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

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HIGH-SPEED SCIENTIFIC SPACECRAFT LAUNCHES WITH COMMERCIAL LAUNCH VEHICLES

Abstract

Reaching the outer solar system and interstellar space beyond has always been challenging due to the long distances and long travel times. Initial work on planetary gravity assists in the early 1960s by Minovitch and Flandro laid the basis for expanding reachable space with then-existing launch vehicles. Such gravity assists have been key enablers for orbital exploration missions to Mercury (MESSENGER), Jupiter (Galileo, Juno, and Saturn (Cassini-Huygens) by trading higher mass for lower launch energy from Earth (C3). They have also enabled close passes to the Sun (Parker Solar Probe) and moderately rapid solar system escape, coupled with fast flybys of various planetary-sized bodies: Mariner 10 (Mercury via Venus), Pioneer 10 (escape via Jupiter), Pioneer 11 and Voyager 1 (escape via Jupiter and Saturn), Voyager 2 (escape via Jupiter, Saturn, Uranus, and Neptune: the "Grand Tour"), and New Horizons (escape via Jupiter and Pluto). Two of these missions hold the first and second places for the most energetic launches (New Horizons: C3 = 157.7502 km2/s2; Parker Solar Probe: C3 = 152.222 km2/s2). Disadvantages in using Earth and Venus gravity assists to increase spacecraft injected mass to Jupiter and beyond include the time penalty and the need for a customized propulsion system to provide a deep-space maneuver (DSM). For "timely" transits to Neptune with a large orbiter or rapid solar system escape with an Interstellar Probe, more capable launch vehicles can be enabling by pushing the injected mass versus C3 curves "to the right." While the most extreme speeds asymptotically away from the Sun (7 to 8 au/yr) can be achieved with fast Jupiter gravity assists and super-heavy lift launch vehicles (SHLLV) such as the Space Launch System (SLS) surmounted by multiple upper stages, solar system escape speeds larger than those achieved by Voyager 1 are possible with existing and upcoming large commercial launch vehicles. Such vehicles include the Falcon-Heavy, New Glenn, and Vulcan Centaur. Better performance accrues with the fully expendable versions of these vehicles and/or with "refueling" in a low-Earth orbit, with performance versus launch cost as a central trade. Even better performance can be projected with SHLLVs in development, such as the Starship Super Heavy and Long March 9. We discuss some of the possibilities and trades such newer vehicles can enable in the near term for continued – and more distant – exploration of the solar system and beyond.