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ANALYSIS OF REQUIRED THRUST LEVEL AND WARNING TIME TO PERFORM COLLISION AVOIDANCE MANOEUVRES FOR LOW-THRUST SATELLITES

Abstract

The presence of space debris in Earth orbits has become an important factor to consider for day-to-day spacecraft operations. Future trends regarding the number of satellites, number of space debris objects and tracking capabilities of these objects suggest that satellites in low-Earth orbits will continue to require collision avoidance manoeuvres (CAM's) on a regular basis within their lifetime to resume operational activities safely. At the same time, low thrust satellites are becoming the more popular in space flight, especially for (mega)-constellations, replacing conventional chemical propulsion systems with more efficient electrical ones. While propellant consumption is reduced using low-thrust propulsion systems, CAM design becomes more challenging. Smaller thrust levels go hand in hand with less manoeuvrability and a longer time required to perform a certain manoeuvre, such as a collision avoidance manoeuvre. This constraint is more evident for satellites which do not possess an on-board engine, since these satellites rely on attitude control systems and external environmental accelerations to perform collision avoidance manoeuvres.

This study will explore the relationship between the thrust arc duration, time of initiating thrust and thrust magnitude, when performing a collision avoidance manoeuvre. The relationship between the time instant of initiating a CAM compared to the time of closest approach (TCA) and the separation distance at the time of closest approach is investigated. This is done both for constant thrust, as well as for short-duration thrust arcs. This analysis is performed for a variety of common CAM design techniques and in different test cases to understand the constraint that a small thrust magnitude brings regarding timing and the time instant of performing a CAM decision. These CAM techniques are summarised in a literature overview, both regarding techniques operationally in use as well as optimised techniques mostly discussed in literature.

The resulting outcome of this study has consequences for CAM design for low-thrust satellites, which often differs significantly from high-thrust CAM design, as well as space traffic management in general. Many satellites without an active propulsion system do not perform any collision avoidance manoeuvres, while they are still involved in potentially dangerous conjunctions. The results of this study can help bridge this gap and allow a wider variety of satellites to perform CAM's.