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A PRE-DESIGN ANALYSIS TOOL FOR THE ATMOSPHERIC RE-ENTRY OF SPACECRAFT

Abstract

Access to space is a major goal for nations and designing transport to achieve it is a major discipline in aerospace activities. Defining the right trajectory of a re-entry vehicle is crucial for the mission success. However, during the atmospheric re-entry, a strong interaction exists between aerothermodynamics mechanisms, flight dynamics and vehicle shape. A predominant factor in designing a hypersonic re-entry vehicle is aeroshape control: ranging from a ballistic flight design (e.g. Stardust, Mirka) providing intrinsic aerodynamic stability, to semi-ballistic (Apollo, ARD, AFE) including guidance and control, and finally spacecraft configurations (Space Shuttle, PRE-X, IXV, HYPMOCES) involving active trajectory and attitude control. Therefore, during pre-design phase of atmospheric re-entry vehicles, several flight points, vehicle geometries and many configurations (rudders, wings positions and size, inflatable systems, flaps size. . .) have to be explored before achieving the optimum. CFD (Computational Fluid Dynamics) performances being (still) cost-consuming in terms of CPU time and man labour, their number is limited in many projects whenever computations matrix would be demanded in extenso for building both accurate aerodynamic and aerothermodynamics databases. In addition, their use during the pre-design phase can turn out inappropriate especially when the aeroshape is not yet fixed. Therefore, engineering methods that are able to quickly and accurately compute aerodynamic forces and moments coefficients and heat loads distribution remain attractive tools as long as confidence is put on simplified methods (Reduced Models). Since 2006, ONERA has been developing a platform so-called FAST/MUSIC, which is the assembling of a multi-objects trajectory computational tool including GNC (MUSIC) and a geometric treatment and aerothermodynamic modelling tool (FAST). FAST/MUSIC demonstrates an alternative but effective approach to CFD and GNC to prepare the pre-design phase of atmospheric re-entry vehicles within reliable estimates of aerodynamic forces and moments coefficients and wall heat flux distribution during 3DDL or 6DDL pre-flights within an attractive response time. A permanent update of solutions is then realized. Usually, engineering codes exhibit results with rather good agreement obtained in regions such as nose, wing leading edge and windward side, but some discrepancies can be observed for regions influenced by a more complex flow such as shock-boundary layer interaction or elliptic flow regions (blunted object like capsules for instance). For those cases, new advanced modelling based on a non-local method is presented and successfully compared to experimental and CFD data regarding aerothermodynamics for several application cases, past and present: ARD and AOTV capsules, Pre-X, IXV, HYPMOCES.