National Aeronautics and
Space Administration

HEOMD-001

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HUMAN EXPLORATION AND OPERATIONS EXPLORATION OBJECTIVES

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REVISION AND HISTORY PAGE

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-	CRD HEO-001	Initial Baseline Release	9/7/16

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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 these objectives is to translate and bridge the gap between Agency-level human exploration strategy as articulated in NASA's Journey to Mars (J2M) publication and other programmatic documentation into clear and discrete objectives for implementation by HEOMD organizations and HEOMD-led missions. These objectives can also be used to help inform, identify, and/or prioritize Agency technology and science investments. These 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 Flight Test Objectives (FTOs) are created or updated in the normal course of business, those plans and products shall align to these objectives. The HEOMD exploration objectives will inform, and be informed 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 Phase 2 are not yet 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 the potential to bear relevance beyond the Phase 2 timeframe. 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

These objectives are applicable 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 managed via a Change Request (CR) to the Executive Secretary of the Directorate Program Management Council (DPMC). CRs shall be dispositioned through the HEOMD DPMC.

2.0 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The documents listed in this paragraph are applicable to the extent specified herein.

TABLE 2.1-1 APPLICABLE DOCUMENTS

Document Number	Document Revision	Document Title
N/A	N/A	N/A

2.2 REFERENCE DOCUMENTS

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

TABLE 2.2-1 REFERENCE DOCUMENTS

Document Number	Document Revision	Document Title
N/A	June 28, 2010	National Space Policy of the United States of America
P.L. 111-267	October 11, 2010	National Aeronautics and Space Administration Authorization Act of 2010
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	Current Revision	ESD Requirements

3.0 EXPLORATION OBJECTIVES IN A STRATEGIC CONTEXT

The National Space Policy of the United States of America directs that the Administrator of NASA shall:

- *Set far-reaching exploration milestones. By 2025, begin crewed missions beyond the Moon, including sending humans to an asteroid. By the mid-2030s, send humans to orbit Mars and return them safely to Earth.*

The NASA Authorization Act of 2010 establishes the following as a matter of national policy:

- *A long term objective for human exploration of space should be the eventual international exploration of Mars.*

The 2014 NASA Strategic Plan codifies this national policy 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 document, *Journey to Mars: Pioneering Next Steps in Space Exploration* expands upon the exploration of Mars as Agency policy and defines HEOMD's top-level strategy for implementing this policy. 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 three defined capability periods of exploration, starting with Earth Reliant exploration, through the Proving Ground of cislunar space, and culminating with Earth Independent exploration where human missions to the Mars system are possible. Each capability period 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 the Earth Reliant period 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 the Proving Ground are in earlier phases of formulation and development. Meanwhile, the capabilities needed for

operations in the Earth Independent period are contingent on knowledge and experience that is expected to be gained in the previous two periods. 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 advancement 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.

The National Space Policy, NASA 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. Implementation of the top-level strategic guidance is underway via mission and hardware capability specific products. These products include Level 1 requirements, ConOps, FTOs, 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.

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, these objectives define specific thresholds and milestones that must be accomplished with capabilities in development over an extended but reasonably manageable period of time in order to proceed to the next phase. These objectives provide guidance to enterprise and program planners for developing mission and hardware specific products within a strategic context and can help inform, identify, and/or prioritize Agency technology and science investments across the Agency. These objectives also inform, and are informed by, architectural studies that assess challenges and opportunities from now through the Mars surface horizon. Finally, these objectives are open to lessons learned from technology advancement, science discoveries, mission development and mission operations, and thus may be adapted to and inform adjustments to Agency strategy. The role of these objectives is illustrated in Figure 3.0-1, below.

