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HIGH-ENERGY MISSIONS ANALYSIS FOR NANOSATELLITES USING ABLATIVE PULSED PLASMA THRUSTERS

Abstract

Ablative Pulsed Plasma Thrusters (APPTs) were the first Electric Propulsion devices ever to be flown on board a spacecraft, and continue to be used today in missions were simplicity, robustness and scalability to different power levels are dominant requirements. Therefore, they find a natural niche of application in small-spacecraft missions, where mass, volume and onboard power are at a premium, in spite of their low overall efficiency and not fully understood physical operating principles.

In this work, we investigate the possibility of performing high-energy (a shorthand for high v, high total impulse) missions, such as orbit raising or even deep-space missions, using APPTs on board small spacecraft. The design of such missions is far from trivial, as the high specific impulse values desirable to obtain a high payload ratio are generally obtained at the expense of impulse bit (the impulse produced at each pulse) vs discharge energy. This implies a high number of shots, which could strain the capacitor capabilities, or high values of discharge energy, which would increase capacitor weight and imply low firing frequencies, due to power limitations on board a small spacecraft. Consequently, total mission times could become long, of the order of many months, or even a few years.

Until recently, such missions have been outside the realm of possibility, mainly because of the weight of the capacitors that would be needed. With recently developed supercapacitors, currently in the process of space qualification, they now might become possible, due to highly improved energy densities, opening a wealth of applications, including ambitious missions on string budgets. A deeper analysis will be necessary beforehand, as APPTs with such discharge energies were never actually tested, even if insight can be gained from experiments on similar devices.

This paper presents a preliminary study of a potential use of an APPT as a simple and robust primary propulsion system for such missions. As an example, a LEO (Low Earth Orbit)-to-LLO (Low Lunar Orbit) transfer is analyzed. The main operating parameters of an APPT propulsion system, obtained analytically by using previously developed scaling laws in a preliminary design, are then used in a simplified mission analysis, initially limited to a preliminary Orbit Analysis, in terms of Dynamics, Geometry, Maneuver and Maintenance, Earth-Moon Transfer and Delta-V Budget, to check if the mission can be realistically implemented. Various dedicated software will be used, such as JAQAR Astrodynamics package and STK/Astrogator.