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:

Deep Space Transport

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

<table>
<thead>
<tr>
<th>Leg 1 - Simulated Mars Arrival Burns</th>
<th>Leg 2 - Simulated Heliocentric SEP Thrust and Crew Departure / Arrival</th>
<th>Leg 3 - Simulated Earth Departure and &quot;No Go Decision&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulated Segment of Mars Mission:</td>
<td>Simulated Mars Mission Comparison</td>
<td>Simulated Mars Mission Comparison</td>
</tr>
<tr>
<td>Earth SOI</td>
<td>Notable Action for each Leg:</td>
<td>Notable Action for each Leg:</td>
</tr>
<tr>
<td>Orion launches and delivers crew to DSG and DST integrate stack in <strong>Near Rectilinear Halo Orbit (NRHO)</strong></td>
<td>DST with Orion departs DSG and performs fast transfer into <strong>Lunar Distant High Earth Orbit (LDHEO)</strong></td>
<td>DST uses SEP in LDHEO to demonstrate long duration maneuvers without leaving Earth sphere of influence</td>
</tr>
<tr>
<td>Orion departs DST and performs fast transfer into <strong>Lunar Distant High Earth Orbit (LDHEO)</strong></td>
<td>New Orion launches to LDHEO and rendezvous with DST and original Orion (Option to swap crew before Shakedown)</td>
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</tr>
<tr>
<td>New Orion launches to LDHEO and rendezvous with DST and original Orion (Option to swap crew before Shakedown)</td>
<td>DST performs maneuver to target Lunar Gravity Assist (LGA) 1</td>
<td>DST performs final Earth departure checks but does not perform final maneuver to target Earth departure LGA</td>
</tr>
<tr>
<td>DST catches LGA 1 that targets LGA 2</td>
<td>DST catches LGA 2 back to NRHO via slow transfer</td>
<td>DST inserts into cislunar and rendezvous with Gateway</td>
</tr>
<tr>
<td>Orion departs DST and returns crew to Earth</td>
<td>Orion departs DST and returns crew to Earth</td>
<td>Orion departs DST and returns crew to Earth</td>
</tr>
</tbody>
</table>

**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

- Deliver payloads to cislunar space
- Deep Space Gateway
- Orion
- Communications System
- Deep Space Transport
- Earth
- Moon
- Mars

• 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 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
- Orion
  - Transfer crew and cargo from Earth to cislunar space and back to Earth
- Deep Space Transport
- Communications System
  - Earth-to-Mars communication

Crew Operations in Martian Vicinity

Earth
Moon
Mars
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>
</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>
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<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**
- **Mars**
- **Deep Space Gateway**
- **Launch**
- **Orion return (no crew)**
- **Orion return**
- **Orion launch**
- **Checkout before each mission**

**Legend:**
- Red: Launch
- Yellow: Loiter
- Green: High Thrust Chemical
- Blue: Low Thrust Electric
Example Phase 4 Mission Elements

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