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Space Launch System Upper Stage Technology Assessment

Jon Holladay, PhD (NASA MSFC)
Bryan Hampton (ZPFC)
Timothy Monk (ZPFC)

The Space Launch System (SLS) is envisioned as a heavy-lift vehicle that will provide the foundation for future beyond low-Earth orbit (LEO) exploration missions. Previous studies have been performed to determine the optimal configuration for the SLS and the applicability of commercial off-the-shelf in-space stages for Earth departure. Currently NASA is analyzing the concept of a Dual Use Upper Stage (DUUS) that will provide LEO insertion and Earth departure burns. This paper will explore candidate in-space stages based on the DUUS design for a wide range of beyond LEO missions. Mission payloads will range from small robotic systems up to human systems with deep space habitats and landers. Mission destinations will include cislunar space, Mars, Jupiter, and Saturn.

Given these wide-ranging mission objectives, a vehicle-sizing tool has been developed to determine the size of an Earth departure stage based on the mission objectives. The tool calculates masses for all the major subsystems of the vehicle including propellant loads, avionics, power, engines, main propulsion system components, tanks, pressurization system and gases, primary structural elements, and secondary structural elements. The tool uses an iterative sizing algorithm to determine the resulting mass of the stage. Any input into one of the subsystem sizing routines or the mission parameters can be treated as a parametric sweep or as a distribution for use in Monte Carlo analysis. Taking these factors together allows for multi-variable, coupled analysis runs. To increase confidence in the tool, the results have been verified against two point-of-departure designs of the DUUS. The tool has also been verified against Apollo moon mission elements and other manned space systems.

This paper will focus on trading key propulsion technologies including chemical, Nuclear Thermal Propulsion (NTP), and Solar Electric Propulsion (SEP). All of the key performance inputs and relationships will be presented and discussed in light of the various missions. For each mission there are several trajectory options and each will be discussed in terms of delta-v required and transit duration. Each propulsion system will be modeled, sized, and judged based on their applicability to the whole range of beyond LEO missions. Criteria for scoring will include the resulting dry mass of the stage, resulting propellant required, time to destination, and an assessment of key enabling technologies. In addition to the larger metrics, this paper will present the results of several coupled sensitivity studies. The ultimate goals of these tools and studies are to provide NASA with the most mass-, technology-, and cost-effective in-space stage for its future exploration missions.