National Aeronautics and Space Administration

# HEO SE&I Update
## NASA Advisory Council
## Human Exploration & Operations Committee

**Greg Chavers**
**Acting Deputy Associate Administrator for HEO SE&I**
**Exploration Systems Development Mission Directorate**
**19 January 2022**

# Outline

- **Overview of Systems Engineering & Integration Organizational Functions**
- **Recent accomplishments**
- **Forward work**

# STRATEGY & IMPLEMENTATION FLOW

NATIONAL POLICY

- Space Policy Directive 1
- Send the first woman and first person of color to the Moon

AGENCY STRATEGY

- Moon to Mars Strategy
- Programmatic requirements, budget, risk

ARCHITECTURE ASSESSMENTS

- Campaign manifests, capability gaps, requirements, technical integration, and science and technology utilization

HEO SE&I is the delegated authority for ***technical integration*** across HEO divisions

**HEO DIVISIONS & DEVELOPMENT PROGRAMS**

TRADE STUDIES | ELEMENT PERFORMANCE | ELEMENT FORMULATION | TECHNOLOGY & UTILIZATION PUSH / PULL | TECHNICAL INTEGRATION / HEO PRODUCTS

BUDGET & RISK PROFILES

# HEO SE&I Functional Descriptions

## Systems Engineering & Integration Deputy Associate Administrator

Responsible for ensuring the overall HEO strategy is reflected in program requirements; leads architecture, formulation mission planning and provides technical direction for HEO activities (Moon, Mars and other human missions)

### Strategy and Architecture

Translates Agency vision into an integrated HEO portfolio that supports national exploration goals through development of campaigns and architectures and performing formulation activities

### Capability Integration

Articulates capability needs for lunar and Mars missions, identifies integration and overlap between mission needs, and develops strategies for advancing key capabilities that support those needs

### Science and Utilization

Integrates science and technology goals from mission directorates and international partners to develop HEO utilization goals, objectives and requirements for Artemis missions, and the cross-platform research strategy to prepare for human missions to Mars

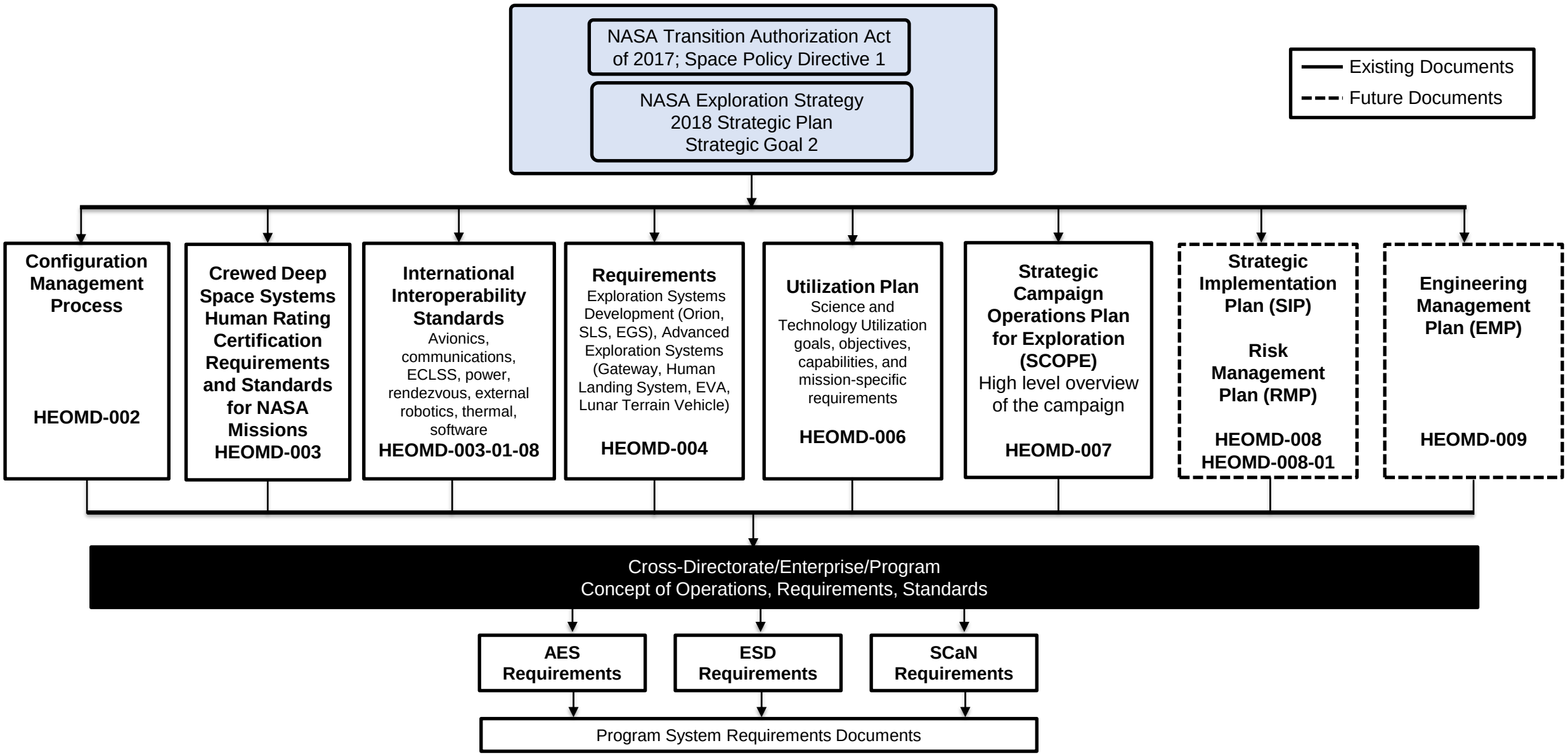
### Technical Integration

Focused on ensuring agency strategies are achieved through HEO systems and programs, establishes and maintains HEO top-level requirements, and allocates to the various campaign elements and initiatives

### Portfolio Integration

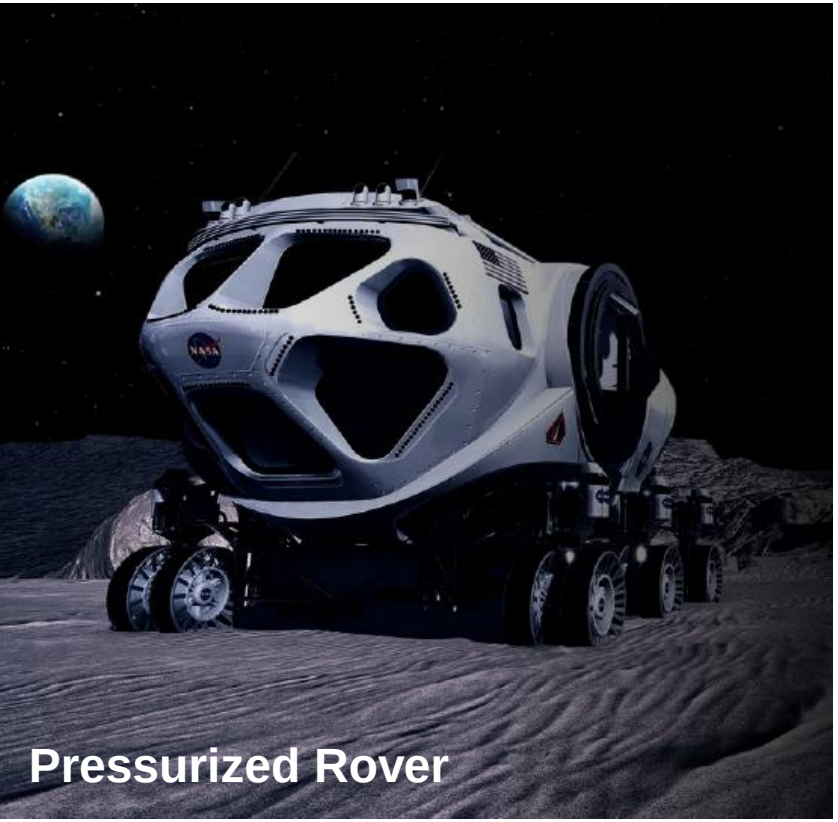
Provides cross-cutting support to HEO systems and programs coordinating activities, boards, schedules and driving issue resolution