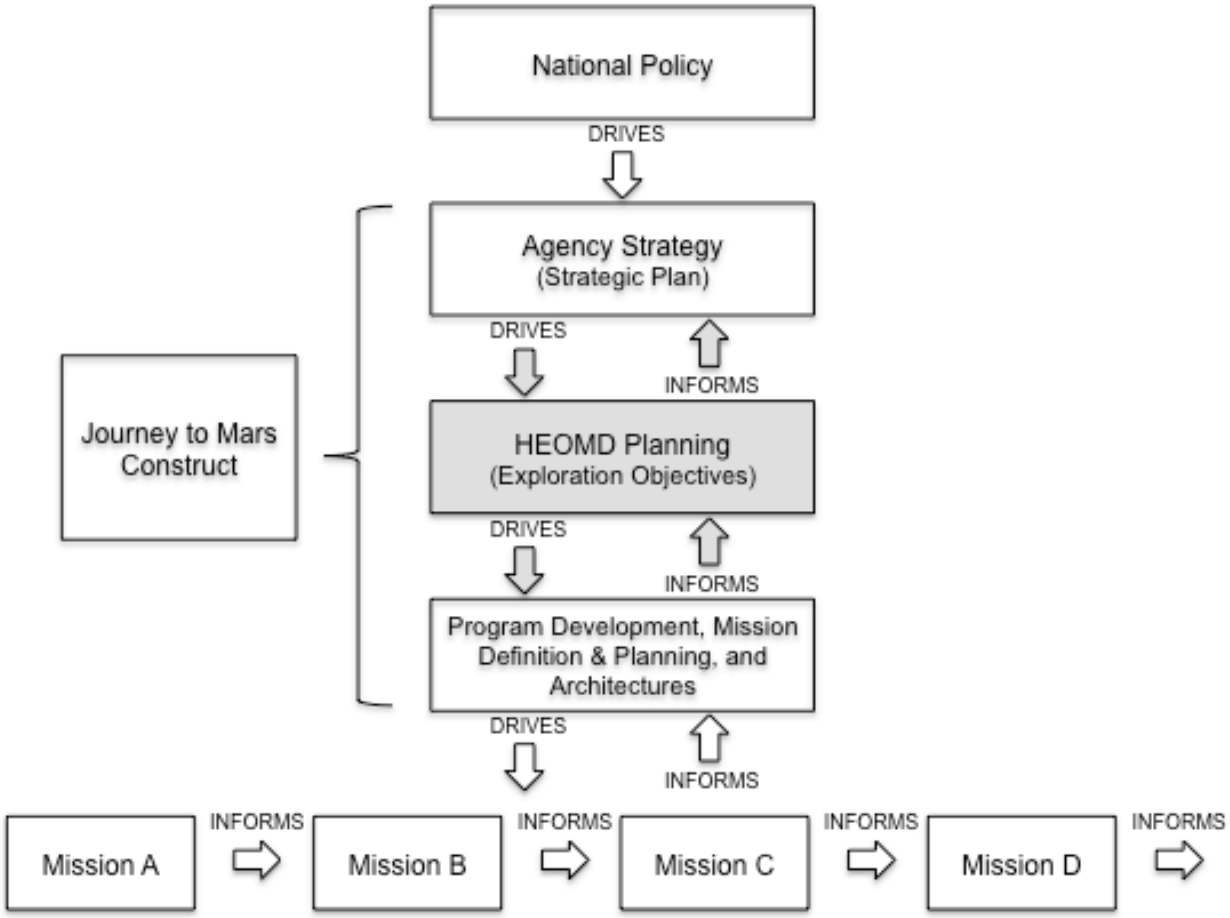

FIGURE 3.0-1 EXPLORATION OBJECTIVES IN CONTEXT

4.0 EXPLORATION PHASES

The Earth Reliant, Proving Ground, and Earth Independent periods are divided into phases, with a capstone demonstration defining the gate between each phase and the next. All activities are part of an integrated strategy that builds from experience gained in the Earth Reliant period, and informs objectives, capabilities, and missions in the Proving Ground and Earth Independent periods.

