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# A LOOSELY-COUPLED MULTI-PHYSICS FEM SOLVER FOR HYPERSONIC FLOWS

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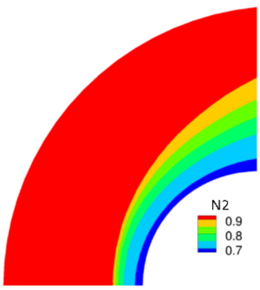
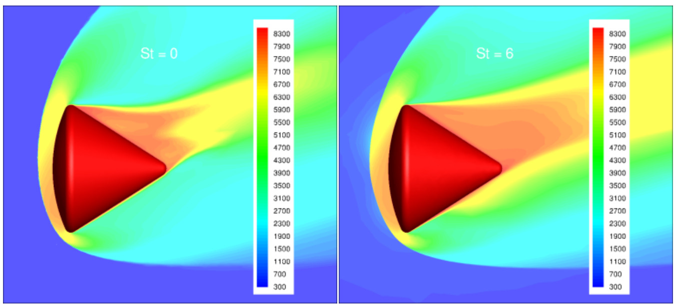
The aerospace industry is showing renewed interest in hypersonic transport vehicles. Hypersonic flight regimes involve phenomena that pose considerable thermal non-equilibrium problems, as the high temperatures in the shock layer cause changes in chemical composition that populate vibrational and electronic energy levels. On the positive side, at these high temperatures, chemical species undergo ionization leading the way to electromagnetic technologies that can boost aerodynamic performance.

To numerically address the difficulties of these complex flow physics, the HALO3D solver described in this paper solves the RANS, species transport and vibrational-electronic energy equations outlined in [1], as well as the magneto-hydrodynamics equations described in [2], in a loosely-coupled manner. The discretization uses an edge-based FEM, combining the accuracy and robustness of FEM with the large selection of FVM flux schemes specifically developed for compressible flows.




Numerical results from two test cases are illustrated here. The left figure plots the nitrogen mass fraction contour of a Mach 6.13 chemical and thermal non-equilibrium flow past a cylinder. The rightmost two figures compare the temperature contours of an Apollo-like re-entry capsule, without (middle) and with (right) an imposed magnetic field at Mach 13.26. The HALO3D multi-physics solver is efficient and robust for high-Mach non-equilibrium flows.

## REFERENCES

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