NASA’s Moon to Mars Architecture: Avenues for Engagement

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Deep Space Exploration Priorities

“…Human and robotic space exploration missions will land the first woman and person of color on the Moon, advance a robust cislunar ecosystem, continue to leverage human presence in low-Earth orbit to enable people to live and work safely in space, and prepare for future missions to Mars and beyond.”

— The White House U.S Space Priorities Framework, Dec 2021
Benefits to Humanity

Why We Explore

Investigations in deep space, on the Moon, and on Mars will enhance our understanding of the solar system, Earth, the human body, and how to perform new operations while we are out there exploring.

Accepting audacious challenges and succeeding through perseverance and tenacity in the face of adversity motivates current and future generations to dare mighty things.

What we choose to do, how we do those things, and who we do them with greatly impacts our place in the world today, our quality of life, and our possibilities for the future.
NASA’s Moon to Mars Strategy and Objectives
A blueprint for future human exploration (Architecting from the Right)

Requested feedback on these objectives in summer 2022 from the following key stakeholders:

NASA workforce: our greatest asset
International partners: our key current and future, anticipated collaborators
U.S. industry, academia, DOE, NIH, NSF, etc.: our national leaders in space research and capabilities
Architecting from the Right

Moon to Mars Objectives

NASA Mission Directorates

ESDMD
SOMD
STMD
SMD
ARMD

Moon-to-Mars Architecture
Robotic
Future/External

Characteristics & Needs
Objectives & Goals

Science

Lunar/Planetary
Heliophysics
Human & Biological
Physics & Physical
Science Enabling
Applied Science

Infrastructure

Lunar Infrastructure
Mars Infrastructure

Transportation & Habitation

T&H Goal
Ops Goal

Operations

Recurring T ends

RT-1
RT-2
RT-3
RT-4
RT-5
RT-6
RT-7
RT-8
RT-9
Architecting from the Right

The Architecture process requires a decomposition of Moon to Mars Objectives to element functions and mission use cases to complete the process of “architecting from the right.” This establishes the relationship of executing programs and projects to the driving goals and objectives.
### Example Objective Decomposition

Example of the full distillation of the objectives into lunar-specific Use Cases, Functions, and Elements for the *Human Lunar Return* segment using one of 12 Transportation and Habitation Objectives.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Use Cases</th>
<th>Functions</th>
<th>Characteristics &amp; Needs</th>
<th>Objectives &amp; Goals</th>
</tr>
</thead>
</table>
| Exploration Ground Systems | Transport crew and systems from Earth to cislunar space | • Provide ground services  
• Stash and integrate  
• Manage consumables  
• Enable vehicle launch  
• Provide multiple launch attempts  
• Provide alerts  
• Transport crew and systems from Earth to cislunar space | | |
| Space Launch System | Staging of crewed lunar surface missions from cislunar space | • Vehicle rendezvous, prop ops, docking, and undocking in cislunar space  
• Provide Position, Navigation, and Timing capability in cislunar space  
• Provide crew habitation in cislunar space | | |
| Orion Spacecraft Human Landing System Deep Space Logistics Gateway | Physical assembly of integrated assets in cislunar space | • Transport elements from Earth to cislunar space  
• Docking/berthing of spacecraft elements | | |
| Space Launch System Orion Spacecraft Gateway | Crew transport between cislunar space and lunar surface | • Transport crew and systems from cislunar space to lunar surface  
• Transport crew and systems from lunar surface to cislunar space | | |
| Human Landing System | Return crew and systems from cislunar space to Earth | • Transport crew and systems from cislunar space to Earth  
• Recover crew, systems, and cargo after splashdown | | |
| Orion Spacecraft & Exploration Ground Systems | | | | |

**ARCHITECTING FROM THE RIGHT**

**Objectives & Goals**

- **TH-1**
  - Develop cislunar systems that crew can routinely operate to and from lunar orbit and the lunar surface for extended durations.

