Toxicity Sample Return Tech Demo

Presentation at LPI

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Agenda

• Introduction
• Concept objective
  – Customer benefits (including toxicity assessment)
• Concept Overview by Mission Phase
  – Overview
  – Launch and cruise
  – Landing and surface
  – Rendezvous and return
• Additional information
• Back up material
Introduction

• Before humans can explore the surface of Mars we must have soil and atmospheric sample(s) to determine if and what the human toxicity threat might be.

• This mission would address complementary objectives of HEOMD, SMD, and OCT for multiple future missions

• The implementation would be Class C/D, with emphasis on SR technology needs but organized around a well-architected set of scientific, technical and programmatic objectives and constraints

• This is a grab-and-go mission concept with the landing site selected to minimize planetary protection issues. The approach to Earth contamination could be addressed by various technologies for breaking the contamination chain or (as a default) use of Cobalt 60 in the sample canister to sterilize the sample

• This mission could be accomplished in the 2018-2024 timeframe, and doing so would provide impetus for both potential MSR and planning for human exploration of Mars
Concept Objectives

• Provide technology demonstration and a sample with direct benefits to HEOMD, SMD and OCT for future missions

• HEOMD benefits:
  – Provide initial understanding of physical and chemical toxicity for human mission design

• SMD benefits:
  – Demonstration of capabilities for future potential MSR including: Mars surface ascent, sample packaging, planetary protection, sample capture in Mars orbit, return to Earth

• OCT benefits:
  – Develop and demonstrate technologies for sample packaging and planetary protection, Mars surface ascent, sample capture in Mars orbit
Toxicity Measurements

• Objective – make measurements necessary to characterize the risks to future human explorers due to biohazards, material toxicity, and dust/granular materials. Provide initial basis for developing requirements for maintaining the health and safety of humans during a mission to Mars
  – Specifically does not encourage sampling a Planetary Protection designated “special region”

• Effects of concern
  – Inhalation toxicity (acute and chronic effects to respiratory system)
  – Dermal toxicity (skin irritant/allergic response and abrasion effects; breach of water barrier)
  – Ocular Toxicity (chemical – eye irritant/allergic responses; and physical – abrasion effects/scratches or embedding)

• Chemical characteristics
  – Chemicals and heavy metals; Acid/base conditions and buffering capacity
  – Activation (reactivity, amount of free radicals available)
  – Compatibility/interaction with spacecraft systems especially life support

• Physical characteristics
  – Structure, particle size, texture,
  – Entrainment in spacecraft systems especially life support
Planetary Protection

- Proposed Planetary Protection mission category V (restricted Earth-return) with a reduce risk (likelihood) of adverse effects associated with exposure to $<10^{-6}$
  
  - Containment
    - Breaking chain of contact and sealed sample container (brazing)
    - Propose use of sterilization by Gamma radiation $^{60}$Co (1.17 to 1.33MeV)
      - Doses as high as 30Mrads produce minimal changes in isotopic composition, elemental composition, or crystallographic structures
      - No terrestrial organisms are known whose probability of survival is $>10^{-6}$ at a dose of 20Mrads at room temperature
      - SNC meteorites absorbed 10-300Mrad cosmic radiation during 0.5 to 15 Myear transit between Mars and Earth
Concept Overview

- Derived from entry and landing technologies proven on Mars Pathfinder (MPF) and Mars Exploration Rover (MER),
- Solar electric propulsion (SEP) orbiter technology developed for “NEO Surveyor”, using flight-validated SEP thrusters,
- Mars Ascent Vehicle (MAV) and sample canister and capture/transfer system based on concepts from prior MSR studies
- The mission would launch the SEP orbiter and lander/MAV on a single launch vehicle and be injected toward Mars together
- The vehicles would then separate, the SEP orbiter flying a longer but more efficient SEP trajectory to a highly elliptical Mars orbit, while the lander flies a shorter direct transfer.
- For the "grab and go" sample needed, large areas of Mars, including the lower elevations of the northern hemisphere, are suitable.
Concept Overview (cont.)