# HEO Products – Current and Planned



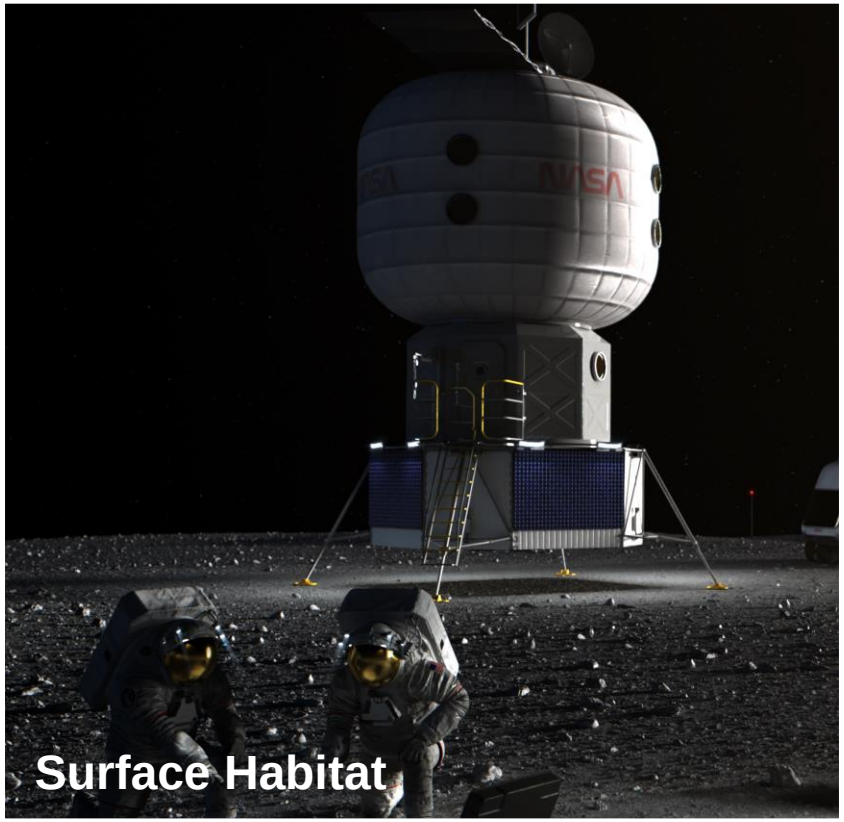
# Strategy & Architectures

# Major Hardware Concepts in Formulation



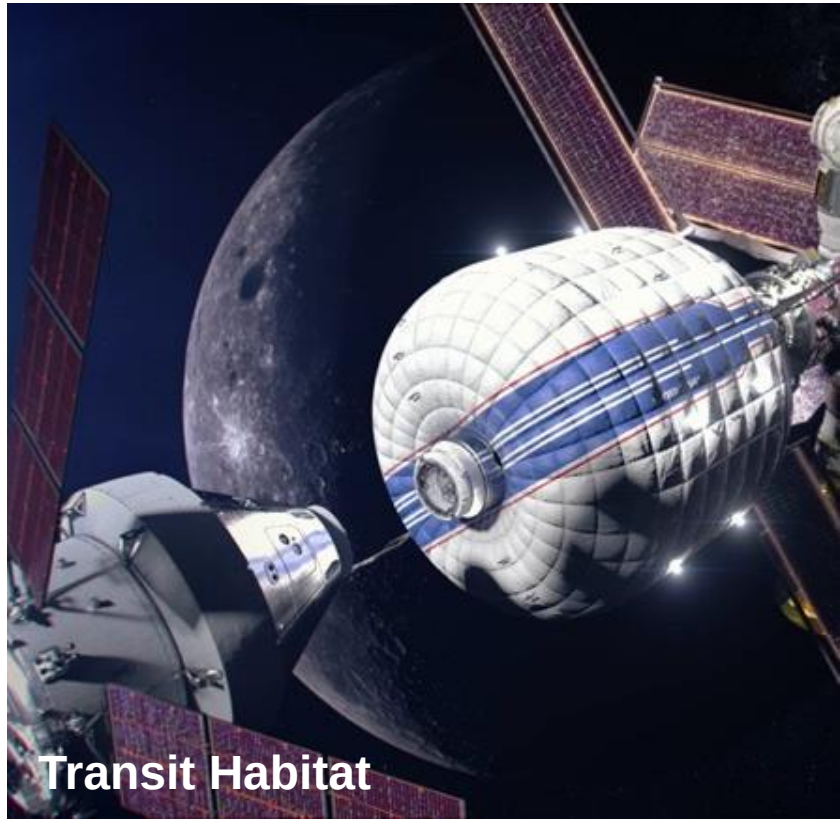
## Pressurized Rover

- Habitation for 30 days for 2 crew
- Rear suitport allows astronaut egress and ingress of the vehicle via the spacesuits, leaving the suits outside the pressurized volume
- Provides volume for spares and logistics
- Power generation and energy storage for lunar environment
- Dust and radiation protection
- Reuse for multiple missions of 15-year lifetime
- Capability also identified in current concepts for first human mission to Mars



## Surface Habitat

- 2-4 crew – medical, exercise, galley, crew quarters, stowage
- 30-60 day capable habitat
- EVA capable via air lock with suit maintenance capability
- Power generation, recharge capability for surface assets
- Communication hub for surface assets
- Reuse for multiple missions of 15 year lifetime



## Transit Habitat

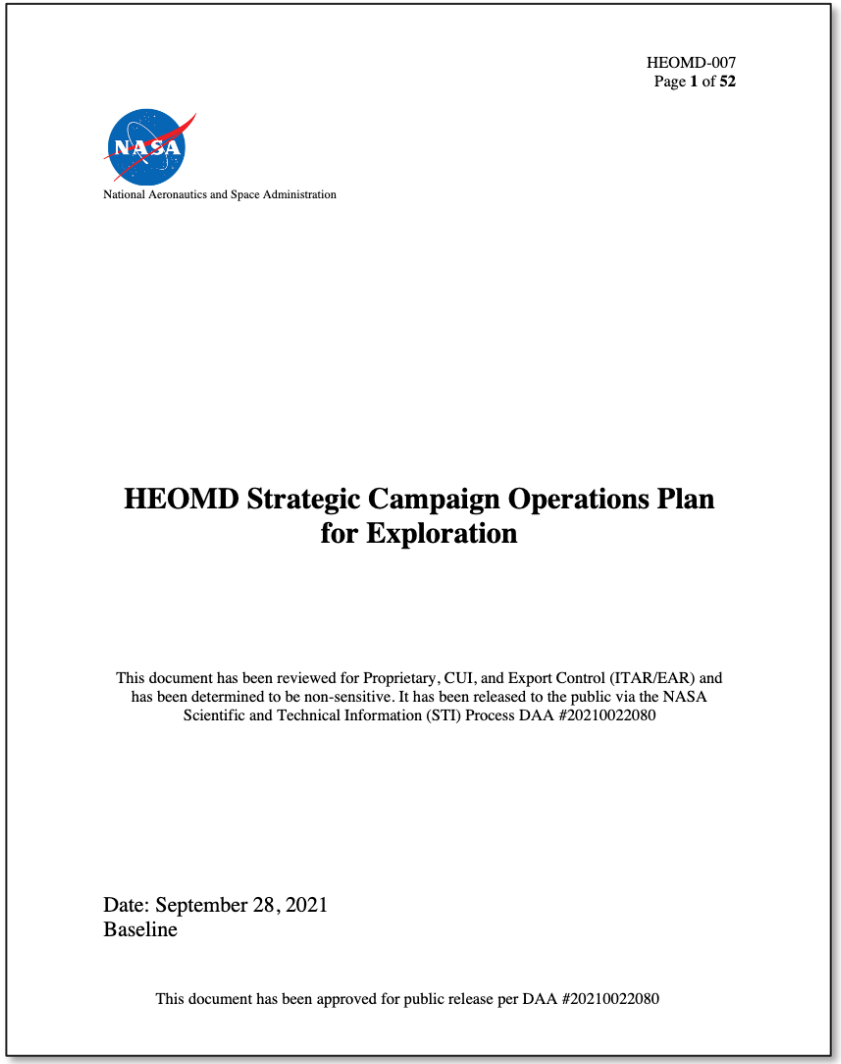
- Keep crew healthy and productive during long duration, deep space stays including:
  - Shakedown missions at Gateway and while free-flying with interim propulsion
  - Lunar-Mars analogs
  - Up to 1100-day Mars transit and orbital stays
- Demonstrate needed capabilities to live for long durations beyond low Earth orbit
- Build on ISS and commercial investment in deep space habitation

