National Aeronautics and
Space Administration

**HEOMD-001**

**REVISION A**

**RELEASE DATE: 07/31/2017**

# HUMAN EXPLORATION AND OPERATIONS EXPLORATION OBJECTIVES

***Publicly available: Release to Public Websites Requires Approval of Chief, Office of Primary Responsibility***

## REVISION AND HISTORY PAGE

| Revision No. | Change No. | Description | Release Date |
|---|---|---|---|
| - | - | Initial Baseline Release | 09/07/2016 |
| A | CR-HEO-0002 | Revision A (Reference CR HEO-0002, Released on May 23, 2017) approved at the Directorate Program Management Council (DPMC) on July 31, 2017) | 07/31/2017 |

| REVISION | DATE | SUMMARY OF CHANGES |
|---|---|---|
| Initial Baseline | 9/7/2016 | - |
| RevA | 5/11/2017 | 1. Grammatical corrections as necessary<br>2. Added detail on formalized HEOMD Configuration Management Process<br>3. Updated Reference Documents table to include NASA Transition Authorization Act of 2017 and added language from the Act for strategic context traceability<br>4. Updated graphic displaying the Exploration Phases<br>5. Elevated Phase descriptions from previously Section 4 to revised Section 3<br>6. Added graphic showing role of HEOMD-001 in the HEO document/process flow<br>7. Added Implementation Principles section including context description and tables listing specific items<br>8. Replaced references of initial cislunar habitation with Deep Space Gateway and Mars-class transit vehicle with Deep Space Transport<br>9. Removed references to the Asteroid Redirect Mission as the Capstone for Phase 1<br>10. Revised acronym list based on content changes |

## TABLE OF CONTENTS

FIGURES



TABLES

# 1.0 INTRODUCTION

## 1.1 PURPOSE

This document establishes the integrated set of Exploration Objectives for all exploration activities in the Human Exploration and Operations Mission Directorate (HEOMD). The purpose of the Exploration Objectives is to translate and bridge the gap between agency-level human exploration goals as articulated in NASA's Strategic Plan and other programmatic documentation into clear and discrete objectives for implementation by HEOMD organizations and HEOMD-led missions. The Exploration Objectives can also be used to help inform, identify, and/or prioritize agency technology and science investments. The Exploration Objectives are intended to be dynamic, and will be updated as necessary to reflect changes in agency strategy, improving scientific and technical knowledge, accumulated operational experience, availability of resources, and/or programmatic lessons learned. As HEOMD and other executing organizations evolve, and as relevant HEOMD constituent organizational plans and mission products such as Mission Objectives (MOs) are created or updated in the normal course of business, those plans and products shall align to the Exploration Objectives. The HEOMD Exploration Objectives will inform, and be driven by, future updates to the NASA Strategic Plan. While not explicitly stated in the exploration objectives listed in this document, the health and safety of crew is implicit in all of the HEOMD objectives.

The objectives for exploration phases beyond the Earth-Moon system (see Section 4) are not defined in this document. However, this is not intended to preclude investment by HEOMD or stakeholder organizations in planned missions and early-stage technology activities with potential relevance for crewed missions beyond the Earth-Moon system. This strategy allows NASA the opportunity to remain agile and to continue to refine its plans over time while maintaining the focus on exploration of the martian surface as the horizon goal. NASA's planning will continue to be informed by advances in technology and scientific knowledge, as well as by opportunities presented by growing government/commercial capabilities and international participation.

The exploration objectives contained herein are intended to inform program requirements and revisions as necessary.

## 1.2 SCOPE

The Exploration Objectives apply to all HEOMD organizations responsible for conducting exploration activities.

## 1.3 CHANGE AUTHORITY/RESPONSIBILITY

The NASA Office of Primary Responsibility (OPR) for this document is the HEOMD Associate Administrator. Proposed changes to this document shall be submitted via a Change Request (CR) to the HEOMD Configuration Management Receipt and Release Desk for consideration and disposition. All such requests will adhere to the HEOMD Configuration Management Process documented in HEOMD-002.

