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THE IMPACT SATELLITE FRAGMENTATION MODEL

Abstract

IMPACT is a hypervelocity collision and explosion model developed by The Aerospace Corporation to predict the characteristics of debris generated by fragmentation events. Used for over 30 years, it is a semi-empirical model that has supported a wide range of orbital debris analyses including satellite risk assessment, on-orbit event analyses, flight test and mission planning, debris mitigation and spacecraft design studies, and long-term debris environment evolution and space safety analyses. The model interconnects empirical expressions with conservation laws and boundary conditions to model debris generation from individual fragmentation events.

A series of efforts to study available on-orbit data and newly-generated ground-test data during the past decade have added to the understanding of on-orbit fragmentation events, particularly with regard to explosion events, sub-catastrophic breakups, smaller fragment characteristics, and more diverse modern satellite construction materials. These insights have led to a number of upgrades of the IMPACT collision and explosion model. The model's capabilities have been expanded to represent sub-catastrophic and asymmetric fragmentation events, more accurately model fragment material differences and their relationships to area-to-mass ratios, model smaller fragments, and relate ground-based and on-orbit data. Additional insights have been gained through the integration of individual model improvements in the context of maintaining overall model consistency.

This paper provides an overview of the current IMPACT model, discussing the design and expressions used in the current collision and explosion algorithms, changes over the past decade, and implications of insights from both on-orbit and ground test data. Modeling techniques discussed include representation of fragmentating object material differences, sub-catastrophic fragmentations, and small fragment modeling. Interactions between different model improvements will be discussed, including small versus large fragment characteristics and sub-catastrophic versus catastrophic fragmentation events. Model updates will be considered in the context of fragmentation event data. Future directions for development will also be considered based on the insights from the aggregated data and model updates.