Science and Exploration Missions Enabled by the Space Launch System

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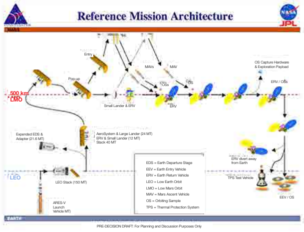
Introduction:
America is on the verge of once again having a heavy lift launch capability called the Space Launch System (SLS). A number of concepts for science missions were explored during Constellation [1,2]. We have selected a diverse set of missions to study that span the SLS design space and we will focus our efforts on three concepts enabled by the SLS launch capability, 1) a human-tended exploration platform at one of the earth-moon lagrange points; 2) Mars Sample Return and 3) the Interstellar Probe mission.

The Exploration Platform:
We have been studying an architecture for Cislunar Development that includes early deployment of an Exploration Platform at one of the Earth – Moon Lagrange points. The Exploration Platform provides a flexible basis for future exploration, since it reduces cost through reuse of expensive vehicles and reduces the number of launches needed to accomplish missions. International Space Station (ISS) industry partners have been working for the past two years on concepts for using ISS development methods and residual assets to support a broad range of exploration missions. These concepts have matured along with planning details for NASA's Space Launch System (SLS) and Multi-Purpose Crew Vehicle (MPCV) to allow serious consideration for a platform located in the Earth-Moon Libration (EML) system. We further propose using the mass margin available on the 2017 uncrewed ORION/SLS test flight to launch secondary science payloads that advance science and exploration objectives.[3]

There is an opportunity to deliver payload to the lunar surface or lunar orbit on the unmanned Multi-Purpose Crew Vehicle (MPCV)/Space Launch System (SLS) test flight currently scheduled for 2017. There is approximately 4.5 metric tons of mass margin on this flight and in current planning, the MPCV does not need an engine as the trajectory is a free return to earth. Leaving the MPCV main engine off would create a volume of 3.66 cubic meters in the aft section. That volume could contain a payload on the order of 2200 kg, enough for a Discovery class landed mission with a prospecting rover. The forward section has ample volume for a landed mass on the same order as the aft section but the dimensions are a more constrained. However, it is ample for a number of Discovery class mission concepts; 1) a number of cubesats, 2) a static lander such as the first node of a lunar geophysical network, 3) a communications satellite pre-deployed before the human tended exploration platform to assist with far-side exploration. Concepts for missions of this nature can be done for Discovery class mission budgets (~$450 million) and would best be done as a joint venture by the NASA Science Mission Directorate and Human Exploration Operations Mission Directorate using the highly successful Lunar Reconnaissance Orbiter as a program model.

SLS Cargo Version, Block I, 70t to LEO

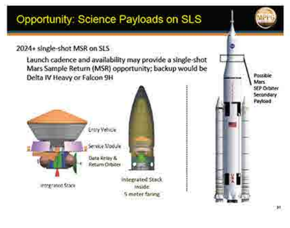
Mars Sample Return:
The highest-priority flagship mission for the decade 2013-2022 is the Mars Astrobiology Explorer-Cacher (MAX-C), which was to begin a three-mission NASA-ESA Mars Sample Return campaign extending into the decade beyond 2022. [4] With NASA's announcement of the intent to fly a rover mission in 2020 based on Curiosity, we are assuming for now that the 2020 mission will be similar to the MAX-C rover and will cache samples as part of its mission. We recognize that the mission goals will be set by the Science Definition Team and will adjust our concept as necessary when more is known about the Mars 2020 mission goals and objectives. For the purpose of our study, we will consider using the SLS for the part of the mission that would retrieve the samples from the surface of Mars and return the samples to the Earth. The elements we are including in our study are, 1) the entry, descent and landing system (EDL) or Sky Crane; 2) the ascent vehicle carrying the samples from the surface of Mars; 3) a small sample fetch rover for contingency, 4) orbiter including autonomous rendezvous and docking with the sample and 5) the earth return spacecraft. We will consider the delivery of the sample to the EML platform with sample return to Earth by the Orion crew.


Reference Mission Architecture

EDS = Earth Departure Stage
EEV = Earth Entry Vehicle
ERV = Earth Return Vehicle
LEO = Low Earth Orbit
LMO = Low Mars Orbit
MAV = Mars Ascent Vehicle
OS = Orbiting Sample
TPS = Thermal Protection System

PRE-DECISION DRAFT: For Planning and Discussion Purposes Only

Mission Architecture from Earlier Constellation/ARES-V Study

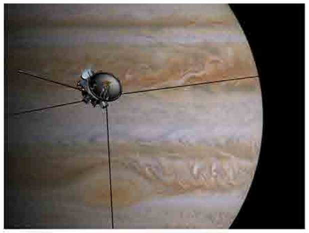

Opportunity: Science Payloads on SLS

2024+ single-shot MSR on SLS

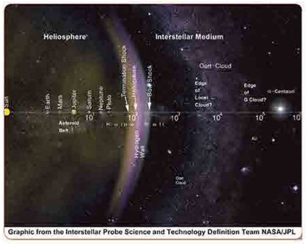
Launch cadence and availability may provide a single-shot Mars Sample Return (MSR) opportunity; backup would be Delta IV Heavy or Falcon 9H