## 2.0 DOCUMENTS

### 2.1 APPLICABLE DOCUMENTS

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-002 | Baseline | HEOMD Configuration Management Process |
| N/A | June 28, 2010 | National Space Policy of the United States of America |
| P.L. 115-10 | March 21, 2017 | National Aeronautics and Space Administration Transition Authorization Act of 2017 |

### 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 |
| --- | --- | --- |
| NP-2014-01-964-HQ | February 2014 | NASA Strategic Plan 2014 |
| N/A | June 21, 2012 | Human Exploration and Operations Mission Directorate (HEOMD) Program Management Council Charter |
| NP-2015-08-2018-HQ | October 8, 2015 | NASA’s Journey to Mars: Pioneering Next Steps in Space Exploration |
| GER-2013 | August 2013 | Global Exploration Roadmap |
| ESD 10002 | Rev. E September 7, 2016 | Exploration Systems Development (ESD) Requirements |
| ESD 10012 | Rev. E December 15, 2016 | Exploration Systems Development (ESD) Concept of Operations |
| N/A | N/A | NASA’s Strategic Knowledge Gaps |

## 3.0 EXPLORATION OBJECTIVES IN A STRATEGIC CONTEXT

The NASA Transition Authorization Act of 2017 directs that the long-term goals of the human space flight and exploration efforts of NASA shall be:

1. To expand permanent human presence beyond low-Earth orbit and to do so, where practical, in a manner involving international, academic, and industry partners;

2. Crewed missions and progress toward achieving this goal in paragraph (1.) to enable the potential for subsequent human exploration and the extension of human presence throughout the solar system; and

3. To enable a capability to extend human presence, including potential habitation on another celestial body and a thriving space economy in the 21st Century.

4. To achieve human exploration of Mars and beyond through the prioritization of those technologies and capabilities best suited for such a mission in accordance with the stepping stone approach to exploration.

The NASA Strategic Plan codifies this law as agency policy under Strategic Goal 1:

- *Strategic Goal 1: Expand the frontiers of knowledge, capability, and opportunity in space.*

In support of this Agency Strategic Goal 1, HEOMD is responsible for three Objectives that are relevant to the establishment of the Exploration Objectives:

- *Objective 1.1: Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.*

- *Objective 1.2: Conduct research on the International Space Station (ISS) to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity.*

- *Objective 1.3: Facilitate and utilize U.S. commercial capabilities to deliver crew and cargo to space.*

NASA's goal is much broader than launching a single human mission to Mars. Instead, the larger human Mars exploration goal provides an overall strategic focus for a broad range of activities, with the ultimate purpose of extending human presence into the solar system, from low-Earth orbit to cislunar space, Mars, and beyond. HEOMD has identified key Strategic Principles for enabling sustained human exploration across multiple decades. HEOMD strategy, development, and mission planning align and are guided by these principles.

- **FISCAL REALISM:** Implementable in the *near-term with the buying power of current budgets* and in the longer term with budgets commensurate with economic growth*;*

- **SCIENTIFIC EXPLORATION*:*** *Exploration enables science and science enables exploration;* leveraging scientific expertise for human exploration of the solar system.

- **TECHNOLOGY PULL AND PUSH:** Application of high Technology Readiness Level (TRL) technologies for near term missions, while focusing sustained investments on *technologies and capabilities* to address the challenges of future missions;

- **GRADUAL BUILD UP OF CAPABILITY:** *Near-term mission opportunities* with a defined cadence of compelling and integrated human and robotic missions, providing for an incremental buildup of capabilities for more complex missions over time;

- **ECONOMIC OPPORTUNITY:** Opportunities for *U.S. commercial business* to further enhance their experience and business base;

- **ARCHITECTURE OPENNESS AND RESILIENCE:** Resilient architecture featuring multi-use, evolvable space infrastructure, minimizing unique developments, with each mission leaving something behind to support subsequent missions;

- **GLOBAL COLLABORATION AND LEADERSHIP:** Substantial *new international and commercial partnerships,* leveraging current International Space Station partnerships and building new cooperative ventures for exploration; and

- **CONTINUITY OF HUMAN SPACEFLIGHT***: Uninterrupted expansion of human presence into the solar system* by establishing a regular cadence of crewed missions to cislunar space during ISS lifetime.

## 4.0 EXPLORATION PHASES

Near- and far-term human exploration mission planning is divided into phases. All activities are part of an integrated strategy that builds from experience gained in Phase 0, and informs objectives, capabilities, and missions in Phases 1, 2, 3 and beyond. The Exploration Objectives mirror this approach and are also organized by phases.

