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Solving Problems Caused by Small Micrometeoroid and Orbital Debris Impacts for Space-Walking Astronauts

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The external handrails used by the International Space Station (ISS) crew during extravehicular activity (EVA) are exposed to MMOD impacts that cause craters with raised edges, called "crater lips" (figure 1). These crater lips are often very sharp and represent an EVA cut-glove hazard. There have been several cases of craters reported to the ISS handrail team. For instance, the ARES HVIT group identified six craters on a single 13.7-in.-long handrail from an ISS pump module (PM) returned on the last Space Shuttle mission, STS-135. This PM handrail was exposed to MMOD impacts for 8.7 years. The largest crater on the PM handrail measured 1.85-mm diameter (outside) with a 0.33-mm lip height (figure 2). The size of the other five craters ranged from 0.12 mm to 0.56 mm in diameter, with crater lips that ranged from 0.01 mm to 0.08 mm high. Other MMOD craters have been observed on ISS handrails and EVA tools (figure 3).

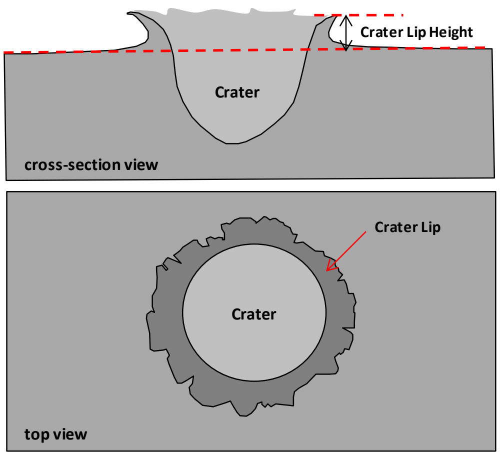

Figure 1.– MMOD impact craters into metals typically exhibit raised sharp-edged "crater lips."

If the crater lips from hypervelocity impacts are large enough, they can tear or cut into the materials used in the EVA gloves. Crater lip heights of 0.01 in. (0.25 mm) were found to be sufficient to cut EVA glove materials in ground experiments coordinated by the NASA EVA engineering community. These experiments were performed after there were several incidents of cut gloves reported on EVAs during STS-109, STS-110, STS-116, STS-118, STS-120, STS-125, and other missions. Some of these glove cuts were large enough to result in early termination of the EVA. For instance, on STS-118, during a routine glove inspection, one of the EVA crew members noticed a possible tear on the thumb of his left glove. To be safe, EVA managers decided to end the spacewalk after about 5.5 hours, and examination and photography of the glove performed during suit removal revealed the extent of the glove tear (figure 4). A similar incident occurred during the third EVA of STS-120. MMOD craters are not the only possible cause of this glove damage, but are one of the leading possible causes.

