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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

COMPUTATIONAL PLASMA PHYSICS SIMULATIONS OF ELECTRIC SAIL FORCE GENERATION

Abstract

The electric sail (a.k.a. electric solar wind sail or E-sail) is a new concept for propellantless space propulsion, first proposed in 2004 by Pekka Janhunen of the Finnish Meteorological Institute. An electric sail would consist of several long wires, deployed radially from the body of the spacecraft, and maintained in position by rotating the spacecraft. The wires would be held at a high positive electric potential via an electron gun, and the resulting electric field would deflect the charged ions in the solar wind, which would then propel the spacecraft in accordance with Newton's third law. 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 thrust of electric sail is predicted to be proportional to $r^{-7/6}$ (r = radial distance from the sun) as compared with r^{-2} for a solar sail. This means that the electric sail has the potential to dramatically outperform the solar sail for missions to the outer solar system.

In a paper for the 66th International Astronautical Congress, we introduced a fully theoretical model for the interaction of the solar wind with the wires of an electric sail. In addition, we compared the results of this model with four other proposed theoretical models (found in the literature) for this interaction. Here, we continue this work by developing one and two dimensional computational plasma physics simulations and comparing the simulation results with each of the aforementioned analytic models. This will allow us to further refine the estimates for the force that can be expected to be supplied by an electric sail (for use in future performance analyses and trade studies).

We conclude the paper with a detailed exposition of an experiment currently under development which will enable us to test the theories described above in a laboratory setting. The experiment involves simulating the solar wind via an ion source similar to the ion sources used in the testing of instruments to be used on deep space satellites. This particle stream will then be directed at a section of charged wire representing an electric sail wire, and the force on the wire will be measured directly. Such a test will be an important next step in verifying the analytic and computational models outlined in the first part of the paper.