Toxicity Sample Return Tech Demo.

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Summary: 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. We propose a largely single-string, technology demo-class mission that would retire risk for many challenging, primary sample return (SR) technologies (e.g., sample packaging, Mars surface ascent, sample capture in Mars orbit, and return to Earth), and capture public attention at the same time.

Unlike current concepts for Mars Sample Return (MSR) that want carefully selected samples for life detection, a toxicity sample can be a grab-and-go. Since this is not a life-science mission per se, the landing site would be 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.

Concept Objective: Such a mission would address complementary objectives of HEOMD, SMD, and OCT for multiple future missions, bringing them together in strategic partnership. The implementation could be Class C/D, with emphasis on SR technology needs but architected around a well-constrained set of objectives for toxicity determination.

The concept addresses all three Challenge Areas: 1 (investigation of toxicity); 2 (demonstration of Mars ascent and other SR needs); and 3 (surface system operations). It could be accomplished in the 2018-2024 timeframe, and doing so would provide impetus for both MSR and planning for human exploration of Mars.

Concept Description: The concept is derived from entry and landing technologies proven on Mars Pathfinder (MPF) and Mars Exploration Rover (MER) , Phobos Surveyor solar electric propulsion (SEP) orbiter technology [1] developed for NEO Surveyor, and Mars Ascent Vehicle (MAV) and sample canister and capture/transfer system knowledge and concepts from prior MSR studies. The mission would use a SEP stage and MPF/MER lander, launched on a single launch vehicle (LV, Fig 1) and injected toward Mars together. The vehicles would then separate (Fig. 2 and 3), flying a longer but more efficient SEP trajectory to a highly elliptical Mars orbit, while the lander flys 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.

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. In orbit the SEP vehicle would locate the sample canister optically, capture it, and return to Earth. Direct reentry at Earth would use a scaled-down Stardust capsule. Total launch mass is roughly 2000 kg including margin, consistent with the Mars injection performance of several available launch vehicles.

The SEP stage 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. The SEP orbiter would arrive at Mars (with C3=0) 3 months after this launch. 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 stage places the sample canister into the Earth Return Capsule and departs for Earth, arriving ~1.5 years after collection. It would not attempt to match velocities with Earth, but releases the Earth Return Capsule near Earth on an appropriate hyperbolic entry trajectory to the recovery site.

The MAV (Figure 4) concept consists of two catalog STAR-13B solid rocket motors (SRMs) from ATK and employs a demonstrated passive 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. These two stages would be 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. 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 passive guidance system, demonstrated by the Navy in 1958 [2] 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 apoapse-kick SRM would be incorporated into the sample canister itself and fired by a timer approximately at apoapse. 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. The rendezvous, capture (Figure 5), and injection back to Earth would be accomplished over a few month period.

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 MAV canister. The second stage would be rotated into position on top of the first prior to spin-up and 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.

References: : [1] Jared Lang et al., "Phobos Exploration Using Two Small Solar Electric Propulsion Spacecraft," Paper GLEX-2012.03.2.4x12737. [2] Peter Pesavento, "U.S. Navy's Untold Story of Space-Related Firsts", *Spaceflight*, Vol. 38, pp. 239-245, July 1996.

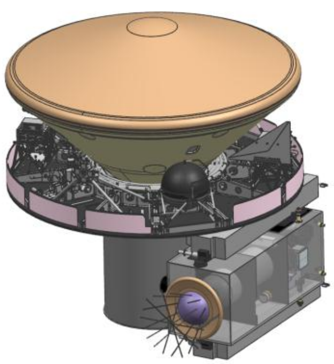

Figure 1) Launch Configuration design concept

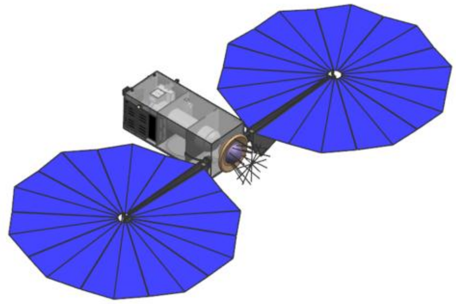

Figure 2) Deployed Orbiter/Return Vehicle design concept

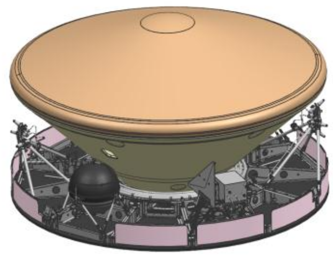

Figure 3) Lander Vehicle in Transit to Mars design concept

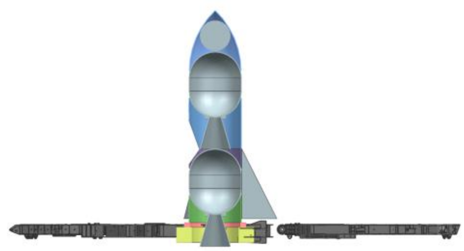

Figure 4) Upright MAV ready for launch showing SRBs and sample canister design concept

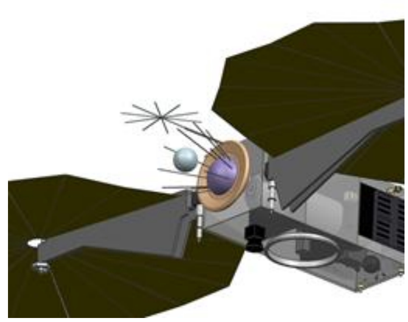

Figure 5) Capsule Capture into Earth Reentry Vehicle design concept