready to receive the personnel.
Variant	Modifier term that is applied to DRM-H-001 and DRM-H-002 in HLS-CONOP-006. Variant DRMs are a representation of how the capability established by the primary DRM may be used in different operational contexts and external environments than would be seen during a mission represented by the primary DRM.

APPENDIX B
OPEN WORK

B1.0 TO BE SPECIFIED (HEADING-APPX STYLE - ALL CAPS AND BOLD)

The table To Be Specified Items lists the specific To Be Specified (TBS) items in the document that are not yet known, is used when something is to be decided or confirmed at some point in the future and in the place of TBD, TBR, TBC, TBX. 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 B1-1 TO BE SPECIFIED ITEMS

TBS Number	Section	Description
TBS-CONOPS-006-001	**4.4.3.4.3**	The DRM-H-002 Surface Asset ConOps is not yet released as of the release of this ConOps; document number is not available.

B2.0 FORWARD WORK

The table Forward Work lists the specific Forward Work (FWD) issues in the document that are not yet known, used for issues/items that are not yet completed, and is also used to capture work that will mature/evolve through further analysis. Include any CR comments that were dispositioned as Forward Work. 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 B2-1 FORWARD WORK ITEMS

FWD	Section	Description