THE SPACE LAUNCH SYSTEM AND MISSIONS TO THE OUTER SOLAR SYSTEM

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Introduction

America's new heavy lift launch vehicle, the Space Launch System (SLS), enables a variety of planetary science missions. In addition to human space flight, the SLS can be used for most, if not all, of the National Research Council's (NRC) Planetary Science Decadal Survey missions to the outer planets. [1] The SLS performance enables larger payloads and faster travel times with reduced operational complexity when compared to the original concept studies.

We will outline a number of mission concepts drawn from the Decadal Survey. All of our studies are preliminary and used the spacecraft designs from the mission concept studies submitted to the NRC. The exception to this is the Europa Clipper mission which came about as a descope of the Jupiter Europa Orbiter that was originally part of the EJSM Flagship mission. Our goal is to investigate what the capabilities of the SLS would bring to these important science missions.

Europa Clipper - Mission Class: Flagship

Our analysis shows that a launch on the SLS would shorten the Clipper mission travel time by more than five years over earlier mission concept studies [3]. The direct ballistic trajectory eliminates the need for Venus and Earth flybys, simplifying overall mission design. The SLS provides sufficient launch mass margin allowing for increased radiation shielding mass as well as expansion of the science payload. Using the SLS for the Europa mission will provide a model for other outer planet missions.

Mission Overview	Original Design	With the SLS
Launch Vehicle	Atlas V 551	SLS Block 1b
C3	15 km^2/sec^2	95 km^2/sec^2
Launch Mass	3582 kg	3582 kg
LV Mass Margin	1113 kg	100 kg
Science Payload Mass	104 kg	104 kg
Launch Date	November 2021	June 2022
Arrival Date	2027	2024
Cruise Duration	6.5 years	2.1 years
Trajectory	Venus – Earth – Earth Gravity Assist (VEEGA)	Ballistic, Direct

Jupiter Trojan Tour and Rendezvous
Mission Class: New Frontiers

Our mission concept replaces unavailable Advanced Stirling Radioisotope Generators (ASRGs) in the original design with solar arrays. Our new approach allows for a much broader target selection; all of the L4s and some of the L5s are available targets. The SLS capability allows for extra tankage for more propellant, yields twice the delta-v of the original mission design, and offers many more target opportunities. [3]

Mission Overview	Original Design	With the SLS
Launch Vehicle	Atlas V 541	SLS Block 1b
C3	75 km^2/sec^2	95 km^2/sec^2
Launch Mass	1175 kg	2120 kg
Mass Margin	25 kg	2880 kg
Science Payload Mass	51 kg	51 kg
Launch Date	2019-2022 (launch window every 13 months)	Sept 2024
Arrival Date	2029-2032	2030
Cruise Duration	10 years	5.8 years
Trajectory	Jupiter Gravity Assist (JGA)	Jupiter Powered Swingby

Comet Surface Sample Return
Mission Class: New Frontiers

Although in our mission concept, the SLS launches later than the NRC mission study (October 2025 instead of the original launch date of January 2021), it reduces the total mission time, including sample return, by by more than 5 years. [4] The direct trajectory simplifies mission operations. The improved launch mass margin allows for increased propellant, sample return mass, or science payload for in situ investigations at the target.

Mission Overview	Original Design	With the SLS
Launch Vehicle	Atlas V 521 (SEP Option)	SLS Block 1b
C3	26 km^2/sec^2	95 km^2/sec^2
Launch Mass	1440 kg	2725 kg
LV Mass Margin	0 kg	2775 kg
Science Payload Mass	127 kg	127 kg
Launch Date	January 2021	October 2025
Arrival Date	2034	2032
Cruise Duration	13 years	7.3 years
Trajectory	ΔVEGA	Jupiter Unpowered Swingby

Saturn Atmospheric Entry Probe
Mission Class: New Frontiers

Though Saturn arrival time remains the same in our concept as the arrival date in the NRC study (2034), launching on the SLS shortens the mission travel time by three years with a direct ballistic trajectory. [5] This eliminates the need for Earth flyby and a deep space burn maneuver, simplifying overall mission design and reducing operational cost. The improved launch mass margin allows for increased science payload, such as additional probes, and potential orbital science opportunities at Enceladus or Titan.

