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PERFORMANCE AND ENVIRONMENTAL TEST RESULTS OF A NOVEL ELECTRIC PROPULSION TECHNOLOGY FOR SMALL SATELLITES

Abstract

Results from performance characterization and environmental testing of a novel electric propulsion system particularly well suited for small satellite missions are presented. The results are incorporated into simulations of three small satellite missions of contemporary interest, demonstrating new capabilities enabled by the technology; existing propulsion solutions are also included for comparison.

As tested, the system includes the thruster head, power electronics, and propellant supply and feed system. The novel propulsion technique is based on ion electrospray, which refers to the electrostatic extraction and acceleration of ions from an ionic liquid—a zero-vapor pressure conductive salt that remains in the liquid phase over a wide range of temperatures. In order to extract these ions, electric fields on the order of 1 V/nm are required. Such intense fields are routinely achieved at the tip of electrically-stressed liquid menisci, or Taylor cones, which have sizes from a fraction of a micrometer to several micrometers and are produced at the end of sharp emitter structures, such as sharpened capillaries or needles biased with respect to a downstream extractor aperture. One propulsion system can contain tens of thousands of individual emitter structures, each producing a beam of ions and collectively producing enough thrust for many interesting small satellite applications.

High-fidelity performance characterization of the propulsion system includes emitted current, applied voltage, direct thrust measurements via a magnetically levitating thrust stand developed specifically for this purpose, and operational lifetime. Results obtained to date show 1.2 mA, 1100 V, 120 μN, and 200 h, respectively. Environmental testing includes total dose radiation, thermal vacuum, and vibration and shock tests. Testing shows radiation hardening up to 10 krad, operability from 0 to 80 C, and survivability to the Atlas V launch profile.

Simulations and cost function analyses of single and multi-satellite constellations are presented for a 350-km imaging mission, a LEO to GEO transfer orbit, and a lunar reconnaissance mission based on the obtained performance and environmental testing data. Results indicate that contract value per day can be used to inform propulsion subsystem adoption decisions: the tradeoff between mission or maneuver time and launch mass dominates the cost function results. We demonstrate that the system described here is attractive for many missions and also indicate where other choices may be more appropriate.