SPACE DEBRIS SYMPOSIUM (A6)
Modeling and Risk Analysis (2)

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RELATIVE VELOCITY AS A METRIC FOR PROBABILITY OF COLLISION CALCULATIONS

Abstract

As part of the NASA initiative for space asset protection against space debris, the Goddard Space Flight Center Conjunction Assessment (CA) team routinely performs conjunction risk assessment for 19 of its high-value assets. Probabilistic risk assessment is conducted based on the Probability of Collision (Pc), which is routinely calculated using three methods: a two-dimensional integral approach (2-D), a three-dimensional integral approach (3-D), and a Monte Carlo numerical method. The 2-D method assumes the trajectory of the secondary object is linear relative to that of the primary object during the entire encounter; the 3-D method does not. One advantage of this assumption is that it is much less computationally intensive than the other methods and, thus, requires shorter compute times. For the high relative velocities typically observed in conjunctions, both methods for calculating Pc should yield similar results. However, a break down of the linearity assumption occurs at low relative velocities between the conjuncting bodies.

The first part of this paper discusses determination of the operational relative velocity threshold at which this linear assumption becomes invalid. This analysis requires investigating well-defined encounter geometries for use in a parametric trade space study, by varying close approach miss distance, relative velocity, and object covariances, then evaluating them using the two different Pc calculation methods. The threshold is then determined as the relative velocity at which the two solutions diverge.

The second part of this paper is a statistical study of conjunctions between representative asset orbits and the debris environment to determine the likelihood of encountering a low relative velocity close approach that violates the previously determined threshold. This is accomplished by developing a statistical model of the debris environment and predicting close approaches between a randomly-generated secondary object and the representative asset. This simulation process is repeated iteratively so that relative velocity statistics can be generated and the relative velocity distribution can be inferred.

The statistical analysis produces a cumulative probability distribution function that gives the probability of occurrence at or below a specific relative velocity. From these distributions, the probability of encountering a low relative velocity event, as the threshold is defined in the first part of this analysis, is very unlikely. Therefore the assumption of linearity for calculating the Pc is sufficient for the vast majority of conjunctions encountered in routine operational risk assessment. This result represents a significant conclusion for conjunction assessment in satellite operations.