Preparing for Seismic Investigations Using the Inertial Measurement Unit on the Volatiles Investigating Polar Exploration Rover (VIPER) Lunar Mission.

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Introduction: The Volatiles Investigating Polar Exploration Rover (VIPER) mission is set to launch for the lunar South Pole as part of NASA's Commercial Lunar Payload Services (CLPS) program [1]. The rover will traverse the areas around several permanently shadowed regions near Mons Mouton for approximately 100 days to characterize the distribution and physical state of lunar polar volatiles in lunar cold traps and regolith [1]. There is still a lack of consensus regarding how deep volatiles may be stored in the lunar crust [2,3,4,5]. The Regolith and Ice Drill for Exploration of New Terrains (TRIDENT), VIPER's drill, will reach a maximum of 1020 mm into the surface. Thus, accessing deeper depths will require geophysical exploration.

We are characterizing how the VIPER inertial measurement unit (IMU) can capture rover movements as a seismometer to interrogate variations in lunar subsurface structure. Lewis et al., [6] demonstrated how the IMU on the Curiosity rover on Mars could be used for gravity science. The IMU selected for VIPER is the Northrup Grumman LN-200S IMU [7], which has three MEMS accelerometers to measure in three axes [8]. VIPER IMU data will be sampled at 100 Hz during select rover operations for active seismic studies.

Methods: Our goals are to 1) quantify the IMU sensitivity to seismic signals generated by VIPER and its systems; 2) characterize the rover transfer function; and 3) to develop seismic methods for assessing subsurface structure with these signals. In seismology, observed signals are made of four components: the instrument response, the source function, the transfer functions of rover itself, and the ground response. With a clear characterization of the accelerations caused by the rover's movements, the variability in seismic velocities and other properties of the lunar subsurface can be isolated and related to the presence of volatiles or other near-surface resources.

Source Characterization: TRIDENT will be the primary source of seismic energy that will be measured by the IMU. It has both percussive and rotational modes, at 16.2 Hz and 2 Hz, respectively [9]. Engineering models of the drill were tested and recorded by seismometers in a field test on the Bishop Tuff in Long Valley Caldera, California. Both the rotary and percussive modes of the instrument were recorded by a seismometer located a meter away from the source.

Rover Response: To characterize the transfer functions of each rover component, two IMUs with similar performance characteristics to the LN-200S will be used for each experiment as per [10]. One IMU will be located on the ground, ideally measuring only the IMU's instrument response, while the other will be located within 1m of the active instrument to estimate the IMU's location on the rover itself. By subtracting the power spectra of the control IMU from the IMU collocated with each instrument, the noise floor of the IMU and the transfer function between the ground and rover components can be approximated.

Preliminary Conclusions: While most of the Long Valley Caldera drill test data falls below the threshold of what an IMU should detect, some resonances from the percussive drilling may be observable in IMU data. In the drill test, the seismometer was not attached to the drill; as a result, the energy measured in the Bishop Tuff are likely smaller than what would be measured by an IMU coupled to a seismic source due to attenuation in the volcanic ash of the site. Furthermore, the instrument sensitivity may be different under lunar and vacuum conditions, affecting attenuation and total energy transmitted. Thus, further experiments are needed.

Future Work: Forthcoming experiments of the TRIDENT in a vacuum chamber on various substrates will be used to further constrain the expected IMU measurements during drilling operations on the lunar surface. Additionally, VIPER is using a new wheel design and suspension system that has never flown before. As a result, numerous studies of the wheel and suspension system have been conducted, including a 40 km endurance test [11]. As the wheels and suspension continue testing before launch, it is critical to measure expected accelerations on the IMU both for the wheels as a seismic source when the rover is driving and as a conduit of seismic energy during drilling and other activities.

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