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DRAGSAILS FOR ORBITAL DEBRIS REMOVAL

Abstract

The use of an aluminized mylar solar sail, deployed from a unique CubeSat platform (herein referred to as TipSat), for reducing the orbital altitude of another attached spacecraft is examined. The TipSat houses the spooled sail that is deployed at system end-of-life. The TipSat is equipped with an autonomous attitude control capability that orients the sail to take advantage of the decelerating effects of solar radiation pressure and atmospheric drag. The control scheme favors the maximum decelerating effect of these natural forces based upon the orbital position of the system. For operations in higher LEO orbits (altitudes above 700 km), solar radiation pressure exerted on the sail lowers the spacecraft's altitude until atmospheric drag predominates and removes the spacecraft, sail, and TipSat from orbit. A sail steering algorithm was developed to optimally implement this concept of operations. When the sail velocity vector is parallel to the sail normal, the sail is pointed normal to the sun vector for maximum deceleration. At all other times, the sail is turned edge on to the sun to preclude orbit raising due to solar pressure. Below 700 km, the sail is pointed normal to the velocity vector at all times, as atmospheric drag rapidly increases in magnitude over solar pressure effects. The efficacy of the approach was demonstrated in a simulation incorporating orbital mechanics, solar radiation pressure, and atmospheric drag forces. A range of spacecraft masses (11-150 kg), practical solar sail lengths (50-200m), and initial orbital altitudes (2000-700km) were simulated. The configuration was found to be effective, defined as removing a spacecraft from orbit in less than 12 years, for systems under 25 kg in mass and for initial altitudes under 2000 km. More massive spacecraft operating above 750 km carry too much orbital momentum to deorbit in reasonable time periods by solar pressure alone. Besides putting an upper bound on practical system mass, the simulation provided bounds for practical sail slew times, leading to preliminary sizing of the TipSat attitude control system components.