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Impact-Induced Mission Effects and Risk Assessments (3)

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CST: A NEW SEMI-EMPIRICAL TOOL FOR SIMULATING SPACECRAFT COLLISIONS IN ORBIT

Abstract

At present, the largest part of the catalogued space debris population consists of fragments originated by accidental explosions of spacecraft and upper stages, but it is expected that hypervelocity collisions could become the primary source of new debris in the mid-term future. For this reason, understanding the physical processes involved in such collisions is essential, because space debris evolution models are significantly sensitive to the number, size, velocity and area-to-mass distributions of fragments originated by such large impact events. In this context, this paper provides a general description of a new Collision

Simulation Tool (CST) developed in the framework of the ESA contract “Numerical simulations for spacecraft catastrophic disruption analysis”, carried out by the Center of Studies and Activities for Space CISAS “G. Colombo” of the University of Padova (prime contractor) and etamax space GmbH. The CST makes possible to model a large variety of collision scenarios involving complex systems such as entire satellites with many design details included, and provides statistically accurate results with a computational effort orders of magnitude lower than hydrocodes. To this end, the simulation approach implemented in the new tool is based on a hybrid modelling strategy, in which every colliding object is described as a gross net of Macroscopic Elements representing spacecraft elementary building blocks. On one hand, individual fragmentation of Macroscopic Elements is addressed through the use of semi-empirical breakup models applied, at element level, only to those spacecraft parts which are involved in the collision. On the other hand, structural distortion, fracture and separation of satellite broken parts are considered with a discrete-element approach through the simulation of momentum transfer to Macroscopic Elements through the net, taking into account energy dissipation inside elements and across links. In the last part of this paper, preliminary results are shown with respect to the CST validation process. Validation is done by comparing the tool predictions with empirical data from ground-based impact tests on simple targets (single plates and multi-wall structures) as well as spacecraft models. In the first case, the tool capability of predicting ballistic limit equations of well-known structures and shields is verified. In the second case, fragments distributions calculated by the software are compared with those derived from published experiments on micro-satellites.