Paper ID: 41434
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15th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Modelling and Risk Analysis (2)

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DRAG AND SOLAR SAIL DEORBITING: RE-ENTRY TIME VERSUS CUMULATIVE COLLISION PROBABILITY

Abstract

Solar and drag sailing have been proposed as passive end-of-life deorbiting methods, and technological demonstrators are under development. Drag sailing is of benefit for end-of-life disposal of small to medium satellites from orbits of altitude up to 1000 km. Further outside this orbit range, a region extending from high LEO (i.e. 1000 km) up to about 10,000 km, can be identified where solar sailing is of interest. In the drag dominated regime the required area-to-mass-ratio for a sail spacecraft is primarily dependant on the semi-major axis, growing exponentially with increasing altitude. In the solar radiation pressure dominated regime, the required area-to-mass ratio strongly depends on both semi-major axis and inclination of the initial orbit. The deorbiting phase, at least in the first phase, is achieved on an elliptical orbit, not a circular orbit like in the case of drag sail with inward deorbiting. The performance of the sailing strategy is determined by four parameters: the required effective area-to-mass ratio to deorbit the spacecraft, which determine the sail size given the satellite's mass, the time to deorbit and the augmented collision probability caused on and by the sail through its passage in the LEO protected region densely populated by space debris. During deorbiting the satellite passes through the debris environment. The cumulative collision risk can be quantified as a function of the collisional cross-section present in orbit and the time of exposure of this cross-section to the flux of debris present in the environment. While in the drag dominated region is expected that the cumulative collision probability during deorbit does not change if a sail is used, this assumption may not hold if the deorbit exploits the build-up of the eccentricity to reach higher-density regions. This paper will compute the required sail area to deorbit from a wide range of orbital regions, from LEO to MEO and will compute for these solutions the cumulative collision probability with the SDM debris evolution tool. A trade-off between the time to deorbit (which will be considered as a variable of the problem and not set to 25 years) and the cumulative collision risk will be performed to design the sail size so that the deorbiting will have the minimum effect onto the debris population. Based on the launch trends in LEO to MEO for the past 5 years, an assessment of the application of deorbit sailing to future nanosatellites will be made.