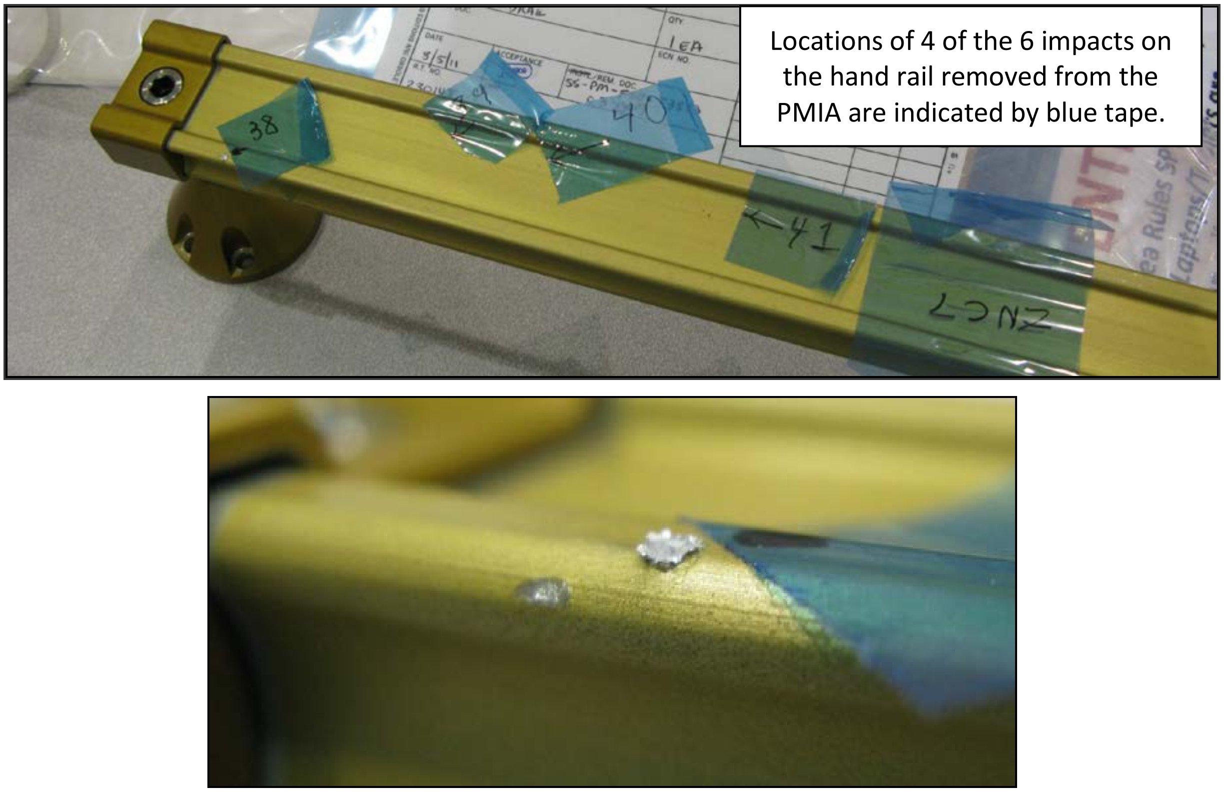

Figure 2.– The JSC HVIT group found six craters on one handrail removed from the ISS Pump Module Integrated Assembly (PMIA) and returned on STS-135. The largest crater found on the PMIA handrail (#38 in overview) was 1.85-mm in diameter with 0.33-mm-high crater lips.

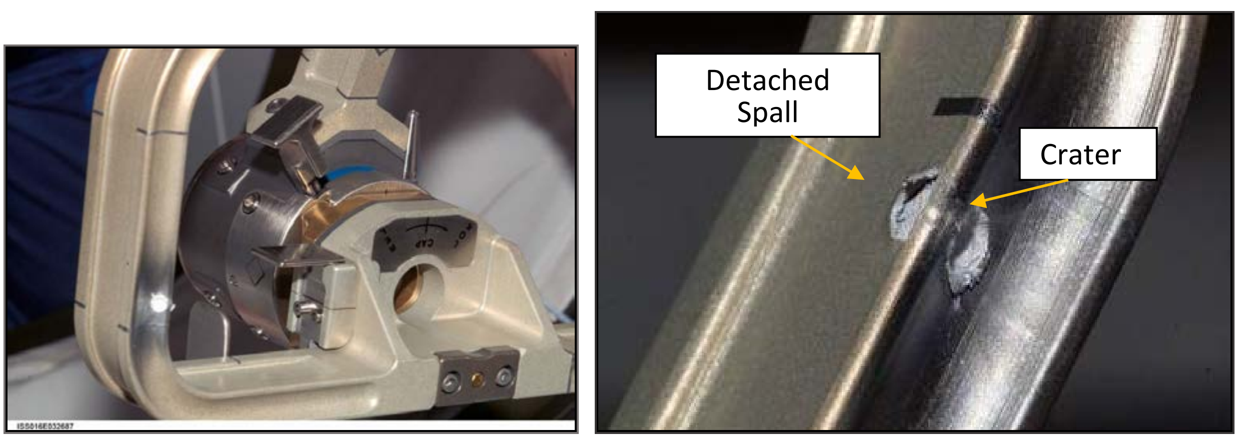

Figure 3.– Prior to STS-123 EVA, the ISS crew found a nearly 5-mm diameter crater on the EVA D-handle tool stored externally on ISS. Note that the detached spall from the side opposite the MMOD impact crater also has sharp edges. The D-handle is made of materials that are similar to those used in a typical ISS dog-bone handrail.

