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

COMPUTATIONALLY EFFICIENT APPROACHES FOR LOW-THRUST COLLISION AVOIDANCE ACTIVITIES

Abstract

Low-thrust propulsion technologies are experiencing a continuous increase both in their performance and the range of platforms that can equip them. Particularly interesting are novel propulsion solutions for small satellites in Low Earth orbit, enlarging the envelope of missions they can perform. However, although low-thrust propulsion provides significant advantages in propellant efficiency, it also suffers from a smaller control authority compared to impulsive thrusters. This aspect must be considered during mission design, allocating longer times for phases such as achieving the initial operational orbit or post-mission disposal (when implement). But one of the main challenges is to react to unforeseen situations, including collision avoidance activities. While impulsive propulsion allows for efficient Collision Avoidance Manoeuvres (CAMs) performed just a few orbits before the predicted close approach, low thrust CAMs can require a longer acting time. Moreover, the higher complexity of low thrust CAM models makes it more computationally costly to perform parametrical analyses and optimisations to inform the decision-making process.

This work proposes advanced models for low thrust CAMs, based on semi-analytical techniques such as averaging or multiple scales. They expand previous results from the Manoeuvre Intelligence for Space Safety (MISS) software tool. The focus is placed on developing and validating refined models for the characterisation of the phasing change at the predicted close approach induced by the low-thrust action, as this constitutes the leading contribution to collision probability reduction. The results allow to characterise the required manoeuvre lead time as a function of the control authority, which provides a decision deadline for satellite operators faced with a potential conjunction. The increase in accuracy and performance provided by the improved model for phase change is quantified by comparing with previous equations in MISS and high-precision numerical reference solutions. Its computational efficiency is then leveraged to perform detailed sensitivity analyses for representative test cases, highlight their qualitative characteristics. Finally, a roadmap for possible improvements and synergies with other techniques (like artificial intelligence) are briefly discussed.