COMPUTATIONAL ANALYSIS OF THE FLOWFIELD PAST A CAPSULE RETURNING AT SUPER-ORBITAL SPEED

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In this paper we report and discuss the results of design analyses of a capsule entering the Earth atmosphere at super-orbital speed, in the framework of a sample return mission from Mars.
The design utilizes a spherically blunted 45-degree half-angle cone forebody (see Fig.1), with an ablative heat shield.

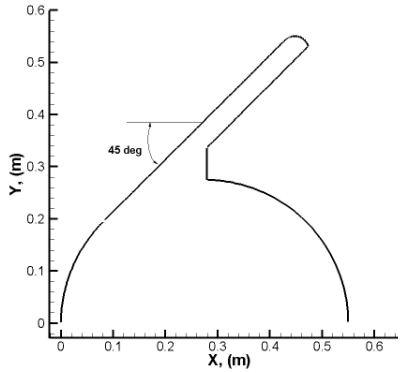

Figure 1. Vehicle configurations with quotes.

Aerodynamic and aerothermodynamic design analyses refer to the loading condition of the flight scenario foreseen for the capsule and are used to address vehicle aerodynamic and aerothermodynamic databases.
All the design analyses have been performed at several levels. For instance, vehicle aerodynamic assessment has been extensively addressed through engineering-based design approach as, e.g., hypersonic panel methods (HPM); then, a number of fully three-dimensional non-equilibrium Computational Fluid Dynamics (CFD) simulations of the hypersonic flowfield past the entry vehicle have been performed.
In particular, CFD simulations are performed at several discrete points of a reference re-entry trajectory according to the *trajectory-based design approach*.
The range between Mach 3 and 42 was analyzed, considering only continuum regime (supersonic and hypersonic speed ranges) with the air modeled as a mixture of several gas species.
In particular, twenty six trajectory points have been considered for a total number of 30 CFD simulations to address the impact on capsule aerothermal performances of the flowfield contamination by the chemical species coming from heat shield ablation. The chemical model proposed considers the air and the blowing species coming from heat shield ablation as a mixture of 32 species in thermo-chemical non-equilibrium conditions.
As an example of preliminary CFD results, Fig. 2 shows the Mach number contours field that takes place past the capsule when it is flying at M_∞=33.07, α=0 deg, and H=57.07 km.

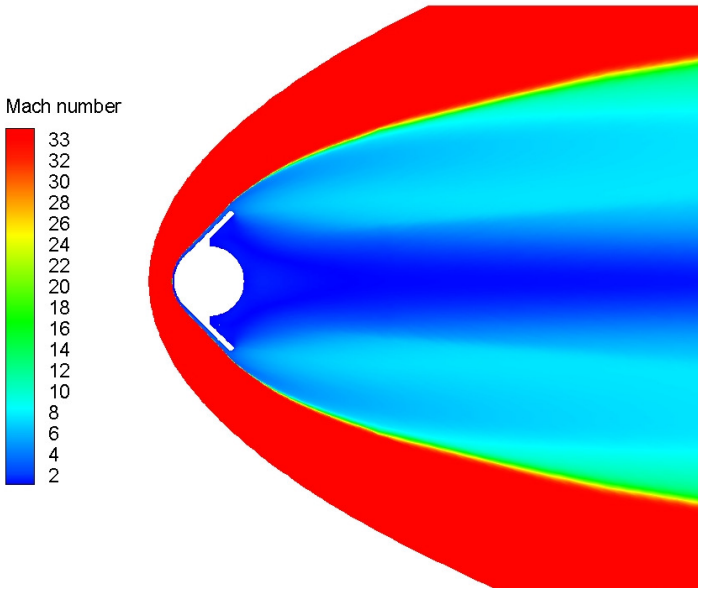

Figure 2. Mach number contours field on capsule pitch plane at 57.07 km altitude and M=33.07.

The ablation products in the boundary layer mainly consist of H_2, C_2H, C_2H_2, CO, C, and H. For example, Figure 3 highlights C, CO mass fractions field past the re-entering capsule at 57.07 km altitude and M=33.07.

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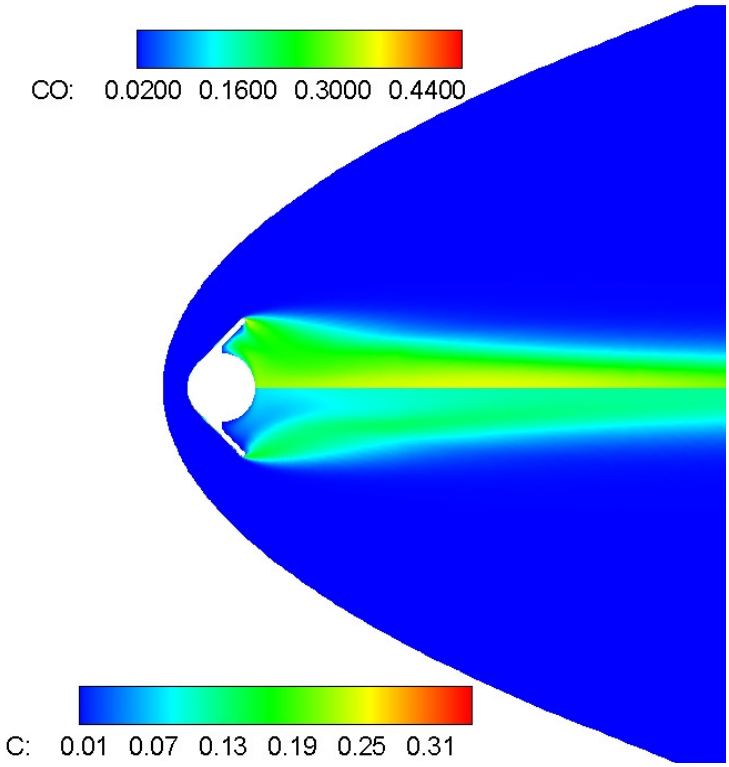

Figure 3. C and CO mass fractions at M_∞=33.07, α=0 deg, and H=57.07 km.