GEOHAZARDS ON THE MOON AND THE IMPORTANCE OF THE INTERNATIONAL LUNAR NETWORK (ILN).

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Introduction: Seven of the 28 shallow seismic events recorded by the Apollo passive seismic experiment (PSE) network released energy equivalent to earthquakes with magnitudes of 5 or greater. On Earth, such quakes can cause extensive damage to structures near the epicenter. Unexpected structural damage to a lunar habitat could have devastating results and thus, lunar seismicity may present a significant geohazard to long-term human habitation.

Seismic Hazard? Lunar seismicity is 3-5 orders of magnitude lower than Earth. However, the propagation of quake energy is strikingly different on the Moon than on the Earth. The Moon is largely anhydrous and its crust is extensively fractured; the resulting high lunar Q values mean that moonquake attenuation is low. The maximum signal from a shallow moonquake can last up to 10 minutes with a slow tailing off that can continue for hours in total duration, and moonquakes tend to produce seismic waves of higher frequency than earthquakes. Ground motion is the most important factor in causing structural damage, and on the Moon, the observed ground motion of the PSE instruments during moonquakes were typically less than 1 nanometer and artificial seismic signals dampened out within ~ 10 km. However, the Apollo PSEs never recorded a strong shallow moonquake directly below the seismic network.

One mechanism for generation of shallow moonquakes may be lithospheric stress at terrain boundaries such as basaltic mare or large impact basins. If this mechanism is valid, siting a lunar base on the edge of the largest, deepest lunar basin (SPA) could put it at increased seismic risk. We do not yet have enough data on strong, shallow moonquakes to understand their cause, depth, or lateral distribution. Predicting where shallow moonquakes may occur is important for the next phase of lunar exploration.

To evaluate a potential lunar seismic risk, two approaches are needed. First, further research to understand and effectively model lunar ground motion and acceleration by applying advanced terrestrial models and numerical techniques to the lunar environment is crucial. Second, a long-lived, global lunar seismic network needs to be established to globally characterize lunar seismicity and establish the origin, frequency, and propagation of strong moonquakes.

The ILN Mission: NASA's Science Mission Directorate's (SMD) International Lunar Network Anchor Nodes Mission continues its concept development. The mission will establish two-four nodes of the International Lunar Network (ILN), a network of lunar geophysical stations envisioned to be emplaced by the many nations collaborating on this joint endeavor. The US stations of the ILN, called the Anchor Nodes, are being planned by NASA Marshall Space Flight Center (MSFC) and the Johns Hopkins University Applied Physics Laboratory (APL), with contributions from JPL, ARC, GRC, DOD, and industry.

The Anchor Nodes project has progressed through pre-Phase A design activities and is currently conducting an extended risk reduction program. Risk reduction activities include propulsion thruster testing; thermal control testing and demonstration; low power avionics development; composite coupon testing and evaluation; landing leg stability and vibration; and demonstration of landing algorithms in the MSFC Lunar Lander Robotic Exploration Testbed, which was established in support of risk reduction testing to demonstrate ILN capabilities. An MSFC test vehicle using an Anchor Nodes-like design and a compressed air propulsion system is in use for demonstration of control software. A second version of the MSFC vehicle is planned that will utilize an alternate propulsion system for longer duration flight and descent testing. The upgraded test vehicle will also integrate flight-like components for risk reduction testing, such as landing sensors (cameras, altimeters), instruments, and structural features (landing legs, deployment mechanisms).

International Participation: Representatives from space agencies in Canada, France, Germany, India, Italy, Japan, the Republic of Korea, the United Kingdom, and the United States agreed on a statement of intent for near and long-term evolution and implementation of the ILN. Working groups are addressing potential landing sites, interoperable spectrum and communications standards, and a set of scientifically equivalent core instrumentation to carry out specific measurements.

Summary: The concept of an International Lunar Network provides an organizing theme for US and International landed science missions in the next decade by involving each landed station as a node in a geophysical network. Creation of such a network will dramatically enhance our knowledge regarding the internal structure and composition of the moon, as well as yield important knowledge for the safe and efficient construction and maintenance of a permanent lunar outpost.