NUMERICAL SIMULATION OF THREE-DIMENSIONAL HYPERSONIC VISCOUS REACTING FLOWS

Miguel Hermanns, Germany & Spain
Supervisors: H. Deconinck & G. Degrez

When a space ship enters in a planetary atmosphere, or when an airplane flies at very high speeds, the large kinetic energy of the motion leads to very high temperatures downstream of the bow shock. This increase in temperature induces the air not to behave like a perfect gas, since dissociation and ionization of Oxygen and Nitrogen takes place, leading to a so called calorically imperfect gas. This deviation from the perfect gas behavior has an important impact on the temperature and pressure distributions over the space ship surface, leading to significantly different thermal loads and flight control settings.

In the present project an existing three dimensional Navier-Stokes solver called *Euphoria* is extended to handle hypersonic flow problems with equilibrium chemical reactions and vibrational excitation. For this purpose, the library *Pegase*, which computes gas properties taking into account chemical and vibrational excitation effects, is coupled to *Euphoria* to substitute the existing perfect gas relationships.

To simplify the handling of *Pegase*, a new interface, called *EASYPegase*, is developed. This interface not only simplifies the use of the complex library *Pegase*, but also allows to switch back to the perfect gas relationships in a transparent manner for *Euphoria*. This is a desirable feature if subsonic and supersonic flows should also be computed in an efficient manner using the same Navier-Stokes solver.

The resulting three dimensional hypersonic viscous reacting flow solver is validated not only with two dimensional computations performed in the past at the Von Karman Institute, but also with a three dimensional test case proposed in the former *Hermes* R \& D program of the European Space Agency.

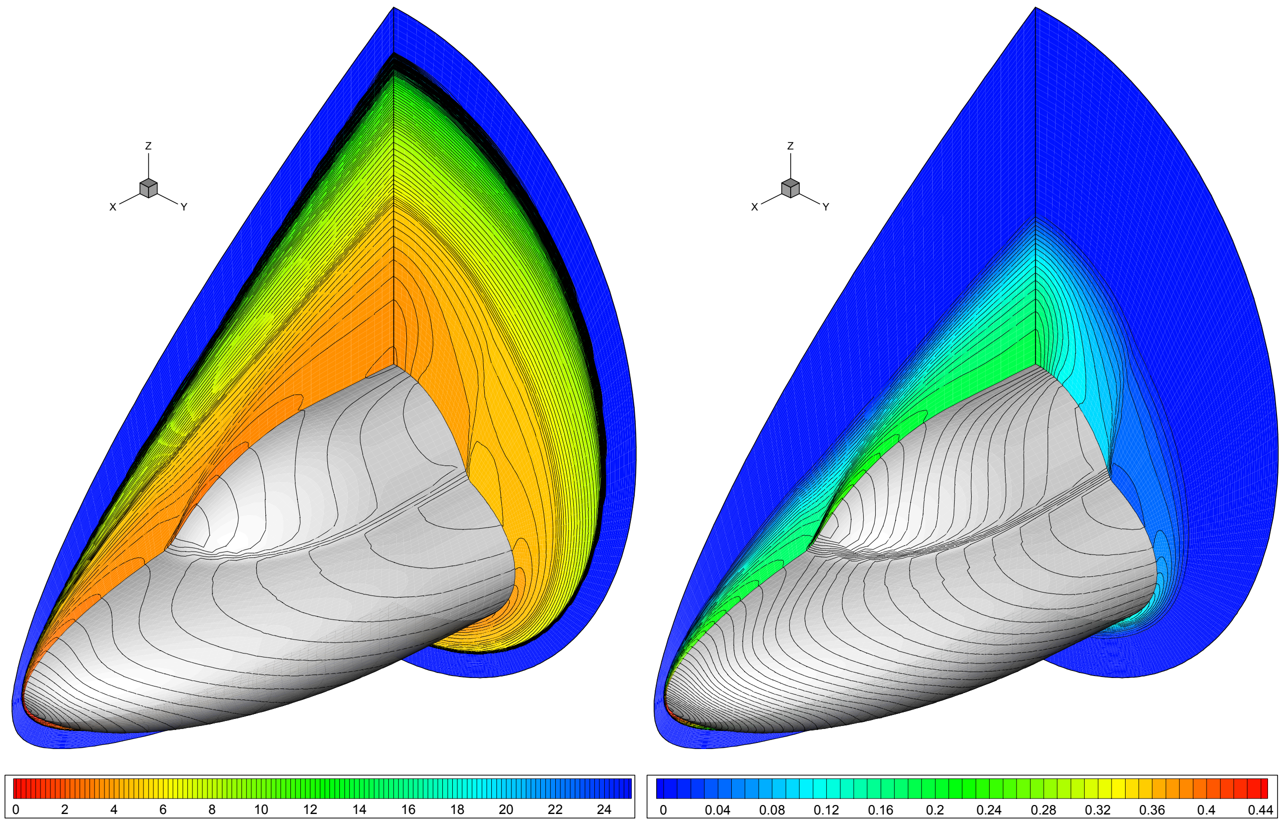

Figure 1: Hypersonic inviscid reacting flow past a double ellipsoidal shaped atmospheric reentry vehicle at $M_\infty = 25$, $\alpha = 30°$ and 75 km altitude: Mach number (left image) and Atomic Nitrogen mass fraction (right image) contour maps on the symmetry and outlet planes