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Mars Sample Return Landed with Red Dragon

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A Mars Sample Return (MSR) mission is the highest priority science mission for the next decade as recommended by the recent Decadal Survey of Planetary Science. However, an affordable program to carry this out has not been defined. This paper describes a study that examined use of emerging commercial capabilities to land the sample return elements, with the goal of reducing mission cost. A team at NASA Ames examined the feasibility of the following scenario for MSR: A Falcon Heavy launcher injects a SpaceX Dragon crew capsule and trunk onto a Trans Mars Injection trajectory. The capsule is modified to carry all the hardware needed to return samples collected on Mars including a Mars Ascent Vehicle (MAV), an Earth Return Vehicle (ERV) and Sample Collection and Storage hardware. The Dragon descends to land on the surface of Mars using SuperSonic Retro Propulsion (SSRP) as described by Braun and Manning[IEEEAC paper 0076, 2005]. Samples are acquired and deliverd to the MAV by a prelanded asset, possibly the proposed 2020 rover. After samples are obtained and stored in the ERV, the MAV launches the sample-containing ERV from the surface of Mars. We examined cases where the ERV is delivered to either low Mars orbit (LMO), C3 = 0 (Mars escape), or an intermediate energy state. The ERV then provides the rest of the energy (delta V) required to perform trans-Earth injection (TEI), cruise, and insertion into a Moon-trailing Earth Orbit (MTEO). A later mission, possibly a crewed Dragon launched by a Falcon Heavy (not part of the current study) retrieves the sample container, packages the sample, and performs a controlled Earth re-entry to prevent Mars materials from accidentally contaminating Earth.

The key analysis methods used in the study employed a set of parametric mass estimating relationships (MERs) and standard aerospace analysis software codes modified for the MAV class of launch vehicle to determine the range of performance parameters that produced converged spacecraft designs capable of meeting mission requirements. Subsystems modeled in this study included structures, power system, propulsion system, nose fairing, thermal insulation, actuation devices, and GN&C. Best practice application of loads and design margins for all resources were used. Both storable and cryogenic propellant systems were examined. The landed mass and lander capsule size provide boundary conditions for the MAV design and packaging. We estimated the maximum mass the Dragon capsule is capable of landing. This and the volume capability to store the MAV was deduced from publically available data from SpaceX as well as our own engineering and aerodynamic estimates.

Minimum gross-liftoff mass (GLOM) for the MAV were obtained for configurations that used pump-fed storable bi-propellant rocket engines for both the MAV and the ERV stage. The GLOM required fits within our internal estimate of the mass that Dragon can land at low elevation/optimal seasons on Mars. Based on the analysis, we show that a single Mars launch sample return mission is feasible using current commercial capabilities to deliver the return spacecraft assets.