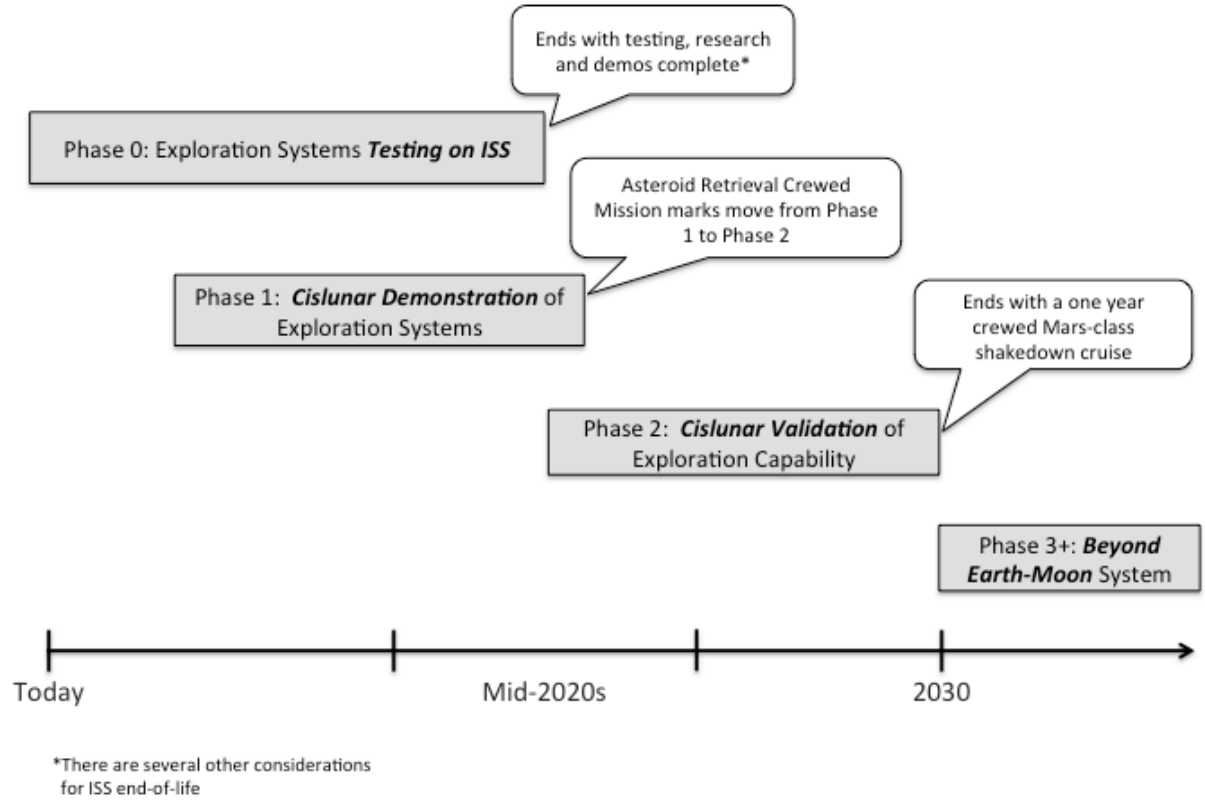

FIGURE 4.0-1 EXPLORATION PHASES

4.1 PHASE 0: EXPLORATION SYSTEMS TESTING ON ISS

This phase encompasses NASA's current human exploration activities aboard the International Space Station (ISS). The ISS enables exploration objectives in the Proving Ground and Earth Independent phases. Human exploration activities on ISS will 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. Phase 1 culminates in the capstone demonstration of the Asteroid Redirect Crewed Mission (ARCM) in the mid-2020s.

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. Phase 2 culminates in the capstone demonstration of a one year crewed “shakedown cruise” of a Mars transit habitation capability in the 2030 timeframe.

4.4 PHASE 3+: BEYOND EARTH-MOON SYSTEM

This phase covers Earth Independent activities that build on what is learned on ISS and in cislunar space to enable human missions to the Mars vicinity, including the Martian moons, and eventually the Martian surface.

5.0 OBJECTIVES

5.1 ORGANIZATION

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

5.1.1 Objective Category: Transportation

In the Earth Reliant and Proving Ground 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 the Earth Independent timeframe, 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.

5.1.2 Objective Category: Working in Space

In the Earth Reliant and Proving Ground timeframe, Working in Space encompasses three areas: science, deep space operations, and in-situ resource utilization. Science focuses on enabling science community objectives. 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 extraction techniques for their potential use in human exploration architectures. In the Earth Independent timeframe, 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 these objectives.

