

# STS-118 Radiator Impact Damage

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During the August 2007 STS-118 mission to the International Space Station, a micro-meteoroid or orbital debris (MMOD) particle impacted and completely penetrated one of shuttle Endeavour's radiator panels and the underlying thermal control system (TCS) blanket, leaving deposits on (but no damage to) the payload bay door. While it is not unusual for shuttle orbiters to be impacted by small MMOD particles, the damage from this impact is larger than any previously seen on the shuttle radiator panels.

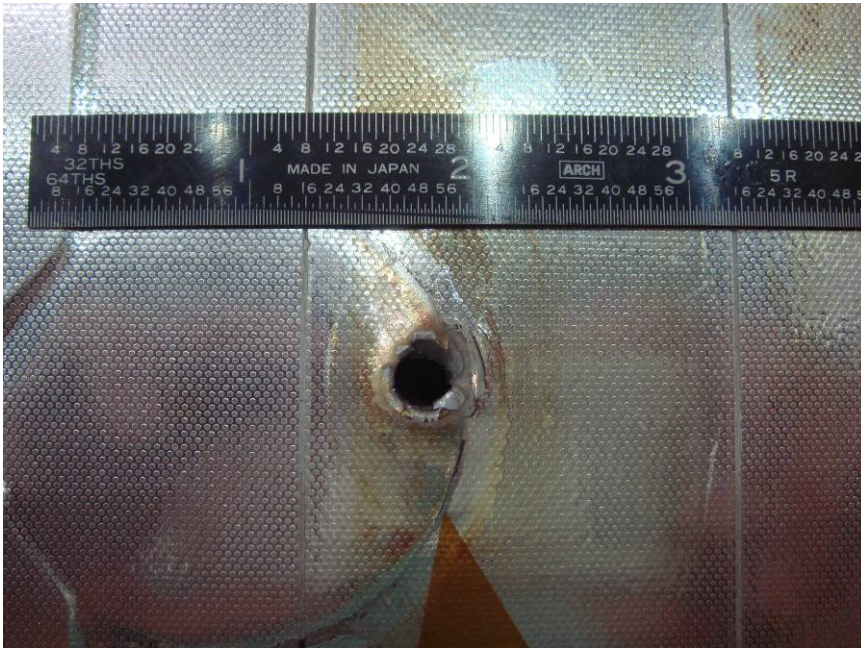
A close-up photograph of the radiator impact entry hole is shown in Figure 1, and the location of the impact on Endeavour's left-side aft-most radiator panel is shown in Figure 2. The aft radiator panel is 0.5-inches thick and consists of 0.011 inch thick aluminum facesheets on the front and back of an aluminum honeycomb core. The front facesheet is additionally covered by a 0.005 inch thick layer of silver-Teflon thermal tape. The entry hole in the silver-Teflon tape measured 8.1 mm by 6.4 mm (0.32 inches by 0.25 inches). The entry hole in the outer facesheet measured 7.4 mm by 5.3 mm (0.29 inches by 0.21 inches) (0.23 inches). The impactor also perforated an existing 0.012 inch doubler that had been bonded over the facesheet to repair previous impact damage (an example that lightning can strike the same place twice, even for MMOD impact). The peeled-back edge around the entry hole, or "lip", is a characteristic of many hypervelocity impacts. High velocity impact with the front facesheet fragmented the impacting particle and caused it to spread out into a "debris cloud." The debris cloud caused considerable damage to the internal honeycomb core with 23 honeycomb cells over a region of 28 mm by 26 mm (1.1 inches by 1.0 inches) having either been completely destroyed or partially damaged. Figure 3 is a view of the exit hole in the rear facesheet, and partially shows the extent of the honeycomb core damage and clearly shows the jagged "petaled" exit hole through the backside facesheet. The rear facesheet exit hole damage including cracks in the facesheet measures 14 mm by 14 mm (0.55 inches by 0.55 inches). The remnants of the impacting particle and radiator panel material blown through the rear facesheet hole also created two penetrations in the TCS blanket 115 mm (4.5 inches) behind the rear facesheet. Figure 4 shows these two impacts, which are located 75 mm (3 inches) apart. Some deposits of material were found on the payload bay door beneath the TCS blanket, but no additional damage occurred to the door.

