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Space Transportation Solutions for Deep Space Missions (4-D2.8)

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FAST SOLAR SYSTEM TRANSPORTATION WITH ELECTRIC PROPULSION POWERED BY DIRECTED ENERGY

Abstract

Fast solar system transit requires high thrust-to-weight ratios, high specific impulse, and high system specific power (W/kg) for ample acceleration. Chemical and nuclear thermal rocket architectures suffer from low payload mass fractions and slow transfers to interplanetary destinations, and require complex in-space staging operations to assemble the required fuel mass. Solar electric propulsion and chemical-solar hybrid options allow for greater fuel efficiency and fewer launches, but at the cost of longer transit times.

Breakthrough improvements are possible with laser driven electric propulsion, where an Earth based, large-aperture laser array directs energy onto a deep space electric propulsion vehicle's photovoltaics. Narrowband intensity gain over broadband sunlight enables order-of-magnitude reductions to on-board power system specific mass (kg/kW). When coupled with low specific mass electric propulsion systems that are capable of achieving high thrust density and efficiency, rapid deep space missions are enabled without advanced nuclear or exotic systems. Unlike nuclear approaches, laser driven systems are readily scaled across a broad range of masses, from CubeSats to human missions. Parametric mission studies for directed energy electric propulsion architectures are presented that consider a range of specific mass and specific impulses. Propulsion system power requirements as a function of payload mass are calculated to derive power and aperture requirements for the directed energy driver and to size the interplanetary spacecraft photovoltaics. In this parameter space, it is found that revolutionary solar system transit times are enabled with the combination of a DE Launch Technology Array (DELTA) laser array and low specific mass electrospray thruster arrays. A path towards large-scale implementation is discussed, including technology development through CubeSat demonstration missions.