VIPER Geospatial Data for Site Selection and Traverse Planning Ross A. Beyer[1,2], O. Alexandrov[2], E. Balaban[2], A. Colaprete[2], M. Shirley[2], J. Martinez-Camacho[3], and M. Siegler[3]. [1]SETI Institute (rbeyer@seti.org), Mountain View, CA, [2]NASA Ames Research Center, Moffett Field, CA, [3]Planetary Science Institute, Tucson, AZ, and Dept of Earth Sciences, Southern Methodist University, Dallas, TX

The Volatiles Investigating Polar Exploration Rover (VIPER) mission will conduct exploration science by mapping volatiles near the Lunar South Pole [1] starting in late 2024. VIPER's "Mission Area," is approximately 8 × 7 km centered at 31.6218° E, 85.42088° S within which VIPER will land and carry out its primary mission. We have also identified an "Extended Mission Area" which we may be able to explore, these areas are described by:

Primary POLYGON((30.48 −85.368, 32.626 −85.367, 32.666 −85.49, 30.461 −85.491, 30.48 −85.368))

Extended POLYGON((27.986 −85.14, 33.571 −85.146, 33.728 −85.509, 27.693 −85.50, 27.986 −85.14))

whose coordinates are in a longlat system.

Selection of the landing site within this area and the traverse route are still pending. This abstract describes the variety of geospatial data that has been collected and is being used to perform analysis for landing site selection and traverse planning in these areas.

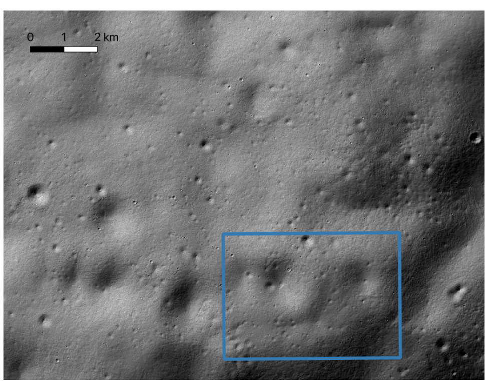

Figure 1: Shaded-relief of SfS terrain over the Extended Mission Area, Primary Mission Area outlined in blue.

Terrain: Initial studies [2, 3] used 20 m/pixel Lunar Orbiter Laser Altimeter (LOLA) data, but when the Mission Area was selected, we began work on a higher resolution terrain model. We started with improved LOLA shot data [4], and Lunar Reconnaissance Orbiter Camera (LROC) narrow angle image data [5]. We bundle-adjusted the LROC images that covered the area. We built stereo models from in the area where we could and aligned them to LOLA. We performed subsequent bundle adjustment rounds so that the images were well-aligned to each other and the terrain. All of these tasks were performed with the Ames Stereo Pipeline [6, 7]. Then we applied the Shape-from-Shading (SfS) algorithm [8] to generate a 1 m/pixel terrain model that covered the entire 14 × 11 km Extended Mission Area (Fig. 1).

Of course, many areas (especially crater floors) are unlit in all of the 800+ LROC images. If these areas were small enough, the SfS algorithm attempted to interpolate across the unlit areas. Larger areas are filled in with improved LOLA data, and then blended to the SfS terrain. A "weight" product is produced to show which pixels were SfS pixels, which were LOLA, and which were blended. A "mask" product is created to show which areas were un-illuminated and were either interpolated or filled with LOLA. A "height error" map is produced to estimate the relative error across the model, but the absolute error is the RMS error of the LOLA product.

Once a 1 m/pixel terrain product exists, many other corollary products can be produced that are all based on the terrain. A one-meter slope map is one of those products, and others are described below.

Orthoimages: A consequence of the bundle-adjustment needed for SfS is that the individual LROC images are now pixel-aligned to one another, and can be ortho-projected onto the 1 m/pixel terrain to create a set of LROC NAC orthoimages. It is very valuable to have this set of images and be able to flip them on and off to evaluate locations as they contain a variety of different lighting and texture information aligned to the terrain model. These orthoimages allow us to calculate a count map showing for each pixel in the extended mission area how many illuminated LROC NAC pixels there were (Fig. 2).

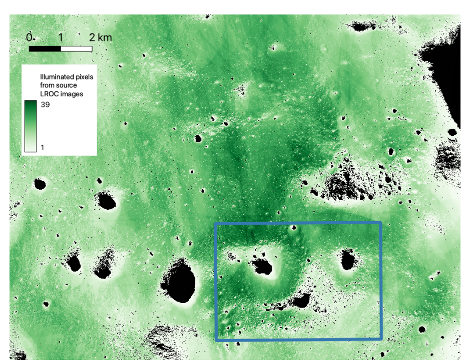

Figure 2: Extended Mission Area Map showing number of illuminated pixels from source LROC NAC images.

The difficulty with polar sites is that the solar azimuth swings around and it can be difficult to make mosaics without having to make several distinct mosaics where illumination directions are batched together and none of which tells the whole story. We have developed the concept of a maximally-lit mosaic [9] which takes all of the overlapping images, and for each pixel in the output mosaic selects the brightest pixel from the source images. This produces a mosaic that is representing all of the illuminated areas and is useful for providing an "overview" of the terrain for planning purposes (Fig. 3).

