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SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
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A FRACTAL FRAGMENTATION MODEL FOR BREAKUP OF AEROSPACE VEHICLES

Abstract

Where flight vehicles such as aircraft, cruise missiles, UAVs, sounding rockets, launch vehicle or re-entry system are operated or tested, a safety analysis is required in order to estimate and limit the risk to all parties.

All possible failure modes need to be considered. When a vehicle breaks up due to extreme stresses, the characteristics of the resulting fragments need to be estimated, in order to track their paths to the ground, and to estimate their hazard to other craft, assets, personnel, and the public. Previously, such data was only available from recovered fragments, and thus as snapshots of particular vehicles at specific conditions.

This paper describes the development and verification of a new statistical model for the fragmentation of such flight vehicles. The model is based on a theory of 'fractal fragmentation' whereby the vehicle first breaks into, say, six fragments with a certain distribution; then if sufficient energy remains, each fragment breaks into six more fragments in similar proportions – and so on, to any 'degree' (even fractional). The output is in terms of populations of mass classes, each split into two ballistic coefficients.

This model is one element of a debris catalog generation methodology (described in a companion paper) which is one tool in the Range Safety Template Toolkit (RSTT) being developed for the Australian Department of Defence in support of weapon trials and research aerospace vehicle operations.

The model has been tuned and tested against known cases of explosion and breakup, mainly for aluminium-skinned sounding rockets, launch vehicles, payload experiments, and satellites. It was found that with minimal tuning, the one model would match known data ranging in severity from a few fragments (degree 1) to thousands of fragments (degree 4).