**Characteristics & Needs**

- Demonstrate transportation of crew and systems from Earth to stable lunar orbit.
- Demonstrate staged operation of crew transportation from stable lunar orbit with accessibility to both Earth and the lunar South Pole.
- Demonstration of crew transport from stable lunar orbit to lunar surface and from lunar surface to Martin Marietta NVH.
- Operate crew transportation system in uncrowed mode for extended periods on the lunar surface.
- Demonstrate safe return to Earth of crew and systems from stable lunar orbit.
A group of tightly-coupled systems, functions, and capabilities that perform together to accomplish architecture objectives.

Ex: Transportation Systems: Contain common functions (e.g. RPOD) & need to ensure end-to-end allocation for crew transport from Earth to destinations to safe return.

A portion of the architecture, identified by one or more notional missions or integrated use cases, illustrating the interaction, relationships, and connections of the sub-architectures through progressively increasing operational complexity and objective satisfaction.

Ex: Human Lunar Return integrated use case similar to current Artemis IV operations.
1. Objectives decomposition to Use Cases & Functions
2. Element allocations and traceability performed to initial Segment (HLR)
3. Program requirements & ConOps implement allocated architecture needs
4. Unallocated functions (gaps) re-enter SAC process
5. SAC trades and analysis identify element solutions or definition of new program/projects
6. Definition of next segment and included elements begins
7. Repeat
Segments and Sub-architectures

**Segment**: A portion of the architecture, identified by one or more notional missions or integrated use cases, illustrating the interaction, relationships, and connections of the sub-architectures through progressively increasing operational complexity and objective satisfaction.

**Sub-architecture**: A group of tightly-coupled systems, functions, and capabilities that perform together to accomplish architecture objectives.

**Focus for ACR 22**
- **Human Lunar Return**: Initial capabilities, systems, and operations necessary to re-establish human presence and initial utilization (science, etc.) on and around the Moon.
- **Foundational Exploration**: Expansion of lunar capabilities, systems, and operations supporting complex orbital and surface missions to conduct utilization (science, etc.) and Mars forward precursor missions.
- **Sustained Lunar Evolution**: Enabling capabilities, systems, and operations to support regional and global utilization (science, etc.), economic opportunity, and a steady cadence of human presence on and around the Moon.
- **Humans to Mars**: Initial capabilities, systems, and operations necessary to establish human presence and initial utilization (science, etc.) on Mars and continued exploration.

**Focus for ACR 23**
- Communication, Positioning, Navigation, and Timing
- Habitation
- Human Systems
- Logistics
- Mobility Systems
- Power
- Transportation
- Utilization Systems
Human Lunar Return Segment

- Exploration Ground Systems
- Orion Spacecraft
- Space Launch System
- Gateway
- Deep Space Logistics
- xEVA Systems
- Human Landing System
- Comm, Positioning, NAV, Timing (CPNT)
- Commercial Lunar Payload Services
Moon to Mars Exploration Strategy

Scientific exploration and operations at the Moon will help prepare for the first human missions to Mars.
Areas for Collaboration

The Moon to Mars architecture is flexible, and there are opportunities to contribute, creating opportunity.

- Power Infrastructure and Distribution
- Communication and Navigation
- Lunar Environment Mitigation
- Robotics and Mobility
- Logistics
- Utilization Operations
- Lunar Sampling and Curation
- Habitation and Crew Health Systems
- Exploration Systems and Operations Analog Testing
Architecture Concept Review Products

Architecture Definition Document
Detailed documentation of a snapshot of NASA’s human spaceflight architecture and exploration strategy

Moon to Mars Architecture Summary
High-level overview of NASA’s Moon to Mars architecture and exploration strategy

White Papers
Six papers on architecture study details for frequently discussed topics
Engagement and Feedback

• The Moon-to-Mars architecture will be continually refined based on the development of our current programs, inputs from U.S. commercial and academic space communities, international partners, other stakeholders, and ongoing work to increase detail on the architecture products.

• A NASA-led in-person workshop is planned for June 27th – 28th. It will be geared toward soliciting feedback via small group discussions from U.S. commercial and academia on the Moon-to-Mars architecture processes and documentation. The location of the workshop will be in the greater D.C. area.

• Stakeholders can also provide feedback through nasa.gov/MoontoMarsArchitecture and during existing interactions, including conference meetings and partner discussions.