

# Effects of Cavities on Hypersonic Boundary Layer Transition on the Shuttle Orbiter

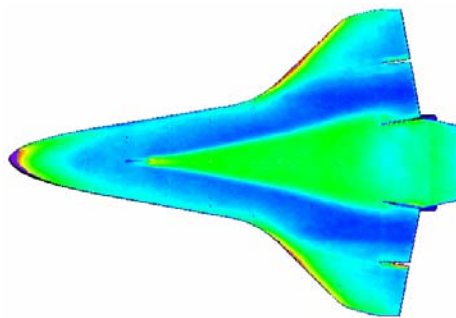
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As part of NASA's Shuttle Return to Flight (RTF) program, the Aerothermodynamics Branch (AB) at Langley Research Center is utilizing hypersonic wind tunnels to assess the effects of damage to the Shuttle Orbiter's thermal protection system (TPS). One of the major issues during Shuttle re-entry is tile damage in the form of cavities (gouges or holes). This research explores the effects of such cavities on hypersonic boundary layer transition on the Orbiter. The ultimate goal is to develop an experimentally derived correlation for predicting hypersonic boundary layer transition as a function of the cavity dimensions (length, width, and depth) and local boundary layer edge properties, since excessive heating has the potential of causing serious damage to the Shuttle's TPS. With this correlation, NASA will enhance its capability to assess tile damage on any given mission and determine whether or not it is necessary for an astronaut to go outside of the vehicle to repair the damage.

For this study, cast ceramic Shuttle models (scaled at 0.0075), each machined with a different sized cavity, were used. At this stage in testing, the cavities have all been of rectangular shape (representative of a missing tile or tile array) and located at  $x/L = 0.3$  on the centerline of the Orbiter in the presence of a favorable pressure gradient. The variations in the cavity dimensions in these models provide data to assess the effects of length, width, and depth on boundary layer transition. Eventually, further testing may be performed which focuses on TPS damage topology more consistent with actual impact damage (gouges with different shapes/angles of entry and exit) and sites away from the Orbiter centerline.

Tests were performed in Langley's 20-inch Mach 6 Air and 15-inch Mach 6  $CF_4$  facilities. To obtain data, all models were finished with a phosphor coating. The ratio of the light intensities produced during the tests provided global temperature data, which was then reduced to global heating data. From this global heating data, boundary layer transition can be inferred. A representative heating image is shown in Figure 1.



**Figure 1.** Example of global heating data. Boundary layer transition, indicated by higher heating levels, can be seen beginning at the cavity site.

This research is ongoing, but preliminary results suggest that cavity length is the driving factor for boundary layer transition downstream of the damage site. Cavity depth and width seem to have an effect as well; however more testing will likely be necessary in order to form a more precise correlation.