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Mars Sample Return Using Commercial Capabilities: Propulsive Entry, Descent, and Landing of a Capsule Form Vehicle

This paper describes a critical portion of the work that has been done at NASA, Ames Research Center regarding the use of the commercially developed Dragon capsule as a delivery vehicle for the elements of a high priority Mars Sample Return mission. The objective of the investigation was to determine entry and landed mass capabilities that cover anticipated mission conditions. The "Red Dragon", Mars configuration , uses supersonic retro-propulsion, with no required parachute system, to perform Entry, Descent, and Landing (EDL) maneuvers. The propulsive system proposed for use is the same system that will perform an abort, if necessary, for a human rated version of the Dragon capsule. Standard trajectory analysis tools are applied to publically available information about Dragon and other legacy capsule forms in order to perform the investigation. Trajectory simulation parameters include entry velocity, flight path angle, lift to drag Ratio (L/D), landing site elevation, atmosphere density, and total entry mass, in addition engineering assumptions for the performance of the propulsion system are stated. Mass estimates for major elements of the overall proposed architecture are coupled to this EDL analysis to close the overall architecture. Three synodic launch opportunities, beginning with the 2022 opportunity, define the arrival conditions. Results state the relations between the analysis parameters as well as sensitivities to those parameters. The EDL performance envelope includes landing altitudes between 0 and -4 km referenced to the Mars Orbiter Laser Altimeter datum as well as minimum and maximum atmosphere density. Total entry masses between 7 and 10 mt are considered with architecture closure occurring between 9.0 and 10 mt. Propellant mass fractions for each major phase of the EDL - Entry, Terminal Descent, and Hazard Avoidance - have been derived. An assessment of the effect of the entry conditions on the Thermal Protection System (TPS) currently in use for Dragon missions shows no significant stressors. A useful payload mass of 2.0 mt is provided and includes mass and grow allowance for a Mars Ascent Vehicle (MAV), Earth Return Vehicle (ERV), and mission unique equipment. The useful payload supports an architecture that receives a sample from another surface asset and sends it directly back to Earth for recovery in a high Earth orbit. The work shows that emerging commercial capabilities as well as previously studied EDL methodologies can be used to efficiently support an important planetary science objective. The work also has applications for human exploration missions that will also use propulsive EDL techniques.