MOTE LUNAR PENETRATOR ARRAYS FOR RAPID EXPLORATION OF EXTREME LUNAR TERRAINS T. Marshall Eubanks[1], W. Paul Blase[1], [1]Space Initiatives Inc , Newport, Virginia 24128 USA; tme@space-initiatives.com;

Introduction: Ballistic penetrators will support lunar science by allowing precursor missions to difficult to reach terrain, and by allowing for the rapid creation of instrument and communications arrays on the lunar surface [1, 2, 3].

Space Initiatives Inc (SII) has developed small "Mote" ballistic penetrators to provide commercial support for robotic and crewed operations on and near the Moon. The ∼1.5 kg Mote penetrators will have on-board processing, communications and sensors, and can be deployed from a CubeSat deployer. Motes could be delivered by a dedicated mission (and orbiter or even a lunar flyby) or, as shown in Figure 2, could be carried by lander transporting material to the lunar surface under NASA's Commercial Lunar Payload Services (CLPS) program. After deployment, Motes fall ballistically, impacting the surface at up to 300 m/s and penetrating 1 meter or more into the typical lunar regolith, resulting in a a sensor array spread, in a nominal mission with ± 10 m s^{-1} kick velocity, over ∼1 km of the lunar surface (see Figure 2).

Mote Ballistic Penetrator Instrumentation:. SII is developing a standard instrument package including a three axis accelerometer, three axis magnetometer, and subsurface thermometers and geophones. Mote penetrators within view of the Earth can also carry COMPASS Very Long Baseline Interferometry (VLBI) Beacons to enable their accurate global positioning on the lunar near-side [4]. Any deployment would immediately provide geotechnical information about the upper 1-2 meters of regolith in the penetrator landing area, from the penetrator deacceleration profile and its depth of penetration. Information about the thermal characteristics of the penetrated regolith will be provided by measurements of the temperature in the penetrator bore.

Deploying into Shackleton Crater: Ballistic penetrators will enable the rapid deployment of instruments into the most difficult lunar terrains, including the permanently shadowed regions. Figure 2 shows the deployment of Motes into Shackleton crater from a supposed CLPS landing delivery on the rim of the crater. In this mission profile the Motes are deployed 24 km downrange and 5 km above the mean lunar surface and take ∼78 seconds to reach the crater floor, ∼2.8 km below the mean lunar surface. At the time of their landing, the CLPS lander will still be well above the surface of the Crater rim and would be able to observe IR emissions from the gas plumes emitted by surface volatiles vaporized by Mote impacts. The chosen landing site is the ∼210 m high "mound unit," the largest feature on the Shackleton Crater floor [5]. The horizontal spread of the Mote's landing sites is sufficient to blanket the mound unit with penetrators.

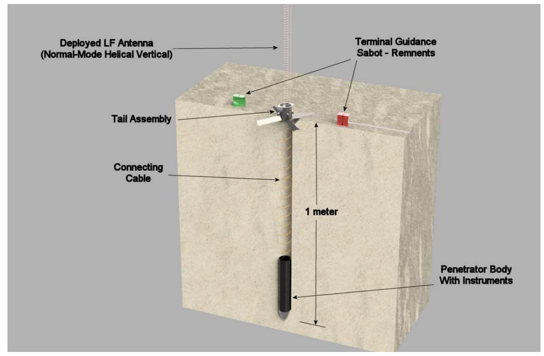

Figure 1: A Mote penetrator after deployment with a nominal 1 meter penetration into the lunar regolith. The electronics and most of the scientific payload would be carried in the penetrator itself and would be automatically deployed below the lunar surface. Cameras, other instruments, and communication antennas are carried in the tail section left on the surface.

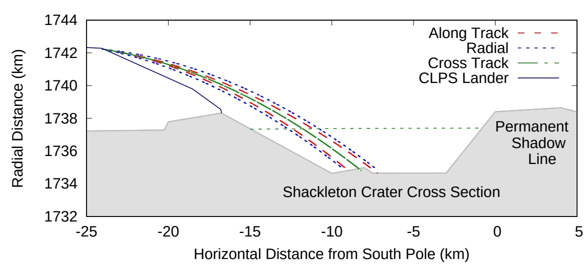

Figure 2: Deployment of Mote Penetrators into the Shackleton Crater PSR. The Motes are assumed to be deployed from a CLPS Lander early enough in the landing sequence to proceed into the center of the PSR, while the CLPS lander proceeds to soft land at the crater rim.

References: [1] S. Smrekar, et al. (1999) *J Geophys Res* 104(E11):27013 doi. [2] T. M. Eubanks, et al. (2020) in *Lunar and Planetary Science Conference* vol. 51 of *Lunar and Planetary Science Conference* 2805. [3] T. M. Eubanks, et al. (2020) in *Lunar Surface Science Workshop* vol. 2241 5167. [4] T. M. Eubanks (2020) *arXiv e-prints* arXiv:2005.09642. arXiv:2005.09642. [5] M. T. Zuber, et al. (2012) *Nature* 486(7403):378 doi.