Paper ID: 67550
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IAF SPACE PROPULSION SYMPOSIUM (C4)
Joint Session between IAA and IAF for Small Satellite Propulsion Systems (8-B4.5A)

Author: Mr. Maximilien Berthet
University of Tokyo, Japan

Prof. Kojiro Suzuki
University of Tokyo, Japan

A STUDY ON SOLAR SAILING FOR LOW-POWER ORBIT-ATTITUDE CONTROL OF SMALL SATELLITES IN LEO

Abstract

Solar sails are a practical and attractive technology for low-power propulsion. While solar sailing itself requires no power, power is usually needed for attitude control. Small satellites are especially well-suited to solar sailing due to advances in the miniaturisation and stowability of deployable reflective structures. On one hand, flight experiments and academic studies to date have mainly focused on solar sail applications for orbit control, and low Earth orbit (LEO) has been used as a convenient proving ground. On the other hand, the solar radiation pressure (SRP) effect responsible for solar sailing could also be used for low-power attitude control, which remains an untapped resource in current LEO solar sail missions. If a solar sail could be used to provide combined orbit and attitude control for small satellites, then mass and power savings may be achieved compared to conventional control technologies, increasing the budgets available for other systems. In response, the present simulation study evaluates candidate methods to achieve both orbit and attitude control of general small satellites via solar sail. First, a design trade is conducted to determine the required properties of the sail including its shape, via sensitivity analysis of the main governing design parameters. It is shown that a right square pyramid-shaped sail naturally emerges as the best candidate to provide low-power combined orbit-attitude control via SRP. Then, the unique merits of the proposed propulsion technology are demonstrated using a high-fidelity orbit-attitude simulation platform. It is shown that the pyramidal sail successfully provides reversible orbit raising and lowering via solar sailing propulsion in LEO over a wide range of orbital conditions, as well as fast de-orbit at end of life enhanced by passive attitude control. Potential applications include station keeping, orbit transfer, and space debris mitigation. The paper closes with an assessment of the costs and benefits of the proposed pyramidal sail compared to alternative technologies for low-power orbit-attitude control in LEO. It is hoped that this work will help to create new pathways for small satellite solar sailing in LEO.