Figure 5 illustrates the relationship of the facesheet entry hole to the TCS blanket damage, which may indicate the direction of the impacting particle. The image on the left side of Figure 5 shows an overhead view of the damaged radiator after the facesheet holes were cored out of the panel. The entry hole location and the two underlying TCS blanket damage sites are annotated on the image. Section A-A, running through the entry hole and TCS blanket damage locations, describes a 25° angle from the longitudinal axis of the shuttle. The 2<sup>nd</sup> impact angle can be seen in section A-A on the right side of Figure 5. An average 17° angle of impact to the surface normal was derived by measuring the angles of the two damage sites in TCS blanket to the entry hole.

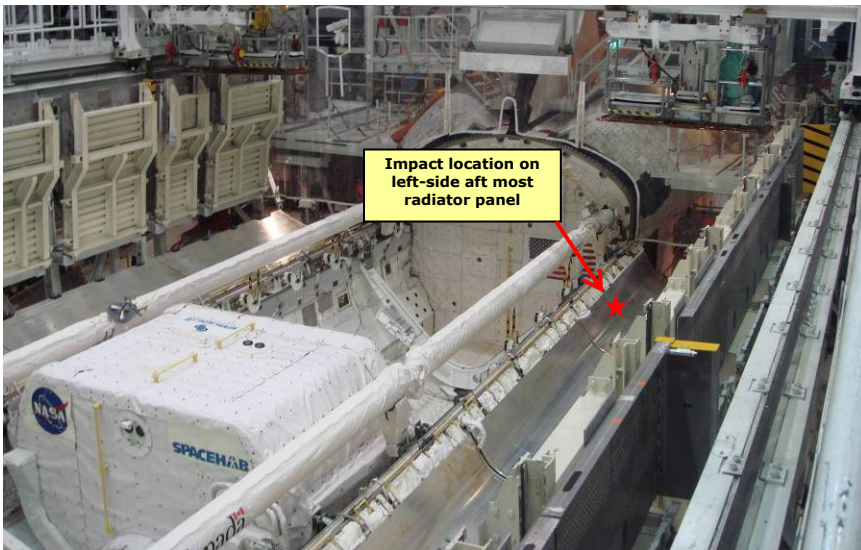
As part of the radiator repair procedure, intact core samples were collected of the outer thermal tape, outer facesheet, honeycomb core, and rear facesheet. Swabs of the two impact damage areas on the TCS blanket were also collected. Micro-meteoroid and orbital debris impacts usually leave residual particulate from the impactor material in and around the damaged area. This residue is collected, analyzed, and in many cases, a determination can be made as to the impactor source as micro-meteoroid or orbital debris. In some cases, specific types of orbital debris particles can be identified, such as rocket propellant or electrical components. To perform this analysis, the samples were transferred to the NASA Johnson Space Center (JSC) Hypervelocity Impact Technology Facility (HITF) in Houston, Texas. Scanning Electron Microscope (SEM) equipped with Energy-Dispersive X-ray (EDX) Spectrometry tools are being used to identify potential residue material from the impactor and to identify the elemental makeup of the impactor. Early results from this analysis indicate that the impacting particle was a titanium-rich orbital debris particle containing traces of zinc and possibly antimony.

Additionally, hypervelocity impact tests are being conducted at the NASA White Sands Test Facility (WSTF) on realistic simulated shuttle radiator panel material in order to duplicate the observed damage and to estimate the impacting particle size, given information from field data and SEM analysis on particle density, impact velocity, and impact angle. Early impact test results suggest that the particle size was on the order of 1.5 mm to 2.0 mm in diameter assuming that the particle was orbital debris. Final

results of the SEM/EDX analysis and the hypervelocity impact tests will be described in a post-flight MMOD damage report.