# HEOMD Strategic Campaign Operations Plan for Exploration (HEO-007)

ESDMD SE&I released HEO-007, Strategic Campaign Operations Plan for Exploration (SCOPE) on the NASA Technical Reports Server, making it publicly available. The SCOPE, baselined in August 2021, connects national policy and NASA's strategic plan with the agency's human spaceflight activities and implementation at the division and corresponding program levels.

The document introduces exploration goals and ground rules and assumptions, including high-level concepts of operations, across four human exploration campaign segments, from low-Earth orbit to Mars.

Having the SCOPE publicly available will help facilitate discussions with existing and potential partners who may offer contributions to Artemis or initial human missions to Mars.



HEOMD-007
Page 1 of 52

National Aeronautics and Space Administration

**HEOMD Strategic Campaign Operations Plan for Exploration**

This document has been reviewed for Proprietary, CUI, and Export Control (ITAR/EAR) and has been determined to be non-sensitive. It has been released to the public via the NASA Scientific and Technical Information (STI) Process DAA #20210022080

Date: September 28, 2021
Baseline

This document has been approved for public release per DAA #20210022080

Available on NASA Technical Reports Server:
https://ntrs.nasa.gov/citations/20210022080

# EXPLORATION CAMPAIGN AND CAMPAIGN SEGMENTS

## HUMAN PRESENCE IN LEO

PARTNER ENABLED

## HUMAN LUNAR RETURN

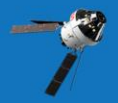
## SUSTAINED LUNAR PRESENCE

PARTNER ENABLED

## HUMANS TO MARS

ISS AND COMMERCIAL LEO PLATFORMS

SLS BLOCK 1



ORION

NEAR-TERM ARTEMIS MISSIONS

SLS BLOCK 1B

SLS BLOCK 2

COMMERCIAL CARGO

GATEWAY

Increased Crew Size & Longer Durations in Micro-gravity

TRANSIT HABITAT AND MARS TRANSIT

COMMUNICATIONS RELAYS

HUMAN LANDING SYSTEM

SURFACE UTILITIES

SURFACE HABITAT

LOGISTICS LANDER

Fission Surface Power

MARS ASCENT VEHICLE

Habitation Systems

Mobile Expedition Duration / Mobile Exploration Range

Partial Gravity Operations

PRESSURIZED ROVER

PRESSURIZED ROVER

LUNAR TERRAIN VEHICLE

In-Situ Resource Utilization

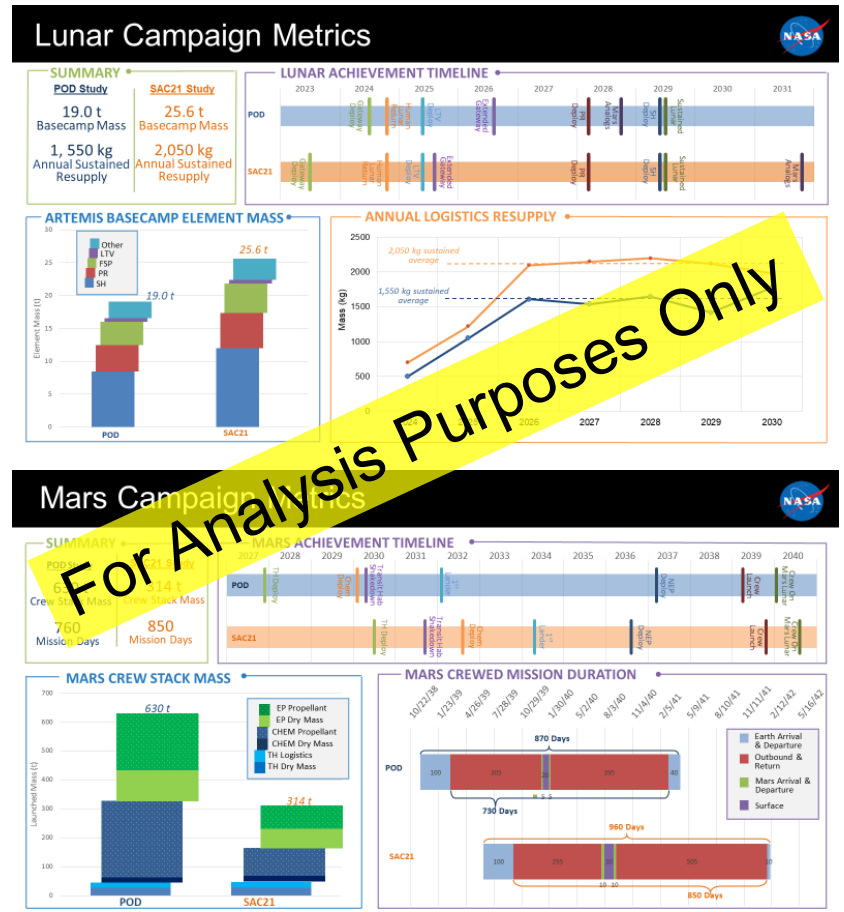
MARS TERRAIN VEHICLE

Autonomous Robotics Systems & Contingency Crew Transportation

20220118

# Strategic Analysis Cycle FY21 (SAC21) Campaign Summary

- **Strategic Analysis Cycles used to drive analysis and trades over respective FY**
  - Sets ground rules and assumptions for use in FY
- **Completed SAC21 analyses, key takeaways:**
  - Refinement of Artemis Basecamp end state and nominal mission timeline
    - Need to focus on build-up to end state
  - Fielding a human Mars mission concurrent with Artemis has pros & cons: Limited resources, Mars forward philosophy for the Moon to save future costs
    - Need to continue assessing affordability and risk trades
- **Leveraged to develop SAC22 campaign**
  - Anchored in PPBE FY23
  - Informed by SAC21 campaign, affordability, and risk analyses and current programmatic constraints



# Key Architecture Trades – FY22

## Lunar

- Artemis Base Camp (ABC) Build-Up Order & Schedule
- Integration of “All Chemical” Capabilities & Elements
- Surface Element Delivery & Capabilities
- Integrate Logistics Delivery
- Traverse planning in conjunction with SMD

## Mars

- Interim Mission Options (Orbital and Other)
- Mars In-Space Propulsion & Mission Duration
- Integration of “All Chemical” Capabilities & Elements
- Follow-On Mission Options & Schedule

## Overall Campaign

- Affordability – timing of DDTE and key deliveries
- Comparison of metrics between SAC21 and SAC22

