SPACE DEBRIS SYMPOSIUM (A6)
Hypervelocity Impacts and Protection (3)

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INFLUENCE OF MULTI-DEBRIS AERODYNAMIC INTERACTIONS DURING UNCONTROLLED ATMOSPHERIC REENTRY ON THE ON-GROUND IMPACT ASSESSMENT

Abstract

During the last forty years, around 16,000 tons of space debris ranging from ten microns to several meters have re-entered into the Earth atmosphere. Ten to forty percents of this mass is estimated to have impacted land. Due to the critical aerothermodynamics environment encountered during atmospheric entry, the debris ablate and even break up. The great number of produced fragments can evolve independently or interact together for a while. Protected from the upstream flow by the main object, one or more secondary fragments could reach the ground whereas they would be totally destroyed otherwise. In addition, compared to the case of independently evolving objects, the aerothermodynamics conditions temporary encountered in the wake of the main object might significantly modify trajectories of the secondary fragments. However, this complex situation has not been currently considered by existing atmospheric debris codes for the on-ground impact assessment.

Several authors have considered and proposed to treat the aerodynamic interactions between several objects, either via numerical simulations but not coupled with the whole trajectory or by developing analytical methods but far to be representative with this issue. As a matter of fact, CPU cost of usual CFD tools is too high for trajectory coupling process and the space debris problem requires the use of codes having short response time, that numerical simulations do not allow.

Therefore, a new analytical methodology valid for the smaller debris located in the whole front fragment shock region, and having a short response time to quickly calculate debris trajectories has been developed. This so-called semi-analytical method allows to obtain each flight point conditions until impact at ground by extrapolating the aerothermodynamics data, extracted from numerical reference fields computed using an axisymmetric finite volume method. Considering a whole debris trajectory descent, one or several numerical reference fields can be involved accordingly to the different flow regimes encountered (hypersonic and supersonic flows, rarefied and continuous regimes…). So that, we can estimate aerodynamical coefficients as well as the heat flux applied to secondary objects located anywhere in the wake. The survival or the destruction of secondary fragments is then addressed with our approach, particularly efficient in terms of CPU effort while being reasonably accurate.

The present investigations will propose scenarios of orbital fragment impacts scattering on Earth surface according to conditions of hypersonic formation flying during atmospheric reentry.