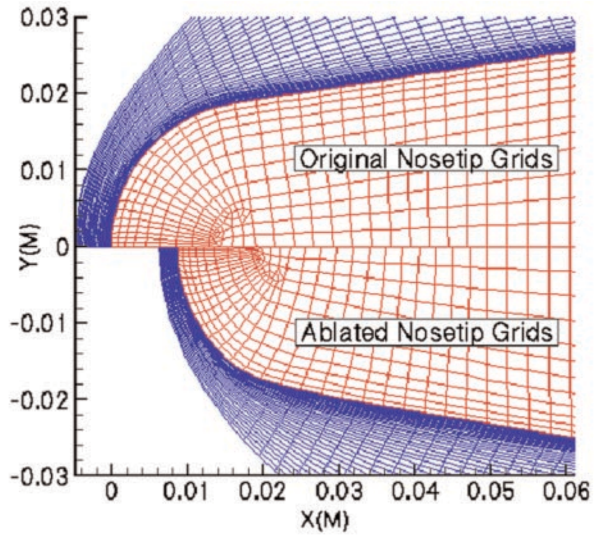
Computational Aerothermodynamics

Sandia National Laboratories is a leader in the modeling of material thermal response of hypersonic flight vehicles that encounter severe aerothermodynamic environments. These vehicles include stockpile reentry systems and advanced and exploratory precision flight systems. A wide variety of computational technology has been developed at Sandia to perform both the thermal analysis and the design of high-temperature sensors and instrumentation for hypersonic systems. Over the years, Sandia has amassed a wealth of experience in the design and application of ablative thermal protection systems for reentry vehicles and launch systems.

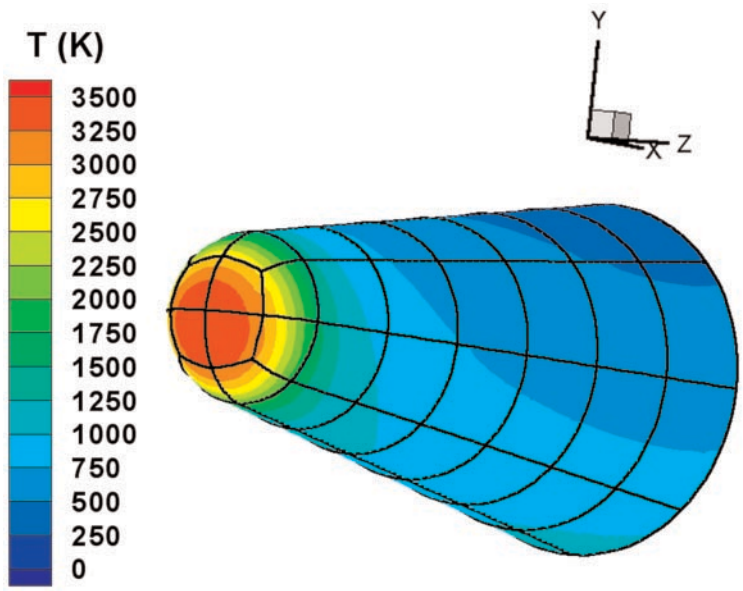
The computational codes for aerothermal analysis and material thermal response are applied over a wide range of velocity and density ranges. Historically, one-dimensional and two-dimensional thermal response codes that account for material pyrolysis and charring effects have been used in the determination of ablation and shape change on a hypersonic vehicle. More recently, a higher fidelity, unstructured, finite-element thermal response code (COYOTE) has been developed for three-dimensional applications. Capability within COYOTE exists for a simple heat-of-ablation or Q* model and an equilibrium surface chemistry model for non-decomposing materials. COYOTE's surface energy balance accounts for the recession of the ablating surface and the resultant movement of the finite element mesh.

CALORE, a finite element general heat transfer code, is currently under development within Sandia's SIERRA framework to take advantage of the latest in numerical algorithms in an object-oriented code design. CALORE's unstructured grid design will lead to improvements in overall analysis turnaround time and allow for efficient coupling with other mechanics (e.g., fluids, structural, trajectory) in a massively parallel computing environment.



The IRV-2 vehicle (left) was a U.S. Air Force-sponsored reentry vehicle flown in support of the Maneuvering Systems Technology (MaST) Program. Recently, coupled fluid/thermal ablations calculations have been performed on geometries similar to the IRV-2 vehicle to simulate the ablation characteristics of thermal protection systems. Simulations of the carbon-carbon nosetip show the amount of surface recession and mesh deformation of both the fluid (blue) and thermal (red) meshes on representative trajectories.

Sandia's aerothermodynamics research has largely focused on coupled ablation simulations. Work is being conducted to combine high-temperature fluid mechanics (SACCARA), material thermal response (COYOTE), and flight dynamics (TAOS) in a fully coupled aerothermodynamics analysis capability. As the surface material ablates, the trajectory of the vehicle is altered as a function of the changing forces and moments resulting from the shape change. In addition, work has been initiated to model the effects of the decomposing heat shield materials.



Surface temperatures on carbon-carbon nosetip flying in excess of Mach 20 at angle of attack demonstrate the large variations in the thermal environment to which that material is exposed.

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