A core understanding of NASA's exploration strategy is that sending humans to the Mars system is an extraordinarily challenging endeavor, and therefore a strategy for human exploration of Mars needs to be flexible and allow for evolution over time based on scientific discoveries and technology advancements. Therefore, there are multiple defined exploration phases, starting with Phase 0, through Phase 1 and 2 in cislunar space, and culminating with missions in Phase 3 and beyond, where human missions to the Mars system are possible. Each Exploration Phase is defined by increasing mission complexity, and builds upon the scientific knowledge, technical advances, and operational experience of the previous period to explore and extend capabilities for deep space exploration, leading to the eventual human exploration of the surface of Mars.

While Phase 0 is characterized by the extensive experience base of operations in low-Earth Orbit (LEO), the maturing commercial crew and cargo capability and a well-developed exploration research agenda, the implementing capabilities for Phases 1 and 2 are in earlier stages of formulation and development. Meanwhile, the capabilities needed for operations in Phase 3 and beyond are contingent on knowledge and experience that is expected to be gained in the previous Phases. Therefore, while the capabilities envisioned are reasonable

extrapolations based on the current state of knowledge, they are still conjectural at this point. In addition, as noted earlier, there are additional technology risk-reduction activities, capability advancements and spaceflight missions planned and/or being executed by HEOMD and other stakeholder organizations that may not be explicitly traced to the current Exploration Objectives, but which have the potential to revolutionize the way we explore, discover, and work in space.

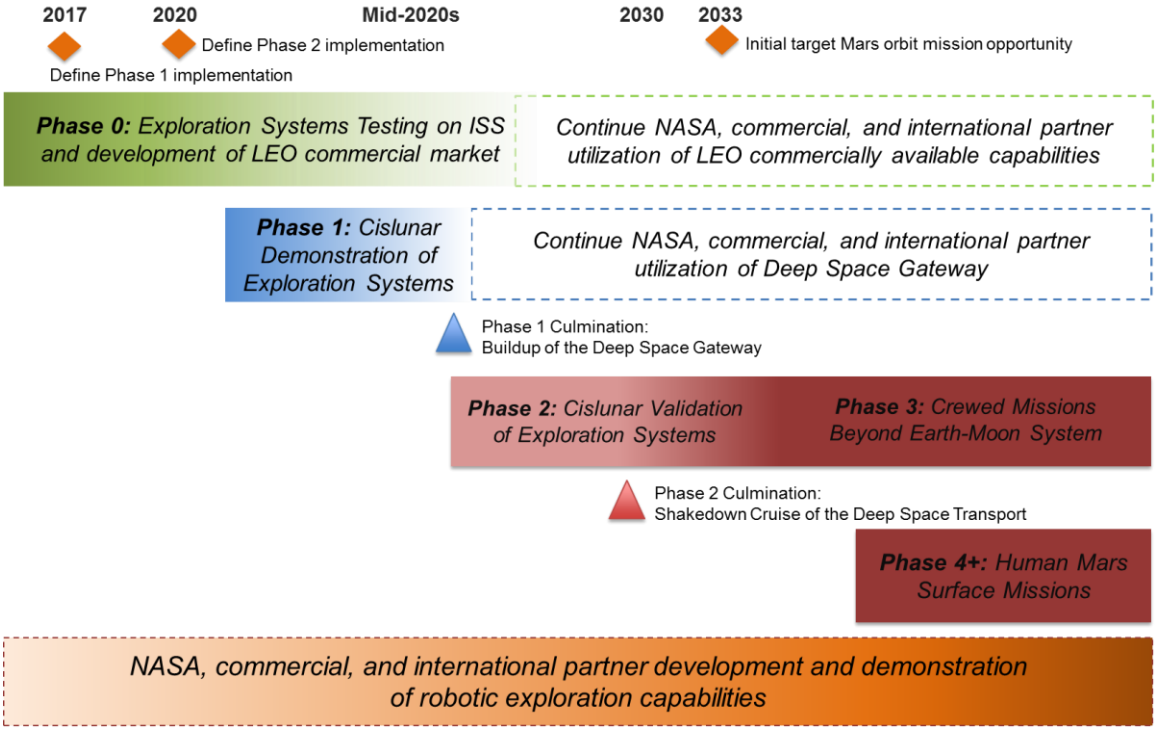


**FIGURE 4.0 EXPLORATION PHASES**

## 4.1 PHASE 0: EXPLORATION SYSTEMS TESTING ON ISS

This phase encompasses NASA's current human exploration activities aboard the International Space Station (ISS) that enable exploration objectives in cislunar and deep space. Human exploration activities on ISS leverage the station as a test bed to demonstrate key exploration capabilities and operations and enable the move away from an Earth-reliant frame of operations. The agency is also facilitating a robust commercial crew and cargo transportation capability in LEO, stimulating new markets and fostering an emerging commercial space industry that will mature to support future missions.

