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Author: Mr. Aleksander Lidtke
University of Southampton, United Kingdom, al11g09@soton.ac.uk

Dr. Hugh G. Lewis
University of Southampton, United Kingdom, H.G.Lewis@soton.ac.uk

COLLISION PROBABILITY ASSESSMENT FOR ACTIVE DEBRIS REMOVAL MISSIONS

Abstract

Increasingly larger investments are being made world-wide in technologies necessary to perform Active Debris Removal (ADR) due to a growing concern about the sustainability of spaceflight. In-orbit validation of certain concepts appears likely in the near future with potential implementations to follow shortly afterwards. Little to no attention appears to be given to the risks associated with such missions, however, which raises concerns about the impact of ADR missions themselves.

Active Debris Removal is, undoubtedly, going to target the most densely populated orbital regimes in order to remove objects that have the highest chance of causing in-orbit collisions. An ADR mission failure is, therefore, highly undesirable as it would only increase the number of uncontrolled objects in the given regime. Furthermore, the severity of such an event would be tremendous as any collisions or breakups in the densely populated regions would have the potential to cause a series of further collisions given the high spatial density of objects in such regimes.

This study conducts an assessment of the likelihood of an in-orbit collision occurring between an ADR mission's space segment and all uncontrolled objects in the public catalogue published by USSTRATCOM. In order to perform this task a conjunction detection algorithm has been developed, which uses interpolation of the trajectories of the objects to formulate an analytical expression for their relative motion and to find the time of closest approach and the corresponding relative position. Another algorithm is applied to the conjunctions to compute the maximum probability of a collision taking place. The entire framework has been verified against the Conjunction Analysis Tools in AGI's Systems Toolkit on a set of 20 exemplar conjunctions and relative error smaller than 1.5% has been achieved.

An example ADR mission scenario is analysed – the total number of conjunctions together with the resulting accumulated collision probability are computed. The results are discussed in the context of mission architecture selection. This investigation is of importance mainly for the trajectory that the ADR vehicle will follow to rendezvous with its target(s) as well as during the deorbiting phase. In some cases this also relates to the selection of the deorbiting technology (e.g. the "ion beam shepherd") and the propulsion subsystem concept (e.g. low-thrust propulsion).

Overall conclusions as to the active debris removal architecture selection are drawn and the importance of assessing the associated collision risk is highlighted. Recommendations regarding the mission concept are also made.