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END-OF-LIFE EARTH RE-ENTRY FOR INCLINED GEOSYNCHRONOUS ORBITS

Abstract

The end-of-life disposal for Geosynchronous Earth Orbits (GEO), suggested by the IADC mitigation guidelines, is to move the satellites into graveyard orbits. Nevertheless, the increasing collision probability in GEO due to the instability of graveyard orbits indicate the need to investigate alternative end-of-life disposals for GEO. For high-altitude orbits, a promising strategy is to achieve atmospheric re-entry by exploiting the lunisolar perturbations with suitable maneuvers, such as the INTEGRAL mission. According to some researches, there exist fast re-entry highways for inclined geosynchronous orbits. Furthermore, low-thrust maneuvers are much more cost-efficient than the impulsive maneuvers. In this work, for geosynchronous orbits, we exploit the lunisolar perturbations as well as low-thrust maneuvers to achieve fast re-entry.

We propose a double-averaged dynamical model for long-term orbit propagation. For the force model, the geopotential up to the fourth order, the third-body potential of the Sun and the Moon up to the fourth degree, and solar radiation pressure are considered. Moreover, the different inclinations of the Sun and the Moon with respect to the equator (the fundamental plane) are retained to show the actual lunisolar perturbing effects. Then, different kinds of maps are computed to described the long-term variation of eccentricity and the orbital lifetime (the time of reaching the maximum eccentricity). Accordingly, the feasible set of initial orbital elements is obtained, leading to a required eccentricity growth with an acceptable orbital lifetime to achieve fast re-entry. To make use of the obtained feasible set and shorten the re-entry time, we propose a low-thrust maneuver strategy to adjust the orbital elements. The minimum-fuel model is formulated and the effect of the aforesaid nature perturbations on the terminal conditions is taken into account to achieve satisfactory precision in a low-thrust maneuver. The minimum-fuel problem is solved by the indirect optimization method. We also investigate the characteristics of the e (eccentricity) -ω (argument of perigee) phase space in the presence of low-thrust maneuvers.

The results obtained in this work demonstrate that the inclined geosynchronous orbits with well selected eccentricity, RAAN and argument of perigee, could achieve a fast re-entry. On the other hand, if the initial orbital elements are not suitable, the proposed low-thrust maneuver strategy is applied to jointly work with the effects of nature perturbations, so a fast re-entry is achieved successfully. Our work is of great value for the sustainable development of GEO.