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MODELING OF ORBITAL AND ATTITUDE DYNAMICS OF NANOSATELLITES CONTROLLED VIA ACTIVE ELECTROSTATIC CHARGING

Abstract

The large-scale exploration of airless bodies, such as asteroids and moons, is gaining interest, however it is limited by mobility issues: the lack of atmosphere, low gravity, and unknown soil properties pose difficult challenges for many forms of traditional locomotion. The environment in proximity of these bodies is electrically charged due to interactions with solar wind and UV radiation. The EGlider concept would be able to overcome these mobility issues by leveraging the natural environment, allowing operations in close proximity of the surface, while enabling long duration missions by minimizing propellant consumption. The EGlider is an advanced concept for small satellite mobility and propulsion, which relies on the electric fields naturally present around airless bodies in order to generate forces and torques useful for maneuvering. It does so by extending electrically charged appendages, which enable it to electrostatically soar above the surface. By differentially charging its electrodes it can also produce torques to control its attitude. The charges are maintained by continuous active ion or electron emission from the spacecraft, in order to cancel out the neutralizing influx of charges from surrounding plasma. An investigation of the spacecraft-plasma interaction was carried out. This included studying the effect of electrode geometry and calculating the charge-to-mass ratios required to enable several mission scenarios. Long, thin wire electrodes were identified to be the most power-efficient and would allow power-to-weight ratios achievable with current nanosatellite technologies. High electrode potential represents the main limiting factor for the system design. In order to test the feasibility of active control by means of differential charging, a simple 2D model was developed, and a PID controller was tested in a simulation environment. The results confirmed that good performance could be obtained for both position and attitude control. Finally, a dedicated software was developed for future simulation and testing of control strategies for the EGlider. This software allows to study the trajectory and attitude of an arbitrarily configured spacecraft in the proximity of an arbitrarily defined main airless body. The spacecraft can be assembled from basic parts, each with specified electrical, mass and optical properties. Efficient models allow to calculate gravitational and electrical interactions with the rotating main body and the local plasma field, as well as SRP effects. Control models can be implemented as simple plug-in functions and easily tested. The preliminary validation campaign showed good matching with the reference cases that have been analyzed.