Deep Space Gateway - Enabling Missions to Mars

Mars Study Capability Team – Michelle Rucker, John Connolly
Introduction

• The Global Exploration Roadmap reflects that human missions to Mars remain the consensus horizon goal of participating agencies
  – Sustainable human missions, including missions to the lunar surface, will be enabled by international cooperation

• NASA analyses and planning for Mars missions have informed Global Exploration Roadmap timing and content
Deep Space Gateway & Transport Extensibility to Mars

• There are many opportunities for commonality between Lunar vicinity and Mars mission hardware and operations
  – Best approach:
    • Identify Mars mission risks that can be bought down with testing in the Lunar vicinity
    • Then explore hardware and operational concepts that work for both missions with minimal compromise

• Deep Space Transport will validate the systems and capabilities required to send humans to Mars orbit and return to Earth
  – Deep Space Gateway provides a convenient assembly, checkout, and refurbishment location to enable Mars missions

• Current deep space transport concept is to fly missions of increasing complexity
  – Shakedown cruise, Mars orbital mission, Mars surface mission
    • Mars surface mission would require additional elements
Phase 2:

Deep Space
Gateway (DSG) Concept

Deep Space Transport (DST) Concept

PHASE 2
180-Day DST Checkout and
1-Year Shakedown Cruise
Shakedown Cruise
Simulating Key Segments of Mars Orbital Mission

Simulated Segment of Mars Mission:

Leg 1 - Simulated Mars Arrival Burns

Leg 2 - Simulated Heliocentric SEP Thrust and Crew Departure / Arrival

Leg 3 - Simulated Earth Departure and "No Go Decision"

Notable Action for each Leg:

Earth SOI

NRHO to LDHEO Fast Transfer

LDHEO Maintenance and Maneuvers

LDHEO to NRHO Slow Transfer 100-200 days

Deep Space Gateway

Orion #1 launch and delivers crew to DSG and DST integrate stack in Near Rectilinear Halo Orbit (NRHO)

Orion #2 launches to LDHEO and rendezvous with DST and original Orion (Option to swap crew before Shakedown)

High-Earth Orbit

Orion #1 & Crew Launch

Orion #2 Launch

Orion #1 return

Orion #2 & Crew return

Notable Action for each Leg:

1. Orion launches and delivers crew to DSG and DST integrate stack in Near Rectilinear Halo Orbit (NRHO)

2. DST with Orion departs DSG and performs fast transfer into Lunar Distant High Earth Orbit (LDHEO)

3. DST uses SEP in LDHEO to demonstrate long duration maneuvers without leaving Earth sphere of influence

4. New Orion launches to LDHEO and rendezvous with DST and original Orion (Option to swap crew before Shakedown)

5. Orion #1 departs DST and returns to Earth

6. DST performs maneuver to target Lunar Gravity Assist (LGA) 1

7. DST catches LGA 1 that targets LGA 2

8. DST performs final Earth departure checks but does not perform final maneuver to target Earth departure LGA

9. DST catches LGA 2 back to NRHO via slow transfer

10. DST inserts into cislunar and rendezvous with Gateway

11. Orion departs DST and returns crew to Earth

Mars Mission Comparison

<table>
<thead>
<tr>
<th></th>
<th>Shakedown Cruise</th>
<th>Mars Orbital Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Engine Starts</td>
<td>~ 7</td>
<td>~ 7</td>
</tr>
<tr>
<td>Max Single Burn Duration</td>
<td>~ 0.8 hr</td>
<td>~ 0.8 hr</td>
</tr>
<tr>
<td>Total Chem Burn Duration</td>
<td>~ 1.9 hr</td>
<td>~ 2.4 hr</td>
</tr>
<tr>
<td>SEP Burn Duration</td>
<td>~ 90 d</td>
<td>~ 329 d</td>
</tr>
</tbody>
</table>

Shakedown Cruise validates Deep Space Transport for cargo and human missions to Mars
Example Phase 2 Mission Elements
DST Checkout and Shakedown Cruise

- Retire infant mortality and integration risks
- Uncrewed period between Checkout and Shakedown Cruise similar to Mars long stay mission
- 100-300 days of DST Habitat crewed operation prior to Shakedown Cruise
First human mission to Mars’ sphere of influence:
- First long duration flight with self-sustained systems
- Autonomous mission, extended communication
- First crewed mission with limited abort opportunities
Example Phase 3 Mission Elements

Mars Orbital Mission

- **Space Launch System**
  - Deliver payloads to cislunar space

- **Deep Space Gateway**
  - Transfer crew and cargo from Earth to cislunar space and back to Earth

- **Deep Space Transport**

- **Orion**
  - Transfer crew and cargo from Earth to cislunar space and back to Earth

