High-C3 Applications for NASA's Space Launch System

Robert W. Stough

For numerous high-interest science targets in the outer solar system and elsewhere, the limits of available launch vehicles have placed significant constraints on mission designs. Even for the current generation of heavy-lift launch vehicles, baseline capabilities still impose limitations, for example, the outer solar system in areas such as launch window availability, transit time, science payload mass, time at destination, etc. Initial studies show benefits for ultra-high C3 missions from configurations of NASA's Space Launch System (SLS) adding third or fourth payload stages.

Designed to meet NASA's requirements for human exploration of the Moon, Mars, and beyond, SLS offers enhancing and enabling capabilities for a variety of missions. The initial Block 1 configuration delivers the needed performance to launch astronauts to lunar orbit; evolved configurations have the ability to deliver infrastructure needed for sustained exploration. SLS offers robust payload mass, volume, and characteristic energy that can be used not only for human exploration but for challenging science missions, including planetary science and astrophysics, among others.

Recently, the SLS Program studied adding commercially available rocket stages for use as a 3rd stage or as 3rd and 4th stages to the Block 2 vehicles, e.g. using the LOX/LH2 Atlas Centaur stage along with a Star 48 series solid propellant stage on top of the Exploration Upper Stage. Studies show that while the baseline Block 2 vehicle can deliver about 8 t to Europa Clipper's C3=83, the addition of a Centaur upper stage would raise that mass to more than 15 t. The New Horizons spacecraft, with mass less than 0.5 t, launched toward Pluto with a C3 of 158 km2/sec2. By comparison, a Block 2 vehicle with Orion 30B and Star 48BV payload motors could launch equivalent mass to a C3 more than double that of the New Horizons launch. (While the study has been conducted based on contemporary cryo stages and solid stages, this analysis provides real-world data for the range of performance this capability enables even as the specific stages available evolve.) Studies have shown it may be possible to reach 80-90 AU within a decade.

As preparations are underway for the next Planetary Science and Astrobiology Decadal Survey, multiple mission concept studies have shown enabling or significantly enhancing benefits from launch on an SLS with additional stages, including proposed missions to the Neptune system, Enceladus and the Pluto system. Potential benefits include increased launch windows, reduced transit times, and/or greater spacecraft/payload mass. Benefits from a multistage SLS configuration have also been identified by a proposed Interstellar Probe mission, which would see greatly reduced transit time to the interstellar medium, and planetary defense, in which SLS could enable mitigation of a short-warning potentially hazardous object.

Today, SLS is making progress toward its initial launch capability and toward both future launches and future capabilities. All of the major flight hardware for its Artemis I debut launch is currently at NASA's Kennedy Space Center (KSC) for stacking, except the core stage, which is currently in preparations for a "Green Run" hot firing at NASA's Stennis Space Center (SSC).

Major hardware elements for engines, booster and core stage have been produced for Artemis II and III, and development hardware has been produced for the Block 1B configuration of the rocket.

NASA is committed to SLS as a key component of its launch architecture. Agency planning manifests outline the launch vehicle's role in human lunar exploration over the next decade as it moves from its Block 1 configuration to its intermediate Block 1B configuration and its ultimate Block 2 configuration. In addition, NASA has issued contracts with prime contractors for SLS hardware for delivery well into the 2030s.