Mars Sample Return Using Commercial Capabilities: ERV Trajectory and Capture Requirements

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Mars Sample Return was presented as the highest priority planetary science mission of the next decade [1]. Lemke et al. [2] present a Mars Sample Return mission concept in which the sample is returned directly from the surface of Mars to an Earth orbit. The sample is recovered in Earth Orbit instead of being transferred between spacecraft in Mars Orbit. This paper provides the details of this sample recovery in Earth orbit and presents as such a sub-element of the overall Mars sample return concept given in [2].

We start from the assumption that a Mars Ascent Vehicle (MAV), initially landed on Mars using a modified SpaceX Dragon capsule, has successfully delivered the sample, already contained within an Earth Return Vehicle (ERV), to a parking orbit around Mars. From the parking orbit, the ERV imparts sufficient Delta-V to inject itself into an earthbound trajectory and to be captured into an Earth orbit eventually. We take into account launch window and Delta-V considerations as well as the additional constraint of increased safety margins imposed by planetary protection regulations. We focus on how to overcome two distinct challenges of the sample return that are driven by the issues of planetary protection: (1) the design of an ERV trajectory meeting all the requirements including the need to avoid contamination of Earth's atmosphere; (2) the concept of operations for retrieving the Martian samples in Earth orbit in a safe way. We present an approach to retrieve the samples through a rendezvous between the ERV and a second SpaceX Dragon capsule.

The ERV executes a trajectory that brings it from low Mars orbit (LMO) to a Moon-trailing Earth orbit at high inclination with respect to the Earth-Moon plane. After a first burn at Trans-Earth Injection (TEI), the trajectory uses a second burn at perigee during an Earth flyby maneuver to capture the ERV in Earth orbit. The ERV then uses a non-propulsive Moon flyby to come to a near-circular Moon-trailing orbit. To perform the Earth Orbit Rendezvous (EOR), a second Dragon capsule is then launched from Earth and a similar lunar flyby is performed to rendezvous with the ERV. The requirements for rendezvous, close proximity operations and capture of the sample canister are described. A concept of operations for sample retrieval is presented along with design specifications of the ERV, the required modifications to the Dragon capsule, as well as the hardware, software, sensors, actuators, and capture mechanisms used. In our concept, a container is mounted to the front hatch of Dragon, capable of accommodating the sample canister and sealing it from the rest of the capsule. The sample canister is captured using a robotic arm with a magnetic grappling mechanism. Dragon then performs a propulsive maneuver to return to Earth for a controlled re-entry while the ERV (sans sample container) is left in the Moon trailing orbit. Contingency cases and related mitigation strategies are also discussed, including the advantages and disadvantages of performing the ERV rendezvous with a crew.

[1] Visions and Voyages for planetary Science in the decade 2013-2022, Nat'l Academy Press, 2010.

[2] Mars Sample Return Using Commercial Capabilities, L.G. Lemke, J. Bowles, A. Gonzales, L. Huynh, and C. Stoker, to International Planetary Probes Workshop, June 17-21, San Jose, CA 2013