Paper ID: 28109
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SPACE DEBRIS SYMPOSIUM (A6)
Modelling and Risk Analysis (2)

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IMPACT FRAGMENTATION MODEL DEVELOPMENTS

Abstract

The IMPACT fragmentation model has been used by The Aerospace Corporation for more than 25 years to model orbital altitude explosions and hypervelocity collisions. The model is semi-empirical, combining mass, energy and momentum conservation laws with empirically derived relationships for fragment characteristics such as number, mass, area-to-mass ratio, and spreading velocity as well as event energy distribution. Model results are used for a number of analysis types including assessment of short-term risks to satellites from orbital altitude fragmentations, modeling the long-term evolution of the orbital debris environment and forensic assessments of breakup events.

A new version of IMPACT, version 6, has been completed and incorporates a number of advancements enabled by a multi-year long effort to characterize more than 7000 debris fragments from over three dozen historical on-orbit breakup events. These events involve a wide range of causes, energies, and fragmenting objects. Special focus was placed on the explosion model, as the majority of events examined were explosions. Revisions were made to the mass distribution used for explosion events, increasing the number of smaller fragments generated. The algorithm for modeling upper stage large fragment generation was updated. A momentum conserving asymmetric spreading velocity distribution algorithm was implemented to better represent sub-catastrophic events. An approach was developed for modeling sub-catastrophic explosions, those where the majority of the parent object remains intact, based on estimated event energy. Finally, significant modifications were made to the area-to-mass ratio model to incorporate the tendencies of different materials to fragment into different shapes. This ability enabled better matches between the observed area-to-mass ratios and those generated by the model. It also opened up additional possibilities for post-event analysis of breakups.

The paper will discuss a number of the modifications that have been made to improve the IMPACT model and why these modifications were made. Comparisons between observational data and the model predictions will be discussed in the context of these model revisions and the overall behavior of model results. A number of future areas of investigation that were uncovered in the process of the analysis efforts will also be reviewed.