The Volatiles Investigating Polar Exploration Rover (VIPER) Mission Update, A. Colaprete[1], R. C. Elphic[1], M. Shirley[1], K. Ennico-Smith[1], D. S. S. Lim[1], K. Zacny[2], J. Captain[3], M. Seigler[4], E. Balaban[1], R. Beyer[1,5], L. Falcone[1], Z. Mirmalek[1,6], D. Lees[1], [1]NASA Ames Research Center, Moffett Field, CA, [2]Honeybee Robotics, Pasadena, CA, [3]NASA Kennedy Space Center, FL, [4]Planetary Science Institute, Tucson, AZ, and the Department of Earth Sciences, Southern Methodist University, Dallas,TX, USA, [5]SETI Institute, [6]BAERI Institute.

Introduction: The Volatiles Investigation Polar Exploration Rover (VIPER) mission is a lunar polar volatiles prospecting mission developed through NASA's Science Mission Directorate (SMD) Planetary Science Division with launch in late 2023 [1]. The mission includes a rover-borne payload that (1) can locate surface and near-subsurface volatiles, (2) excavate and analyze samples of the volatile-bearing regolith, and (3) demonstrate the form, extractability and usefulness of the materials. VIPER's primary mission goal is to characterize the distribution of water and volatiles across a range of thermal environments. This characterization will assist in understanding the origin of lunar polar volatiles and also help evaluate the In-Situ Resource Utilization (ISRU) potential of the lunar poles. VIPER will be optimized for lunar regions that receive prolonged periods of sunlight (short lunar nights); prospectively, the mission duration will be more than 90 Earth days, and result in a traverse distance of up to 20 km.

Measurement Goals: A critical goal to both science and exploration is to understand the form and location of lunar polar volatiles. The lateral and vertical distributions of these volatiles inform us of the processes that control the emplacement and retention of these volatiles, thereby helping to formulate ISRU architectures. While significant progress has been made from orbital observations [2-6], measurements at a range of scales from centimeters to kilometers across the lunar surface are needed to validate "volatile mineral models" for use in evaluating the resource potential of volatiles at the Moon. To this end, the primary mission goals for VIPER are to (1) provide ground truth for models and orbital data sets, including temperatures at small scales, subsurface temperatures and regolith densities, surface hydration and hazards, (2) correlate surface environments and volatiles with orbital data sets, and (3) address key hypotheses regarding polar volatile sources and sinks, retention and distribution, key to developing economic models and identifying excavation sites.

Rover and Payload Design: The VIPER rover system design meets these scientific requirements as well as requirements imposed by the unique lunar polar environment, schedule, and budget. Detailed analyses of traverses, including rover models that include power, data, and mobility models, have found that a solar powered rover with Direct to Earth (DTE) communications could meet all mission goals within about one and a half Lunar days (mission length ~35 Earth days). Therefore, the simplest design utilizes only solar power with no radiogenic heating (e.g., Radioisotope Thermoelectric Generators (RTGs) or RHUs) or other non-solar/battery power systems.

The rover navigation system utilizes eight cameras, including gimbaled stereo navigation cameras located on a 2 meter mast, fixed stereo cameras at the rear of the rover, and hazard cameras near each rover wheel. LED lamps provide illumination for these cameras as needed. The position and pose of the rover are determined using a star tracker and Inertial Measurement Unit (IMU).

Table 1 VIPER Payload / Measurement Summary

Instrument	Measurements	Observations
NSS	Thermal and Epithermal Neutrons	Water Equivalent Hydrogen and burial depth along traverse
NIRVSS	NIR reflectance spectra from 1300-4000 nm	Surface composition (minerology, hydration, frosts) along traverse and from drill cuttings pile
	Imaging (2048 x 2048 pxl max resolution) with 7 color LEDs from 348 to 940 nm	Context imaging below the rover along the traverse; High resolution imaging (<100 um/pxl) at drill sites
		Imaging of drill cuttings pile
	Thermal Radiometry at 10, 14, 18 and 6-25 um	Surface temperatures under the rover and during drilling down to <100 K
MSolo	Mass spectra between 1-70 amu	Subliming surface volatiles along traverse and from drill cuttings pile
		Key isotope ratios
TRIDENT	Excavation of subsurface material in 10 cm increments down to 100 cm	Regolith geomechanically properties, including discerning ice-rich from dry regolith
	Subsurface temperatures at 2 locations (separated by 20 cm)	Subsurface temperatures and thermal conduction