## 4.2 PHASE 1: CISLUNAR DEMONSTRATION OF EXPLORATION SYSTEMS

This phase covers demonstration of the integrated Space Launch System (SLS) and Orion spacecraft and other exploration activities primarily occurring in cislunar space to support short-

duration objectives as well as closure of key strategic knowledge gaps. Phase 1 culminates in the initial operations capability of the Deep Space Gateway (DSG) in the mid-2020 timeframe.

### 4.3 PHASE 2: CISLUNAR VALIDATION OF EXPLORATION SYSTEMS

This phase covers validation of integrated SLS, Orion, habitation, crew, and in-space transportation systems in cislunar space in preparation for Mars-class missions, as well as closure of key strategic knowledge gaps. Phase 2 culminates in the demonstration of a one year, Mars-class crewed "shakedown cruise" of the Deep Space Transport (DST) in the 2030 timeframe.

### 4.4 PHASE 3+: BEYOND EARTH-MOON SYSTEM

This phase covers beyond cislunar space activities building on what is learned in Phases 0 – 2 to enable human missions to the Mars vicinity, including the martian moons, and eventually the martian surface.

## 5.0 IMPLEMENTATION PRINCIPLES

The NASA Transition Authorization Act, and NASA Strategic Plan set the top-level strategic context and overall direction for exploration at the national and agency (i.e. above the HEOMD) level.

As HEOMD's exploration mission planning matures, it is imperative that the activities identified to meet the Exploration Objectives are bounded by common guidance. Moreover, in an effort to close the gap that exists between the Exploration Objectives and detailed planning for architectural analyses, hardware development, and mission design, a HEOMD has outlined a series of Implementation Principles to define a framework that:

- Provides further definition on implementation of the key Strategic Principles
- Focuses mission planning activities on how to address Exploration Objectives
- Bounds internal study activities by providing a consistent framework for planning
- Enables a clearer path to decision-making by identifying decision drivers
- Eliminates extraneous activity from the planning horizon
- Allows for traceability to defined goals and objectives

**TABLE 5.0 IMPEMENTATION PRINCIPLES**

| IP Identifier | Implementation Principle |
| --- | --- |
| IP-01 | Robust international partnerships among existing and new partners are important |
| IP-02 | Operate ISS as long as beneficial:<br>• Test Mars-class systems (e.g., ECLSS) and operations concepts<br>• Promote LEO commercialization |
| IP-03 | ISS as a catalyst for the ultimate goal of commercial self-sustainability in LEO without NASA as a primary tenant or landlord |

| | |
| --- | --- |
| IP-04 | Balance interests and capabilities of international and commercial partners in the architecture; evaluate commercial capabilities and bring online when available |
| IP-05 | Flight Rate:<br>• One crewed Orion/SLS exploration mission per-year beginning in 2023<br>• One SLS cargo mission per year starting in 2027 |
| IP-06 | Goal of cislunar phases is build up and validation of the crewed DST. Target date for shakedown cruise of the DST is the 2030 timeframe |
| IP-07 | Target departure date of DST from cislunar space on a crewed Mars vicinity mission is 2033. |
| IP-08 | A minimal, crew-tended DSG remains long-term in cislunar space to facilitate successive crewed deep space missions and sustain mission cadence; this should drive the definition of the DSG. The DSG can support commercial and international partner interests (e.g., staging for international partner lunar landings) with contributed elements |
| IP-09 | The DSG in cislunar space is the staging point for Mars-vicinity missions. The DSG supports buildup, departure and return of the DST to/from cislunar space; DSG continues operations and human missions in parallel with DST Mars vicinity missions |
| IP-10 | The DST is reusable and is returned to cislunar space for refurbishment in between Mars vicinity missions |
| IP-11 | Human exploration systems to be provided through innovative procurement methods and industry contributions leveraging other existing system developments. |
| IP-12 | Engage in a coordinated dialogue with the agency, external stakeholders, SMD and STMD on cislunar and Mars exploration decisions |
| IP-13 | Use common systems, sub-systems, modules, and components to the furthest extent possible |

The Implementation Principles define the general framework and assumptions by which HEOMD intends to implement the Exploration Objectives. As such, the Implementation Principles themselves are not part of the direct flow from the Exploration Objectives to lower level products. Framed by the Implementation Principles, execution of the top-level strategic guidance is underway via mission and hardware capability specific products. These products include Level 1 requirements, design concepts of operations, mission objectives, potential manifests, and others (along with associated analytical capabilities) that define hardware capabilities and mission-specific planning. These products, in turn, are used by exploration programs to develop, build, test, and fly hardware, and by mission planners to develop detailed mission timelines and other lower level products.

