DEBRIS IMPACT DETECTION INSTRUMENT FOR CREWED MODULES

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When micrometeoroid or debris impacts occur on a space habitat, crew members need to be quickly informed of the likely extent of damage, and be directed to the impact location for possible repairs. This is especially important because the outer walls of pressurized volumes are often not easily accessible, blocked by racks or cabinets. The goal of the Habitat Particle Impact Monitoring System (HIMS) is to develop a fully automated, end-to-end particle impact detection system for crewed space exploration modules. The HIMS uses multiple passive, thin film piezo-polymer vibration sensors to detect impacts on a surface, and computer processing of the acoustical signals to characterize the impacts. Development and demonstration of the HIMS is proceeding in concert with NASA's Habitat Demonstration Unit (HDU) Project. The HDU Project is designed to develop and test various technologies, configurations, and operational concepts for exploration habitats.

This paper describes the HIMS development, initial testing, and HDU integration efforts. Initial tests of the system on the HDU were conducted at NASA's 2010 and 2011 Desert Research and Technologies Studies (Desert-RATS or D-RATS). The HDU lab module, as seen from above, has an open circular floorplan divided into eight wedge-shaped Segments. The side wall of the module – the surface used for this technology demonstration – is a hard fiberglass composite covered with a layer of sprayed-on foam insulation. Four sensor locations were assigned near the corners of a rectangular pattern on the wall of one segment of the HDU lab module. The flat, self-adhesive sensors were applied to the module during its initial outfitting. To study the influence of the wall's construction (thickness and materials), three sets of four sensors were installed at different layer depths: on the interior of the module's wall, on the exterior of the same wall, and on the exterior of the foam insulation. The signal produced when a vibration passes through a sensor is first sent through a pre-amplifier. The amplified signal then is sent to the data acquisition and data processing systems. The vibration data from the sensors are then processed and reduced to a form suitable for presentation to the crew.

For the HIMS HDU technology demonstration, particle impacts were simulated by firing a pneumatic pellet gun at the exterior wall section. Impact signals from the sensors were recognized by the data acquisition system when they occurred, producing a "trigger" event. The data acquisition system ran continuously,

allowing it to retain a certain amount of pre-trigger data, which provided the full event data from all sensors. In the first phase of the demonstration, conducted at JSC and at the 2010 D-RATS, the HIMS data-acquisition and recording functions were housed in their own stand-alone, portable computer. The system simply recorded each event's data on the computer for later analysis. Background noise data were also collected by recording all sensor outputs during normal HDU operations. The combined data were used to develop the software to detect, discriminate, and characterize the impacts. Detection was accomplished by setting a trigger level higher than the system's background noise and lower than the lowest test impact's signal. Non-acoustic false signals (typically electrical spikes) were rejected using a waveform-duration criterion, based on the ratio of energy to peak voltage. The position of the impacts is derived using a technique of multilateration, analyzing the differences in signal arrival times at the different sensor locations. The degree of impact penetration is determined by analyzing signal strength as a function of time. Upon completion of this first phase, the HIMS system located the point of impact to within 8 cm, provided a measure of the impact energy / damage produced, and was insensitive to other acoustic events.

The second phase of the HIMS HDU technology demonstration, completed at the 2011 D-RATS, assessed the performance of a fully automated, real-time version of the system. This system was integrated into the HDU systems, using the lab's data-acquisition, network, processing, and information display infrastructure. The stand-alone computer, used in the first phase, also demonstrated the real-time software and provided easier access to diagnostic information. The integrated system passes the processed results of an impact event to the crew "Caution/Warning" system, which displays information on a tablet computer. The impact location is displayed graphically on an image of the module wall, along with a table listing the position, severity, and time of the event. The real-time HIMS yielded the expected level of performance (8-cm location accuracy, good false-alarm rejection) demonstrated by the developmental system in the first phase.

As the HDU project moves forward as part of NASA's Advanced Exploration Systems Program, the HIMS is now being advanced for more complex structures, including multi-layer composites and inflatable modules. Work this year involves extending the system to the Bigelow multi-layer inflatable for the International Space Station, a structure which may particularly benefit from the inclusion of this type of impact monitoring system. This structure presents new challenges since the signals will experience greater attenuation as they travel on this highly-damped structure, but correspondingly the background noise levels should be lower. Based on previous successful hypervelocity tests on multi-layer insulation (MLI), fabrics and stretched membranes, we expect that only minor modifications will be required to our system to optimize it for use with this type of structure. In particular, we are amplifying the signals at the sensors to

accommodate the anticipated lower signal levels, and to permit longer cable runs than the current five meters. The aim of this year's study is to determine the optimal sensor spacing, and identify the likely relative background noise levels on structures of this type.