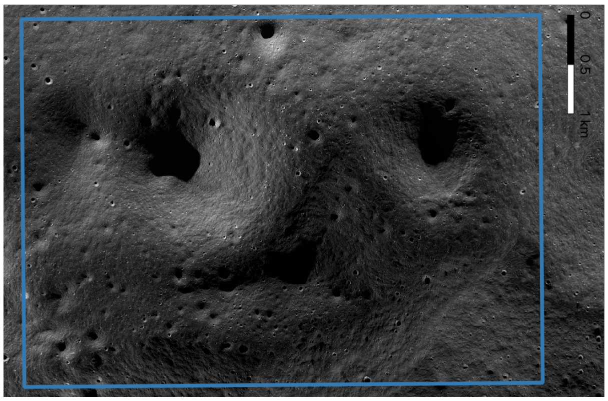

Figure 3: Maximally-lit mosaic of the Primary Mission Area.

Ice Stability Depth Map: The SfS model is converted to a mesh and a technique based on Siegler et al. [10] is applied which provides an estimate at each facet for the stability depth of ice. This is determined from a calculation of the depth profile of the maximum temperature (after many years of iteration to achieve a dynamic equilibrium), and the depth profile of a 1 mm/Ga loss rate. The loss rate changes with depth due to the inhibiting effects of the overburden, like a lag deposit that slows down diffusive loss. Some locations never cross this profile, and ice would not be "stable" against loss at any depth. In other locations, such as permanent shadow, the entire maximum temperature profile is below the 1 mm/Ga profile, and ice is stable from the surface down (until you cross the geotherm). VIPER is interested in the depths we can reach with NSS measurements, and accessible by the one-meter drill. We simplify the map to show areas where ice is stable at the surface, shallowly buried (0-50 cm), deeply buried (50-100 cm), or not stable within the top meter at all (Fig. 4).

While these maps mark the depth to which ice would be stable from sublimation, ice is not necessarily present as that depends on the local history of ice supply, loss and impact driven overturn. Therefore VIPER measurements will serve as a test of past delivery and retention of ice in these regions.

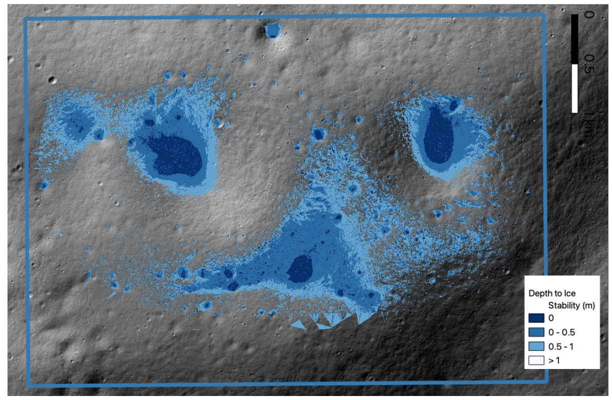

Figure 4: Ice Stability Depth Map of the Primary Mission Area.

Illumination and Communications Maps: The 1-m/pixel terrain maps combined with SPICE data of the Moon, the Sun, and the Deep Space Network Stations allow calculation of more precise solar illumination and Earth-communication maps which must be calculated every few hours for the duration of the mission as the Sun and Comm shadows significantly change.

Next Steps: The VIPER team will continue to build and refine the data products discussed above, and generate others for the Primary and Extended Mission Areas. The VIPER Team anticipates releasing all of this geospatial data to the PDS.

References: **[1]** A. Colaprete et al. "The Volatiles Investigating Polar Exploration Rover (VIPER) Mission Update". In: *LPSC*. Vol. 2678. 2022, p. 2675. **[2]** R. A. Beyer et al. "VIPER Site Selection". In: *LPSC*. Vol. 2678. 2022, p. 2479. **[3]** M. Shirley et al. "VIPER Traverse Planning". In: *LPSC*. Vol. 2678. 2022, p. 2874. **[4]** M. K. Barker et al. In: *P&SS* 203, 105119 (2021). DOI: 10.1016/j.pss.2020.105119. **[5]** M. Robinson. *LROC 2 EDR V1.0, LRO-L-LROC-2-EDR-V1.0*. Tech. rep. NASA PDS, 2009. **[6]** R. A. Beyer, O. Alexandrov, and S. McMichael. In: *ESS* 5 (2018), pp. 537–548. DOI: 10.1029/2018ea000409. **[7]** R. Beyer et al. *NeoGeographyToolkit/StereoPipeline 3.1.0*. 2022. DOI: 10.5281/zenodo.6562267. **[8]** O. Alexandrov and R. A. Beyer. In: *E&SS* 5.10 (2018), pp. 652–666. DOI: 10.1029/2018EA000390. **[9]** O. Alexandrov and R. A. Beyer. "Multi-View Shape-from-Shading for Planetary Images with Challenging Illumination". In: *LPSC*. Vol. 48. 2017, p. 3024. **[10]** M. A. Siegler et al. In: *Nature* 531.7595 (2016), pp. 480–484. DOI: 10.1038/nature17166.