Mission Overview	Original Design	With the SLS
Launch Vehicle	Atlas V 401	SLS Block 1b
C3	49 km^2/sec^2	125 km^2/sec^2
Launch Mass	957 kg	957 kg
Mass Margin	177.9 kg	743 kg
Science Payload Mass	10.5 kg	10.5 kg
Launch Date	August 2027	July 2030
Arrival Date	2034	2034
Cruise Duration	7 years	4 years
Trajectory	Single Earth Gravity assist	Ballistic, Direct

Uranus Orbiter with Probes
Mission Class: Flagship

The SLS shortens travel time for an Uranus mission by four years with a Jupiter swing-by trajectory. It removes the need for a solar electric propulsion (SEP) stage used in the NRC mission concept study. [6] The improved launch mass margin allows for increased science payload such as an additional probe and more propellant for an extended Uranus system tour.

Mission Overview	Original Design	With the SLS
Launch Vehicle	Atlas V 531	SLS Block Ib
C3	11.83 km^2/sec^2	100 km^2/sec^2
Launch Mass	4123 kg	3350 kg
LV Mass Margin	82 kg	2450 kg
Science Payload Mass	189 kg	189 kg
Launch Date	August 2020 (Annual opportunities)	March 2020
Cruise Duration	13 years	9 years
Trajectory	SEP with Earth Grovity Assist (EGA)	Jupiter Swingby

ATLAST - Astrophysics

Two other mission concepts we are investigating that may be of interest to this community are the Advanced Technology Large Aperature Space Telescope (ATLAST) and the Interstellar Explorer also referred to as the Interstellar Probe.

The ATLAST 16 m enables the characterization of exoplanets and the search for extraocular life. It allows scientists to explore the modern universe, investigate super massive black holes (SMBH), reconstruct the stellar history of hundreds of galaxies and measure the mean density profile of dwarf spheroidal galaxies (dSph) to constrain the nature of dark matter.
The SLS is the only vehicle capable of deploying telescopes of this mass and size in a single launch. It simplifies mission design and reduces risks by eliminating the need for multiple launches and in-space assembly.

Interstellar Explorer - Heliophysics

The concept of a probe to the interstellar medium grew from the studies that accompanied the initial planning for a "Grand Tour" mission to the outer planets of the solar system. In 1976 a study was undertaken at the Jet Propulsion Laboratory (JPL) of an "interstellar precursor mission" as a stepping-stone from the outer solar system to interstellar flight. The ultimate reach of the Voyagers is limited and it is clear that further progress requires a faster, deeper probe of near interstellar space.
While many exotic approaches to rapid, solar-system escape have been discussed over the past four decades, none of these is currently sufficiently advanced to implement on a mission during the next 10 to 15 years. However, with a new capability (the Exploration Upper Stage) being considered for the NASA Space Launch System (SLS) extremely large launch injection energies (C3= 200 km^2/s^2 to 350 km^2/s^2) should be possible for an interstellar probe. [7]

Summary: The first launch of the SLS is scheduled for 2018 followed by the first human launch in 2021. The SLS in its evolving configurations will enable a broad range of exploration missions which will serve to recapture the enthusiasm and commitment that permeated the planetary exploration community during the early years of robotic exploration. [8] NASA and the International Exploration Community should explore ways to utilize the SLS for Planetary Science Missions. The world needs a launch vehicle with the performance that today only the SLS will provide.

References: [1] The Committee on the Planetary Science Decadal Survey, Visions and Voyages for Planetary Science in the Decade 2013-2022. (2011), 4-7. [2] Goldstein B. et al. (2014) Europa Clipper Update, SBAG, p. 10. [3] Brown M. (2010) Trojan Tour Decadal Study, 21-43. [4] Veverka J. et al., (2010) Comet Surface Sample Return (CSSR) Mission, 6-20. [5] Beebe R. et al., (2010) Saturn Atmospheric Entry Probe Mission Study, 9-20. [6] Hubbard W. B. et al., (2010) Ice Giants Decadal Study, 19-48. [7] McNutt R. L. et al. (2014) Enabling Interstellar Probe With The Space Launch System (SLS), IAC-14-D4.4.2. [8] Elsperman M. S. and Klaus K. (2014) IAA WAS0210.