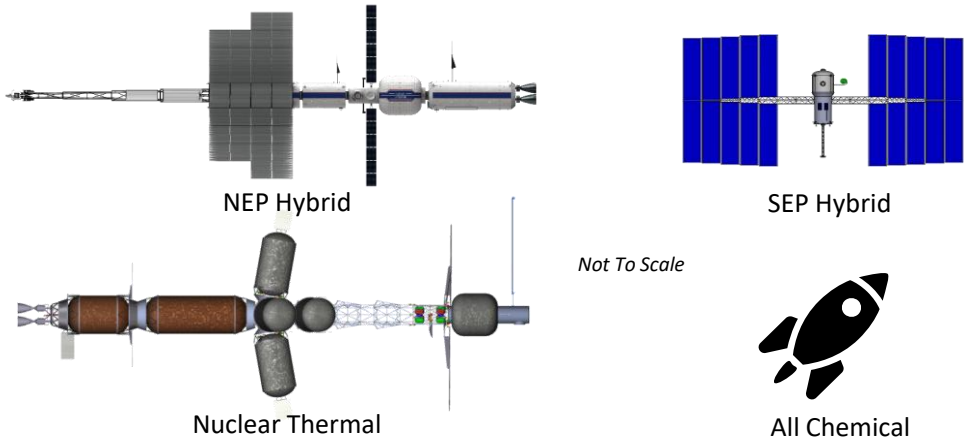
# Mars Assessments of Alternatives

**Purpose**

To provide status of the in-space transportation conceptual development for human Mars missions (further discussed in white paper) and identify decision points for Mars Transportation.

**Context**

- Mars Architecture Team (MAT) is assessing four transportation concepts for human Mars missions
  - 1) Solar Electric Propulsion (SEP)/Chemical Hybrid, 2) Nuclear Thermal, 3) Nuclear Electric Propulsion (NEP)/Chemical Hybrid, and 4) All Chemical propulsion systems
- Mass has been utilized as preliminary metric, but comprehensive programmatic assessment is planned for FY22




**Key Points**

- Mars transportation architecture is shaped by both physics and policy (or ground rules in lieu of policy)
- Each architecture is “better”, depending on the preferred selection criteria (fast, cheap, minimum development, etc.)
- FY22 analysis is intended to begin defining high priority decision gates and developing critical data needed to support decisions
- Provide understanding of the performance characteristics for each architecture in the context of a comprehensive set of metrics

# Potential Opportunities for International Partner Participation

## Architecture areas in formulation and open to international participation:

- Power infrastructure and distribution
- Communication and Navigation
- Logistics
- Robotics and Mobility
- Habitation and Crew Health Systems
- Lunar Environment Mitigation
- Utilization Operations
- Lunar sampling and curation
- Exploration Systems and Operations Analog Testing
- Other areas TBD


Dec. 2021: Completed a series of technical interchange meetings with JAXA regarding their interest in developing the Artemis Pressurized Rover. Forward work continues in 2022.

**Study agreement in place with JAXA. Agreements with CSA, ASI, ESA in work.**

# Science & Technology Utilization

# Science & Technology Utilization

## INTEGRATING ACROSS MISSION DIRECTORATES

Integrate science and technology goals from mission directorates and international partners to develop HEO utilization goals, objectives and requirements for Artemis missions, and the cross-platform research strategy to prepare for human missions to Mars

---

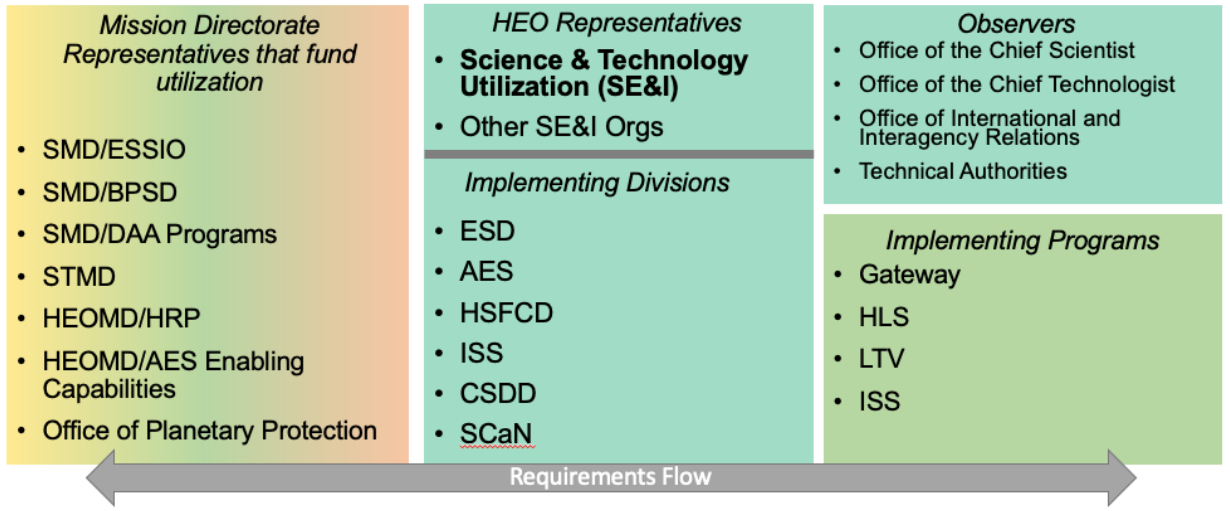
## EXAMPLES:

- HEO-006 Utilization Plan joint with SMD and STMD - High level utilization goals, objectives and requirements
  - Utilization capabilities and their phasing over time
  - Mission-specific annexes with mission directorate requirements to enable research solicitations
  - Includes ISS, Commercial LEO, Artemis and Mars
- Co-chair the Utilization Coordination and Integration Working Group (UCIG) with SMD & STMD
- Coordinating HEO process for using our CLPS mass allocations and representative to SMD CLPS manifest selection board

## INTEGRATING WITH ESDMD/SOMD DIVISIONS

- Work with divisions and users on high-level goals, objectives, and strategic plans
- Interface with AES and ESD on approach to implementation and payload manifest for Artemis
- Ensure science and technology inputs are integrated into architecture formulation activities

**UTILIZATION COORDINATION AND INTEGRATION WORKING GROUP (UCIG) REQUIREMENTS FLOW**



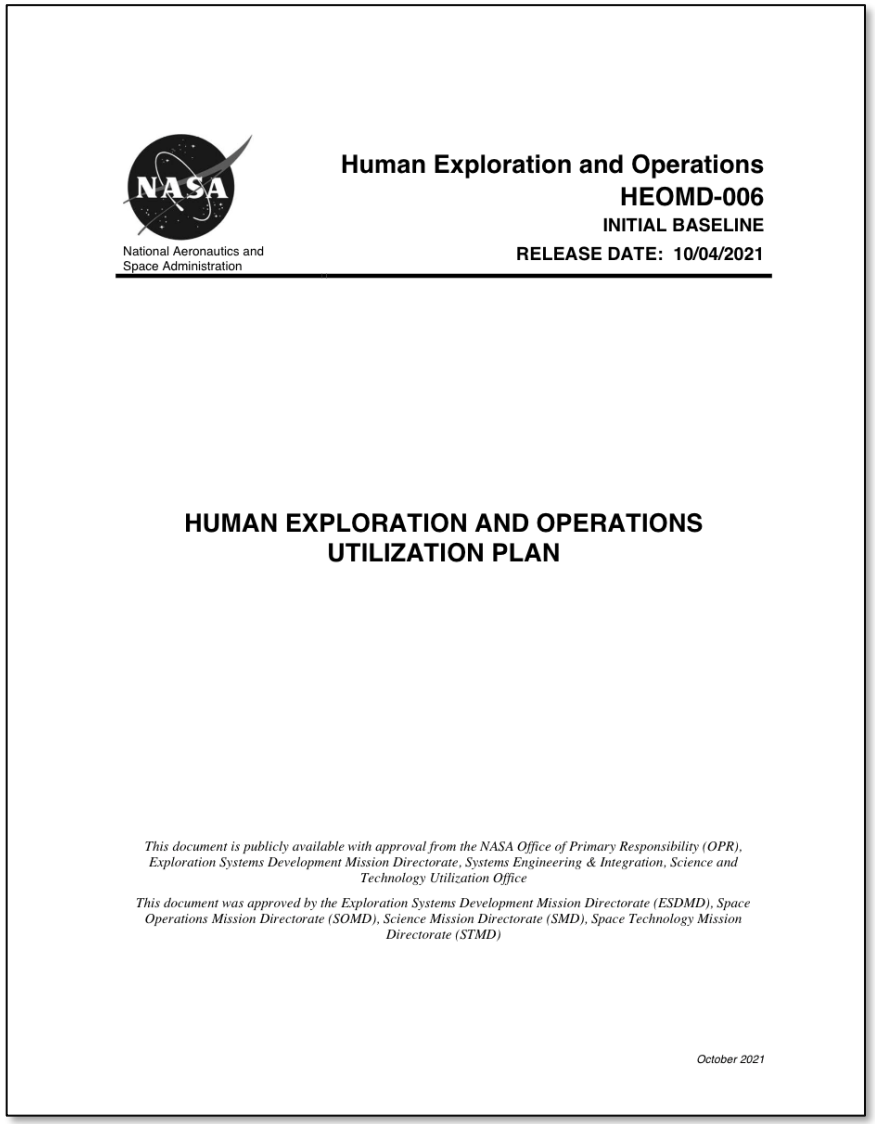
# Human Exploration and Operations Utilization Plan (HEO-006)

