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AEROTHERMODYNAMICS MODELLING OF COMPLEX SHAPES IN THE DEBRISK ATMOSPHERIC REENTRY TOOL: METHODOLOGY AND VALIDATION

Abstract

In the frame of the French Space Operation Act (LOS) signed in 2008, CNES is in charge of ensuring the right application of the law, for every mission launched or operated from the French territory. To predict the debris survivability during an atmospheric re-entry and assess the prospective risk on ground, CNES develops its own certification tool named DEBRISK, based on an object-oriented approach

The main idea of the object-oriented approach is to simplify the vehicle geometry from the break-up altitude into individual simple shapes, defined by the user. The trajectory, the thermal heat load and the possible ablation processes are computed for each fragment. Finally, the demise altitude or the casualty area (in case of survivability) is provided. Most methods implemented within DEBRISK to compute drag forces and thermal heat fluxes are based on engineering methods developed in the 60's and used as well in similar tools (e.g. ORSAT, ORSAT-J, DRAMA).

Unfortunately, this approach is limited to primitive shapes: usually spheres, cylinders, boxes/flat plates. Whenever more complex shapes need to be modeled, an analogy is usually made with one of the primitives available. This approach suffers from simplifying assumptions and results in large uncertainties on the survivability calculations. The objective of this work is to present a new methodology to introduce more complex shapes within DEBRISK with the goal to deal accurately with the atmospheric reentry of more realistic objects.

The methodology consists in setting up a CFD numerical database from which aerodynamics and aerothermodynamics models are derived using interpolation schemes. More than 2000 CFD computations were performed using the MISTRAL code. Thereby, an optimization method, based on the principle of a

rotating mesh, has been developed and allows to build a unique mesh of the computation domain for any attitude of the object considered. Consequently, the time of CFD calculations is drastically reduced while keeping a reasonable precision. Special attention has been given to the normalization of the variables in order to limit eventual interpolation errors to a minimum.

In order to validate this methodology, experiments are carried out in the VKI Longshot hypersonic tunnel using hollow cylinders and hemispherical shells. Aerodynamic coefficients are determined for a wide range of attitudes using a non-intrusive free-flight technique. Local pressure coefficients and heat fluxes are also measured, from which the total power received by the objects is estimated.

A good agreement has been observed between experiments and numerical predictions.