AE 298
Study of non-equilibrium phenomena in chemically reacting hypersonic flows

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December 11, 2017

One of the greatest challenges in aerospace engineering is the development of vehicles able to flight at hypersonic speeds ($M \gg 5$). In this flight regime, aircraft travel at speeds significantly larger than the average speed of the molecules in the gas. As a result, the molecules begin to pile up into a compressed layer in front of the nose vehicle, forming a region of high temperature, referred to as the shock layer. The shock layer is bound by a strong bow shock on one hand and by the vehicle surface on the other hand. The temperatures within the shock layer, in the tens of thousands of degrees Kelvin, bring about chemical reactions, thermal radiation and ablation of the surface of the vehicle.

The accurate description of the physics occurring in the shock layer is crucial to the design of the next generation hypersonic aircraft. To this aim, computational fluid dynamics (CFD) and computational chemistry are used to construct physically accurate mathematical models able to describe these harsh environments. This project is divided in two parts: i) use of reaction dynamics solver to determine rate parameters for the characterization of the chemical processes occurring in the gas; ii) application of the model to the solution of the flow field around a hypersonic vehicle. The project is supported by the US Air Force.