The Exploration Objectives (along with the Implementation Principles) captured in this document will bridge the gap between the multi-decade agency strategic goals and objectives on the one hand, and programmatic requirements including exploration systems, capabilities, and their associated focus on current and near-current hardware and mission development or formulation on the other. In the context of an integrated and evolving exploration capability, the Exploration Objectives also define milestones that must be accomplished with capabilities in development

over an extended, but reasonably manageable, period of time to proceed to the next phase. The Exploration Objectives provide guidance to enterprise and program planners for developing mission and hardware specific products within the strategic context of the Implementation Principles, which in turn helps inform, identify, and/or prioritize technology and science investments across the agency. The Exploration Objectives also drive, and are informed by, architectural studies that assess challenges and opportunities from now through the Mars surface mission horizon. Finally, Exploration Objectives are open to lessons learned from technology advancement, scientific discoveries, mission development and mission operations, and thus may be adapted to, and inform, adjustments to agency strategy. The role of these artifacts is illustrated in Figure 5.0, below.

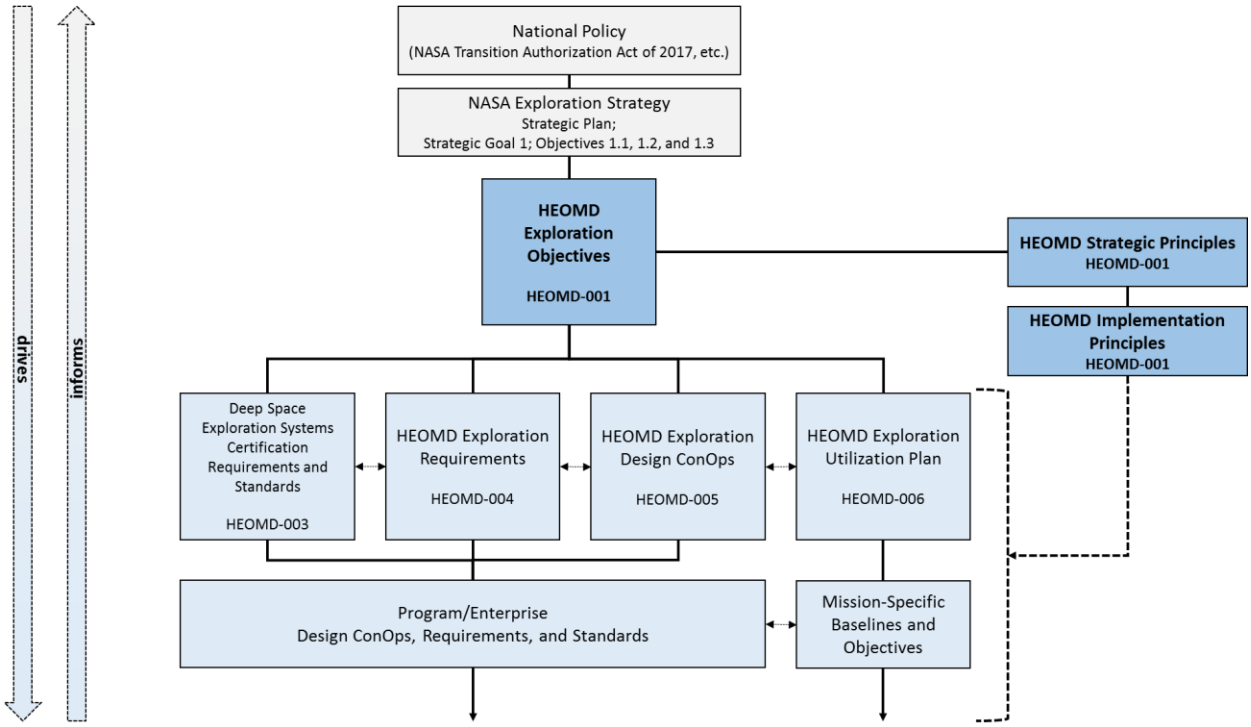


**FIGURE 5.0 HEOMD EXPLORATION OBJECTIVES, STRATEGIC PRINCIPLES, AND IMPLEMENTATION PRINCIPLES IN CONTEXT**

## 6.0 OBJECTIVES

### 6.1 ORGANIZATION

For ease of organization, the objectives are grouped into three cross-cutting categories.