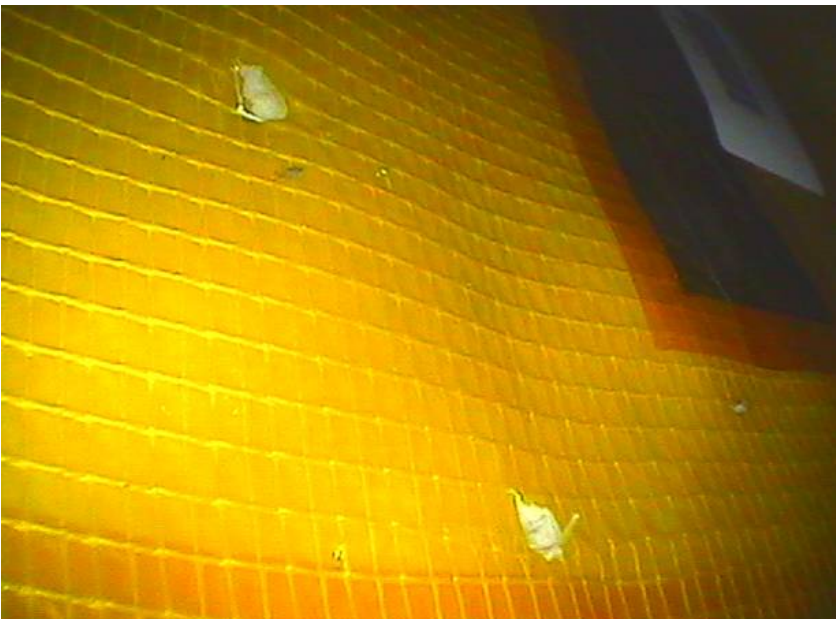
**Figure 1:** Entry-hole damage (5.5mm diameter hole) to Endeavour's left-side aft-most radiator panel observed during post-flight inspection.



**Figure 2:** Impact damage location on Endeavour's left-side radiator panel # 4 (LH4)



**Figure 3:** 12mm by 19mm hole in the rear facesheet of the radiator panel



**Figure 4:** Damage to thermal control system blanket (two impact locations)

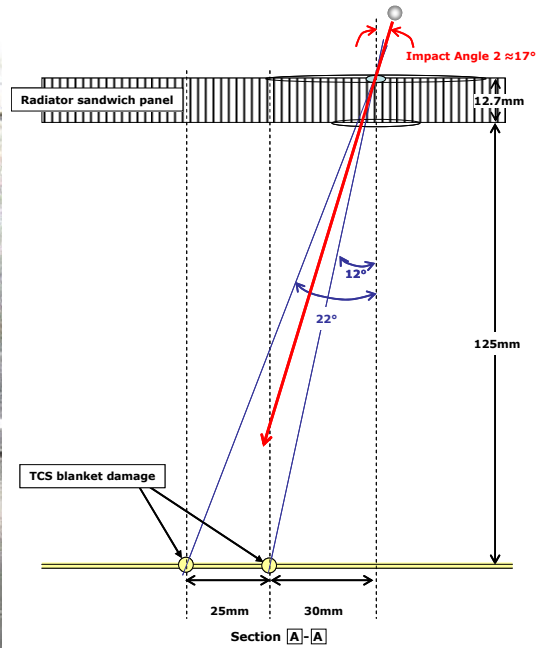
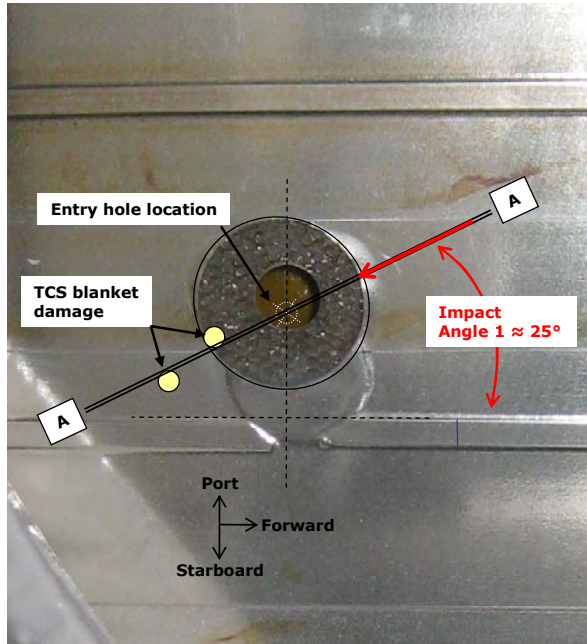


Figure 5: Estimated orientation of MMOD impactor