Identifies and describes NASA's science and technology utilization goals and objectives that will be enabled by human missions.

These goals and objectives have been defined by NASA's Science Mission Directorate (SMD), Space Technology Mission Directorate (STMD),and HEO Mission Directorate (HEOMD).

The goals and objectives will be used to identify how human missions will support the science and technology communities to conduct fundamental research about our universe and solve the scientific and technological challenges for sustaining and expanding human exploration

The scope of the Utilization Plan is applicable to Artemis lunar exploration missions; SMD, STMD,and HEOMD utilization goals for HEOMD platforms; and agency exploration strategy using the International Space Station (ISS), the Gateway, Human Landing System (HLS), and lunar missions to prepare for future missions to Mars.



National Aeronautics and Space Administration

**Human Exploration and Operations**
**HEOMD-006**
**INITIAL BASELINE**
**RELEASE DATE: 10/04/2021**

**HUMAN EXPLORATION AND OPERATIONS UTILIZATION PLAN**

*This document is publicly available with approval from the NASA Office of Primary Responsibility (OPR), Exploration Systems Development Mission Directorate, Systems Engineering & Integration, Science and Technology Utilization Office*

*This document was approved by the Exploration Systems Development Mission Directorate (ESDMD), Space Operations Mission Directorate (SOMD), Science Mission Directorate (SMD), Space Technology Mission Directorate (STMD)*

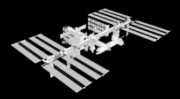
*October 2021*

| HEO-006 Utilization Plan Sections | | | CR Release | TCM Dates | DPMC |
|---|---|---|---|---|---|
| **Main Volume:** Goals and Objectives | | | ✓ 24 June ’21 (CR HEO-0015) | ✓ 12 Aug ’21 | ✓ 4 Oct ‘21 |
| **Annex 1:** Cornerstone Utilization Capabilities Complex/Cross-Program Use Cases | | | ✓ 24 Aug ’21 (CR HEO-0019) | ✓ 4 Nov ’21 | Feb ’22 ACB/ECB TBD |
| | **Annex 1.1**: Model Traverse Approaches | | | ✓ 9 Dec ’21 | |
| | **Annex 1.2**: End-to-End Sampling Strategy | | | ✓ 17 Nov ‘21 | |
| | **Annex 1.3**: Integrated Planetary Protection | | | ✓ 21 Oct ’21 | |
| | **Annex 1.4**: Extended Missions | | | ✓ 21 Oct ’21 | |
| | **Annex 1.5**: Integrated Crew Research | | | ✓ 21 Oct ’21 | |
| | **Annex 1.6**: Robotic Utilization for HEO Assets | | | ✓ 9 Dec ’21 | |
| | **Annex 1.7**: Integrated Instrument Strategy | | | ✓ 17 Nov ‘21 | |
| | **Annex 1.8**: Complex Operations in Cold/Shadowed Regions | | | ✓ 17 Nov ‘21 | |
| **Annex 2:** Phasing of Capabilities and Facility Requirements | | | July ‘22 | TBD | Nov ‘23 |
| **Annex 3:** Integrated LEO-Mission-Specific Requirements | | | | | |
| | **Annex 3.1**: One-Year Missions | | TBD ‘22 | TBD | July ‘22 |
| | **Annex 3.2**: Commercial LEO Dev | | *Under discussion with CLD* | | |
| **Annex 4:** Artemis Mission-Specific Utilization Requirements | | | | | |
| | **Annex 4.0:** Generic Artemis Mission Utilization Requirements | | TBD ‘22 | TBD | July ‘22 |
| | | **Annex 4.0.1**: Crew Access for Data and Sample Collection | | | |
| | **Annex 4.1**: First Crewed Landing (Artemis 3) | | ✓ CR HEO-0015 | ✓ 19 Aug ’21 | ✓ 4 Oct ‘21 |
| | **Annex 4.2**: HLS Uncrewed Demo Mission of Opportunity | | TBD ‘22 | TBD | July ‘22 |
| | **Annex 4.3**: Second Crewed Landing/ Sortie (Artemis 5) | | TBD ‘22 | TBD | July ‘22 |
| **Annex 5:** Integrated Mars Mission-Specific Utilization Requirements | | | *Using community input to SMD- scheduled in May* | | |

# Capability Integration

# Capabilities Integration

**CAPABILITY** | The ability to complete a task or meet an exploration objective through Architecture, Engineering, Development, Technology, Operations or Research for a given set of constraints and level of risk.



## Current Capabilities

Capabilities we have today, established and flight validated on the International Space Station, robotic missions….

THE DIFFERENCE IS THE **GAP**

## Future Needed Capabilities

Anticipated future capabilities based on national space policy, planned mission architectures, agency strategic planning, and standards.

## GAP CLOSURE APPROACH

- Technology
- Development
- Engineering
- Scientific Research
- Architecture Changes
- Operational Concepts
- Policy Decisions

## TEST LOCATION

- Mars surface
- Mars spacecraft
- Lunar surface
- Gateway/Cislunar
- Orion spacecraft
- ISS/LEO
- Ground Activity

