The Importance of Establishing a Global Lunar Seismic Network. C. R. Neal[1], [1]Dept. Civil Eng. & Geological Sciences, University of Notre Dame, Notre Dame, IN 46556, USA [neal.1@nd.edu].

Introduction. Lunar seismicity is about equal to that of intraplate earthquakes, including those that have been catastrophic [1]. Data from the Apollo seismic network continues to yield information regarding seismicity, structure, and the lunar regolith [2-8]. This paper builds upon the work of [9].

Four types of Moonquakes occur [3,10]. **1) Deep Moonquakes** – the most abundant type with >7,000 events recognized [5,6,11] originating from 700-1,200 km depth. These small-magnitude events (<3) are strongly associated with tides [3,10] and originate from specific locations (nests). To date, 318 nests have been identified [6]. **2) Thermal Moonquakes** – much smaller in magnitude than 1). Recorded events originated from many isolated locations within a few km of each Apollo seismic station [12], occurring at regular monthly intervals. The highest activity occurred 2 days after sunrise probably triggered by thermoelastic stresses at the lunar surface. **3) Shallow Moonquakes** – the strongest type, with the 3 largest ones recorded being >5 magnitude [9,13-15]. Exact focal depths are unknown because all recorded events were outside the limited network. Indirect evidence [15] suggests depths between 50-200 km. They are not correlated with tides but may be associated with boundaries between dissimilar surface features. **4) Meteoroid Impacts** - while most of the energy of an impact is expended excavating a crater, some is converted to seismic energy. Between 1969-1977, >1,700 events representing meteoroid masses of 0.1-100 kg were recorded. Events generated by smaller impacts were too numerous to be counted [12,16].

Relevance of Moonquakes. 2 types of moonquakes pose hazards to a long-term Moon base: shallow moonquakes and those caused by meteoroid impacts. [Note: although seismicity generated by the latter should not threaten any structure, a direct impact most certainly would.] Only 28 shallow Moonquakes were recorded in 8 years but they contain greater energy at high frequencies than earthquakes of comparable total energy. While surface waves are more scattered due to the nature of the regolith and prevent efficient long-range propagation, lunar seismic waves are much less attenuated than in Earth [17] so the effects of a shallow moonquake will still be felt much further than a comparable earthquake. The lack of global coverage by the Apollo seismic network has left many unknowns. For example, shallow moonquakes can be of sufficient magnitude (>5) to cause moderate structural damage (on a terrestrial scale). The effect of a >5 magnitude quake on a Moon base could be catastrophic. Currently, we do not know the causes or locations of these moonquakes. Furthermore, sites of meteoroid impact recorded between 1969-1977 are unpredictable. A direct hit from a body >0.1 kg would be catastrophic.

Need for a Global Lunar Seismic Network. This is required to locate the origins of the different types of moonquakes, especially those that could compromise a Moon base. **1)** A statistical analysis of meteorite impact sites is required to determine if the Moon base site has a statistically low probability of receiving a sizeable meteoroid impact. **2)** Understanding the nature and location of shallow moonquakes is required so the Moon base site is not in a seismically active area. These examples are prudent in terms of safety and to protect the required investment.

Required Technological Advances. An international group of scientists has been investigating the challenges of establishing a global **Lu**nar **Se**ismic **N**etwork [18-20] through the **LuSeN** mission. A modest network requires 8 seismometers (preferably 10) to be deployed around the Moon and be active for 5-7 years. Soft and hard landing options have been explored. Both have their limitations, which require technological advances in 3 inter-related areas: 1) Deployment - mass must be reduced through hardware miniaturization; 2) Hardware - needs to be more robust such that the mass required for deployment can be reduced; 3) Power - development of robust mini radionuclear thermoelectric generators (RTGs) that can maintain a power supply of 3-5 watts over 5-7 years yields a huge mass reduction. Developing such technology for a LuSeN-type mission will allow for similar exploration of Mars and beyond.

Conclusions. A global lunar seismic network is required to safely establish a long-term Moon base. The Apollo seismic experiment highlights the dangers of shallow (tectonic) moonquakes and meteoroid impact events to any habitable structure. Shallow moonquakes need to be better characterized, and the effect of ground motion needs to be investigated [8], along with a statistical analysis of meteoroid impact locations. The Moon is a technology test bed for establishing such networks on Mars and beyond to facilitate safe exploration as well as advance our understanding of planetary interiors.

References: [1] Nakamura Y. PLPSC 11th, 1847. [2] Nakamura Y. et al. (1976) *PLSC 7th*, 3113. [3] Nakamura Y. et al. (1982) *JGR 87*, A117. [4] Lognonné P. et al. (2003) *EPSL 211*, 27. [5] Nakamura Y. (2003) *PEPI 139*, 197. [6] Nakamura Y. (2005) *JGR 110*, E0101. [7] Strangway D. (1985) in *Lunar Base Space Act*., 265. [8] Johnson D. et al. (1982) *JGR 87*, 1899. [9] Oberst J. & Nakamura Y. (1992) *2nd Conf. Lunar Base Space Act*., 231. [10] Lammlein et al. (1974) *Rev. Geophys. Space Phys. 12*, 1. [11] Bulow et al. (2004) *LPS XXXV* #1184. [12] Duennebier F. & Sutton G.H. (1974) *JGR 79*, 4351. [13] Nakamura Y. (1997) *En. Planet. Sci*., 513. [14] Nakamura Y. (1979) *PLPSC 10th*, 2299. [15] Nakamura Y. (1980) *PLPSC 11th*, 1847. [16] Latham G.V. et al. (1978) *PLPSC 9th*, 3609. [17] Nakamura Y. & Koyama (1982) JGR 87, 4855. [18] Neal C.R. (2002) *The Moon Beyond 2002 Wksp, LPI*. [19] Neal C.R. et al. (2003) *LPS XXXIV*, # 2035. [20] Neal C.R. et al. (2004) *LPS XXXV* # 2093.