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ENABLING LOW-COST CHALLENGING MISSIONS WITH SMALL SPACECRAFT BY USING HIGH-ENERGY PULSED PLASMA THRUSTERS: PRELIMINARY PRO-PULSION SYSTEM DESIGN

Abstract

Small spacecraft are inherently cheaper to build and launch, even if they may pose formidable design challenges, especially for high Delta-v orbit transfers, lunar and interplanetary missions. The development of a propulsion system that is, at the same time, simple, robust and scalable, is of paramount importance to enable this type of missions at the cost levels affordable to the players more frequently interested in them, like academic institutions and small companies, especially in developing countries. In the last decades, increasingly ambitious missions have been planned and executed using small spacecraft. Although different types of propulsion systems have been developed and implemented on Cu-beSats, NanoSats and MicroSats, these have provided, in general, low values of total impulse, thus precluding their application to high Delta-v missions. Particularly stringent mass, volume and power constraints make scaling down electric propulsion systems, beneficial in reducing total propellant mass due to their high specific impulse, far from trivial. Among the many types of electric thrusters developed, Pulsed Plasma Thrusters (PPTs) have been one of the most successfully employed on small spacecraft, due to their low overall system complexity, which makes them eminently scalable, reliable and robust. These characteris-tics are especially evident in solid-propellant (ablative) PPTs, with their lack of moving parts. High values of total impulse entail corresponding-ly high values of impulse bit, the impulse produced by each pulse, un-less reliable capacitor operation for a very large number of cycles can be achieved. This, in turn, translates into a large value of discharge en-ergy, roughly proportional to impulse bit. As specific impulse has been seen to increase with increasing values of discharge energy per unit area of ablated propellant, the benefit of operating PPTs at high energies is twofold. By developing capacitors with high energy densities and capable of operating for sev-eral millions of charge-discharge cycles, high values of both total im-pulse and specific impulse will be attained, with reasonable mass values of the capacitor bank and the propellant bar. The continuous increase in capacitor energy densities will soon reach values making PPT operation in these energy ranges possible. While such high-energy PPT propulsion systems need to be actually designed and tested, to ensure that there are no showstoppers, a preliminary system design is nevertheless interesting, to provide research directions. Low-thrust trajectory simulations are needed in order to further optimize the design and are described in a companion paper, based on the calculations performed here.