28th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Joint Session between IAA and IAF for Small Satellite Propulsion Systems (5A-C4.8)

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PASSIVE, WATER-BASED PROPULSION SYSTEM AS A CUBESAT DRAG-MAKEUP PROPULSION UNIT FOR VERY LOW EARTH ORBIT OPERATIONS

Abstract

There are many advantages for satellites operating in a very low earth orbit (VLEO) as operating closer to the Earth's surface will provide the scientific instruments an opportunity to observe the subjects at a much closer distance. Another advantage of launching satellites into VLEO is that these satellites will deorbit much faster, not contributing to the growing orbital debris problem. The obvious drawback for these lower altitude satellites is the drastically reduced mission lifetime. As an example, a 3U CubeSat at 250 km altitude will deorbit in approximately seven days. If a drag-makeup propulsion unit is integrated into these satellites, however, the mission life can be extended to several weeks. This is still considerably shorter than typical satellite missions, but a few weeks of operation can be sufficient for many missions that the CubeSats typically perform. Researchers at the U.S. Naval Academy (USNA) are developing a low-cost, passive drag-makeup propulsion system called Water Vapor Independent Satellite Propulsion System (WISP), capable of providing enough thrust to overcome the drag forces at 250 km altitude without requiring electrical power for thruster operation or attitude control. The main propellant is liquid water. Using a membrane, the liquid water is separated from the water vapor that is allowed to escape into the chamber. The water vapor is then expelled through a nozzle to generate thrust, enough to match the drag force created by the satellite. After the initial activation of the system where the nozzle throat is opened, the system will generate thrust continuously, completely passively, until all water in the tank has been depleted. The external aerodynamic surface will provide heating of the propellant through conduction, preventing the propellant from freezing. Pointing of the satellite will be accomplished by deploying aerodynamic drag surfaces to cause the 3U CubeSat to point its long axis in the ram-direction in a shuttlecock orientation. The proposed aerodynamic stabilization and drag makeup mechanism, WISP, can extend the mission life of a 3U CubeSat to about four weeks while taking up about 1U volume of the satellite. This paper will focus on the construction and testing of the propellant tank and feed mechanism that leverages key characteristics of expanded polytetrafluoroethylene (ePTFE) membrane. This design enables a completely passive method for liquid-gas phase separation of the propellant. The general design and operation concepts of the WISP will also be discussed.