### 6.1.1 Objective Category: Transportation

In the Phase 0 – 2 timeframe, transportation objectives encompass four areas: crew transportation, heavy-lift, in-space propulsion, and deep space navigation and communication. Crew transportation is focused on providing the ability to transport at least four crew to cislunar space. Heavy-lift is focused on providing beyond LEO launch capabilities to include crew, co-manifested payloads, and large cargo. In-space propulsion is focused on providing in-space propulsion capabilities to send crew and cargo on Mars-class mission durations. Deep space navigation and communication is focused on providing and validating cislunar and Mars system navigation and communication. In Phase 3 and beyond, "transportation" objectives will include: the ability to transport and return at least four crew and cargo to and from the Mars vicinity, moons, and surface; the ability to land payloads on the surface of Mars; provide navigation and high band width communications for deep space human exploration.

### 6.1.2 Objective Category: Working in Space

In the Phases 0 – 2 timeframe, Working in Space encompasses three areas: science, deep space operations, and *in situ* resource utilization. Science focuses on enabling the broader scientific community objectives while also filling gaps in scientific knowledge needed to inform design and development of the human system that will be employed at targeted destinations. Deep space operations focus on providing capabilities in the areas of extra-vehicular activity (EVA), staging, logistics, human-robotic integration, and autonomous operations. *In situ* resource utilization focuses on understanding the nature and disposition of volatiles and other resources and their associated extraction techniques for their potential use in human exploration architectures. In Phase 3 and beyond, “working in space” objectives will include: Mars vicinity and surface operations capabilities including EVA, element staging, self-reliant logistics, human-robotic integration, and autonomous operations. Enabling science community objectives and production of *in situ* resources for ascent propellant and life support consumables are also included in the Exploration Objectives.

### 6.1.3 Objective Category: Staying Healthy

In the Phase 0 – 2 timeframe, staying healthy encompasses two areas: deep space habitation, and crew health. Deep space habitation focuses on providing beyond LEO habitation systems sufficient to support at least four crew on Mars-class mission durations and dormancy. Crew health focuses on validating crew health and performance, and developing mitigation protocols for Mars-class missions. In the Phase 3 and beyond timeframe, "staying healthy" objectives will include providing crew health, performance and mitigation protocols for Mars missions based on experiences gained in Phases 0-2. This includes a Mars surface habitation capability sufficient to support crew on Mars surface missions including the required system dormancy in the relevant environment periods with minimal refurbishment.

## 6.2 VALIDATING COMPLETION OF PHASE OBJECTIVES

The objectives defined in this document will be addressed by the program activities that are already planned, in development, and/or operational.

### 6.2.1 Prioritization of Objectives

The Exploration Objectives are not prioritized. In the future, they may be classified into minimum and full success criteria categories if deemed necessary.

### 6.2.2 Measurement of Objective Achievement

Achievement of the objectives will be defined in lower level documents that are traced to the exploration objectives.

## 6.3 PHASE 0 OBJECTIVES

**TABLE 6.3 PHASE 0 OBJECTIVES**

| Objective Identifier | Objective | Objective Category |
| --- | --- | --- |
| P0-01 | Acquire routine round-trip U.S. crew transportation to LEO | Transportation |
| P0-02 | Acquire routine U.S. cargo transportation to LEO | Transportation |
| P0-03 | Evaluate communications with increased delay | Working in Space |
| P0-04 | Demonstrate in-space exploration class extra-vehicular activity (EVA) technologies | Working in Space |
| P0-05 | Demonstrate exploration environmental control and life support system (ECLSS) and environmental monitoring technologies and validate real-time on-orbit environmental monitoring | Working in Space |
| P0-06 | Validate in-space fire detection, suppression, and cleanup technologies suitable for exploration missions | Working in Space |
| P0-07 | Demonstrate radiation monitoring technologies in LEO and evaluate radiation mitigation capabilities | Working in Space |
| P0-08 | Demonstrate autonomous operations in LEO | Working in Space |
| P0-09 | Demonstrate human and robotic mission operations | Working in Space |
| P0-10 | Evaluate technologies that may enable operations with reduced logistics capabilities | Working in Space |
| P0-11 | Demonstrate docking and close-proximity technologies and operations | Working in Space |
| P0-12 | Enable science community objectives in low earth orbit | Working in Space |
| P0-13 | Demonstrate crew acclimation to/from zero-g | Staying Healthy |
| P0-14 | Demonstrate medical diagnosis capability and treatment protocols for exploration missions | Staying Healthy |
| P0-15 | Demonstrate protocols to understand crew task performance and operations planning for human space missions | Staying Healthy |
| P0-16 | Demonstrate countermeasures to mitigate the hazards of long duration spaceflight | Staying Healthy |
| P0-17 | Demonstrate long duration viability & stability of food and pharmaceuticals | Staying Healthy |

