Ablation of carbon-phenolic materials in hypersonic flows

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Ablation is a critical element in hypersonic systems being developed by NASA for space exploration and by the US Air Force for national defense. To be safe and effective throughout the extreme conditions of reentry, designs must anticipate and be robust to changes in the aerodynamic shape and surface roughness due to ablation. Hand-in-hand with the development of computational capabilities has been a need for data to both validate models and identify key physical mechanisms.

This talk will focus on lightweight carbon-phenolic composites, a successful material technology developed at NASA for planetary entry systems. In order to study ablation of carbon-phenolic materials, laboratory experiments are implemented with the goal of simulating aerothermal loads encountered in real flight conditions. Based on fundamental experiments, high-fidelity models are developed for the different physical phenomena encountered at high temperatures, including porous media flow transport, heat transfer, polymeric decomposition via pyrolysis, and carbon oxidation.

We will discuss how X-ray micro-tomography has become an invaluable tool to understand the micro-structure and behavior of porous architectures used in carbon-phenolic heatshields. Micro-CT data, together with supercomputing capabilities, constitute the foundation of modern computational tools that allow physics-based predictive simulations of material response at extreme temperatures.