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

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SYSTEM ENGINEERING A SOLAR THERMAL PROPULSION MISSION CONCEPT FOR RAPID INTERSTELLAR MEDIUM ACCESS

Abstract

We examine a solar thermal propulsion (STP) system to rapidly access the local interstellar medium via a solar perihelion burn. This approach uses several Venus and Earth gravity assists to fly out to Jupiter and then would dive towards the Sun. Approaching within 3 solar radii a perihelion burn would be performed, maximizing the spacecraft's ΔV to achieve high Solar System escape velocities. A unique aspect of the STP mission concept is that the Sun is not only used as a gravity well for an Oberth maneuver,

but also to heat the fuel to ultra-high temperatures (>3000 K), enabling a monopropellant burn with high specific impulse (Isp). An in-depth modeling exercise found this approach to be preliminarily feasible, with escape velocities of around 9 AU/yr achievable with current technology, and up to 16 AU/yr with significant future technological advances.

While the current STP design is capable of providing just under 91 AU/yr, there are many technology developments that could increase escape velocity. The technologies vary from items that could be implemented in the near term, like turbopumps driven by the hydrogen, to items requiring more extensive development programs like thin coatings which do not erode in superheated hydrogen. It is assumed that these upgrades can be implemented in the future without incurring any additional mass penalty over the baseline design. Thus, it predicts best case performance, and actual values would likely be lower. Ultimately, if all technological paths could be implemented, the overall performance as a best-case scenario could reach approximately 16 AU/yr.

After reviewing the STP approach, and comparing it to a solid rocket motor (SRM), it was found that with currently available technology, SRM outperforms STP with an escape velocity of approximately 12 AU/yr. However, future advances in heat exchanger lining materials, turbo pumps, and advanced heat exchanger geometries may enable solar thermal propulsion to provide higher escape velocities, which would provide one of the fastest ways to exit the solar system. Of particular importance is heating the hydrogen to 3,500K. Another enhancement to maximize escape velocity was to use a perihelion burn as a kick stage for a nuclear electric propulsion system, which could achieve escape velocities of up to 19.5 AU/yr.