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SPACE PROPULSION SYMPOSIUM (C4)
New Missions Enabled by New Propulsion Technology and Systems (6)

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IMPROVED MODELING TECHNIQUES FOR ELECTRIC SAIL PERFORMANCE ANALYSIS WITH APPLICATIONS TO OUTER SOLAR SYSTEM MISSIONS

Abstract

The electric sail is a relatively new concept for propellantless space propulsion. It would use the momentum of the solar wind to produce low amounts of thrust through the interaction of an electric field generated by the craft with the solar wind ions, similarly to the manner in which a solar sail extracts the momentum of photons. The electric sail is expected to have particular application to outer solar system missions as its thrust depends both on the density of the solar wind as well as local properties of the solar wind plasma. The overall thrust dependence of the electric sail is predicted to be $1/r^{7/6}$, as compared with $1/r^2$ for a solar sail, for which thrust depends only on photon density. This means that the electric sail has the potential to dramatically outperform the solar sail for missions to the outer solar system. Studies conducted to date predicting the performance of an electric sail, particularly for missions to outer solar system targets and the heliosheath, have made a number of simplifying assumptions. The mathematical models used to-date have assumed that:

- The velocity of the solar wind is constant
- The velocity of the sail is always << the velocity of the wind
- The sail thrust direction can be turned without reducing the total thrust magnitude

The above assumptions, while useful for initial studies, do not account for the following issues:

- The velocity of the solar wind actually varies significantly, both in time and with radial distance from the sun
- The relative velocity of the sail to the wind will become increasingly important, especially for heliosheath missions (e.g. previously modeled missions have shown final velocities $> 10\%$ of solar wind velocity)
- In order to turn the sail, the generated electric field must be modulated (i.e. portions of the sail must be turned off) , which will result in a reduction in the sail's thrust

This paper presents an improved model of electric sail performance which takes into account the issues described above. The improved model is used to refine current predictions for electric sail performance with respect to the time required to fly-by or rendezvous with targets in the outer solar system, as well as the flight time required to reach the heliosheath.