Assessing Collision Algorithms for the NewSpace Era

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ABSTRACT

The space industry has been subject to increasing levels of disruption and innovation over the last two decades driven by a growing commercial element. Fueled by the resulting competition, this era of ‘NewSpace’ deviates from the traditional use of the space environment. A range of novel mission concepts are emerging, such as on-orbit servicing, active debris removal, and new larger constellations, as well as ongoing changes in the physical and orbital characteristics of the spacecraft population. An earlier investigation by the authors into these developments indicated that they have significant implications for modelling the space debris environment, both in terms of the validity of the assumptions made and the results generated.

A new investigation of the spacecraft population launched between 1980 and 2017 (source: ESA’s DISCOS database) identified an increase in the number of spacecraft being deployed into similar target orbits. This has resulted in a shift from a more random spatial distribution of objects to a situation with greater spatial structure. We believe that this has the potential to introduce errors in the estimation of collision probabilities by different collision algorithms used in evolutionary models of the space debris environment. With collisions expected to be an increasing and leading source of space debris it is important that we understand the performance of collision models and their sensitivity to different factors. Errors introduced in these models have potential implications for the definition of standards and guidelines across the space industry.

To investigate this hypothesis two probabilistic algorithms were identified as being used in current evolutionary debris models: The Cube approach (Liou et al., 2003); and the Orbit-Trace method (based on Öpik 1951). In addition, an analytical approach using pre-filters (Hoots et al., 1984) was considered for comparison.

We implemented and tested the Cube approach against the Jovian moons case used in the original validation of the algorithm. This testing highlighted several elements of the model that require careful consideration. First of these is the number of iterations of the algorithm required. When investigating individual collisions, the average collision rate estimate for a single pair of objects fails to converge after more than 7 billion steps. This represents an error in the collision probability for object pairs, but averaging across the whole debris population would result in a regression to the mean collision rate. Consequently, these results indicate that the Cube approach is less suitable for estimating the collision risk of individual objects, for example when identifying the potential debris targets for active debris removal or for assessments of subsets of the population, such as satellite constellations.

The second identified element for consideration was the typical size of the cube used. We evaluated the average collision rate for the Jovian moon scenario using a range of cubes with side lengths ranging from 0.1% to 20% of the average semi-major axis of the objects. Results showed an increase in the estimated collision rates for increasing cube size. This also represents a source of error unless an appropriate cube size can be defined in advance. Further, this cube size has to address the spatial structure of satellite systems, such as constellations, appropriately. Work is ongoing to meet these challenges related to the cube size.

Taking these considerations into account the Cube approach will now be assessed against scenarios representing the NewSpace era and using alternative models for comparison.