NASA'S SPACE LAUNCH SYSTEM (SLS) PROGRAM: MARS PROGRAM UTILIZATION. Todd A. May, SLS Program Manager (XP01) and Stephen D. Creech, SLS Strategic Development Manager (XP01), George C. Marshall Space Flight Center, Huntsville, Alabama.

NASA's Space Launch System is being designed for safe, affordable, and sustainable human and scientific exploration missions beyond Earth's orbit (BEO), as directed by the NASA Authorization Act of 2010 and NASA's 2011 Strategic Plan. This paper describes how the SLS can dramatically change the Mars program's science and human exploration capabilities and objectives. Specifically, through its high-velocity change (ΔV) and payload capabilities, SLS enables Mars science missions of unprecedented size and scope. By providing direct trajectories to Mars, SLS eliminates the need for complicated gravity-assist missions around other bodies in the solar system, reducing mission time, complexity, and cost. SLS's large payload capacity also allows for larger, more capable spacecraft or landers with more instruments, which can eliminate the need for complex packaging or "folding" mechanisms. By offering this capability, SLS can enable more science to be done more quickly than would be possible through other delivery mechanisms using longer mission times.

Background

The SLS initial configuration comprises a 27.5-foot (8.4-meter)-diameter core stage powered by four liquid oxygen/liquid hydrogen (LOX/LH_2) RS-25 core stage engines (space shuttle main engines) presently in NASA's inventory, combined with five-segment solid rocket boosters (SRBs) currently in the testing phase, to lift 70 metric tons (t) of payload to low-Earth orbit (LEO) (Figure 1). This is the basic Block 1 configuration for the first two BEO flights of the Orion Multi-Purpose Crew Vehicle (MPCV). The first Orion BEO mission in 2017 will be an autonomous flight of the full-up spacecraft around the Moon to verify its performance for crewed flight in 2021, on a longer-duration circumlunar mission to further verify system integrity. With these as anchor flights, NASA is investigating other potential payloads and missions, both internally and with domestic and international partners.

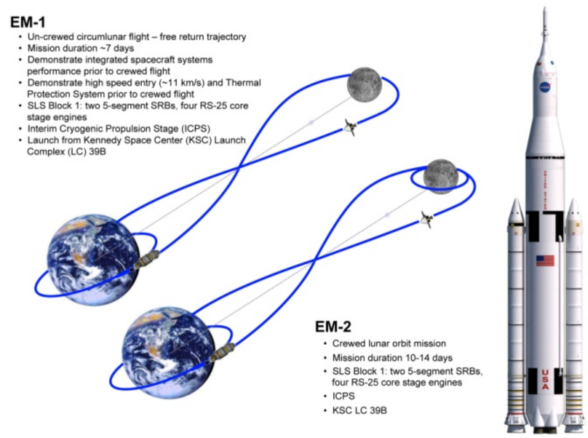

Figure 1. Initial SLS/Orion Exploration Missions.

The SLS development strategy also includes a series of on-ramps for affordably increasing both the capacity and sustainability of this unique national asset. Through a series of planned block upgrades (Figure 2), the SLS will be evolved to a 105-t (Block 1A) and a 130-t (Block 2) capability. This plan delivers a flexible platform for reaching Mars and performing entirely new missions.

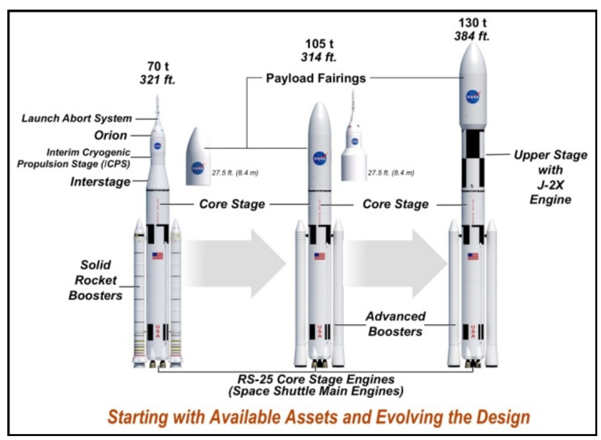

Figure 2. SLS Block 1 (70 t), Block 1A (105 t), and Block 2 (130 t).

