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

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LASER-POWERED ELECTRIC PROPULSION FOR INTERSTELLAR PRECURSOR MISSIONS

Abstract

In the last 30 years, the space community has proposed concepts for an Interstellar Heliopause Probe which could reach 200 AU within a scientist's career lifetime (< 30 years). However, no mission has yet been defined that does not need extensive technology development. Interstellar precursor missions such as the FOCAL mission to the Sun's gravitational focus (> 500AU) or the exploration of the Oort Cloud (> 1000AU) are clearly not realistic with the current propulsion systems. The Thousand Astronomical Unit (TAU) mission was an interstellar precursor mission concept, studied by JPL in the late 1980s, which could have reached 1000 AU within a 50-year trip time. The challenging ΔV needed (> 100 km/s) could be achieved with a nuclear electric propulsion system including a nuclear fission reactor in the 1-MWe class with a specific mass of 12.5 kg/kWe and advanced ion thrusters with a specific impulse of 12,500 s. While The NASAs HiPEP ion thruster has demonstrated a specific impulse of $\sim$ 10,000 s, the needed lightweight nuclear reactor still exists only on paper. This paper proposes an advanced propulsion concept for challenging interstellar precursor missions, Laser-powered Electric Propulsion (LEP) and identifies its efficiency limitations. A high-power laser beam is aimed at a lightweight photovoltaic (PV) collector on the target spacecraft, where it is converted to electric power for an ultra-high specific impulse EP system. The PV collector/converter on the spacecraft can be tuned to the laser wavelength, thus achieving high monochromatic conversion efficiencies, currently $\sim$ 50% with the potential to reach 80% in the near future. The TAU mission could profit greatly from the LEP concept. The nuclear reactor is replaced by a monochromatic PV collector with a specific mass of just 1 kg/kWe; such a lightweight power source could pave the way to challenging missions beyond the heliopause such as FOCAL and the exploration of the Oort Cloud, with travel times well within a scientist's career lifetime.