Paper ID: 90485
oral
student

22nd IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Orbit Determination and Propagation - SST (9)

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STOCHASTIC INTEGRATION FOR RE-ENTRY ANALYSIS

Abstract

Recent years have seen a large increase in space traffic. This fact has generated the need to produce regulations for the sustainable use of space, as well as provide services to satellite operators and other involved actors. Among these services is re-entry analysis, both to verify that the regulation is complied with and to produce notices to air traffic managers or civil protection services. The key outcome of the re-entry analysis of a spacecraft into the atmosphere is determining the time and location of decay to understand the risk on the ground. It is a complex problem given the stochastic nature of the trajectory evolution in the lower layers of the atmosphere. In addition, small differences in time translate into great differences in the location of the spacecraft touchdown. One of the challenges when analyzing re-entry is the correct management of the uncertainty. Uncertainty can come from non-modelled effects, for example, how uncontrolled attitude dynamics, or insufficient knowledge of the forces involved affect the re-entry evolution. In this study, the exploration of different methods to address the previous challenges in the initial stage of a re-entry is proposed. The goal is to implement a stochastic propagator to adequately quantify the uncertainty in the state propagation of a re-entering spacecraft, and compare it with a higher-fidelity deterministic propagation scheme. Therefore, from a dynamical point of view, two models are to be compared: a simple point mass model with relatively basic representation of the perturbing forces, involving a stochastic propagation scheme, and a full six degrees of freedom (6DOF) model, including attitude dynamics and involving deterministic propagation. The 6DOF simulator could include the possibility of having active control and will be validated against the data obtained during GOCE re-entry. Regarding the integration, two separate schemes are employed: for the deterministic case a Runge-Kutta 4 method is selected, while for the second case a stochastic Runge Kutta is proposed, originally designed to tackle stochastic differential equations. This is possible if we model the spacecraft's dynamics as a stochastic system. The comparison will be made on the performances of the two algorithms, especially on the capability of the stochastic one to have a refined prediction with a less accurate dynamical model. The proposed approach will be tested in representative scenarios to have a clear vision on the reliability of a stochastic propagator. A Monte-Carlo method will be used for statistically obtaining the re-entry window.