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MULTI-FACETED REFLECTIVE SOLAR SAILS FOR NON-CONTACT DEORBITING OF SPACE DEBRIS

Abstract

This study presents a novel non-contact deorbiting strategy utilizing multi-faceted reflective solar sails for controlled space debris removal. Unlike traditional methods that rely on direct mechanical interaction, pre-installed DeOrbitSail technology for propellant-free deorbiting, or active laser-based deorbiting, this strategy employs a multi-faceted solar sail space system to focus and reflect sunlight, effectively modulating solar radiation pressure (SRP) to gradually induce orbital decay. The proposed system consists of multiple deployable solar sails equipped with Reflectivity Control Devices (RCDs), which dynamically adjust the relative position between the sails and the target debris while controlling solar radiation pressure to influence the debris trajectory.

A comprehensive SRP interaction model is developed to quantify the effect of reflected solar pressure on the target debris. The orbital dynamics equations governing both the solar sail spacecraft and the debris object are formulated in an inertial reference frame, incorporating solar radiation pressure, gravitational perturbations, and attitude-dependent factors. To enhance deorbiting efficiency, a cooperative control strategy is proposed, integrating an optimal hybrid-triggered deorbiting strategy to maximize the application of non-contact forces while minimizing energy consumption.

Numerical simulations validate the feasibility of the proposed approach, demonstrating significant improvements in deorbiting efficiency compared to traditional contact-based debris removal techniques. The results further highlight the effectiveness of event-triggered solar sail control in maintaining system stability while optimizing the deorbiting process. This work lays the foundation for future applications of reflective solar sails in space debris mitigation, offering a fuel-free, reusable, and cost-effective solution to support sustainable space operations.