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LONG-TERM EVOLUTION AND LIFETIME ANALYSES OF GEOSTATIONARY TRANSFER ORBITS WITH SOLAR RADIATION PRESSURE

Abstract

Geostationary transfer orbits (GTOs) are highly perturbed by the combined effect of solar radiation pressure (SRP), Earth's oblateness, luni-solar third-body gravity, and atmospheric drag. Consequently, the dynamical evolution of GTOs is quite complicated and hard to predict. Many researchers have studied the dynamical evolution, decay, and lifetime of GTOs. However, most studies considered objects with low area-to-mass ratio (AMR) (<0.02). In our recent research, we have found that there are quite a number of space debris with larger AMR between 0.02 and 1 and the effect of SRP is noteworthy.

In our latest simulations, we found that under the effects of SRP, the GTO shows some different characteristics in the long-term evolution. The SRP will induce an extra periodic oscillation of the eccentricity, the period of which is twice the period of the oscillation induced by the solar third-body gravity. As the AMR increases, the amplitude of the eccentricity oscillation also increases. The enhanced periodic oscillations of the eccentricity and perigee height have a significant impact on the dynamical evolution and lifetime of the GTO. Besides, the prominent effect of SRP will increase the precession rate of the GTO about the pole of the orbital plane of the Sun, and then increase the amplitude of inclination oscillation, which may have important effects on the luni-solar secular resonances, i.e., the inclination-dependent-only resonances, for inclined geostationary transfer orbits (IGTOs).

In this paper, we will adopt a singly averaged, semi-analytical orbital model to study the long-term dynamical evolution of such space debris in GTOs. We will perform a suite of long-term numerical integrations within a realistic dynamical model, aimed primarily at revealing the dynamical lifetime of such orbits and understanding its dependence on initial conditions and other parameters. Comparing the results with the long-term evolution of GTO objects with a low area-to-mass ratio, we will reveal the effects of SRP in details, including its effects on the orbital lifetime, solar apsidal resonances and luni-solar secular resonances. We will also present the orbital lifetime distributions with different AMR and initial conditions to propose suitable mitigation strategies for these GTO objects.