NASA’s Moon to Mars Architecture Workshop

Mars Transportation

Michelle Rucker
ESDMD/Mars Architecture Team
NASA Johnson Space Center
WHEN WILL WE ACHIEVE LUNAR OBJECTIVES?
- Multi-decadal campaign
- Support annual cadence of crewed missions
- Development of permanent infrastructure
- Expansion of economic sphere to the Moon

Earth-Mars Transportation System is one of the most visible and significant parts of the Mars architecture

“Mars Transportation” white paper outlines the challenges of extending human exploration from the Moon to Mars

WHAT FOUNDATIONAL CAPABILITIES ARE NEEDED
- Long-duration microgravity systems
- Partial gravity destination platforms
- Low Earth Orbit assets and infrastructure

WHERE SHOULD SYSTEMS BE?
- Ensure access to the Lunar South Pole
- Capability for non-polar expeditions

HOW WILL WE GET THERE AND RETURN?
- Lunar Microgravity staging in NRHO
- Earth ↔ NRHO ↔ Lunar surface

Surface Mobility

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WHY EXPLORE?
- SCIENCE -
  Understand the universe
  Direct observations
- INSPIRATION -
  “Artemis Generation”
  Overcome challenges
  Succeed with hard work
- NATIONAL POSTURE -
  Enrich lives on Earth
  Technology development
  International partnerships
Mars is *much* farther from Earth than the Moon is.

<table>
<thead>
<tr>
<th></th>
<th>Closest Approach to Earth</th>
<th>Farthest Distance from Earth</th>
<th>Typical Round-Trip “Odometer” Reading</th>
<th>Round-trip Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moon</td>
<td>360,000 km</td>
<td>405,000 km</td>
<td>1,900,000 km</td>
<td>Weeks</td>
</tr>
<tr>
<td>Mars</td>
<td>54,600,000 km</td>
<td>400,000,000 km</td>
<td>1,800,000,000 km</td>
<td>Years</td>
</tr>
</tbody>
</table>

- Round-trip Mars missions may be *twice as long* as our longest duration experience base.
- There will be no way to abort quickly to Earth.
- On-demand resupply will not be possible.
Video File Provided Separately
Optimum Departure Windows ~Every 2 Years
But we must also consider optimum return window

Increasing Energy = Exponential Increase in Vehicle Mass

Higher energy Mars missions require vehicles that are multiple ISS mass equivalents

Minimum Energy Long-Stay Class, ~ 3 Years Roundtrip

High Energy Short-Stay Class, ~ 2 Years Roundtrip

For human mission, we need to wait for alignment for BOTH legs of the trajectory to minimize energy

“When” is a very complicated decision to address.

What is an acceptable roundtrip duration for humans? What are the Surface Cargo pre-deployment needs?
How many rockets do we have and how often can we launch them? What transportation system performance can we afford?
Transportation Energy Needed

• Always about the same amount of energy to get to the Moon and back

• But energy needed to get to Mars and back varies
  ✓ Some years require 20 – 60% more energy than other years
  ✓ Transit propellant mass variations can be equivalent to the assembled ISS mass
Mission Duration
Transitioning from months (ISS) to years (Mars)

MISSION CONSTRAINTS

Lengthy Isolation/Confinement
Communication Delays
Extravehicular Activities
Resource Restrictions

HUMAN CHALLENGES

Health and Well-Being
Physical Performance
Cognitive Performance

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4 transportation options, 2 lander options, and a range of surface systems

Refer to

ESDMD-001, Moon to Mars Architecture Definition Document

for more information
Summary

Mars missions will require significantly more energy and much longer system service life, with more constrained departure windows, than lunar missions.

Shorter total roundtrip duration missions could reduce crew health and performance concerns.

Four In-Space Transportation propulsion technologies are currently under consideration.

Artemis transportation system developments and lessons learned can feed forward to Mars.

Access the white paper with this QR code or at www.nasa.gov/MoonToMarsArchitecture