• Following landing the vehicle would stabilize itself, acquire soil and atmosphere samples, and install them into the MAV mounted sample canister.

• The MAV is then rotated into launch configuration, spun-up and launched. Flight control and staging are passive.

• In orbit the SEP orbiter would locate the sample canister optically, capture it, and return to Earth

• Direct reentry at Earth would use a scaled-down Stardust capsule
Launch and Cruise Phase

Design Concepts

Launch Configuration

SEP Orbiter

Entry/Lander in Cruise
Landing and Surface Phase

Design Concepts

Stowed lander cross section w/MAV

Deployed Lander for Sample Acquisition

Lander in Deployed Airbag

MAV in Launch Configuration
Rendezvous and Return Phase

Design Concepts

Sample Capture

Earth Re-entry Vehicle Release

Earth Re-entry Vehicle
• Mass estimate based on heritage designs of MPF/MER, detailed concept studies from previous MSR and NEO Surveyor studies. Estimate of 2200 kg includes 30% margin on dry mass. Compatible with existing launch vehicle performance for 2018 opportunity.

• Locating the sample capsule in an arbitrary Mars orbit by optical recognition has been proven by analysis from past MSR studies. The very high delta-V capability of the SEP stage would permit it to collect the sample canister from the full set of possible orbits.
• The follow charts provide more details about the elements of the mission.
Launch and Cruise Phase

• The mission would launch the SEP orbiter and lander/MAV on a single launch vehicle and injected toward Mars together.

• The vehicles would then separate, the SEP orbiter flying a longer but more efficient SEP trajectory to a highly elliptical Mars orbit, while the lander flies a shorter direct transfer.

• The SEP orbiter would arrive at Mars (with C3=0) ~3 months after the lander arrives.

• For the "grab and go" sample needed, large areas of Mars, including the lower elevations of the northern hemisphere, are suitable.
Landing and Surface Phase

- For the "grab and go" sample needed, large areas of Mars, including the lower elevations of the northern hemisphere, are suitable.

- The airbag lander would contain the MAV, which in turn contains the sample return canister and acquisition system.

- Following landing the vehicle would stabilize itself, acquire soil and atmosphere samples, install them into the MAV canister, and perform MAV erection, spin-up and launch.

- A spin-table on the main petal of the landed tetrahedron spins-up the rocket to as much as 120 RPM (the rating of the STAR-13B) prior to launch, and the petal actuators would be used to point the main petal to the desired attitude for launch.

- The surface system lifetime need only be hours but could be days depending on power source.

- Communications would use UHF relay through existing assets, or the SEP stage during overhead passes.
Rendezvous and Return Phase

- In orbit the SEP orbiter would locate the sample canister optically, capture it, and return to Earth
- As the SEP vehicle spiraled down (~6 months) to the sample canister orbit, it finds the canister optically and collects optical navigation images to estimate its orbit.
  - The ability to locate the sample capsule in an arbitrary orbit, by optical recognition, has been proven by analysis from past MSR studies.
  - The very high delta-V capability of the SEP stage would permit it to collect the sample canister from the full set of possible orbits.
- After the rendezvous, the SEP orbiter would place the sample canister into the Earth Return Capsule and departs for Earth, arriving ~1.5 years after collection
- SEP orbiter would not attempt to match velocities with Earth, but releases the Earth Re-turn Capsule near Earth on an appropriate hyperbolic entry trajectory to a recovery site
Entry and Lander Vehicle

- Derived from entry and landing technologies proven on Mars Pathfinder (MPF) and Mars Exploration Rover (MER)
- Cruise and EDL systems would be very high heritage from MER
SEP Orbiter and Return Vehicle

- The SEP stage design concept is based on detailed NASA studies of NEO Surveyor: single Aerojet BPT-4000 thruster, with ISP of 1800 s and ~50% efficiency converting 8kw from a deployable, lightweight solar arrays.

