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WATER VAPOR INTEGRATED SATELLITE PROPULSION SYSTEM FOR ORBIT MAINTENANCE IN LOW-EARTH ORBIT NANOSATELLITE MISSIONS

Abstract

Without independent deorbit capability, nanosatellites that arrive on orbit at a nonoperational condition congest valuable orbital space. While deploying nanosatellites to very low altitudes (250km or less) would decrease free space losses for measurement and communications systems, atmospheric drag present at these lower altitudes would cause rapid deorbit operational spacecraft. If a means of maintaining orbit for nanosatellites could be devised within system size, mass, and power constraints, improved hardware performance could be achieved while guaranteeing prompt natural deorbit for dead-on-arrival missions. In order to provide the thrust required to maintain these low orbits for nanosatellite missions, the United States Naval Academy has designed the Water Vapor Integrated Satellite Propulsion system (WISP). This 1U volume, bolt-on passive propulsion system provides orbit maintenance capability for a 3U CubeSat with approximately 2U of volume available for scientific instrumentation and communications hardware while drawing zero power at steady state. By creating a standardized passive propulsion system to complement the standardized CubeSat form factor, access to orbits more favorable to data links, optical measurement systems, and other instrumentation can be provided while significantly simplifying satellite and mission architecture. Prior to launch, the propellant tank and expansion chamber pressures are adjusted to ensure a small differential pressure, causing propellant vapor generated at the separation boundary to flow into the expansion chamber. Designed with near-atmospheric initial operating pressures and containing liquid water as propellant, hazards to technicians, other hardware, and the environment can be minimized during integration. Additionally, utilization of water as propellant significantly reduces the overall environmental impact of the system. As the system may only be activated if the satellite is operational, dead-on-arrival spacecraft would deorbit naturally due to low orbital altitude. WISP produces thrust by vaporizing liquid water passively across a phase separation boundary and accelerating this vapor through a nozzle assembly. Liquid water propellant is vaporized at the separation boundary according to propellant surface tension forces and exposure to the temperatures and pressures experienced at the interface between propellant tank and expansion chamber. The nozzle plane and phase separation boundary properties are tuned specifically to maintain constant inlet pressure to the nozzle as additional vapor is generated, producing thrust sufficient to match atmospheric drag. Throttling hardware is not required as vapor generation and propellant evacuation naturally throttle propellant flow. From an operational perspective, WISP only requires electrical power to open the nozzle plane and initiate flow, after which it will provide sufficient thrust to maintain orbit until propellant is exhausted. Additionally, since WISP provides constant thrust matching drag forces during its useful life, this propulsion system does not cause sufficiently large changes in orbital altitude to decrease performance of communications and scientific hardware. By providing a means of maintaining altitude for orbits favorable to link margins, data collection, and natural end-of-life deorbit, WISP offers a streamlined means of providing independent propulsion capability for nanosatellite missions.