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IMPROVING SATELLITE COLLISION PREDICTION ACCURACY THROUGH AUTONOMOUS SENSOR OBSERVATIONS

Abstract

This research investigates the potential improvements in satellite collision prediction accuracy through the implementation of autonomous observation and processing capabilities on at-risk platforms prior to potential collisions. In Low Earth Orbit (LEO), potentially colliding objects generally pass close together multiple times during the orbits before the Time of the Closest Approach (TCA). These encounters, currently unexploited, present valuable opportunities for satellites equipped with optical sensors – including star trackers – to collect data on secondary objects. By processing this data onboard and utilizing the most recent orbital estimates uplinked from the ground before TCA, significant refinement in positional knowledge of secondary objects can be achieved, enabling more informed manoeuvre decisions and reduced false alarm rates. Previous studies have established the feasibility of this approach from both orbital dynamics and sensor detection performance perspectives. In this work, we evaluate the potential improvements in orbit determination resulting from onboard processing of the space-based observations for different kinds of possible sensors, including star trackers of varying quality. To this end, a simulation environment is established to emulate the full operational concept in realistic conjunction scenarios derived from real-world Conjunction Data Messages (CDMs). Simulations are performed using Ansys' System Tool Kit (STK), which includes the capability of generating synthetic imagery for the space-based observations. Parameters critical to the onboard sensor's resolution, such as focal length and pixel pitch, are parametrically varied across the simulations. Generated images are post-processed to extract orbital information on the detected targets, and then sequential filters are applied to emulate the onboard refinement of positional estimates. For each conjunction scenario, the outcomes of this process are benchmarked against the accuracy of the orbital information that was available from ground at the time of the actual maneuver decision. The objective is to determine under which conditions the proposed approach can bring meaningful improvements in space traffic management and safety.