<table>
<thead>
<tr>
<th>SEP Stage MEL</th>
<th>(System Contingency carried on total flight system)</th>
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<tbody>
<tr>
<td>Attitude Control</td>
<td></td>
</tr>
<tr>
<td>Avionics</td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td></td>
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<tr>
<td>Propulsion</td>
<td></td>
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<tr>
<td>Structure</td>
<td></td>
</tr>
<tr>
<td>Thermal</td>
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<tr>
<td>Telecom</td>
<td>16 kg</td>
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<tr>
<td>Available Payload</td>
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<tr>
<td>Spacecraft Bus Mass (CBE)</td>
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<tr>
<td>System Contingency</td>
<td>0 kg</td>
</tr>
<tr>
<td>Spacecraft Dry Mass</td>
<td>379 kg</td>
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<tr>
<td>Propellant</td>
<td>275 kg</td>
</tr>
<tr>
<td>Total Launch Mass (1 S/C)</td>
<td>654 kg</td>
</tr>
</tbody>
</table>
Mars Ascent Vehicle (MAV)

- The MAV concept consists of two catalog STAR-13B solid rocket motors (SRMs) and employs a demonstrated passive spin-stabilized guidance system.
- Articulating the 2nd stage would fit it within the packaging volume, and enable access for sample transfer; a slip fit could enable simple staging.
- Able to loft a ~5 kg sample canister (likely much larger than needed but could perhaps maximize technology transfer to subsequent missions) into a highly elliptical orbit using only spin-stabilization.
Mars Ascent Vehicle (MAV)

• The passive guidance system, demonstrated by the Navy in 1958 utilizes fins on the first stage which cause the vehicle to precess under aerodynamic torques high in the atmosphere until the second stage is near-horizontal, at which point a horizon-sensor would fire the second stage.

• A small apoapsis kick SRM would be incorporated into the sample canister itself and fired by a timer
  – Like the 1958 design, this SRM would be mounted "backwards" at the center of the oblate spin-stabilized payload so that after half an orbit it is pointed "forward" in the correct orientation to raise the periapsis out of the atmosphere
Sample Acquisition and Preservation

• The sample acquisition system would use a limited-DOF robot arm to reach out between the petals, acquiring suitable samples and placing them in the sample return canister on top of the MAV.

• The canister, as mentioned, would have the apoapsis-kick solid rocket motor embedded on the spin axis. It would also contain the sample along the spin axis to minimize the possibility of an unstable mass distribution.

• The spherical canister would be painted white for easy optical acquisition and tracking.

• At the time the apoapsis-kick motor ignites, additional pyro material could be ignited to sterilize the exterior of the sample canister and to braze shut the lid of the sample container.

• In addition, the sample canister could contain Cobalt-60 to sterilize the sample during the return cruise.
**Additional Data**

- Desire is to keep sample below -20°C with a maximum constraint of 50°C for no more than 3 hours

- Preliminary mass list

<table>
<thead>
<tr>
<th>Element</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Canister</td>
<td>5 kg</td>
</tr>
<tr>
<td>Ascent Vehicle (dry mass)</td>
<td>50 kg</td>
</tr>
<tr>
<td>Lander (dry mass)</td>
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<tr>
<td>Entry System</td>
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<tr>
<td>Cruise Stage</td>
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<tr>
<td>SEP Return Vehicle (dry mass)</td>
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<tr>
<td><strong>Total Dry Mass (CBE)</strong></td>
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</tr>
<tr>
<td>Propellant – Cruise Stage</td>
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<tr>
<td>Propellant – Ascent Vehicle</td>
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</tr>
<tr>
<td>Propellant – SEP Vehicle</td>
<td>275 kg</td>
</tr>
<tr>
<td><strong>System Margin (30%)</strong></td>
<td><strong>405 kg</strong></td>
</tr>
<tr>
<td><strong>Total Mass</strong></td>
<td><strong>2213 kg</strong></td>
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