Paper ID: 73573
oral

20th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Operations in Space Debris Environment, Situational Awareness - SSA (7)

Author: Dr. Juan Luis Gonzalo
Politecnico di Milano, Italy

Dr. Camilla Colombo
Politecnico di Milano, Italy
Dr. Pierluigi Di Lizia
Politecnico di Milano, Italy

SINGLE-AVERAGED MODELS FOR LOW-THRUST COLLISION AVOIDANCE UNDER UNCERTAINTIES

Abstract

The population of low-thrust-enabled spacecraft in Earth orbit is continuously growing, for a wide spectrum of missions. On the one hand, the replacement of impulsive propulsion with electric one in traditional satellites allows for extended lifetime thanks to increased propellant efficiency. On the other hand, propulsion systems manufacturers are introducing increasingly miniaturised electric thrusters that allow to provide control capabilities to small satellites that previously could not include them, even if with a very limited control authority. Together with the increase in collision avoidance (COLA) activities due to the build-up of space debris and space traffic, operators have a need for efficient models for the initial evaluation, analysis, and design of low-thrust collision avoidance manoeuvres (CAM). These models are a foundation for parametric analyses to inform the CAM decision making process, be it operator-driven or automatised, and as first guess for more accurate numerical simulations.

A key dynamical feature of low-thrust manoeuvres in general, and CAMs in particular, is the development of clearly differentiated time scales, mainly oscillatory short-term behaviours linked to the orbital period, and a long-term evolution with characteristic period linked to thrust acceleration magnitude. This allows for highly efficient analytical and semi-analytical solutions based on perturbation methods separating both scales, for instance through averaging.

This work presents a framework for the study of low-thrust COLA activities and CAM design under the effect of uncertainties, based on single-averaged models over the eccentric anomaly. It builds up on previous results for the tangential thrust case in the MISS (Manoeuvre Intelligence for Space Safety) software developed by Politecnico di Milano. The new models allow for the design of non-tangential manoeuvres through the superposition of analytical solutions for the tangential and normal directions. Furthermore, CAM design for probability of collision minimisation is dealt with, modelling the effect of uncertainties through a Gaussian Mixture Model. The performance of the models is assessed through different test cases, with particular focus in analysing their range of validity depending on CAM time and total displacement.

These low-thrust CAM models have applications for Space Traffic Management systems in increasingly congested scenarios and are currently being applied to a project funded by the European Space Agency for the advancement of tools for low-thrust CAM design.