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OSCULATING TO MEAN ELEMENT TRANSFORMATION FOR ACCURATE RE-ENTRY PREDICTION WITH SEMI-ANALYTICAL METHODS

Abstract

Semi-analytical propagation is known to provide a fast and efficient alternative to numerical integration over long time spans when the concern is the orbit evolution as opposite to accurate ephemeris computation. However, the incorrect transformation from (osculating) initial conditions to the initial mean elements used in semi-analytical propagation may produce a tiny shift in the main frequencies of the motion which, in the long term, will result in non-negligible differences between the predicted and actual orbital elements. These differences may be crucial, for instance, to correctly predict the atmospheric re-entry of a space object or to describe the motion of spacecraft in resonance. A common way of transforming the initial osculating elements into corresponding mean elements is by computing the average values of the numerically integrated osculating elements after one or several orbital periods. However, this procedure is just approximate, and commonly misses second order terms on the semi-major axis which have an observable effect in long term propagation. In this work, we compute analytically the mathematical transformation from osculating to mean elements for the main perturbations action on an Earth's artificial satellite, namely, third body luni-solar perturbation, zonal harmonics and solar radiation pressure, and show how the analytical propagation notably improves orbit prediction. As an example, the re-entry prediction of the INTErnational Gamma-Ray Astrophysics Laboratory mission is performed. Indeed, INTEGRAL performed the last disposal manoeuvre in 2015 and will re-enter into the Earth's atmosphere in 2029. In this case an accurate re-entry prediction is needed to ensure that such a large satellite will not leave the Earth's atmosphere after the last deep passage through it to minimise the ground casualty risk.