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EXPLOITATION OF SRP-J2-PHI RESONANCES FOR DE-ORBITATION OF SPACE OBJECTS WITH TIME-VARIANT AREA-TO-MASS RATIO

Abstract

The environmental and operational consequences of the growing spacecraft population in the LEO region are widely acknowledged of serious concern. Resonant orbits have been proposed as a means to speed up the de-orbitation of spacecraft at end-of-life and were investigated for this purpose by the ReDSHIFT team, as part of the Horizon 2020 project. It was shown that the manifest effect of the SRP-J_2 resonance on a spacecraft's orbit eccentricity leads to accelerated re-entry into the Earth's atmosphere, at low energy cost. In our previous work, we expanded the analysis carried out by the ReDSHIFT team on the SRP-J_2 resonance by considering a plate-like, instead of a spherical, spacecraft. We demonstrated that it is possible to generate what we refer to as the ϕ-resonance of considerable strength for a plate spacecraft, in arbitrary orbit, by adopting a specific rotational motion of the spacecraft, i.e., by prescribing a time-variant area-to-mass ratio appropriately through controlled rotational motion.

In this paper, we build on these theoretical results and conduct an extensive numerical investigation of the SRP-J_2-ϕ resonance over the LEO region, covering altitudes from 400 km to 2000 km. The results are obtained by using the state-of-the-art attitude propagator, D-SPOSE, which offers high accuracy modeling of the atmospheric drag effects: these are of paramount importance to establishing a de-orbitation strategy. The results thus obtained are presented in the form of maps illustrating the achievable altitude decrease rate, as a function of the initial orbital parameters, to comprehensively depict the resonance dynamics and to highlight the capabilities and limitations of exploiting such a phenomenon for de-orbitation of spacecraft in LEO. A systematic approach to identify the optimal de-orbitation strategy based on the above-mentioned analysis is presented. We demonstrate the strategy for two distinct scenarios defined by a spacecraft initially on a circular orbit of, respectively, 600 km and 1,100 km altitude, with the associated effective area-to-mass ratios of 0.5 and 1 m^2/kg. The results for these two cases show that the exploitation of the SRP-J_2-ϕ resonance enables the de-orbitation of the spacecraft within the 25-year disposal guidelines.

To evaluate the practicality of the solution, an attitude control law is applied to the spacecraft to enforce the optimal de-orbitation plan. Propagations of the controlled spacecraft subject to SRP, J_2 and atmospheric drag accelerations as well as torques are carried out with D-SPOSE and the energy cost estimates are provided.