## 6.4 PHASE 1 OBJECTIVES

**TABLE 6.4 PHASE 1 OBJECTIVES**

| Objective Identifier | Objective | Objective Category |
| --- | --- | --- |
| P1-01 | Demonstrate SLS Block 1 elements in flight and integrated performance with Orion | Transportation |
| P1-02 | Demonstrate Block 1B trans-lunar injection (TLI) performance, including co-manifested capability | Transportation |
| P1-03 | Demonstrate Orion's ability to support crew in deep space | Transportation |
| P1-04 | Demonstrate Orion's ability in conjunction with additional habitation element(s) to support missions with at least 4-Crew for a minimum of 30 days | Transportation |
| P1-05 | Demonstrate operation of deep space exploration-class propulsion to support on-orbit maintenance, cislunar transfers, and in-space refueling | Transportation |
| P1-06 | Demonstrate ability to stage habitation and other capabilities in deep space for later utilization | Transportation |
| P1-07 | Demonstrate ability for crewed rendezvous and operation with a previously staged element(s) | Transportation |
| P1-08 | Demonstrate autonomous rendezvous, proximity operations, and docking in deep space | Transportation |
| P1-09 | Demonstrate ability to dispose of assets from deep space | Transportation |
| P1-10 | Demonstrate deep space crewed operations up to Mars communications latency | Working in Space |
| P1-11 | Validate ability to conduct EVA in deep space | Working in Space |
| P1-12 | Validate integrated radiation risk mitigation ability to provide As Low As Reasonably Acceptable (ALARA) exposure, including monitoring, mitigation, and operational strategies | Working in Space |
| P1-13 | Demonstrate transition between crewed and uncrewed operations | Working in Space |
| P1-14 | Demonstrate human/robotic interactions in deep space | Working in Space |
| P1-15 | Demonstrate stowage strategies within available volume for deep space missions | Working in Space |
| P1-16 | Demonstrate the collection and return of biological and/or scientific samples including planetary protection protocols | Working in Space |
| P1-17 | Evaluate the nature and distribution of lunar volatiles and extraction techniques and decide on their potential use in human exploration architectures to inform future ISRU development | Working in Space |
| P1-18 | Enable science community objectives in deep space, including addressing HEOMD's strategic knowledge gaps in the lunar vicinity | Working in Space |

| | | |
|---|---|---|
| P1-19 | Enable commercial and international partnership objectives in deep space | Working in Space |
| P1-20 | Demonstrate ability to use systems in cislunar space to enable science, technology, and exploration while in an uncrewed stateEnable commercial and international partnership objectives in deep space | Working in Space |
| P1-21 | Demonstrate/evaluate exploration medical capabilities | Staying Healthy |
| P1-22 | Demonstrate/evaluate human flight operations crew physiological well-being in deep space | Staying Healthy |
| P1-23 | Demonstrate/evaluate human flight operations crew psychological well-being in deep space | Staying Healthy |
| P1-24 | Demonstrate/evaluate human health countermeasures | Staying Healthy |
| P1-25 | Evaluate the effects of deep space on complex organisms, plants, food, pharmaceuticals, and animal models | Staying Healthy |

