# Revision of Space Shuttle Wing Leading Edge Reinforced Carbon-Carbon Failure Criteria Based on Hypervelocity Impact and Arc-Jet Testing

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As part of the shuttle return-to-flight effort, Johnson Space Center's (JSC's) Hypervelocity Impact Technology Facility performed hypervelocity impact (HVI) testing and analysis of shuttle wing leading edge (WLE) reinforced carbon-carbon (RCC) test samples to update WLE threshold failure criteria. After the HVI tests, the samples were exposed to typical reentry heating conditions at the NASA JSC Arc-Jet (AJ) Facility to determine the extent of heating-induced damage growth. It was found from the HVI/AJ testing that non-penetrating pits would lead to burn-through in some areas of the WLE where such burn-through can lead to loss-of-vehicle (LOV) during reentry. Figure 1 shows the resulting damage caused by a 0.8-mm-diameter aluminum hypervelocity impactor and subsequent damage growth due to AJ testing. (Figure results are from Test 6 at 7.07km/s and 0°, 10.7-mm-diameter coating damage and 6.5-mm coating loss on impact side, AJ conditions: 2700°F, 98 psf, 15 min, fail: hole at 830 sec.)

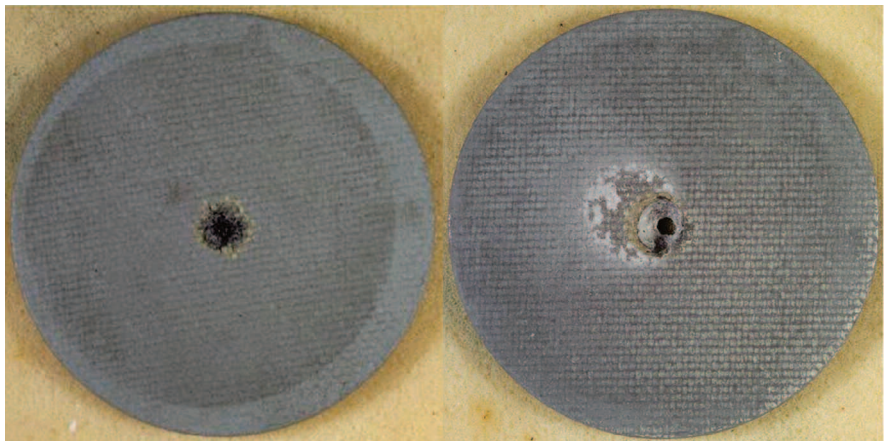

***Fig. 1.*** *Results HVI testing (Test 6) of RCC (on left) and after AJ test (on right).*

For Space Shuttle *Columbia*, STS-107 (February 2003), and previous missions, WLE failure threshold consisted of 1-in.-diameter allowable hole sizes in the RCC on the upper surface and ¼-in. hole size on the lower surface. The results of the recent RCC/AJ testing indicated that the WLE failure criteria for LOV should be reduced for micro-meteoroid orbital debris (MMOD) assessments on Space Shuttle *Discovery*, STS-114 (July 2006), and on future missions. The reduction in allowable damage results in increased MMOD risks for future missions, if all other things remain constant.

The Space Shuttle and International Space Station (ISS) Programs decided to decrease MMOD impact risks to STS-114 and subsequent flights by reversing the orientation of the ISS during the docking phase of the shuttle mission. The change in orientation – essentially flying the ISS "backward" – provided incidental shielding to the shuttle as well as directing MMOD-sensitive areas of the WLE and nose cap away from the majority of the MMOD particle flux. Figure 2 shows the shuttle-ISS docked orientation change with respect to the ISS velocity direction. In all ISS missions prior to STS-114, the belly of the vehicle faced into the ram "velocity" direction of ISS motion and highest MMOD impact flux. The change for STS-114 orients the bottom of the shuttle in the wake direction of the ISS, thus reducing MMOD impacts to the most vulnerable surfaces of the vehicle and improving crew safety and mission success.

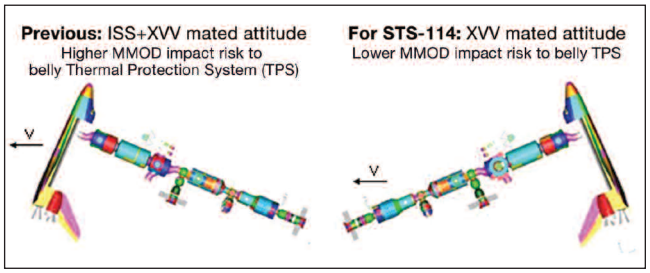


***Fig. 2.*** *Shuttle-ISS docking and flight orientations before and after.*