DragSail Systems for Satellite Deorbit and Targeted Reentry

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ABSTRACT

The safe disposal of spacecraft upon mission completion is necessary to preserve the utility of high-value orbits. The 2018 Nano/Microsat Market Forecast by SpaceWorks estimates that up to 2,600 nanosatellites and microsatellites will be launched into orbit over the next five years. In addition, plans for large commercial constellations consisting of thousands of small satellites in low Earth orbit are currently in development. These constellations will drive the need for reliable deorbit systems.

A dragsail provides an efficient method for accelerating deorbit following the completion of a satellite's operational mission. Unlike propulsive deorbit approaches that require an active host satellite, the passive deorbit approach offered by dragsails does not require a functional host, and dragsails can offer mass savings for deorbit relative to chemical propulsion.

Previous dragsail systems have employed square sails, which tend to tumble due to atmospheric and solar pressure perturbations. In this paper, a square pyramid geometry for the drag sail is evaluated. The pyramid geometry offers the benefit of passive aerodynamic stability about the maximum drag attitude. Through a six degree-of-freedom simulation, the passive aerodynamic stability provided by the square pyramid geometry is shown, and the optimal apex half-angle for the pyramid is determined. The deorbit performance of the square pyramid geometry is benchmarked against a typical square sail design.

Uncontrolled satellite reentry results in large entry corridor uncertainties, with the range of possible reentry trajectories often extending over multiple orbits, and spanning groundtrack swaths that encompass large portions of the globe. To reduce this uncertainty, dragsails can be applied to achieve targeted reentry capability. The change in ballistic coefficient provided by sail deployment can be used as a control parameter to initiate reentry from a very low orbit, thereby reducing the uncertainty in the reentry corridor and the surface impact footprint. The ability to control the reentry corridor to within a fraction of an orbit reduces the impact of satellite reentry on the air traffic control system, and can be used to constrain the probability of debris impact in populated areas. In this work, parametric studies will show the efficacy of targeted reentry using dragsail deployment as a control parameter. The ballistic coefficient ratio before and after dragsail deployment is varied to determine what ratio is required to induce reentry for a range of orbits. Uncertainties on atmospheric density and spacecraft aerodynamics are incorporated into a Monte Carlo analysis that maps the dispersed entry trajectories to a fixed altitude of 60 km.

Through the parametric studies and Monte Carlo analyses presented in this work, dragsail performance is shown for long-term deorbit and targeted reentry, over a range of host satellite orbit and mass characteristics.