## MILESTONE CLOSURE

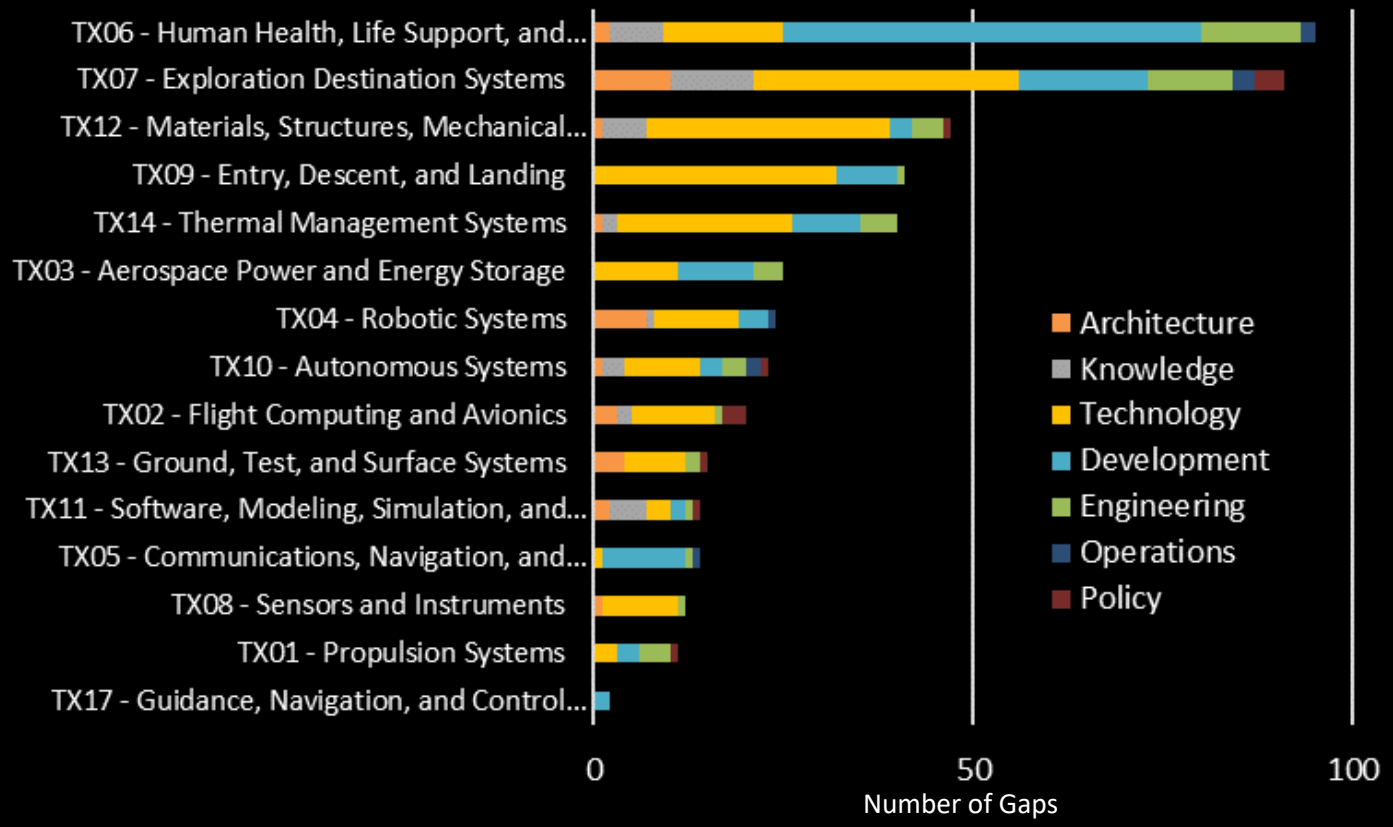
- Tech Demo
- Research Utilization
- Analog Activities
- Verification & Validation
- Qualification Test

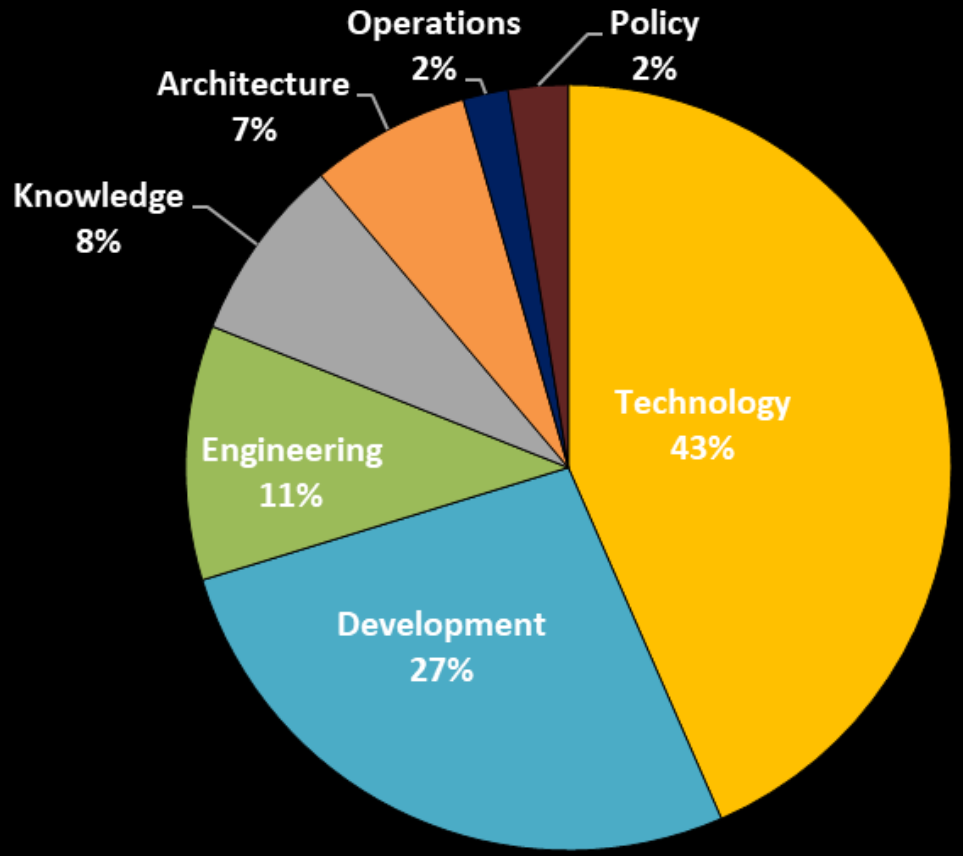
## OUTCOMES

- TRL Advancement
- Technology Infusion
- Updated Procedures
- Countermeasures
- Updated Standards
- Updated Mission Profile

# Gap List Update

FY22 Gap List
474 Gaps



# Technical Integration

# Technical Integration

*Engage Across Mission Directorates and Divisions within ESDMD/SOMD*

- **Collaborates with Division level SE&I functions in order to maintain insight throughout the directorate**
  - Configuration Management and Data Management
  - Risk Management
  - Requirements Development
- **Engages the Technical Authorities (OCHMO, SMA,OCE) for coordination and sign-off of HEO decision memoranda and HEO controlled technical documents**
- **Establishes and maintains HEO top-level requirements for the technical baseline and allocates to the various campaign elements and initiatives.**
- **Leads requirements development in areas such as Human Rating Certification, lunar exploration campaign phases, lunar communications network, and commercial LEO destinations.**

| Document Number | Title | Status |
|---|---|---|
| HEOMD-002 | Human Exploration and Operations Configuration Management Process | Baselined |
| HEOMD-003 | Deep Space Human Rating Certification Requirements and Standards for NASA Missions | Baselined, Rev A |
| HEOMD-003-01-08 | International Interoperability Standards (Avionics, Communications, ECLSS, Power, Rendezvous, External Robotics, Thermal, Software) | Baselined |
| HEOMD-003-04 | International Power System Interoperability Standard to Revision A | CR in Process |
| HEOMD-003-09 | International Docking Interoperability Standard (formerly ISS IDSS) | CR in Process |
| HEOMD-004 | Human Exploration and Operations Requirements | Baselined, Rev C |
| HEOMD-006 | Human Exploration and Operations Utilization Plan-Main Body, Annex 4<br>Human Exploration and Operations Utilization Plan-Annex 1 | Baselined<br>CR in Process |
| HEOMD-007 | HEO Strategic Campaign Operations Plan for Exploration (SCOPE) | Baselined |
| HEOMD-008 | HEO Strategic Implementation Plan (SIMD) | Draft |
| HEOMD-008-01 | HEO Risk Management Planm (SIMD) | Draft |
| HEOMD-008-02 | HEO Formulation Guide (SIMD) | Draft |
| HEOMD-009 | HEO Systems Engineering and Integration (SE&I) Engineering Management Plan | Draft |

| Document Number | Title | Status |
|---|---|---|
| HEOMD-404 | Artemis Base Camp Reference Mission | Version 1, 3/29/21 |
| HEOMD-405 | HEO SE&I-Integrated Exploration Capabilities Gap List | Version 2, 12/17/21 |
| HEOMD-406 | HEO SE&I-Strategy & Architecture, Lunar Specific Ground Rules and Assumptions (GRAs) | Version 1, 10/5/21 |
| HEOMD-407 | HEO SE&I-Strategy & Architecture, Mars Specific Ground Rules and Assumptions (GRAs) | Version 2, 11/4/21 |
| HEOMD-408 | HEO SE&I-Strategy & Architecture, Overarching Ground Rules and Assumptions (GRAs) | Version 2, 11/4/21 |
| HEOMD-410 | HEO Science & Technology Utilization-Lunar Traverse Data Book | Version 1, Pending Release Week of 1/10/22 |
| HEOMD-415 | Reference Surface Activities for Crewed Mars Mission Systems and Utilization | Draft |

