SPACE DEBRIS SYMPOSIUM (A6)
Mitigation and Standards (4)

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6 DOF DRAG AUGMENTATION SAILS DYNAMICS MODELLING TO DRIVE SYSTEM AND DISPOSAL OPERATIONS DESIGN

Abstract

The growth of orbital debris demands for mitigation actions to keep safe the Earth orbital environment for the operational satellites. Guidelines to drive both technology and operations design to displace dismissed satellites depend on the vehicle orbit and size; for small LEO satellites, uncontrolled re-entry is so far the preferred strategy. Different technologies are investigated to re-enter vehicles at the fastest, which shall be light and reliable. The paper discusses the drag augmentation sails coupled dynamics, which drives their design to maximize effectiveness for LEO small satellite re-entry. The drag sail is a passive actuator, deployed at the End-Of-Life occurrence, the authority of which affects both the orbital and attitude dynamics by exploiting both the aerodynamic drag and solar pressure forces. Sail area, shape and optical properties are here assumed as its main design parameters; the drag sail structural interface with the spacecraft body is also considered part of the design variables, in terms of material, configuration, structural features. Both the sail and the spacecraft are modeled as 6DOF discrete surface elements to include the self-shielding and interbody-shielding effects. The aerodynamics effects, the gravitational forces, and the solar radiation pressure (SRP) are included in the implemented tool. Sensitivity of the deorbiting performance and the passive attitude stability to the initial orbit, the solar cycle, the spacecraft body and drag sail and their structural interface features has been assessed: results are obtained to drive both the drag-sail design and operations. In particular, being the solar influence on the atmosphere cyclic, deorbit duration depends on disposal operations epoch and it's either counter-phased or phased for LEO or HEO respectively depending on the solar flux variations. A stable oscillatory motion is observed to be around 400-500km for minimal, and 600-700km for maximal solar activity. The squared flat drag sail shape shows the best trade-off between efficiency and robustness. Large sails are preferred to shorten deorbiting duration and to reduce the intershielding between satellite and sail which has relevant effects on the dynamics. Transparent sails are preferential for most cases since they minimize the interaction with SRP, which has a highly destabilizing effect on the system attitude, the on/off switching action of eclipses further magnifying such effect. However, SRP promotes the decay whenever deorbiting from high altitude highly inclined orbits during low solar activity. Main results are discussed together with the implemented tool architecture and realistic test cases sizing budgets