Interim Cryogenic Propulsion Stage (ICPS)

The ICPS is the SLS cryogenic upper stage that is responsible for placing payloads in stable orbits or injecting payloads onto escape trajectories. It provides the necessary functions (Table 1) to assure reliable payload insertion and safe stage disposal. The ICPS is a near-term solution using modified off-the-shelf hardware, whereas the Cryogenic Propulsion Stage (CPS) planned for future SLS block upgrades would be required to perform up to five engine starts for orbit insertion and transfer in-space (e.g., Centaur) lending to expander cycle engines. The high specific impulse (I_{sp}) reduces propellant mass and burnout mass. The CPS is envisioned to follow a block upgrade approach as the SLS evolves, increasing performance and capability with each

Table 1. ICPS Functional Capabilities.

Main Engine	• Nominal Specific Impulse (Isp): 462 sec • Restarts: Up to 5
Delta V Capability	• Provide ~4 km/s of main propulsive maneuvering
Stage Life	• ~8 Days
LEO Loiter Time	• >6 Hours
Circularize Capability	• Responsible for circularizing itself and payloads from SLS insertion orbit (TBDE) to LEO orbit (TBD)
Attitude Control	• Provides attitude control for itself and payloads during ELO loiter and mission events where ICPS is actively thrusting
Propellant Management & Thermal Control	• Maintain proper conditioning of cryogenic propellants in order to reduce boiloff (TVS, mass gaging, micro-g LAD, etc.)
Stage Health & Monitoring	• Monitor and report stage health
Stage Disposal	• Provide Delta V necessary to properly dispose (TBR)

The ICPS for SLS Block 1 provides mission capture in the range of 25 t to trans-lunar injecttion (TLI), 11 t – 16 t of cargo to Lagrange Point 2 (L2), and limited crew access to L2. As envisioned, an ICPS2 for the SLS Block 1A configuration could provide substantial mission capture on the order of 45 t to TLI (Figure 4). The curves also indicate substantial payload injection capability to Mars and other planetary destinations.

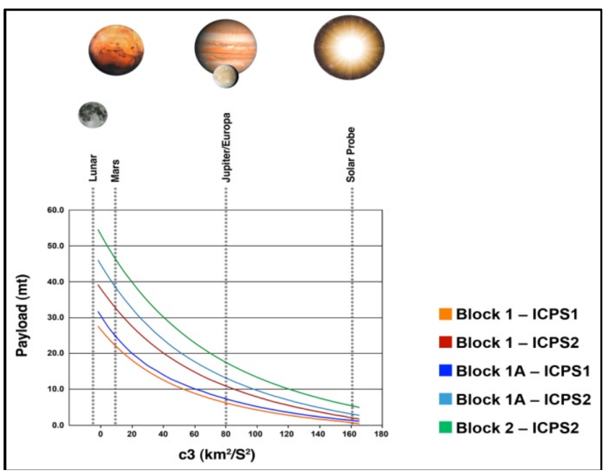

Figure 4. SLS C3 Capabilities.

Mars Program Utilization

The Planetary Science Decadal Survey Mars Panel wants to explore the following three science pathways:

- Surface Field Geology/Astrobiology Pathway
- Subsurface Geology/Astrobiology Pathway
- Network Science Pathway

SLS offers a unique capability for meeting these scientific pathways as well as mitigating human exploration risks. Additional payload capability allows co-manifesting of payloads (orbiters, landers, rovers, etc.) suitable for addressing science objectives in fewer, possibly single, launches. Designing for SLS could redefine Mars sample return strategies such as mission infrastructure, cost, and schedule. Mission planners would benefit from the flexibility to exceed current Evolved Expendable Launch Vehicle (EELV) payload limits and would not be constrained by the Discovery/New Frontiers cost caps.

Additionally, pathways for reducing human exploration mission risks could be coupled with the science pathways and objectives. For example, a Mars sample return mission could be performed using technologies and approaches that lead to risk mitigation for the human exploration mission. Entry, descent, and landing approaches as well as Mars ascent propulsion technologies could be used to accomplish both science and human objectives. SLS offers the flexibility to open the trade space for multiple architectures.

Summary

Overall, SLS enables more ambitious Mars exploration missions at a reasonable cost and on a near-term schedule. The added mass and volume capabilities of SLS could couple science objectives and mitigate human mission risk. Greater performance leads to higher payload margins, faster trip times, and less complex payload mechanisms. SLS's greater payload volume means that fewer deployments and on-orbit operations are required to execute missions. Taking advantage of the full benefits of SLS should be considered in formulation and mission planning for the Mars program.