21st IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Operations in Space Debris Environment, Situational Awareness - SSA (7)

Author: Mr. Jack McHugh
GMV Aerospace & Defence SAU, United Kingdom, jmchugh@gmvnsl.com

Mr. Pau Gago
GMV Aerospace & Defence SAU, Spain, ppgp@gmv.com
Mr. Eduardo Arias
GMV Aerospace & Defence SAU, Spain, earias@gmv.com
Mr. Albert Barasch
GMV-INNOVATING SOLUTIONS SRL, Romania, albert.barasch@gmv.com
Mr. George Muntean
GMV Aerospace & Defence SAU, Romania, gmuntean@gmv.com
Dr. Diego Escobar Antón
GMV Aerospace & Defence SAU, Spain, descobar@gmv.com
Mr. Andrea De Vittori
Politecnico di Milano, Italy, andrea.devittori@polimi.it
Dr. Juan Luis Gonzalo
Politecnico di Milano, Italy, juanluis.gonzalo@polimi.it
Dr. Michele Maestrini
Politecnico di Milano, Italy, michele.maestrini@polimi.it
Dr. Camilla Colombo
Politecnico di Milano, Italy, camilla.colombo@polimi.it
Dr. Pierluigi Di Lizia
Politecnico di Milano, Italy, pierluigi.dilizia@polimi.it

ADVANCED NUMERICAL OPTIMISATION ENVIRONMENT FOR OPERATIONAL COLLISION AVOIDANCE

Abstract

The maturity of electric propulsion has welcomed new parties to populate space at significantly cheaper costs. This is responsible for an increasingly congested space traffic but also for the possibility of mitigating the more frequent close encounters by resorting to collision avoidance manoeuvres with little impact on the mission lifetime. Traditionally, collision avoidance manoeuvre design and optimisation has raised significant research effort, often adopting an analytical approach to solve the problem. Alternatively, this paper puts the focus on a numerical environment for CAM design and optimisation, developed as part of the Collision Risk Estimation and Automated Mitigation (CREAM) initiatives within ESA's Space Safety Programme and with its performance tested against the analytical and semi-analytical methods for CAM design developed in ESA's ELECTROCAM project. Numerical methods are seen to offer a much more flexible approach to optimisation, allowing to develop a single framework which is able to accommodate: CAM design for both impulsive and low-thrust engines, i.e. a single impulse or a continuous manoeuvre profile; a configurable degree of complexity for the system dynamics; a variable definition of the performance metric or cost function and the consideration of constraints tailored to the needs of each specific mission. These constraints bring the developed numerical methods closer to an operational

implementation in the following ways: defining an allowable region of firing which follows required attitude constraints (e.g. a 1D, 2D or 3D region of firing in a local frame); defining time intervals in which to perform the manoeuvre (avoiding eclipses, ensuring satellite visibility from ground stations...); mitigating the deviation with respect to its operational orbit as a consequence of the CAM or alternatively including the design of a sequence of return manoeuvres to recover its original position; limiting fuel expenditure; or evidently, including the consideration of conjunction related thresholds such as probability of collision, miss and radial distances or depth of intrusion criteria. Usually, numerical methods are normally avoided due to its heavy computational usage. To mitigate this issue, the dynamical model implemented to compute the effect of the manoeuvre on the orbit of the satellite is based on a state-transition matrix formulation including non-linear elements from the two-body problem formulation.

This paper illustrates the capabilities of the developed numerical optimisation environment in a variety of collision events and under different orbital regimes, propulsion subsystems, configurations, etc.