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EVOLUTION OF FRAGMENTATION CLOUD IN HIGHLY ECCENTRIC EARTH ORBITS THROUGH CONTINUUM MODELLING

Abstract

A considerable number of fragments orbit around the Earth in highly eccentric orbits, mainly in the geostationary transfer orbits (GTO), believed to have partly originated from the 100 plus fragmentations of parent objects in the same orbit. Many of these objects are characterised by a high area-to-mass ratio (HAMR). HAMR objects in GTO are especially susceptible to forces induced by air drag and solar radiation pressure, and due to resonances possibly also third body perturbations and Earth gravitational perturbances. These complicated dynamics make it difficult to model the evolution of a cloud of such objects, as the spreading depends heavily on their area to mass ratio. Assumptions on the fast distribution of a GTO fragment cloud into forming a band limited by its parent orbit inclination have shown to be inaccurate, and thus oversimplify the problem at hand. Moreover, the time to form a uniformly distributed cloud is higher than the time it takes those particles to re-enter.

This work aims to increase the understanding of this complex dynamics by accurately modelling the evolution of a cloud of fragments in GTO. The fragment cloud is modelled as a continuum, and its spatial density, rather than single objects, are propagated in time using averaged dynamics in Keplerian elements. Such an approach is not only much faster in terms of computational power when compared to the individual propagation of fragments, but it also facilitates impact risk calculations as the chaser spatial density is readily available in a statistical manner. The perturbations considered are atmospheric drag using a model that was specifically developed for highly eccentric orbits, solar radiation pressure, third bodies and a non-spherical central body implemented in the PlanODyn suite.

The model can also be used to robustly find the origin of a fragmentation by propagating a cloud of fragments backward in time. Herein, an example of a break-up in GTO is given, where the cloud, i.e. the initial density for backwards propagation, is contaminated with some fragments from a different break-up.