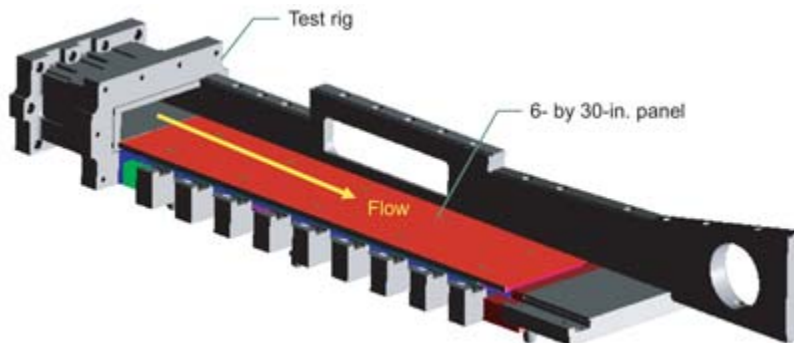


# Cooled Ceramic Matrix Composite Propulsion Structures Demonstrated

NASA's Next Generation Launch Technology (NGLT) Program has successfully demonstrated cooled ceramic matrix composite (CMC) technology in a scramjet engine test. This demonstration represented the world's largest cooled nonmetallic matrix composite panel fabricated for a scramjet engine and the first cooled nonmetallic composite to be tested in a scramjet facility.

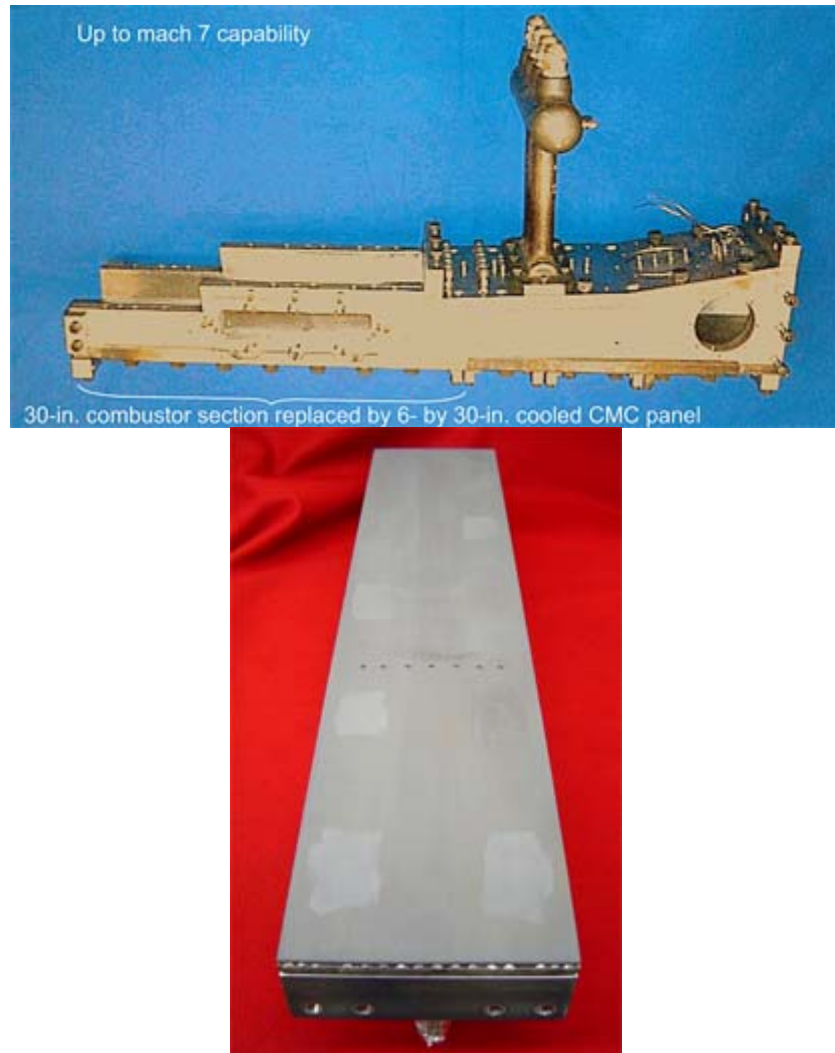


*United Technologies scramjet facility with near sidewall and top panel omitted.*

Lightweight, high-temperature, actively cooled structures have been identified as a key technology for enabling reliable and low-cost space access. Tradeoff studies have shown this to be the case for a variety of launch platforms, including rockets and hypersonic cruise vehicles. Actively cooled carbon and CMC structures may meet high-performance goals at significantly lower weight, while improving safety by operating with a higher margin between the design temperature and material upper-use temperature. Studies have shown that using actively cooled CMCs can reduce the weight of the cooled flow-path component from 4.5 to 1.6 lb/ft<sup>2</sup> and the weight of the propulsion system's cooled surface area by more than 50 percent. This weight savings enables advanced concepts, increased payload, and increased range. The ability of the cooled CMC flow-path components to operate over 1000 °F hotter than the state-of-the-art metallic concept adds system design flexibility to space-access vehicle concepts. Other potential system-level benefits include smaller fuel pumps, lower part count, lower cost, and increased operating margin.

