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NEW AEROTHERMODYNAMIC MODELS AND ATMOSPHERIC RE-ENTRY ANALYSIS FOR CONCAVE GEOMETRY ELEMENTS OF SPACE DEBRIS

Abstract

Since 1957 and the orbital performance of the satellite Spoutnik-1, the human activity in space has generated a great number of space debris. During the last forty years, 16,000 tons of space debris ranging from ten microns to several meters performed a terrestrial atmospheric reentry. Between 10 to 40% of that mass are 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 both French satellites-and-launchers operators and launch operations from French Guyana spaceport.

A Mutual Interest Project (PIC) between ONERA and CNES has been entered into action for one year to provide representative analytical models of the aerothermodynamic phenomena occurring during atmospheric reentry of geometries representatives of generic space debris. In particular, the project focuses on the analytical modeling of the wall pressure and heat flux distribution on concave shape objects, such as the nose fairing, parts of the VEB structure or tank after breaking or burnthrough.

Even though several numerical and experimental studies have considered the pressure and heat flux over frontal facing cavities, upstream conditions considered in open literature do not really cover the widespread conditions encountered during the atmospheric entry of space debris. Moreover, the concave shapes considered might be not limited to frontal facing cavities. Therefore, a large in-house CFD database has been developed with the ONERA CEDRE Navier-Stokes Multi-physics Platform for various flow conditions according to a generic debris flight trajectory including different thermo-chemical flow assumptions in the shock layer (perfect gas, thermochemical equilibrium and nonequilibrium real gas), effect of the attitude and the concave geometry shape. The comparisons between CFD database and the formulations proposed in the Spacecraft-Oriented Codes such as PAMPERO (CNES) and FAST/MUSIC (ONERA) have highlighted the weak performance of Newtonian-like pressure and heat flux distributions computed so far. That is why new analytical models for wall pressure and heat flux distributions for concave-shaped objects have been developed and successfully compared to CFD simulations. The paper will propose an overview of the present research conducted and will focus on the aerothermodynamic study of the atmospheric entry of concave debris as a TA6V tank after break-up. A specific attention will be given to the trajectory and the thermal degradation of such objects.