From MPPG Final Report Summary - 2012

Interstellar Probe:
Though not a planetary science mission by definition, there is an exciting opportunity to launch a probe to interstellar space using the SLS. Sending a spacecraft beyond the heliopause to begin the exploration of our local galactic neighborhood will be one of the grand scientific enterprises of this century. Interstellar space is a largely unknown frontier that holds many of the keys to understanding our place in the galaxy. [5] The proposed Interstellar Probe mission, which will travel to >200 AU in 15 years, is designed to exit the heliosphere and begin exploring the space between the stars. In the course of this journey, Interstellar Probe will investigate unknown aspects of the outer solar system, explore the boundaries of the heliosphere to reveal how a star interacts with its environment, and directly sample the properties of the nearby interstellar medium. These studies will address key questions about the nature of the primordial solar nebula, the structure and dynamics of our heliosphere, the properties of organic material in the outer solar system, the nature of other stellar systems that may also harbor planets, the chemical evolution of our galaxy, and the origins of matter in the earliest days of the universe. This great journey requires high capability propulsion, and we will examine launching the ~1200 kg Interstellar Probe spacecraft on the Block 2, 130 metric ton SLS and then use electric propulsion to accelerate further to achieve a velocity of on the order of 14 AU/yr. Preliminary studies conducted during Constellation using an Ares V as the launch vehicle showed that the mission might be flown using only conventional propulsion and that it could shorten the time to reach 1000 AU over existing launch vehicles by 31 years. [1,2]



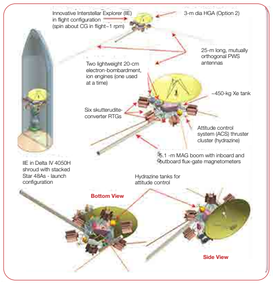
Credit: NASA/Johns Hopkins University Applied Physics Laboratory



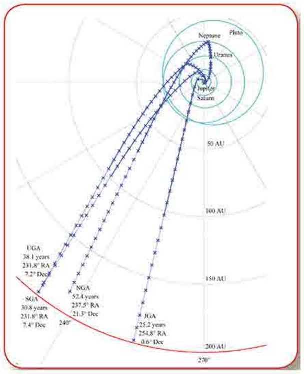
Graphic from the Interstellar Probe Science and Technology Definition Team NASA/JPL

Credit: NASA/Johns Hopkins University Applied Physics Laboratory

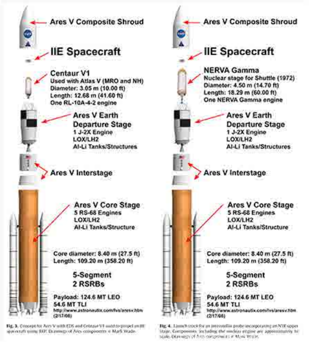
After exiting the heliosphere within a decade of launch, it will be capable of continuing on to ~400 AU. Interstellar Probe will serve as the first step in a more ambitious program to explore the outer solar system and nearby galactic neighborhood.
To accomplish its science objectives, Interstellar Probe should acquire data out to a distance of at least 200 AU, with a goal of reaching ~400 AU. The trajectory should aim for the nose of the heliosphere, the shortest route to the interstellar medium.
The average science data rate should be 25 bps at 200 AU; a lower data rate is acceptable at greater distances. A spinning spacecraft is required to enable the in situ instruments to scan the particle, plasma, and magnetic field distributions and to permit the remote sensing instruments to scan the sky.



Spacecraft Details from Earlier APL/JPL Study
Credit: NASA/Johns Hopkins University Applied Physics Laboratory



Trajectories from Earlier APL/JPL Study
Credit: NASA/Johns Hopkins University Applied Physics Laboratory



Concepts using the Ares V from Constellation Studies

Summary:
The SLS enables not only deep space science and exploration by humans but also can enable ground-breaking science missions throughout the solar system and beyond. Questions that remain to be answered are the nation's will to fly these missions and if the missions are affordable with continued constrained NASA budgets.

References: [1] Committee on Science Opportunities Enabled By NASA's Constellation System, National Re-search Board (2008) Launching Science: Science Opportunities Provided by NASA's Constellation System, 48-52. [2] Langhoff S. et al. (2008) Workshop Report On Ares V Solar System Science., NASA/CP–2008-214592, 19-20. [3] Klaus K. et. al (2012), LEAG (2012). Abstract #3009. [4] Committee on the Planetary Science Decadal Survey; National Research Council (2011) Vision and Voyages for Planetary Science in the Decade 2013-2022, 137-174. [5] NASA Intestellar Probe Science Definition and Technology Development Report (2002), http://interstellar.jpl.nasa.gov/.