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DEVELOPMENT OF NEW ANALYTICAL MODELS FOR PRESSURE AND HEAT FLUX DISTRIBUTION ON SPACE DEBRIS AFTERBODIES

Abstract

Since 1957 and the orbital performance of the satellite Spoutnik-1, the human activity in space has generated a growing number of space debris. During the last forty years, 16,000 tons of space debris ranging from ten microns to several meters long have performed a terrestrial atmospheric reentry. Between 10 and 40% of the reentering mass is estimated to have reached the Earth, representing a potential threat to ground safety. The total casualty area forecast becomes a major issue for all space actors and especially for CNES, which is in charge of ensuring the strict application of the French Space Operation Law (LOS) by 2021, for French satellite- and launcher-operators and for launch operations from French Guyana spaceport.

In order to better predict the risk posed by orbital debris during their atmospheric reentry, phenomena in the "shadow area" of the debris, i.e. the regions that are not directly impinged upon by the incoming hypersonic flow, have been investigated. It was shown that for some simple geometries representative of space debris, the heat flux in the "shadow area" can be of the same order of magnitude as the heat flux at the stagnation point. Moreover, the comparisons between Navier-Stokes simulations, experimental data from open literature and formulations proposed in the Spacecraft-Oriented Codes such as PAMPERO (CNES) and FAST/MUSIC (ONERA) have highlighted the poor performance of Newtonian-like pressure and heat flux distributions in the "shadow area".

That is why new analytical models for wall pressure and heat flux distributions on afterbody of generic space debris have been developed and successfully compared to CFD simulations. These new models are based on a large in-house CFD database developed with the ONERA CEDRE Navier-Stokes Multi-physics Platform for various flow conditions according to a generic debris flight trajectory. The database includes different thermo-chemical flow assumptions in the shock layer (perfect gas, thermochemical equilibrium and nonequilibrium real gas), as well as different debris geometries and attitudes. The paper will present the analytical models and discuss the influence of the new models on the estimation of space debris survivability.