17th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Modelling and Risk Analysis (2)

Author: Dr. Martin Schimmerohn
Fraunhofer EMI, Germany

Dr. Pascal Matura
Fraunhofer EMI, Germany
Mr. Erkai Watson
Fraunhofer - Institut für Kurzzeitdynamik, Ernst-Mach-Institut (EMI), Germany
Dr. Nathanaël Durr
Fraunhofer EMI, Germany
Mrs. Tiziana Cardone
ESA - European Space Agency, The Netherlands
Mr. Don de Wilde
ESA - European Space Agency, The Netherlands
Dr. Holger Krag
European Space Agency (ESA), Germany
Dr. Frank Schäfer
Fraunhofer EMI, Germany

NUMERICAL INVESTIGATION ON THE STANDARD CATASTROPHIC BREAK-UP CRITERIA

Abstract

While the major contribution of space debris today stems from explosion events, forecasts predict that collisions will be the dominant space debris source in the mid-term future, when a critical spatial density of satellites is reached. It is essential for environmental modeling and risk analysis to describe collisional breakup events in terms of resulting fragment characteristics and to understand their dependence on the collision scenario. The NASA Standard Satellite Breakup Model (SSBM) has been adopted by major space agencies for characterizing hypervelocity spacecraft breakups for debris environment modeling. The SSBM is an empirical model based on data from ground tests and observations of on-orbit events. It is a simple model that only uses the mass of the colliding objects and their collision velocity as input parameters. The distinction between catastrophic and non-catastrophic collisions is based on an energy-to-mass ratio (EMR) criterion, which defines catastrophic breakups to occur for an EMR >40 Joule/gram. The simplicity and the empirical nature of the SSBM provide flexibility and fast analyses but also limit the ability to model complex scenarios and depends on the available data.

Besides complex ground experiments like the DebriSat project, we propose to use numerical simulations in order to enhance the data base in a practical and effective way. We established the software tool PHILOS-SOPHIA for systematically studying the effects of on-orbit hypervelocity collisions for a wide range of collision conditions and for complex spacecraft models. PHILOS-SOPHIA is based on a specialized hydrocode solver, which was extensively validated in the context of missile defence studies. We show the tool's ability to simulate directionality and shape effects by directly comparing with hypervelocity impact experiments. The analysis' needs dictate the complexity of the modeling and the required computational effort.

For analyzing the standard EMR breakup criterion, we simulated six different scenarios using ESA's LOFT spacecraft and CubeSat impactors in different collision conditions. In the detailed fragmentation analysis, we find both good agreements and clear deviations between the hydrocode results and the SSBM predictions. Particularly, the collision geometry strongly influences the fragmentation damage and the area-to-mass distributions. Depending on the collision vector, grazing impacts may result in higher or lower fragmentation in comparison with impacts on the center of mass. The EMR criterion does not reflect this complexity and we recommend performing more research on this topic. PHILOS-SOPHIA, thoroughly backed by advanced experiments, can be the tool for this purpose.