New Technologies Advancing Thermophysics by Aaron Brandis, Jonathan Burt, Brenton Taft

Researchers at NASA Ames in California have built a new facility that uses multiple 50-kW continuous wave lasers to add the capability for simulating radiative heating on thermal protection materials. The new facility, the Laser Enhanced Arc-jet Facility (LEAF-Lite), was added to NASA Ames's Interaction Heating Facility arc-jet and now allows for test articles to be heated by both convective and radiative heat flux, making the facility more like flight. Using this new system, researchers can now simulate radiant heating with the laser and convective heating with the arc-jet simultaneously on a single test article. During its initial test in October 2017, the lasers radiatively heated a 6" x 6" Avcoat wedge sample to 405 W/cm^2 while the arc-jet simultaneously provided 160 W/cm^2 of convective heat, resulting in a total heat flux of 565 W/cm^2. Radiative heating is more prevalent in missions with higher atmospheric entry speeds like the Orion space capsule or interplanetary scientific probes. Later this year, scientists will expand the spot size to cover 17" x 17" to test an Orion TPS panel.

For the first time, micro-tomography has recently been used to resolve micro-structures of heatshield materials used by NASA spacecraft during atmospheric entry. These experiments, performed at the Advanced Light Source at Lawrence Berkeley National Laboratory, California, throughout this year provide a tool to non-destructively image 3D structures at scales from hundreds of nanometers to centimeters. An example of such an image providing the rendering of FiberForm microstructure, the carbon preform of NASA's Phenolic Impregnated Carbon Ablator, PICA is shown in Figure 1. The fibrous architecture is resolved in 3D with an unprecedented level of detail, enabling interactive inspection of the material at high resolution and statistical characterization of its structure's variability. This allows for material properties to be calculated and to simulate material response at the micron scale. This opportunity has led to active research efforts, both at NASA and academia, aimed at developing large-scale computational methods based on digital microstructures.

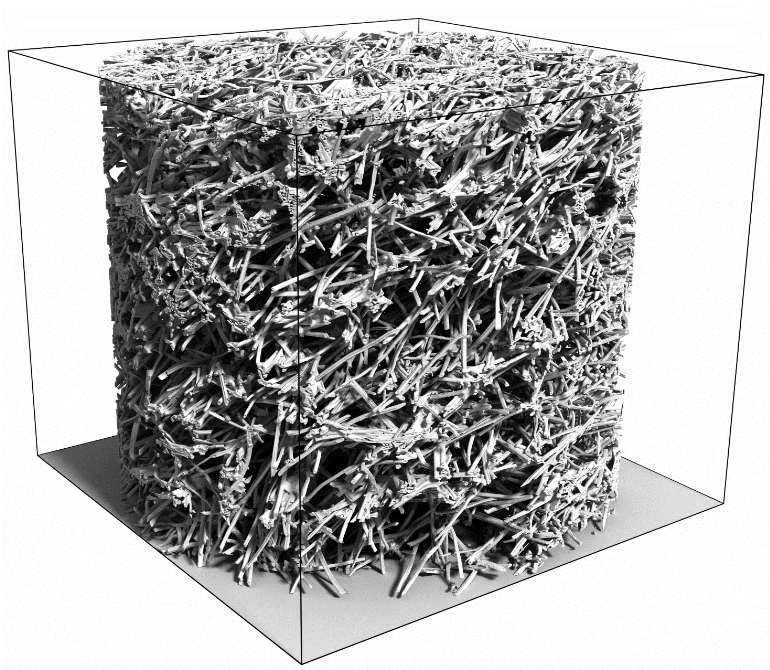

Figure 1. Micro-tomography of FiberForm, the substrate of NASA's Phenolic Impregnated Carbon Ablator. The displayed volume is a ray tracing rendering of a 1.66 mm edge cube.

In March, a preliminary design review was conducted for the high lift motor systems on NASA's X-57 Maxwell electric demonstrator aircraft. The X-57 is intended as a testbed for distributed electric propulsion technologies, and the thrust from two wingtip-mounted propellers is augmented during takeoff and landing by 12 high lift electric motors and propellers that are distributed across the wings. These technologies provide beneficial propulsion-airframe interaction, with substantially increased cruise efficiency through characteristics including a reduction in wing planform area. In a novel thermal management approach for the high lift motors and associated motor controllers, heat pipes are included as part of a passive cooling system that allows convective removal of electrically generated heat through the skin of wing-mounted nacelles. Flight tests are scheduled to begin in 2019, and will utilize a new mission planning tool that incorporates electrical component thermal loads in trajectory optimization calculations, with the goal of maximizing range while meeting the unique thermal management requirements of an all-electric propulsion system.

In September, the U.S. Air Force Research Laboratory's second Advanced Structurally Embedded Thermal Spreader (ASETS-II) flight experiment passed one year of on-orbit operations aboard Orbital Test Vehicle 5. The ASETS-II experiment, as shown in Figure 2, is made of three low-mass, low-cost oscillating heat pipes (OHPs) and an electronics/experiment control box. The three OHPs are of varying configuration (center heating with single- and double-sided cooling) and working fluids in order to isolate specific performance parameters of interest. The ASETS-II flight experiment has exhibited no degradation and has achieved two primary science objectives by measuring the initial on-orbit thermal performance and long duration thermal performance. Having conducted multiple six-week tests, ASETS-II has set a new record for the longest continuous on-orbit operation. Returned flight experiment hardware will be subjected to post-flight testing to assess the presence of any non-condensable gas that may have formed on orbit.

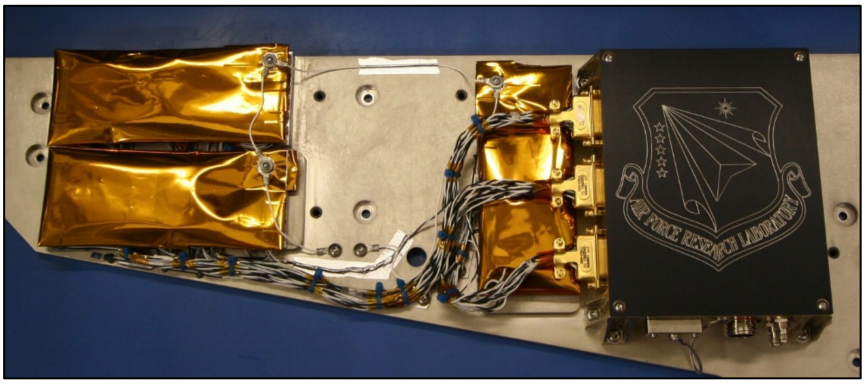

Figure 2. The Advanced Structurally Embedded Thermal Spreader (ASETS-II) flight experiment