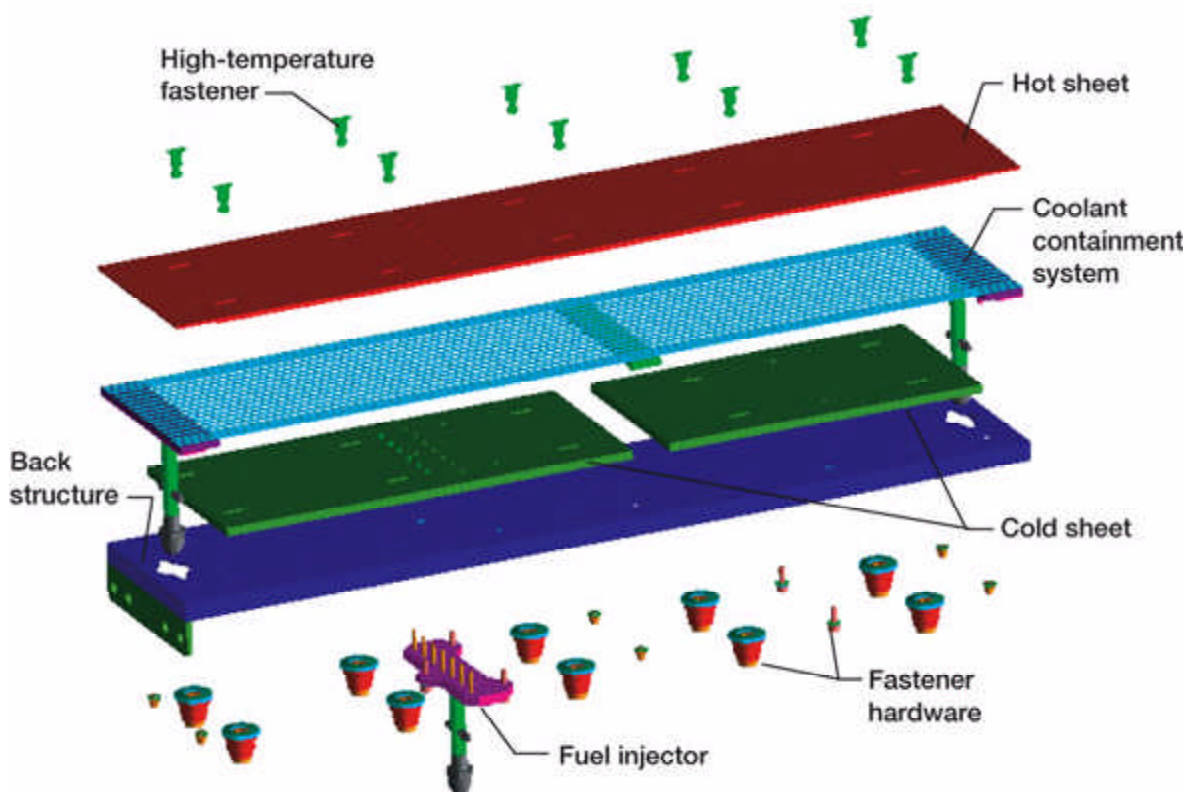


# Subscale Testing of a Ceramic Composite Cooled Panel Led to Its Design and Fabrication for Scramjet Engine Testing



*Exploded view of 6- by 30-in. maintainable panel design.*

High-temperature fasteners are used to mechanically join the hot CMC face sheet to the coolant containment system and the backside supporting structure.

In a partnership between the NASA Glenn Research Center and Pratt & Whitney, a ceramic heat exchanger panel intended for use along the hot-flow-path walls of future reusable launch vehicles was designed, fabricated, and tested. These regeneratively cooled ceramic matrix composite (CMC) panels offer lighter weight, higher operating temperatures, and reduced coolant requirements in comparison to their more traditional metallic counterparts. A maintainable approach to the design was adopted which allowed the panel components to be assembled with high-temperature fasteners rather than by permanent bonding methods. With this approach, the CMC hot face sheet, the coolant containment system, and backside structure (see the preceding illustration) were all fabricated separately and could be replaced individually as the need occurred during use. This maintainable design leads to both ease of fabrication and reduced cost.

During the first stage of the work, subscale panels were fabricated and tested to verify the predicted performance of the maintainable heat exchanger design and to demonstrate the

fabricability of the components. For this stage, 1- by 6-in. cooled CMC samples were tested in a quartz lamp rig at United Technologies Research Center (UTRC) to verify model predictions at a lower heat flux. After heat exchanger performance of the panel assembly was verified with these results, 2.5- by 10-in. panels were fabricated and tested in Glenn's Research Combustion Lab (see the following photograph). In addition to verifying the predictions of heat exchanger performance at higher heat fluxes, fabrication of the 2.5- by 10-in. panels identified processing and manifolding issues that needed to be addressed before the design could be scaled up to larger panel sizes. Fiber architectures and panel coatings were optimized to maximize thermal conductivity through the panel. Also surface coatings were identified which offered both improved oxidation resistance and durability under the extremes of the rocket engine tests. Three panels of this design were tested in the facility. The panels were either carbon-reinforced silicon carbide (C/SiC) or carbon-reinforced carbon (C/C) with a silicon carbide surface coating. Slight modifications to the panel and fastener design as the testing proceeded led to the third panel being tested for a cumulative time of 18.5 min with maximum surface temperatures sustained between 2400 to 2600 °F for 2-min durations.



*Subscale 2.5- by 10-in. maintainable panel assembly before testing in Glenn's Research Combustion Lab.*

The four composite fasteners, which had thermal barrier coatings applied to them, are visible on the panel surface. Closer inspection of the surface reveals several through-the-thickness thermocouples inserted in the CMC face sheet.

In the final phase of this effort, the scale-up of the design and fabrication of a 6- by 30-in. maintainable CMC cooled panel was completed. The well-established system requirements for the Pratt & Whitney Hydrocarbon Scramjet Engine Technology (HySET) vehicle engine were chosen as the baseline requirements for the cooled CMC panel design. The design targeted the combustor section of the flow path panel with maximum heat and pressure loads at M8 and M5 in the vehicle trajectory. This section of the panel represented the highest heat flux section of the flow path that included operable fuel-injection ports. The effort originally focused on hydrocarbon fuels with a modified version added for hydrogen fuels. The heavily instrumented panel will be tested in fiscal year 2004 in the scramjet rig at UTRC. The objectives of the tests are to validate the materials and design in a representative combined aero/thermal/acoustic scramjet engine environment. The panel will be tested at conditions of Mach 7.0 and  $q = 750$  psf cruise test point. It is

anticipated that testing of the 6- by 30-in. panel in the scramjet facility will provide critical information on the performance of CMC heat exchangers, which will be needed for future engine demonstrator programs.

## **Bibliography**

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

**Author:** Martha H. Jaskowiak

**Headquarters program office:** OAT

**Programs/Projects:** PR&T, NGLT