See how the flow goes

Test tile to measure shuttle's re-entry airflow

By Ed Memi

When the Space Shuttle re-enters Earth's atmosphere at 25 times the speed of sound, its Thermal Protection Tile surfaces experience searing temperatures as high as 3,000 degrees. Even with 119 successful shuttle flights on the books—including one that took place last month (see story on Page 39)— there's still a lot that's unknown about airflow around the vehicle, because it's impossible to duplicate similar conditions on the ground.

To get a better understanding of re-entry airflow, Boeing, United Space Alliance and NASA engineers have designed a special 6-inch-by-6-inch (15.2-centemeter-by-15.2-centimeter) test tile, to be installed on the lower side of the orbiter port-side wing near the main landing gear door. The tile will test airflow on three upcoming shuttle flights, beginning with the STS-119 *Discovery* flight this December. The goal is to understand boundary layer transitions, and the data from this experiment will help NASA in its efforts to develop new spacecraft such as the Orion crew exploration vehicle. The data also will help with any hypersonic vehicle and can be extrapolated and correlated to differently shaped spacecraft.

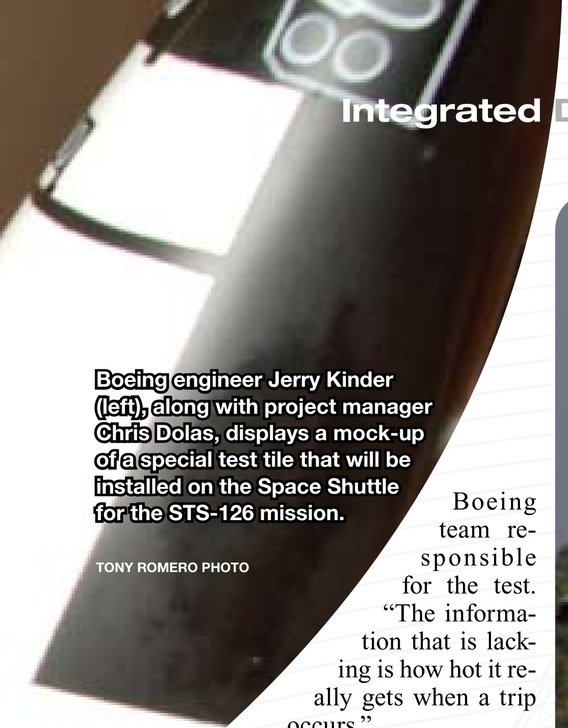
Each orbiter has more than 20,000 tiles. The tiles as well as reinforced carbon-carbon panels and thermal blankets protect the orbiter from heat while on orbit and during re-entry into Earth's atmosphere.

During re-entry, the compression of air on the leading edge of the shuttle forms a protective "blanket," called a laminar boundary layer, around the orbiter. Temperatures within that region are a manageable 2,000 to 3,000 degrees, while just a few inches away from the orbiter's surface the full force of heating results in a total temperature of up to 10,000 degrees.

As long as the orbiter's surface is smooth, the boundary layer keeps the tiles' temperature within the limits of their design. But any interruption in the air flow causes a boundary layer "trip," where turbulence behind the trip point brings down to the surface of the shuttle the extreme heat that was outside the laminar boundary layer. This could cause the tiles to overheat and damage the underlying surface.

The phenomenon is similar to a smooth (laminar) flowing river and water moving uniformly downstream. If you put a large rock in the middle, you'd see that the water before the rock stays in a steady state, but the water flowing past it is very turbulent.

"We don't know when the boundary layer actually trips due to a protuberance. We are installing a calibrated protuberance to measure and record the air speed at which the boundary layer trips as well as the downstream temperature increase that results from the trip," said Project Manager Chris Dolas, who is leading a 20-person



Boeing engineer Jerry Kinder (left), along with project manager Chris Dolas, displays a mock-up of a special test tile that will be installed on the Space Shuttle for the STS-126 mission.

TONY ROMERO PHOTO

Boeing team responsible for the test. "The information that is lacking is how hot it really gets when a trip occurs."

NASA is providing analysis support and some laboratory testing. NASA supercomputers will be used to come up with flow-field computations for the test scenario. Extensive analysis by NASA, USA and Boeing engineers has confirmed that the location of this protuberance tile will not compromise flight control or safety.

Along with the specially designed trip tile, whose protuberance is 0.25 inches high and 4 inches long (0.64-by-10.2 centimeters), the shuttle will have about 10 temperature sensors embedded in the tiles downstream of the trip tile to measure temperatures during re-entry. During the first test flight on STS-119, engineers expect to trip the boundary layer at speeds around Mach 15.

Plans call for additional testing with a 0.35-inch (0.89-centimeter) protuberance on STS-127 for a transition closer to Mach 18. The last test is a 0.45-inch-high (1.1-centimeter) protuberance on STS-128, which would transition at Mach 19. A final phase will add a catalytic coating material on one of the tiles, which would gather catalytic/turbulent heating interaction data. Recorded data will be retrieved after each landing.

"We'll use the data to correlate and fine tune our aero models so that when we build the next generation of spacecraft, we can adjust the shape and materials used based on our understanding of this complex airflow and heating during reentry," said Jerry Kinder, a Boeing engineer in Entry Aerodynamics. ■

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Shuttle comings and goings

February was a busy month for the Space Shuttle Program at Boeing, as the team supported a shuttle mission and prepared for another that's scheduled to launch shortly.

Space Shuttle *Atlantis* completed the 13-day STS-122 mission when it landed Feb. 20 at Kennedy Space Center, Fla. (above). The mission's crew members traveled to the International Space Station to install the European Space Agency's Columbus laboratory, which increases the orbital outpost's scientific capabilities. The mission also delivered a new crew member to the ISS and replaced an expended nitrogen tank on the station's Port One Truss.

Meanwhile, in preparation for the forthcoming STS-123 mission, Space Shuttle *Endeavour* (below), atop the well-lighted mobile launcher platform, arrived at Launch Pad 39A at Kennedy Space Center in the predawn darkness on Feb. 18. The journey from the Vehicle Assembly Building took about five hours. On STS-123, *Endeavour* and its crew will deliver the Japanese Experiment Logistics Module, the first section of the Japan Aerospace Exploration Agency's Kibo laboratory, and the Canadian Space Agency's two-armed robotic system, Dextre. Launch is targeted for March 11.

Boeing is the major subcontractor to United Space Alliance, NASA's prime contractor for shuttle operations, and is the prime contractor for the ISS. Boeing defined the interface requirements between Columbus and the Harmony utility node, the connecting point for the new research laboratory.

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