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ANALYSIS OF THE COUPLED ORBIT AND ATTITUDE DYNAMICS OF SPACE DEBRIS IN GEOSTATIONARY EARTH ORBIT

Abstract

Most of the long term orbit propagation techniques consider that the motion of an uncontrolled space object around its gravity center, referred to as the attitude of the object, has no significant impact on the long term trajectory of the spacecraft. Therefore the orbital propagation can be performed using a constant cross-sectional area of the space debris to estimate drag and solar radiation perturbations. Such a method offers efficient time computation and, in many cases, sufficient accuracy to integrate the orbital evolution over long time scale. That is why it is extensively used to check the compliance of disposal orbits with international rules related to space debris mitigation.

To evaluate a constant cross-sectional area of a space debris, the hypothesis of a tumbling attitude is often made, meaning that each attitude has the same probability to occur. Some studies about telecommunication satellites in GEO showed that the area-to-mass ratio after disposal was constant over the long term and worth approximately 60phase. This result was obtained by comparing the results of orbital propagations with the Two-Lines-Elements provided by NORAD, and tends to prove that these satellites are tumbling.

However, under certain circumstances, the orbit and attitude dynamics are much coupled, with a significant impact on the long term orbital evolution. Attitude evolution directly affects the object's position . Conversely, the induced change of orbital position affects the estimation of non-attitude dependent forces and torques, and so the attitude integration. Previous works presented methods to compute such 12-DoF (Degrees of Freedom) motion. They showed that the coupled dynamics is a chaotic phenomenon and that it requires statistical methods such as Monte-Carlo to be properly modeled.

This paper addresses the integration of coupled orbit and attitude dynamics over the long term for GEO space debris. The TELECOM-2 French telecommunications satellites are chosen as an example. First, the solar radiation coefficients are estimated for several orientations of the spacecraft towards the Sun direction. Secondly, numerical propagations of the 12-DoF motion are performed using the Monte-Carlo method. Uncertainties to the initial attitude and angular velocity are taken into account. Then, the probability to reach the different attitude regimes, either tumbling motion or stabilized orientations , is estimated. The sensitivity to the optical properties of the spacecraft's facets is also studied. Finally, the evolution of the eccentricity vector is analyzed and compared with Two-Lines-Elements.