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

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THE PHYSICS OF HEAT SHIELDING DURING AN OBERTH MANEUVER

Abstract

A powered gravity assist in the Sun's gravitational well is one of the few viable options for reaching interstellar space within 25 years. Because the escape velocity scales with the -1/4 power of distance at the perihelion, it almost becomes necessary to skim the surface of the Sun to be effective. We therefore consider the physics of heat shielding during this flyby, also known as an Oberth maneuver. The requirements differ greatly from those of the recently deployed Parker Solar Probe, motivating a complete reprioritization of factors in the design. These factors include the backscattering of sunlight, radiative heat loss, melting point, sublimation rate, and mass density. We use Kubelka-Munk theory to calculate the expected solar absorptance and emissivity of candidate shield materials. These values are then used to calculate the equilibrium temperature as a function of distance from the sun. A comparison with the melting point provides an estimate of the closest approach. Also considered is the minimum mass per unit area that would be required due to the backscattering coefficient and the rate of sublimation. By assuming a zero-sum tradeoff with the mass of the kick stage, we estimate the impact on the escape velocity due to the ensuing reduction in specific impulse. The results highlight the risk of relying too heavily upon the optical properties of the heat shield to maintain the temperature of the kick stage and spacecraft within operational limits during close approach to the Sun.