66th International Astronautical Congress 2015

SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations (IP)

Author: Mr. Thomas Gemmer
North Carolina State University, United States, trgemmer@ncsu.edu

Prof. Andre Mazzoleni
North Carolina State University, United States, apmazzol@ncsu.edu

IMPROVED MODELING OF ELECTRIC SAIL (E-SAIL) FORCE GENERATION

Abstract

The electric sail (e-sail) is a relatively new concept for propellantless space propulsion. It proposes using the momentum of the solar wind to produce low amounts of thrust through the interaction of an electric field (generated by the craft) with 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 the overall thrust dependence on distance from the sun, r, of the electric sail is predicted to be $1/r^{7/6}$, as compared with $1/r^2$ for a solar sail. This is because the thrust from an electric sail depends both on the density of the solar wind as well as local properties of the solar wind plasma (this is discussed in substantial detail in the paper), while the thrust from a solar sail depends only on photon density (which has a $1/r^2$ dependence). This means that the electrical sail has the potential to dramatically outperform the solar sail for missions to the outer solar system.

Previous studies on the electric sail have predicted its performance based on an expression for the solution of the potential around a sail wire specifically tailored to fit computational data. Here we improve on these initial studies by developing and using a more sophisticated model for the potential field which surrounds the wires used in an electric sail. As opposed to modifying the expression for the potential around a wire in vacuum, as has been done in previous electric sail studies, we use dynamic plasma shielding theory to develop a fully self-consistent solution for the potential around a wire in a plasma in terms of a modified Bessel function. Particle-in-cell simulation results are then used to accomplish high-level verification of the improved model and to fix variable parameters in the theoretical potential functions. We then show how this new model of electric sail potential changes the predicted performance of the electric sail, most notably with respect to how its thrust depends on distance from the sun. Finally, to illustrate the importance of the new model, we present simulation results that compare predicted electric sail performance based the new model to performance based on the previously used model, for a variety of mission scenarios (e.g. to the outer solar system and heliosheath).