HEO Controlled Technical Documents, Decision Memoranda, and Data Managed Products

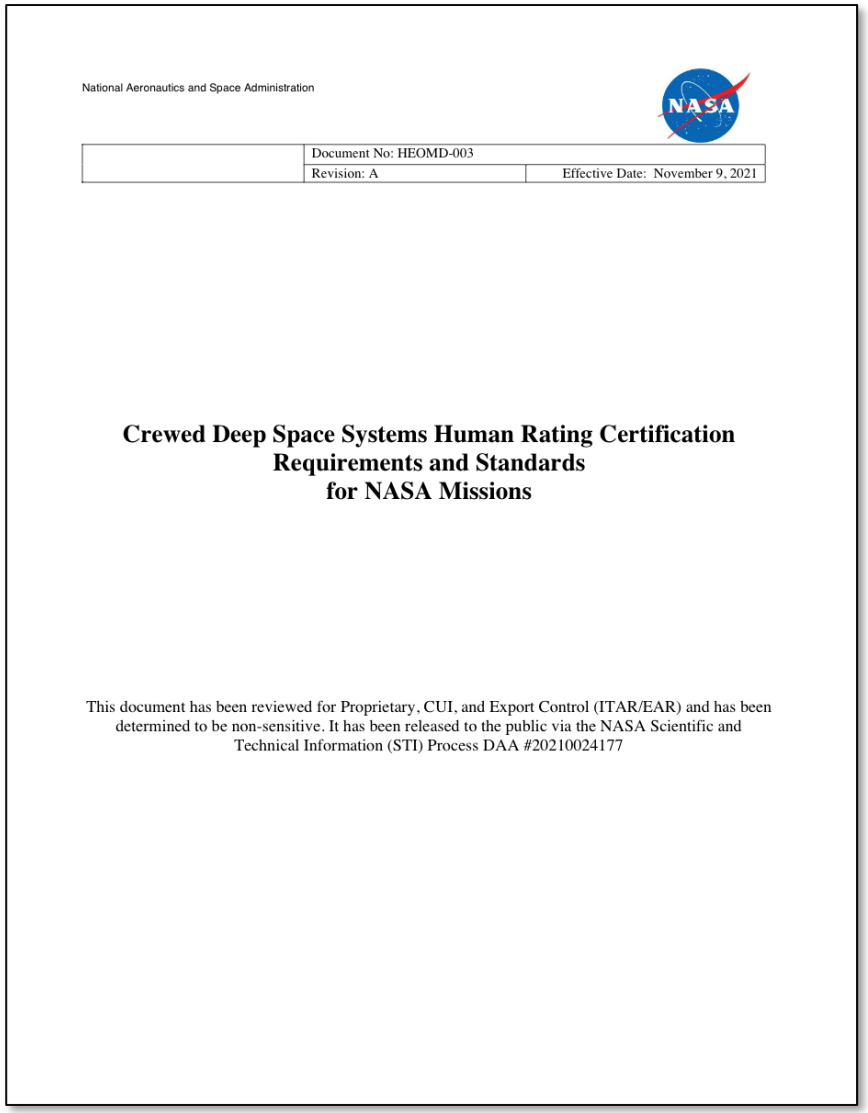
# Crewed Deep Space Systems Human Rating Certification Requirements and Standards for NASA Missions, Rev A (HEOMD-003)

Consolidated set of technical requirements, standards, and processes that NASA Program Managers shall implement for human rating certification of Crewed Deep Space Systems.

Defines requirements, standards, and human rating certification process and products that will be used to certify systems as acceptably safe to carry NASA or NASA-sponsored crewmembers on deep space missions for those programs that are not governed by NPR 8705.2, Human Rating Requirements for Space Systems.

- Orion, SLS, and EGS are governed by NPR 8705.2.

Baselined in March 2021, Rev A added two new requirements for Crew Support and clarified autonomy requirement in support of Sustaining Phase of Artemis. Revised Certification Process section to no longer require a Human Rating Certification Package, rather allow responsible programs to define a Human Rating Plan that leads to the final Certification (Approved at the Directorate Program Management Council (DPMC) on November 9, 2021.



National Aeronautics and Space Administration

| | Document No: HEOMD-003 | |
|---|---|---|
| | Revision: A | Effective Date: November 9, 2021 |

**Crewed Deep Space Systems Human Rating Certification Requirements and Standards for NASA Missions**

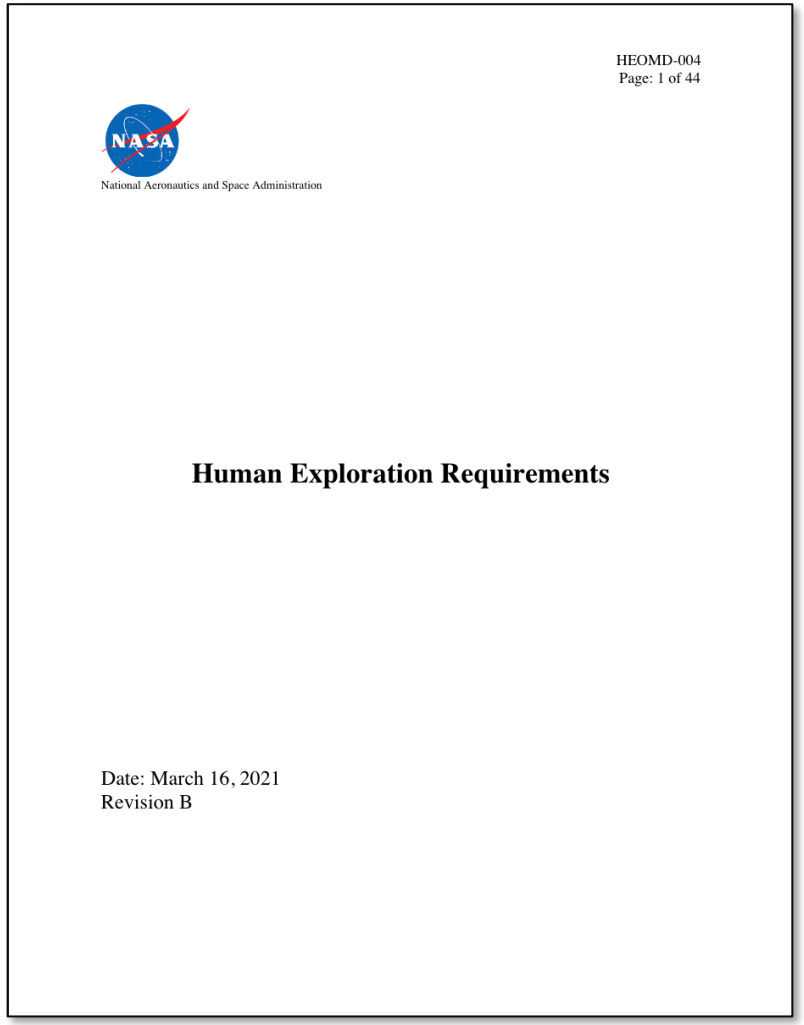
This document has been reviewed for Proprietary, CUI, and Export Control (ITAR/EAR) and has been determined to be non-sensitive. It has been released to the public via the NASA Scientific and Technical Information (STI) Process DAA #20210024177

# Human Exploration Requirements (HEOMD-004), Rev C

Captures requirements controlled by the Human Exploration and Operations Mission Directorate (HEOMD) for the Programs responsible for design, development, and operation of systems to meet HEOMD goals and objectives. These requirements include established Artemis Programs (Orion Crew Vehicle, Space Launch System (SLS), Exploration Ground Systems (EGS)), Human Landing System (HLS), the Gateway(including Exploration Extra Vehicular Activity(xEVA))and Programs/Projectsin formulation (Lunar Terrain Vehicle (LTV)) and new requirements levied on other HEO divisions from this point forward.

