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HIGH-INCLINATION SOLAR ORBITER ENABLED BY SAIL-AUGMENTED ELECTRIC PROPULSION

Abstract

Studying the polar region of the Sun to improve the understanding of its atmosphere and the heliosphere has been a long-stated goal within the heliophysics community. The Solar Polar Imager mission was proposed to address this gap in the body of scientific knowledge by taking observations of the Sun from a sailcraft in a 0.48 au orbit with an inclination of 75 degrees. However, despite nearly twenty years of study, the mission has yet to advance beyond the concept study phase. One of the likely culprits is the state of solar sail technology. To enable this mission, an order of magnitude increase in sail size compared to current flight-proven designs would be required.

In this investigation, an alternative is considered that combines a solar sail and solar electric propulsion (SEP) in a single spacecraft: hybrid low-thrust propulsion (HLTP). By transferring a portion of the ΔV requirements from the sail to an SEP thruster, a smaller sail may be used, thus reducing the development risk of that subsystem to the overall mission. HLTP has previously been shown in the literature to offer shorter flight times than pure sailcraft and reduced propellant mass fractions compared to SEP alone.

This paper compares the performance of HLTP against solar sails and SEP individually on a high-inclination solar orbiter mission based on that of the Solar Polar Imager. This is accomplished by generating mass- and time-optimal trajectories using direct forward-backward multiple shooting. For HLTP to be superior to SEP, it must reduce the propellant mass by more than the added sail mass. A detailed mass budget is therefore included that contains the mass of individual subsystems and the payload. The sail performance required to produce the desired net mass benefit is then characterized with context provided in comparison to the present state-of-the-art. Similarly, the SEP utilization required to produce a shorter flight time than a solar sail alone is determined. Together, these demonstrate that HLTP offers a superior means of enabling a solar polar orbiter in the near future.