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POST MISSION DISPOSAL DESIGN IN THE LAPLACE PLANE LEVERAGING ORBITAL PERTURBATIONS

Abstract

Post mission disposal (PMD) has been of interest in last years as it is one of the most effective measures to mitigate space debris. One of the obstacles of PMD design is high computational cost of optimisation process as numerical orbit propagation of decades is involved. Therefore, the motivation of this research is to exploit semi-analytical dynamics models for orbit propagation to decrease the computational resources needed.

This research focuses on the PMD design of spacecraft targeting an Earth re-entry. The idea is to exploit the natural orbital perturbation to save the propellant needed for the PMD process and enhance the natural effects with impulsive manoeuvres. The dynamics of a spacecraft orbit considering the J_2 perturbation and lunisolar attractions is formulated by a semi-analytical model in the Laplace plane, averaging the dynamics over orbital periods of a spacecraft and a perturbing body, and over one revolution of the variation of right ascension of ascending node of a spacecraft. The last averaging step is the so-called elimination of the node. Past research has attempted to carry it out in the Earth's equatorial frame, in pursuit of getting rid of numerical orbit propagation in the manoeuvre optimisation process. However, the triple averaged model referring to equatorial frame experienced large errors due to complexity of the Earth-Sun-Moon system, in particular the non-coplanarity of ecliptic, equator, and Moon's orbit around the Earth. As it will be demonstrated in this work, the Laplace plane, a balanced position of orbital plane precession induced by J_2 and third-body perturbation, could well overcome this shortcoming. After obtaining the averaged model, the averaged orbital elements of a spacecraft can be computed from the Hamiltonian and the Kozai parameter for given initial averaged orbital elements and the maximum eccentricity relating to the re-entry condition can be computed by only analysing the Hamiltonian after the manoeuvre, without orbit propagation. In this fashion, the disposal manoeuvre, minimising terminal errors and propellant consumption, could be optimised with much less computational effort. Thanks to the simplification, the Hamiltonian representation of the orbital dynamics is reduced to a one-degree-of-freedom system. Then the behaviours of the dynamics and the characteristics of optimisation results can be observed and analysed through the phase space maps. The preliminary results obtained with the averaged model will be used as a first guess and then be refined with high-fidelity models.