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A STUDY OF CRYOGENIC PROPULSIVE STAGES FOR HUMAN EXPLORATION BEYOND LOW EARTH ORBIT

Abstract

This paper summarizes the results of a parametric study to characterize the influence of four design parameters on the design of Cryogenic Propulsive Stages (CPSs) for three candidate missions starting in Low Earth Orbit (LEO). This paper then introduces a viable human exploration architecture based on the development and use of common propulsive elements for all three missions.

The chemical propulsive elements are sized to deliver payloads to a variety of near and deep space destinations in support of future human exploration missions in the 2020 to 2030 timeframe. These destinations are (1) the Moon, (2) a Near-Earth Objects (NEOs), and (3) Mars. For the parametric study, a single CPS is sized for the lunar mission, while a pair of CPSs is sized for the NEO and Mars missions.

For the parametric study, the four design parameters are (1) vehicle Propellant Mass Fraction (PMF), (2) engine Specific Impulse (Isp), (3) the propellant boil-off rate, and (4) the amount of time the CPSs loiter in LEO before the mission starts. A range of values for the four design parameters was established spanning from currently available conservative values to realistic achievable, near-term technology advancement goals. The primary figure of merit for this study is launch mass to LEO

For the common element architecture, the CPS elements were designed based on current state-of-the-art or near-term technologies in order to reduce the technology investment required to achieve these vehicles. A single CPS is required for the Moon mission. For NEO missions, three CPSs are required, with the final CPS requiring a block upgrade to reduce boil-off for NEO operations. For the Mars mission, a larger stage is required for Earth departure, while two of the CPSs with further boil-off reduction are used for Martian operations.

Details are provided on the masses and design of the CPSs, the specific combination of stages required for each mission, and the in-space trajectories required to travel from Low Earth Orbit (LEO) to the selected destinations. All missions are assumed to begin in LEO. Launch manifests to deliver the propulsive elements to LEO were not considered in this study, though efforts were made to constrain the CPS designs such that they would be capable of being launched empty or partially full on existing or proposed near-term launch vehicles.