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DENSITY OF HIGH AREA-TO-MASS OBJECTS IN GEOSTATIONARY AND MEDIUM EARTH ORBITS THROUGH SEMI-ANALYTICAL EQUATIONS AND DIFFERENTIAL ALGEBRA

Abstract

The effect of orbit perturbations is fundamental when analyzing the long-term evolution and stability of the motion of natural or artificial satellites in a planet-centered dynamics. Solar radiation pressure and planetary oblateness are essential to predict the motion of impact ejecta from Phobos and Deimos in orbits around Mars or high area-to-mass spacecraft around the Earth. Similarly, the space debris evolution environment models in geostationary orbit implement the effect of solar radiation pressure, third body perturbations of Sun and Moon, and the effect of the Earth triaxiality J_2 and J_{22}.

In this paper the effect of perturbations on high area-to mass objects in Geostationary (GEO) and Medium Earth orbits (MEO) will be described in terms of secular variation of the orbital elements, taking into account all the aforementioned perturbative forces. The effect of orbit perturbations is described through averaged dynamics equations. The advantage of having a semi-analytical approach lies mainly in the reduced computational cost while maintaining an accuracy compatible with problem requirements also for long-term integrations.

The propagation of clouds of initial conditions under these dynamics is performed using a Differential Algebra (DA) propagator with automatic domain splitting. This allows the fast and efficient computation of a high order polynomial expansion of the final state as a function of the initial state. If a single polynomial is not able to describe the dynamics over the entire set of initial conditions, the initial condition domain is automatically split and separate polynomials are propagated instead. This method allows the propagation of complete debris clouds with a single integration. Besides the further reduction in computational cost, a big advantage of DA over conventional pointwise integration is the fact that it yields an analytical expression for the dependence on initial conditions and system parameters.

This directly allows the computation of an analytical expression for the density of particles in the phase space of eccentricity and longitude. Coupling this expression with the density over one single orbit (derived under a two-body approximation), the spatial density of high area-to-mass objects is obtained.

We use this approach to represent the evolution of a cloud of debris fragments in GEO and MEO. The evolution of the spatial density of high area-to-mass objects in GEO is shown for different initial conditions.