Using the Orbiter Wing Leading Edge Impact Detection System for Micrometeoroid and Orbital Debris Impact Monitoring

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Although the Wing Leading Edge Impact Detection System (WLEIDS) was originally developed to detect damaging ascent debris impacts to the orbiter wing leading edge (WLE), it is also being used to sense micrometeoroid/orbital debris (MMOD) impacts to the WLE. The risk of critical penetration due to MMOD impact remains one of the highest catastrophic risks to the shuttle at approximately 1 in 300 per mission. Monitoring with WLEIDS while on orbit can offer near-real-time knowledge of damaging MMOD impacts. A damaging MMOD impact to a WLE test article is shown in figure 1. The 6.1-mm hole shown in the figure was created by a 2.0-mm aluminum sphere projectile traveling at 6.93 km/s.

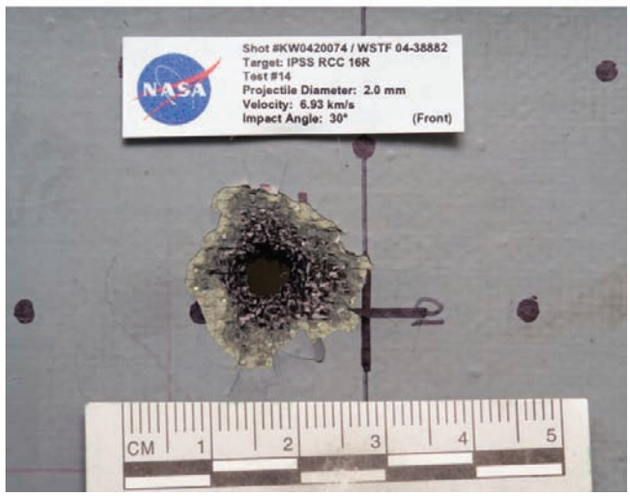

Fig. 1. *MMOD impact damage to WLE test article.*

The WLEIDS consists of an array of 63 accelerometers per wing together with the associated electronic components needed to acquire and transmit measured data to the ground during flight. Accelerometers are located behind the orbiter wing spar at the four attach locations of each WLE panel. WLEIDS accelerometer data are collected by wireless data acquisition sensor units (SUs) mounted in wing cavities near the fuselage; the data are downloaded through wireless relay units to the astronauts' on-board laptops and then are accessed by ground teams for engineering analysis in the Mission Control Center at the Johnson Space Center.

The most obvious limitation in using the WLEIDS, a system whose primary purpose is to monitor ascent (~a 10-minute event) for MMOD impact monitoring, is the limited battery life of the electronic components. Each SU records data for three accelerometers and has a battery life of about 21 hours. Based on testing, dynamic modeling, and flight experience, at least two corners of each WLE panel must be monitored to provide adequate detection and severity evaluation of MMOD impacts. The existing WLEIDS hardware therefore provides two accelerometer groups of sufficient resolution to detect damaging MMOD impacts. These groups are shown in figure 2; in this figure the blue dots represent accelerometers, the blue lines trace the accelerometers to the SUs that collect data for the accelerometers, and the numbered boxes represent WLE panels. MMOD impact monitoring of the WLE, using these two groups, can only be performed for a total of 42 flight hours – a small percentage of the total shuttle mission time of about 2 weeks.

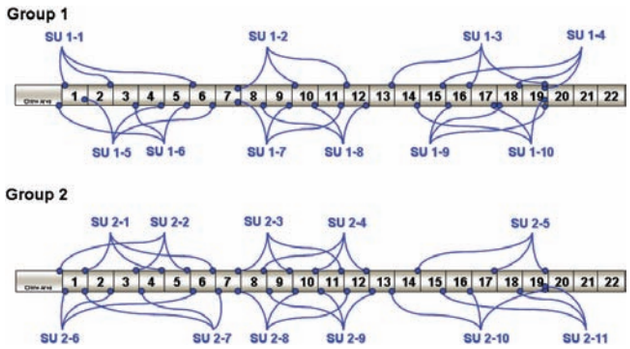

Fig. 2. *WLEIDS MMOD impact monitoring accelerometer groups.*

MMOD impact monitoring is performed during the highest critical MMOD impact risk periods. To best manage the 42-hour battery life of the two groups of accelerometers, the monitoring occurs when the orbiter attitude is such that the most vulnerable surfaces are oriented in the direction of the orbiter velocity vector. Monitoring can happen during orbiter docking and undocking with the International Space Station (ISS), on-orbit inspection of the orbiter Thermal Protection System, water dumps, and other mission activities. A typical WLEIDS MMOD monitoring plan for an ISS mission is shown in figure 3,

in which the normalized MMOD risk to the orbiter WLE is plotted against mission elapsed time (MET). WLE MMOD impact monitoring occurs during those times in which the area under the curve is shaded. Blue shading

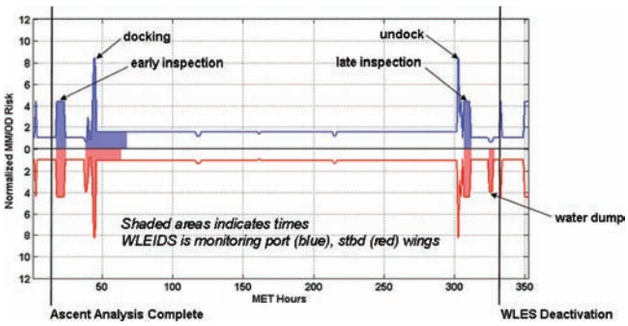

Fig. 3. *WLE MMOD risk vs. MET, indicating when the WLEIDS is monitoring.*

indicates port wing MMOD impact monitoring, and red shading indicates starboard wing monitoring.

Another limitation of using WLEIDS for MMOD impact monitoring is the sensitivity and sampling rate of the accelerometers. While damaging ascent debris impacts to the WLE cause significant localized accelerations at the wing spar, MMOD impact testing and analysis reveals that damaging MMOD impacts to the WLE can result in measured accelerations at the wing spar below the usable range of the accelerometer (i.e., ~0.3g). In addition, due to the extremely high velocities of MMOD vs. ascent debris, the effective sampling rate of WLEIDS (20,000 Hz raw data sampling rate with a 6,000-Hz anti-aliasing filter applied) likely results in clipping of peak accelerations and, thereby, significant uncertainty in the potential damage associated with a measured peak acceleration.

Extending the use of WLEIDS beyond its primary purpose of monitoring ascent debris impacts to the WLE to monitoring MMOD impacts offers both increased awareness of a critical orbiter risk and the opportunity to examine MMOD impact monitoring challenges for consideration in future human spacecraft programs. Due to the increased quantity of orbital debris with time, the MMOD environment continues to become more and more severe. Future programs should consider developing an adequate system with which to monitor and assess MMOD impacts to critical surfaces as part of a robust protect, detect, inspect, and repair approach to managing catastrophic MMOD impact risks.

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