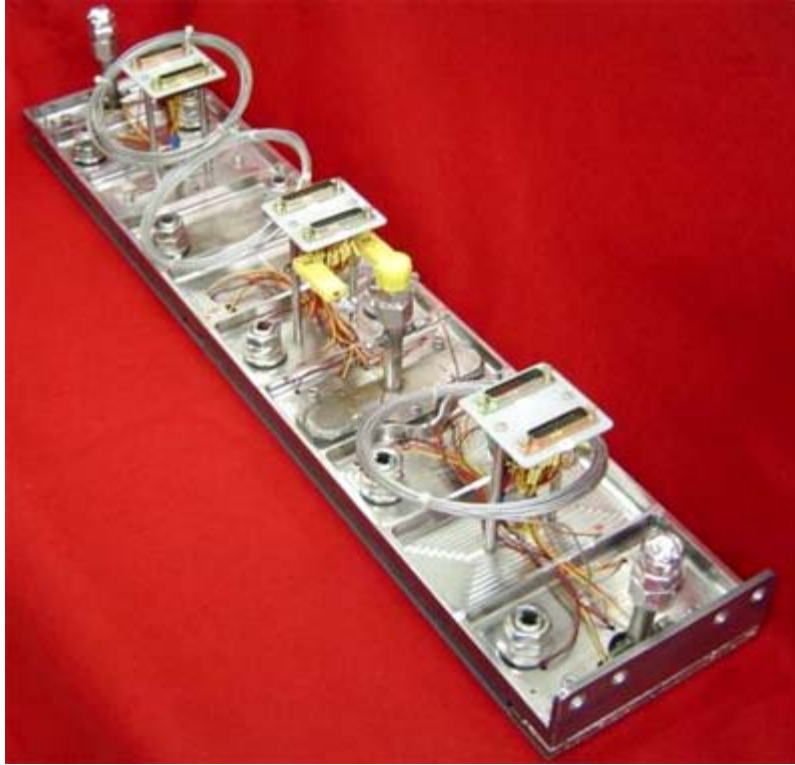
An innovative, cooled CMC design concept was developed in which a CMC hot surface panel was mechanically joined to a metallic coolant containment system by means of high-temperature CMC fasteners. This concept has the advantages of both low-cost manufacture and reparability, and its aggressive development schedule was met by an integrated design and fabrication approach. Initial test results of conceptual designs for cooled 1- by 6-in. coupons evaluated in a quartz lamp rig at United Technologies Research Center were used to validate the basic CMC heat exchanger concept by verifying cooling effectiveness. In the second testing phase, at the NASA Glenn Research Center, rocket engine tests on 2.5- by 10-in. panels were used to optimize the heat exchanger design by identifying critical issues and refining various design variables

before scaling up to the scramjet-engine-scale component. The rocket engine tests evaluated the cooling effectiveness and structural integrity of various design concepts, resulting in planned material downselects and design concept refinement.



*Left: United Technologies scramjet engine displaying section of combustor replaced by cooled CMC panel. Right: As-fabricated CMC panel assembly.*

After successful tests with 2.5- by 10-in. panels, the fabrication process was scaled up to produce 6- by 30-in. panels, the largest cooled CMC panels ever fabricated. These panels were successfully tested in a United Technologies scramjet engine, demonstrating the performance benefits of cooled CMCs in a scramjet engine for the first time. This lightweight, high-temperature, and high-heat-flux component and the technology's adaptability to complex shapes may enable safe, affordable, and reliable future space transportation systems.



*Fully instrumented CMC panel before testing in scramjet rig at United Technologies.*

This project is a collaborative effort between multiple NASA centers, the Air Force Research Laboratory, and industry, from planning through execution. Actively cooled composites were identified as a key technology for the VentureStar aerospike engine, for various hypersonic vehicle propulsion systems, and for meeting Integrated High Payoff Rocket Propulsion Technology goals. Specific applications have targeted various technical performance metrics, and competitive selections have invoked a broad range of industrial partners. Throughout development, a dedicated core group of researchers from Glenn, the NASA Langley Research Center, and the NASA Marshall Space Flight Center has advocated, sustained, and transferred the technology by holding workshops and focusing efforts on specific, measurable, progressive developmental steps. Contract partners have included Pratt & Whitney, Boeing-Rocketdyne, Rockwell Science Center, Snecma (France), GE Power Systems Composites, Goodrich Corporation, Refractory Composites, Inc., and HITCO Carbon Composites, Inc. The concept demonstration by Pratt & Whitney in the Air Force's HySet engine at United Technologies represents a milestone critical to utilizing this technology for low-cost space access.

## **Bibliography**

Jaskowiak, Martha H.; Dickens, Kevin W.; and Lawrence, Timothy W.: Light-Weight CMC Heat Exchanger Panels for Combined Cycle Propulsion Systems. Proceedings of the JANNAF 27th Airbreathing Propulsion Subcommittee Meeting, CPIA-JSC-CD-24, 2003. Available from Chemical Propulsion Information Agency (CPIA).

Jaskowiak, Martha H.; Dickens, Kevin W.; and Lawrence, Timothy W.: Actively Cooled Ceramic Matrix Composite Panels for Aerospace Applications. National Space & Missile Materials Symposium, June 23-27, 2003, San Diego, CA.

**Glenn contact:** Martha H. Jaskowiak, 216-433-5515, Martha.H.Jaskowiak@nasa.gov

**ZIN Technologies contact:** Kevin W. Dickens, 216-433-6491,  
Kevin.W.Dickens@grc.nasa.gov

**Authors:** Martha H. Jaskowiak and Kevin W. Dickens

**Headquarters program office:** Aeronautics Research

**Programs/Projects:** NGLT

**Special recognition:** Turning Goals Into Reality Award 2004