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Scoping MEMS Seismometers for Deployment on the Moon

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Commercial Lunar Payload Services (CLPS) is a NASA program to acquire end-to-end commercial pay-load services between the Earth and lunar surface. The competitive nature of the program is expected to reduce the cost of lunar exploration. Proposals from commercial partners are currently being solicited.

Here, we consider the advantages of including MEMS-type seismometers on one or more landed missions. Micro-Electro-Mechanical Systems (MEMS) sensors are small, lightweight sensors etched on a silicon wafer. A critical question is whether the instrument is likely to detect sufficient moonquakes given missions that may only extend during a single lunar day (approximately two weeks in Earth-time). In order to assess the deployment quantitatively, we can com-pare estimated instrument response and noise characteristics to documented lunar seismicity from Apollo data.

The SEIS-SP sensor is a low-mass, but still relatively broadband seismometer that uses a silicon MEMS sensor. It was developed by Imperial College, the University of Oxford and Kinemetrics. The sensor formed part of the SEIS package on the InSight mission, and was initially deployed on Mars in late 2018. The sensor is a small and robust instrument. It is through-wafer etched and patterned in single-crystal silicon, with a 25 mm die size. Three sensors measure all three components of translational motion. The combined package for InSight had a total mass of 635 g for the sensor heads, electronics board and associated connectors and cabling, making such a system potentially very promising for deployment on future commercial lunar landers. The performance of the current generation of SEIS-SP sensor is limited by the thermal noise floor from gas damping within the package. The noise floor can be further improved by evacuating the chamber. The lunar environment reduces the risks of leaks, making this a low-risk option for the Moon, and potentially improving detection rates. We investigate the effectiveness of deploying the SEIS-SP or other lightweight instruments with similar self-noise and response characteristics for missions of varying lengths.

The Apollo missions included surface deployments of seismometers that ran at multiple landing sites over periods between 1969 and 1977. Using the seismic data available from the seismometers deployed by astronauts during these missions, we investigate the magnitude of moonquakes which would be above the detection thresholds for various MEMS seismometers. Instruments deployed during the Apollo era detected several types of events, including artificial impacts, meteoroid strikes, shallow and deep moonquakes and thermal events. Given several years of operations for the Apollo instruments, we have excellent constraints on the lunar seismicity rate over the multi-year catalog. We also have constraints on diurnal variations for thermal events over the course of the lunar day/night cycle. Thermal quakes occur periodically, with a sharp double-peak at sunrise and a broad single-peak at sunset. Deep moonquakes have a clear correlation with the tidal phase of the Moon, with monthly periodicity of their occurrence times as well as tidally dependent variations in amplitude.

We investigate which types of moonquakes could be detected. Finally, we estimate detection levels for a short-duration mission.