5.1.3 Objective Category: Staying Healthy

In the Earth Reliant and Proving Ground 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 mitigation protocols for Mars-class missions. In the Earth Independent timeframe, Phase 3 and beyond, "staying healthy" objectives will include providing crew health, performance and mitigation protocols for Mars missions. This includes a Mars transit vehicle and surface, habitation capability sufficient to support crew on Mars missions and in radiation environments, including required dormancy periods with minimal refurbishment.

5.2 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.

5.2.1 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.

5.2.2 Measurement of Objective Achievement

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

5.3 PHASE 0 OBJECTIVES

TABLE 5.3-1 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

5.4 PHASE 1 OBJECTIVES

TABLE 5.4-1 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	Transportation
P1-03	Demonstrate SLS Block 1B co-manifested capability	Transportation
P1-04	Demonstrate Orion's ability to support crew in deep space	Transportation
P1-05	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
P1-06	Demonstrate operation of long-duration high power solar arrays and solar electric propulsion (SEP) transportation of in-space propulsion elements	Transportation
P1-07	Demonstrate ability to stage habitation and other capabilities in deep space for later utilization	Transportation
P1-08	Demonstrate ability for crewed rendezvous and operation with a previously staged element(s)	Transportation
P1-09	Demonstrate autonomous rendezvous, proximity operations, and docking in deep space	Transportation
P1-10	Demonstrate ability to dispose of assets from deep space	Transportation
P1-11	Demonstrate autonomous deep space trajectory design, planning, and navigation	Transportation
P1-12	Demonstrate deep space crewed operations up to Mars communications latency	Working in Space
P1-13	Validate ability to conduct EVA in deep space	Working in Space
P1-14	Validate integrated radiation risk mitigation ability to provide As Low As Reasonably Acceptable (ALARA) exposure, including monitoring, mitigation, and operational strategies	Working in Space
P1-15	Demonstrate transition between crewed and uncrewed operations	Working in Space
P1-16	Demonstrate human/robotic interactions in deep space	Working in Space
P1-17	Demonstrate stowage strategies within available volume for deep space missions	Working in Space
P1-18	Demonstrate the collection and return of geologic, biological and/or scientific samples including planetary protection protocols.	Working in Space
P1-19	Evaluate the nature and distribution of volatiles and extraction techniques and decide on their potential use in human exploration architecture	Working in Space
P1-20	Demonstrate crew operations with a natural space object	Working in Space

	in a low gravity environment	
P1-21	Enable science community objectives in deep space	Working in Space
P1-22	Enable commercial and international partnership objectives in deep space	Working in Space
P1-23	Demonstrate ability to use an uncrewed capability to enable science, technology, and exploration	Working in Space
P1-24	Demonstrate/evaluate exploration medical capabilities	Staying Healthy
P1-25	Demonstrate/evaluate human flight operations crew physiological well-being in deep space	Staying Healthy
P1-26	Demonstrate/evaluate human flight operations crew psychological well-being in deep space	Staying Healthy
P1-27	Demonstrate/evaluate human health countermeasures	Staying Healthy
P1-28	Evaluate the effects of deep space on complex organisms, plants, food, pharmaceuticals, and animal models	Staying Healthy

5.5 PHASE 2 OBJECTIVES

TABLE 5.5-1 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 fuel 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	Evaluate 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	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

5.6 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

ARCM	Asteroid Redirect Crewed Mission
ConOps	Concept of Operations
CR	Change Request
DPMC	Directorate Program Management Council
ECLSS	Environmental Control and Life Support System
ESD	Exploration Systems Development
EVA	Extra-Vehicular Activity
FTO	Flight Test Objective
HEOMD	Human Exploration and Operations Mission Directorate
ISS	International Space Station
J2M	Journey to Mars
LEO	Low Earth Orbit
OPR	Office of Primary Responsibility
SEP	Solar Electric Propulsion
SLS	Space Launch System
TLI	Trans-Lunar Injection

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