HEOMD-004 is intended to be utilized in conjunction with HEOMD-003, Crewed Deep Space Systems Human Rating Certification Requirements and Standards for NASA Missions.

Rev C updates included expanded timeframe of requirements effectivity, covering initial lunar missions, sortie missions, and Artemis Base Camp missions. Additional requirements updates were discussed for Gateway, Lunar Terrain Vehicle, and the Human Landing System. New requirements for lunar communications and navigation under Rev C were also covered.



HEOMD-004
Page: 1 of 44

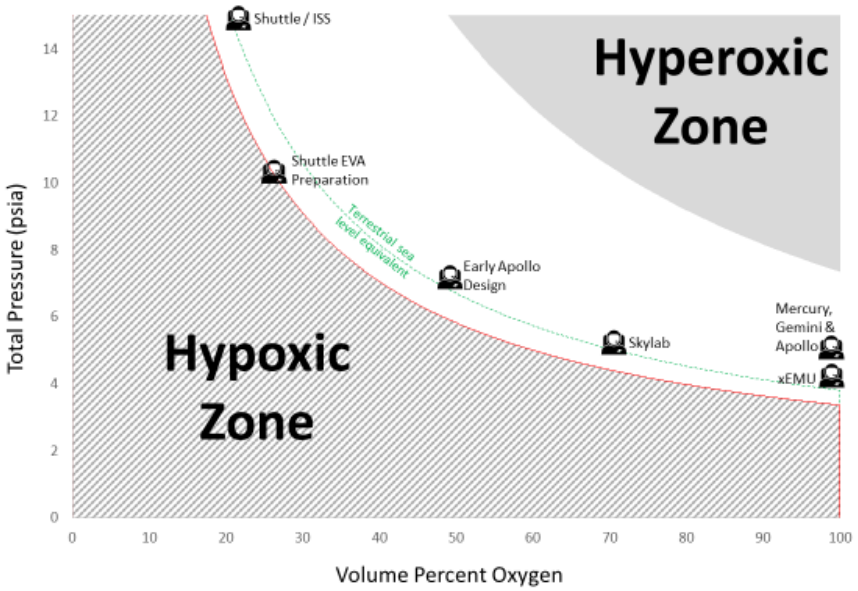
National Aeronautics and Space Administration

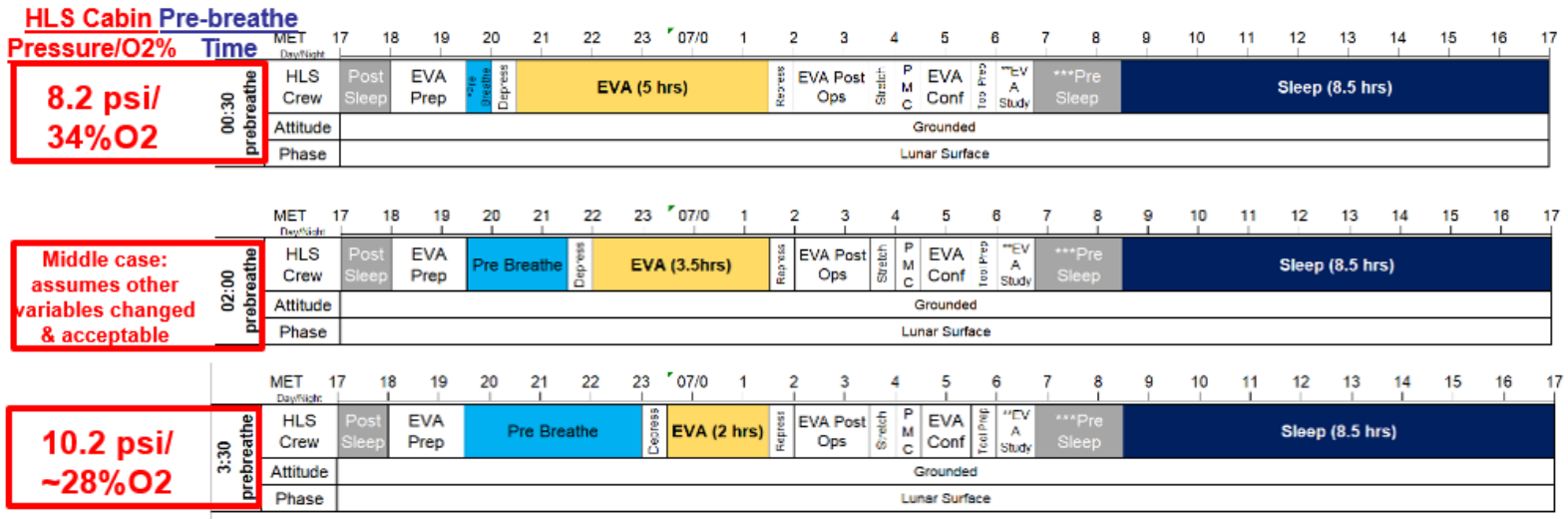
**Human Exploration Requirements**

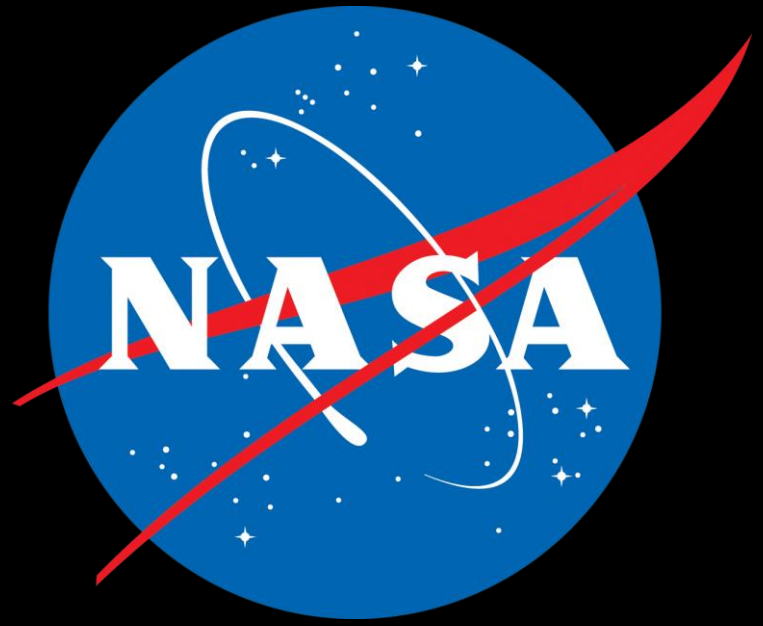
Date: March 16, 2021
Revision B

# Technical Integration to Maximize Objectives While Balancing Risk - Example

- **Majority of NASA atmospheric pressure experience is 14.7 psi, and new system development was continuing along that path.**
  - Lunar surface EVAs would require extensive pre-breathe, limiting valuable surface activities
  - Orion and Gateway were developed to operate at 14.7 psi but can operate nominally at 10.2 psi. However, this still resulted in multi-hour pre-breathes
- **Reducing pressure to 8.2 psi will allow for 30-min pre-breathes, maximizing lunar surface EVA opportunity**
- **HEO SE&I worked with HMTA, AES, and the associated programs (Orion, Gateway, HLS, and lunar surface assets in formulation) to minimize crew risk while maximizing EVA time and to maintain acceptable risk on material flammability.**




NASA