NASA's Space Launch System: High C3 Launch Capability for Science Missions. Stephen Creech[1] and Robert W. Stough[2], [1] Manager, Spacecraft/Payload Integration & Evolution, NASA's Space Launch System, steve.creech@nasa.gov; [2] Utilization Manager, NASA's Space Launch System, robert.w.stough@nasa.gov.

Abstract: As NASA's initial Space Launch System (SLS) Block 1 vehicle enters integration and stacking operations at Kennedy Space Center (KSC) this year in preparation for a 2021 launch, work is in progress on future more powerful variants of the vehicle. Available in the mid 2020s and 2030s, Block 1B and Block 2 will feature increased performance and unparalleled volume for payloads, providing an enabling launch option for science mission planners. The baseline SLS architecture consists of two five-segment solid rocket boosters and four RS-25 LH2/LOX engines. The evolved Block 1B and Block 2 vehicles use a four-engine LH2/LOX upper stage and can be outfitted with an 8.4 m-diameter payload fairing. Additional upper stages can be packaged in the 8.4 m fairing to enable high C3 (in the range of 300 km^2/sec^2) missions to Mercury, the Jovian system, the ice giants, the Kuiper Belt and beyond.

SLS offers performance to meet a range of deep space exploration needs, including lifting the Orion crew vehicle to lunar orbit and emplacing monolithic landers, habitat modules and rovers at the Moon or Mars as well as sending the next generation of astrophysics, heliophysics and interplanetary missions to deep space. With the initial Artemis I vehicle being prepped for launch next year, production of successive builds is accelerating. Much of the second vehicle is manufactured and significant work on elements of the third vehicle is also in progress. The Block 1 vehicle, which uses a single-engine LH2/LOX upper stage known as the Interim Cyrogenic Propulsion Stage (ICPS), lifts 27 metric tons (t) to trans-lunar injection (TLI) and can be outfitted with a 5 m-diameter payload fairing. This vehicle is being evaluated for launching the Europa Clipper mission.

Block 1B, the second major variant, uses the same five-segment solid rocket boosters and four RS-25 engines but replaces the ICPS with a more powerful four-engine LH2/LOX Exploration Upper Stage (EUS). With a lift capability of 38 t to 42 t, depending on whether it's outfitted for Orion with a co-manifested payload or for a payload only, Block 1B can accommodate an 8.4 m-diameter payoad fairing. Available lengths for the 8.4 m fairing are 19.1 m and 27.4 m. The Block 1B crew variant also has 286 m^3 of available volume for a co-manifested payload up to 10 t. Available volume in the 8.4 m-diameter, 19.1 m-long fairing is 621 m^3; the 27.4 m long version contains 988 m^3 of available volume.

The ultimate SLS Block 2 vehicle will onramp evolved solid rocket boosters and several other vehicle upgrades to increase payload mass to TLI to 43 t to 46 t, depending on whether SLS is outfitted for crew or cargo.

The Block 2 vehicle also offers the potential to carry a 10 m-diameter fairing, which would be a game-changer for astrophysics and nuclear-thermal propulsion (NTP) missions.

Additional upper stages packaged with a payload in the large SLS fairing make a new generation of high C3 science missions possible. The Advanced Concepts Office (ACO) at NASA's Marshall Space Flight Center (MSFC) has recently studied adding LH2/LOX upper stages, such as Castor and Centaur stages, along with a solid rocket motor kick stage, such as the Star 48 series, to the Block 2 vehicles. Studies show that while the baseline Block 2 vehicle can deliver about 9 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 record C3 of 158 km^2/sec^2. 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 motors, this analysis provides real-world data for the range of performance this capability enables even as the specific stages available evolve.)

At IPPW, the SLS Program will update the science community on the capabilities of SLS for planetary science missions, particularly high C3 missions and missions that can benefit from superior payload volume. In addition, the Program will provide an update on the status of stacking and assembly operations at KSC and "green run" testing of the SLS core stage at Stennis Space Center (SSC). An update on work on the evolved versions of SLS will also be presented as well as study results of adding third and fourth stages to the Block 2 vehicle to enable new classes of science missions. The information provided can assist mission planners in preparing for decadal studies.