Figure 4.– Damage to the left glove of one of the EVA crew after STS-118 EVA #3.

The ARES Directorate's HVIT group in the Human Exploration Science Office and the Engineering Directorate's Crew and Thermal Systems Division, under the leadership of the EVA Project Office, worked together from 2008 to 2012 to assess the risk of cut gloves from MMOD craters on handrails and develop methods to identify and repair craters on handrails. The HVIT provided assessments of the frequency of craters with lip heights that could result in glove damage and worked with White Sands Test Facility (WSTF) to provide samples of realistic hypervelocity impact damage to handrails to help support development of the tools and procedures used to find and repair damage to handrails. HVIT-WSTF impact tests of handrails in 2011 and 2012 were used to provide samples of impact damage that were used to certify handrail covers that EVA crew fit over impact damage discovered on orbit; the covers prevent gloves from being torn by the MMOD craters. This effort culminated in several changes to EVA hardware and procedures that minimize the risk that sharp edges will the EVA gloves, including the following:

1. Toughening the gloves by adding additional materials to areas that are sensitive to cuts.
2. Monitoring the status of MMOD impacts on the handrails via photographs and maintaining a database of potential sharp edges on handrails, referred to as the ISS Imagery Inspection Management System (IIIMS), for EVA planning purposes. HVIT and Image Science and Analysis Laboratory personnel jointly review photographs of ISS handrails and other surfaces to identify MMOD damage that is documented in the IIIMS database and used to inform EVA crews of potential sharp edges during EVA planning. Currently, the IIIMS contains more than 200 records of MMOD impacts to handrails and other areas that could be contacted during EVA.

3. Developing EVA procedures and tools to detect and repair or cover sharp edges from MMOD impacts on handrails.

Since the above changes were incorporated into EVA hardware and procedures, the incidents of cut gloves have been greatly reduced.

Toughened Thermal Blankets for Micrometeoroid and Orbital Debris Protection

Eric Christiansen, Dana Lear

Thermal blankets are used extensively on spacecraft to provide thermal protection from temperature extremes encountered in space. Typical thermal blankets are relatively thin (1/4-in. to 1/2-in. thick) and provide effective thermal protection, but they can provide only minimal protection from hypervelocity MMOD particles. As a consequence, MMOD shielding is often necessary to supplement the protection provided by thermal blankets alone to meet MMOD protection requirements. Because thermal blankets and MMOD shielding share similar physical space on the outside hull of a spacecraft, an integrated hardware design that performs as a thermal blanket and MMOD shield could yield numerous benefits, such as reduced mass and cost.

The JSC ARES Directorate's HVIT group and the Engineering Directorate's Structural Engineering Division worked together in 2011 and 2012 to integrate MMOD protection with standard thermal blankets (figure 1). These MMOD toughened thermal blankets incorporate one or more layers of materials near the exterior of the blanket that are effective at breaking up MMOD particles; other layers deeper in the blanket that resist fragment penetration; and low-mass, open-cell foam materials that separate the layers and improve MMOD protection. Typical materials used to enhance the MMOD protection of thermal blankets include fiberglass cloth, ceramic fabrics, and high-strength flexible materials. Hypervelocity impact tests were performed at White Sands Test Facility (WSTF) to demonstrate the effectiveness of the toughened blankets (figure 2), which can stop MMOD particles that are 5-mm to 6-mm in diameter, as opposed to the standard thermal blanket, which is completely penetrated by submillimeter-diameter MMOD particles (typically on order 0.5 mm). This translates roughly into a factor of 1000x decrease in MMOD risk of thermal blanket penetration and damage to underlying equipment. The means to determine the location, depth, and extent of MMOD impact damage is obtained by adding impact detection sensors at one or more locations within the blanket (figure 3). The toughened thermal blankets were tested in thermal-vacuum chambers at JSC (figure 4) to prove that the materials integrated into the thermal blanket to improve MMOD protection did not adversely affect the thermal performance of the blankets.