## 6.5 PHASE 2 OBJECTIVES

**TABLE 6.5 PHASE 2 OBJECTIVES**

| Objective Identifier | Objective | Objective Category |
| --- | --- | --- |
| P2-01 | Demonstrate SLS Block 2 TLI performance | Transportation |
| P2-02 | Demonstrate SLS Block 2 co-manifested capability and cargo only capability | Transportation |
| P2-03 | Validate long-duration, long-distance in-space propulsion capabilities, including refueling and long-term propellant storage | Transportation |
| P2-04 | Validate high bandwidth and high data rate deep space communication capabilities to support real-time high resolution video | Working in Space |
| P2-05 | Validate capability and reliability of ECLSS to support a Mars-class mission including dormancy periods | Working in Space |
| P2-06 | Validate Mars-class habitation system transition between crewed and uncrewed operations | Working in Space |
| P2-07 | Demonstrate use of the habitat capability to conduct remote robotic operation of systems | Working in Space |
| P2-08 | Validate Mars habitat integrated system performance and reliability in deep space | Working in Space |
| P2-09 | Demonstrate the ability to conduct extended missions in deep space leading to a Mars-class transit duration | Working in Space |
| P2-10 | Validate maintenance and repair capabilities in deep space with limited or no resupply | Working in Space |
| P2-11 | Validate capabilities to produce and store resources in-situ for ascent propellant and life support consumables in deep space | Working in Space |
| P2-12 | Enable science community objectives in deep space, including addressing HEOMD's strategic knowledge gaps in the martian vicinity | Working in Space |
| P2-13 | Enable commercial and international partnership objectives in deep space | Working in Space |
| P2-14 | Validate exploration medical capabilities in deep space | Staying Healthy |
| P2-15 | Validate human flight operations crew physiological well-being on Mars-class missions | Staying Healthy |
| P2-16 | Validate human flight operations crew psychological well-being on Mars-class missions | Staying Healthy |
| P2-17 | Demonstrate Mars flight mass and form factor exercise system capability and reliability | Staying Healthy |
| P2-18 | Validate human health countermeasures | Staying Healthy |

## 6.6 PHASE 3+ OBJECTIVES

TBD

# APPENDIX A
# DEFINITIONS, ACRONYMS, AND ABBREVIATIONS

## A1.0 DEFINITIONS

### A1.1 DEMONSTRATE

To exhibit the safe operation or use of a device, process, capability or system. Denotes the occurrence of an action or an event that satisfies all or part of an objective.

### A1.2 VALIDATE

Denotes the confirmation that an end product or system satisfies its intended use when placed in its intended environment. Validation is proof that the product accomplishes its stakeholders' expectations and proves whether "the right system was done."

### A1.3 EVALUATE

Denotes measuring the nature, ability or quality of an effect, element, component or subsystem. Evaluation of a component or subsystem is typified by comparison of performance against a mathematical or physics based model. This type of analysis is often used to anchor analytical predictions.

## A2.0 ACRONYMS AND ABBREVIATIONS

| | |
| --- | --- |
| ConOps | Concept of Operations |
| CR | Change Request |
| DPMC | Directorate Program Management Council |
| DSG | Deep Space Gateway |
| DST | Deep Space Transport |
| ECLSS | Environmental Control and Life Support System |
| ESD | Exploration Systems Development |
| EVA | Extra-Vehicular Activity |
| HEOMD | Human Exploration and Operations Mission Directorate |
| ISS | International Space Station |
| LEO | Low-Earth Orbit |
| MO | Mission Objective |
| OPR | Office of Primary Responsibility |
| SEP | Solar Electric Propulsion |
| SLS | Space Launch System |
| TLI | Trans-Lunar Injection |
| TRL | Technology Readiness Level |

# APPENDIX B
# OPEN WORK

## B1.0 TO BE DETERMINED

Table B1-1 lists the specific to be determined (TBD) items in the document that are not yet known. The TBD is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBD item is sequentially numbered as applicable (i.e., <TBD-001> is the first undetermined item assigned in the document). As each TBD is resolved, the updated text is inserted in each place that the TBD appears in the document and the item is removed from this table. As new TBD items are assigned, they will be added to this list in accordance with the above-described numbering scheme. Original TBDs will not be renumbered.

**TABLE B1-1 TO BE DETERMINED ITEMS**

| TBD | Section | Description |
| --- | --- | --- |
| TBD-001 | 5.6 | PHASE 3+ OBJECTIVES |

## B2.0 TO BE RESOLVED

The table To Be Resolved (TBR) Issues lists the specific TBR issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is numbered based on the document number, including the annex, volume, and book number, as applicable (i.e., **<TBR-XXXXX-001>** is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

**TABLE B2-1 TO BE RESOLVED ISSUES**

| TBR | Section | Description |
| --- | --- | --- |