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COMPARATIVE STUDY OF SOLAR ELECTRIC SAIL THRUST MODELING FOR INTERPLANETARY MISSIONS

Abstract

Since the introduction Solar Electric Sailing by Janhunen in 2004 for interplanetary travel, significant progress has taken place in theoretical, laboratory and experimental flight tests. The electric solar wind sail (E-sail) is a newly invented space propulsion concept which uses the natural solar wind dynamic pressure for producing thrust for a spacecraft by Coulomb interaction. The baseline configuration of an E-sail comprises a number of long, thin, conducting and centrifugally stretched tethers; by an onboard electron gun these are kept in a high positive potential. The positively charged tethers repel the solar wind protons and hence produce thrust as well as attract electrons. E-sail gains its efficiency since the effective sail area of the tethers can be millions of times larger than the physical area of the thin tethers wires, thus offsetting the very weak dynamic pressure of the solar wind. Theoretical development has indicated that E-sail is capable of producing a dramatic level of specific acceleration for interplanetary travel propulsion. The almost complete absence of trapped electrons in the E-sail could lead to E-sail thrust about five times higher than otherwise, corresponding to 1N thrust for a baseline construction with 2000 km total tether length. Samples of final-type tether have been manufactured, a CubeSat test mission has been in orbit for measuring the electric sail force and accurate navigability of the sail in variable solar wind has been shown numerically. A study and trajectory calculations for many classes of missions have been made. Several issued have been addressed to look into the mathematical models assumptions to account for the significant temporal and spatial variation (nature of the randomness and uncertainty) of velocity of the solar wind and thrust vectoring of the solar electric sail spacecraft. Dynamic plasma shielding theory has been adopted to develop a fully self-consistent solution for the potential around a wire in a plasma, which introduced changes to the performance analysis for the electric sail, most notably to the thrust dependence on distance from the sun. Considering these aspects, the status of solar electric sailing is comprehensively reviewed in view of their relevance. Variability of Solar Wind Field in the Solar System and Influence of Solar wind field fluctuations on solar electric sail thrust for various solar electric propulsion architecture configuration and thrust vectoring of an electric solar wind sail with a realistic sail shape will be addressed and discussed, including Heliopause Electrostatic Rapid Transit System.