- **Communications System**
  - Earth-to-Mars communication

- **Earth**
- **Moon**
- **Mars**
- **Crew Operations in Martian Vicinity**
PHASE 4
Mars Surface Missions

Emphasis on establishing Mars surface field station
• First human landing on Mars’ surface
• First three missions revisit a common landing site
# Crew Phase Critical Event Sys. Return to Earth Options

<table>
<thead>
<tr>
<th>#</th>
<th>Crew Phase Critical Event</th>
<th>Sys.</th>
<th>Return to Earth Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Lunar Gravity Assist #1</td>
<td>DST/Orion</td>
<td>DST powered return to HEO / Orion return</td>
</tr>
<tr>
<td>5</td>
<td>Lunar Gravity Assist #2</td>
<td>DST</td>
<td>DST powered return to HEO</td>
</tr>
<tr>
<td>5</td>
<td>Earth-Mars Transit (early phase)</td>
<td>DST</td>
<td>DST powered return to HEO (available for limited time post departure - TBD)</td>
</tr>
<tr>
<td>6</td>
<td>Earth-Mars Transit Thrusting</td>
<td>SEP</td>
<td>None – continue to Mars</td>
</tr>
<tr>
<td>7</td>
<td>Mars Orbit Insertion</td>
<td>Chem</td>
<td>Backflip (TBD) – continue mission</td>
</tr>
<tr>
<td>8</td>
<td>Rendezvous &amp; Mars Descent</td>
<td>Lander</td>
<td>Remain in Mars orbit for return</td>
</tr>
<tr>
<td>9</td>
<td>Mars Ascent</td>
<td>Ascent</td>
<td>None – must ascend to orbit</td>
</tr>
<tr>
<td>10</td>
<td>Mars orbit reorientation</td>
<td>SEP</td>
<td>None – continue mission</td>
</tr>
<tr>
<td>11</td>
<td>Trans-Earth Injection</td>
<td>Chem</td>
<td>None – continue mission</td>
</tr>
<tr>
<td>12</td>
<td>Mars-Earth Transit Thrusting</td>
<td>SEP</td>
<td>None – continue mission</td>
</tr>
<tr>
<td>13</td>
<td>Lunar Gravity Assist #3</td>
<td>DST</td>
<td>None – continue mission</td>
</tr>
<tr>
<td>13</td>
<td>Lunar Gravity Assist #4</td>
<td>DST</td>
<td>None – continue mission</td>
</tr>
<tr>
<td>14</td>
<td>Orion Launch</td>
<td>SLS/Orion</td>
<td>HEO Loiter</td>
</tr>
<tr>
<td>14</td>
<td>Earth Return via Orion</td>
<td>Orion</td>
<td>HEO Loiter</td>
</tr>
</tbody>
</table>

## Mars Mission Comparison

<table>
<thead>
<tr>
<th></th>
<th>Orbital</th>
<th>3 Mars Missions</th>
</tr>
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<tbody>
<tr>
<td>Chemical Engine Starts</td>
<td>~ 7</td>
<td>~ 20</td>
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<td>~ 0.8 hr</td>
<td>~ 0.8 hr</td>
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<tr>
<td>Total Chem Burn Duration</td>
<td>~ 2.4 hr</td>
<td>~ 8.0 hr</td>
</tr>
<tr>
<td>SEP Burn Duration</td>
<td>~ 329 d</td>
<td>~ 1000 d</td>
</tr>
</tbody>
</table>
Example Phase 4 Mission Elements

- **Space Launch System**: Deliver payloads to cislunar space
- **Deep Space Gateway**: Transport 100-200t aggregated payloads and crew between Earth and Mars
- **Orion**: Transfer crew and cargo from Earth to cislunar space and back to Earth
- **Communications System**: Earth-to-Mars, Mars surface-to-Mars orbit, and Mars surface-to-surface communication
- **Surface Habitat and Science Lab**: Sustain 4 crew for up to 500 days per Expedition
- **Logistics Carrier**: Deliver equipment and consumables
- **Surface Mobility**: Planetary Space Suits and robotic or pressurized rovers
- **Surface Utilities**: Power, In Situ Resource Utilization
- **Entry-Descent Lander**: Land 20-30 t payloads on Mars
- **Mars Ascent Vehicle**: Transfer crew and cargo from the Mars surface to Mars orbit
- **Crew Operations in Martian Vicinity**:
Key Take Aways

• Cislunar and Lunar surface missions can feed forward to human Mars missions
  – Mars testbed

• Deep Space Gateway provides a convenient assembly, checkout, and refurbishment location to enable Mars missions

• Deep Space Transport shakedown cruise will validate the systems and capabilities required to send humans to Mars orbit and return to Earth
  – DST provides Mars orbital mission capabilities
    • Additional developments will be required for Mars surface mission