Development of accurate tools to predict aerothermal environments and their effects on space vehicles is critically important to achieving the goals of current NASA missions, and to enable the development of advanced spacecraft for future missions by reducing uncertainties during design and development.

Radiative heating was not critical for the Space Shuttle Orbiter, due to its relatively low re-entry velocity, or for entry probes such as Genesis and Stardust, due to their small size. However, the large size and high reentry velocity of the Crew Exploration Vehicle make it imperative to study shock layer radiation phenomena. The conditions encountered in proposed aerocapture missions to Titan, Neptune, and Venus also require study of radiative heat transfer and non-equilibrium thermodynamic and transport properties; these in turn require understanding of the internal structure and dynamics of the constituent gases.

Transition and turbulence effects are particularly complex in hypersonic flows, where special problems are posed by shocks, real gas effects, non-smooth body surfaces with complex and possibly time-dependent roughness distribution, nose bluntness, ablation, surface catalyticity, separation, and the unknown free-stream disturbance environment.

In particular, at the heating rates encountered during hypersonic re-entry, surface ablation products blowing into the boundary layer introduce new interactions, for example chemical reactions and radiation absorption, that strongly affect surface heating rates and integrated heat loads.
Aerothermal analyses and management are also relevant to the design of advanced propulsion systems. A better fundamental understanding coupled with the ability to accurately simulate the aerothermodynamics of highly loaded turbomachinery is needed, along with innovative ideas such as flow control for increasing fan and compressor work factors without sacrificing efficiency and operability. Improvements in turbine cooling effectiveness, secondary flow management, and component matching are also important for high-pressure ratio engines.

Proposals suggesting innovative approaches to any of these issues are of interest. Specific research areas of interest include:

- Computational analysis methods for radiation and radiation transport in the shock layer surrounding planetary entry vehicles;
- Advanced physics based thermal and chemical non-equilibrium models for thermodynamics, transport, and radiation;
- Studies of the interactions of gases in the shock layer with ablating materials from the vehicle thermal protection system;
- Experimental methods and diagnostics to measure the characteristics of hypersonic flow fields, either in flight or in ground-based facilities;
- Software tools coupling radiation, non-equilibrium chemistry, Reynolds-averaged Navier-Stokes, and large eddy simulation codes to enable the design, development, and validation of mission configurations for entry into planetary atmospheres;
- Computational modeling to improve the accuracy of flow simulations for highly loaded turbomachinery; 
- Innovative flow control methods, such as aspiration and bleed, to reduce the losses associated with highly loaded turbomachinery;
- Development of active flow control devices such as Dielectric Barrier Discharge plasma actuators for application to turbomachinery flow control.