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Strategies for Rapid Implementation of Interstellar Missions: Precursors and Beyond (4)

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ENABLING INTERSTELLAR PROBE: SPACE LAUNCH SYSTEM (SLS) TRADES

Abstract

The lowest technology approach for implementing an interstellar probe missions is by using an all-ballistic system with a gravitation assist at Jupiter, yet even this approach remains challenging. Such missions require rapid escape from the solar system, and historically, this has been interpreted to mean at least as fast as the current Voyager 1 asymptotic speed of roughly 3.6 AU per year. Over the years various advanced technologies have been considered for attaining such high speeds by using advanced in-space propulsion technologies including, but not limited to, solar sails, nuclear electric propulsion (NEP), and radioisotope electric propulsion (REP), all both with and without gravity assists at the planets, notably Jupiter. Mass constraints in these various propulsion schemes have remained more challenging than initially thought in providing the required performance. The planned development of the Space Launch System (SLS), and notably the SLS Block 1B with its upper, Exploration Upper Stage (EUS) powered by four RL-10 cryogenic liquid hydrogen/liquid oxygen (LH2/LOX) engines, could provide sufficient launch capability to propel a combination of an interstellar probe and required kick stages to the needed speeds. We consider notional interstellar probe spacecraft in the mass range of 250 kg (Pioneer 10-like) to 500 kg (New Horizons-like) combined with an SLS and kick stages in various combinations with Jupiter flybys to determine the optimal approach along with implied risk postures. In particular we consider three cases (1) an SLS launch with all kick stages used to propel the spacecraft to high injection energy per unit mass (C3) combined with a passive Jupiter flyby, (2) launch to a lower C3 but with a powered Jupiter flyby, and (3) a direct SLS launch to Jupiter, with a passive gravity assist resulting in a close approach to the Sun, followed by a powered solar flyby maneuver (an "Oberth maneuver"). We consider near-term and existing kick-stages with trajectories in the plane of the ecliptic in order to maximize the flyout speed. Such trajectories can accommodate a variety of potential science objectives including the simultaneous close flyby of a large Kuiper Belt Object (KBO) Quaoar, flight toward the "ribbon" discovered by the Interstellar Boundary Explorer (IBEX) mission, and flight toward the solar-gravitational-lens (SGL) imaging line of known exoplanets.