17th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Modelling and Risk Analysis (2)

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

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

A SEMI-ANALYTICAL APPROACH TO LOW-THRUST COLLISION AVOIDANCE MANOEUVRE DESIGN

Abstract

Current and future trends for the scientific and commercial utilisation of near-Earth space depict an increasingly congested and complex scenario. The steady reductions in the cost of access to space brought upon by new launch technologies and the introduction of smaller, more cost-effective platforms have spurred novel mission concepts ranging from small CubeSat-based experiments to large mega-constellations. Inevitably, this will come with a notable increase in collision avoidance activities. Furthermore, a sustainable development model will also require the adherence to end-of-life disposal policies, like the Inter-Agency Space Debris Coordination Committee guideline of 25 years maximum deorbit time for objects in low Earth orbit. This objective can be achieved in an efficient manner using passive deorbiting devices such as sails of tethers, but their large area further increases collision probability with nearby objects. Fortunately, effective collision avoidance manoeuvres (CAMs) by sails can be implemented with sufficient warning time, as recently shown by the outcomes of the ESA-funded project "Environmental aspects of passive de-orbiting devices".

Moving forward, there is a clear need for the development of models and tools for the analysis and design of CAMs in the low-thrust context. Furthermore, the large (and increasing) amount of close approaches to be analysed per day stresses the importance for these tools not only to be accurate but fast. Aiming to address these needs, this work presents a semi-analytical solution for the analysis and design of CAMs using low-thrust. It has been developed under the European Research Council-funded COMPASS project, which aims to exploit dynamical perturbations to tackle key problems in orbital mechanics. The model is based on proximal motion equations and includes the effects of drag and solar radiation pressure and the low-thrust control acceleration. Averaged dynamics are used to obtain compact and efficient expressions, suitable for large simulation campaigns or on-board applications. Different collision avoidance criteria are considered, mainly maximising miss distance or minimizing collision probability. Another key aspect is the utilisation of the b-plane of the nominal encounter to analyse the dynamics of the deflected trajectory, exploiting its separation of phasing and geometry-change effects. Several test cases are presented, including optimal orientation laws for CAMs by deorbiting sails. The numerical results highlight the accuracy and computational efficiency of our approach and support the operational interest of this type of CAMs.