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

Simulated Segment of Mars Mission:

- **Earth SOI**
  - Leg 1 - Simulated Mars Arrival Burns
  - Notable Action for each Leg:
    - NRHO to LDHEO Fast Transfer

- **Deep Space Gateway**
  - Leg 2 - Simulated Heliocentric SEP Thrust and Crew Departure / Arrival
  - LDHEO Maintenance and Maneuvers
  - LDHEO to NRHO Slow Transfer 100-200 days

- **High-Earth Orbit**
  - Leg 3 - Simulated Earth Departure and “No Go Decision”
  - Notable Action for each Leg:
    - DST performs maneuver to target Lunar Gravity Assist (LGA) 1
    - DST performs final Earth departure checks but does not perform final maneuver to target Earth departure LGA
    - DST catches LGA 2 back to NRHO via slow transfer
    - DST inserts into cis lunar and rendezvous with Gateway
    - 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
PHASE 3
First Human Mission to Mars Sphere of Influence

First human mission to Mars’ sphere of influence:
- First long duration flight with self sustained system
- Autonomous mission, extended communication
- First crewed mission with limited abort opportunity
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
- **Communications System**: Earth-to-Mars communication
- **Deep Space Transport**: Crew Operations in Martian Vicinity
- **Orion**: Mars Orbital Mission
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
# Crewed Mars Orbital & Surface Leg

Example Operational Concept

<table>
<thead>
<tr>
<th>#</th>
<th>Crew Phase Critical Event</th>
<th>Sys.</th>
<th>Return to Earth Options</th>
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</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>
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<tbody>
<tr>
<td>Chemical Engine Starts</td>
<td>~ 7</td>
<td>~ 20</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>~ 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>

## Diagram

- **High-Mars Orbit**
- **Deep Space Gateway**
- **High-Earth Orbit**
- **Earth**

- **Launch**
- **Loiter**
- **High Thrust Chemical**
- **Low Thrust Electric**

- **Checkout before each mission**
- **Orion return (no crew)**
Example Phase 4 Mission Elements

- **Space Launch System**: Deliver payloads to cislunar space
- **Deep Space Gateway**: Transport crew and cargo between Earth and Mars
- **Entry-Descent Lander**: Land 20-30 t payloads on Mars
- **Mars Ascent Vehicle**: Transfer crew and cargo from the Mars surface to Mars orbit
- **Communications System**: Earth-to-Mars, Mars surface-to-Mars orbit, and Mars surface-to-surface communication
- **Earth**
- **Moon**
- **Orion**: Transfer crew and cargo from Earth to cislunar space and back to Earth
- **Deep Space Transport, Hybrid SEP Cargo Transport**: Transport 100-200 t aggregated payloads and crew between Earth and Mars
- **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
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
Questions?
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