MICROMETEOROID AND LUNAR SECONDARY EJECTA FLUX MEASUREMENTS: COMPARISON OF THREE ACOUSTIC SYSTEMS.

R. D. Corsaro[1], F. Giovane[2], J.-C. Liou[3], M. Burtchell[4], V. Pisacane[5], N. Lagakos[1], E. Williams[1], and E. Stansbery[3], [1]Naval Research Laboratory, Washington DC, (Bob.Corsaro.ctr@NRL.Navy.mil), [2]Virginia Polytech Institute, [3]NASA/ODPO, [4]U. Of Kent at Canterbury, [5]US Naval Academy.

Introduction: This report examines the inherent capability of three large-area acoustic sensor systems and their applicability for micrometeoroids (MM) and lunar secondary ejecta (SE) detection and characterization for future lunar exploration activities. Discussion is limited to instruments that can be fabricated and deployed with low resource requirements.

Previously deployed impact detection probes typically have instrumented capture areas less than 0.2 square meters. Since the particle flux decreases rapidly with increased particle size, such small-area sensors rarely encounter particles in the size range above 50 microns, and even their sampling the population above 10 microns is typically limited. Characterizing the sparse dust population in the size range above 50 microns requires a very large-area capture instrument. However it is also important that such an instrument simultaneously measures the population of the smaller particles, so as to provide a complete instantaneous snapshot of the population.

For lunar or planetary surface studies, the system constraints are significant. The instrument must be as large as possible to sample the population of the largest MM. This is needed to reliably assess the particle impact risks and to develop cost-effective shielding designs for habitats, astronauts, and critical instrument. The instrument should also have very high sensitivity to measure the flux of small and slow SE particles. is the SE envieonment is currently poorly characterized, and posses a contamination risk to machinery and personnel involved in exploration. Deployment also requires that the instrument add very little additional mass to the spacecraft.

Three acoustic systems are being explored for this application.

Fiber Optic Micrometeroid Impact Sensor (FOMIS): This system uses a thin fabric membrane or drum as the impact surface. This membrane can have a lvery large surface area, and be supported by low-mass frames. An impact on the membrane will generate acoustic vibrations (like a drum head) and can be detected as perpendicular movement of the membrane.

Because the modal vibrations of such a drum are well known, only a few sensors are required for each unit. The sensors selected are non-contact surface-normal fiber optic displacement (FOD) sensors. These are low-cost low-power optical intensity probest (not interference probes) developed at NRL. They measure displacements as large as 0.5 mm with angstrom resolution at frequencies from DC to over 500 kHz.

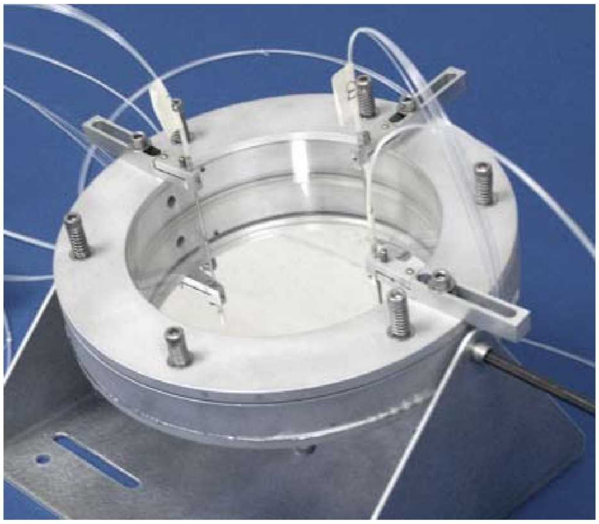

Figure 1. Rear view of a typical FOMIS test system with three FOD sensors mounted on support arms

The capabililties and characterisitics of this system were studied in laboratory tests using low-speed (m/s) and hypervelocity (5 km/s) impacts on devices with diameters as large as 0.7 meters. The particle size detection limit for both high speed (penetrating) and low speed impacts has been typically found to be on the order of a few microns for the configurations tested.

PVDF membrane system: An alternative sensor for a large area drum-type configuration is the piezoelectric sensor. This type of sensor responds to strain in the membrane material, rather than motion. Constraints on the sensor are that it must be low mass so as not to mechanically load the drum, and it must be low stiffness since to detect strain in the membrane material, it must deform with it. A suitable piezoelectric material is polyvinylidene fluoride (PVDF). Two configurations of this system were tested. In one, a small sensor was adhered to the membrane, and for the other the entire membrane was replaced with PVDF film. Particle drop tests were performed on both, using particles from 0.58 to 540 mg mass.

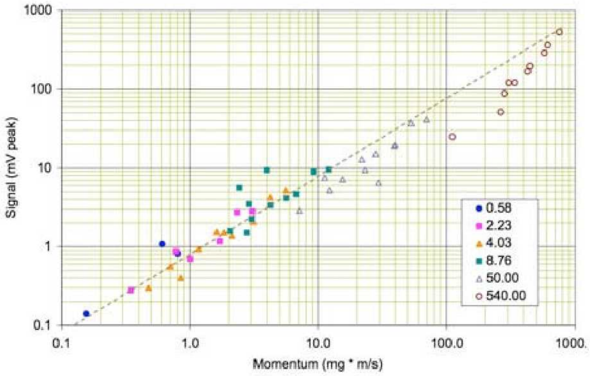

Figure 2. Signal voltage as a fuction of the momentum of the impacting particle.

Only low-speed tests were performed on this configuration. The particle size detection limit for both configurations was similar to that of the FOD system - typically on the order of a few microns for the configurations tested. The PVDF drum would have a small advantage in detecting small, slow SE particles, but this may be offset by its reduced long-term robustness in a large-area deployment in some environments

PVDF system on a stucture (PINDROP): Rather than deploying a special detection surface, this third approach makes use of structures already present. A series of PVDF strain sensors are adhered to a structure, such as a habitat, and the previously developed PINDROP system is used to detect impacts on the structure, locate the impact site, and evaluate the size of the impacting particle.

A series of tests was initially conducted using hypervelocity impacts on various materials, ranging from plastics (HDPE) to metals, and including some space-qualified fabrics. The measured signal level were found to be largest for low-damping materials (i.e. aluminum plate) and lower for high-damping materials (i.e. HDPE). However in all cases the signals from the PVDF sensors were adequate for the intended application.

To study the number and distribution of sensors required to monitor a large structure, a scale mode of a candidate lunar habitat was fabricated and instrumented with an array of PINDROP sensors. The test structure is shown in Figure 3.

Figure 3. Scale model of a lunar habitat instrumented with 20 PINDROP sensors.

A series of tests were conducted on this structure using 0.125 gm particles impacting at 2.5 m/s. Even with these small, slow particles the signal levels were above 10 mV at the far end of the structure even after crossing three impedance discontinuities (i.e. frame supports). As expected, the signal travel times corresponded to the sensor-source separation distance with an effective wave speed of 1066 m/s. Signal strength was as expected for cylindrical spreading, being proportional to the inverse square root of the range (decreasing 3 dB for each factor of two increase in distance). When signals paths crossed corners or regions supported by frames, there was typically 2 to 5 dB of additional loss at each incident.

The conclusion of this study was that an impact by a hypervelocity particle larger than 50 microns would be detected by a sensor placed anywhere on this structure. However to use the relative signal arrival times to localize the point of impact to within 1 meter on the full-size equivalent structure would require approximately 18 sensors. The localization capability is important to guide damage inspection teams.