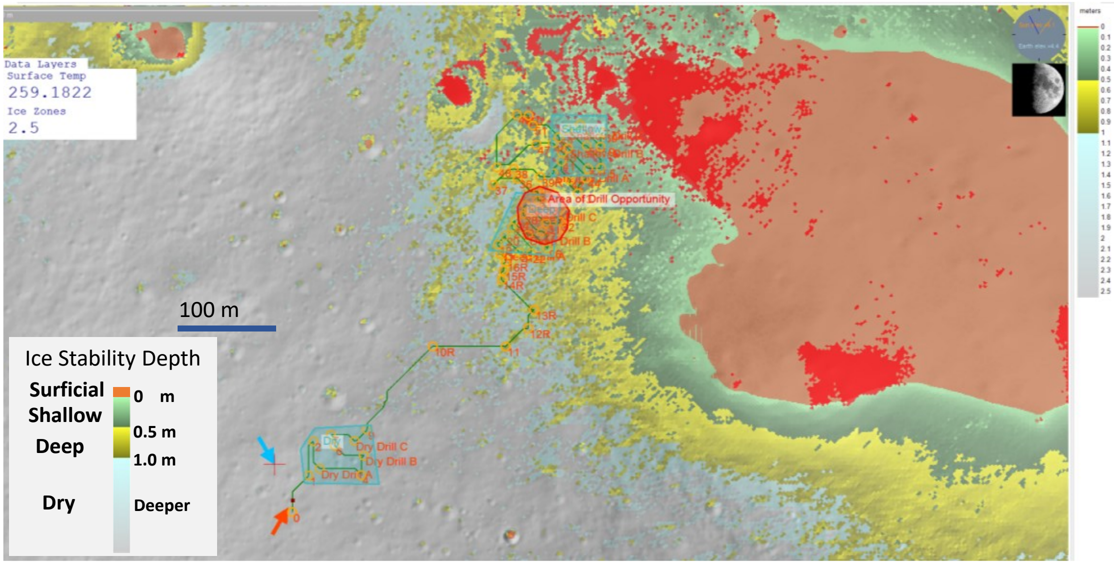

Figure 1 Traverse planning example against high resolution data products within the Mission Area west of the crater Nobile. The colors indicate locations where the subsurface temperature is predicted to allow for long-term water ice stability.

The VIPER payload [7] consists of three "prospecting" instruments which operate continuously while roving, including the Neutron Spectrometer System (NSS), the Near InfraRed Volatiles Spectrometer System (NIRVSS) and the Mass Spectrometer observing lunar operations (MSolo). A 1-meter auguring/percussive drill called the The Regolith and Ice Drill for Exploration of New Terrains (TRIDENT) is used to bring subsurface cuttings to the surface in 10 cm increments where they are interrogated by NIRVSS and MSolo. TRIDENT also includes a temperature sensor at the bit and a heater/temperature sensor combo 20 cm above the bit. As such, TRIDENT would be able to provide downhole temperature and thermal conductivity. A summary of each instrument's measurement and observations is provided in Table 1.

Polar Solar "Safe Havens": Numerous studies have identified regions near the lunar poles that have sustained periods of solar [e.g., 8-9]. In some cases, the periods of sustained sunlight extend across several lunations, while others have very short (<50 hours) nights. While the Earth would set, as seen by the rover, approximately every 2-weeks, these "Safe Havens" could provide enough power, and have lunar-nights short enough, for the rover system to survive. VIPER returns to one of these areas each lunar day to wait out the loss of communications with Earth.

Multi-Lunar Day Mission Traverses: In September 2021 the VIPER Mission Area, an approximately 10 x 10 km area west of the crater Nobile, was approved by SMD. Traverse planning continues within the Mission Area including traverse planning against high resolution data products, for example 1 meter DEM and 4 meter thermal maps (Figure 1). The mission planning is organized into two phases, including an "early" phase during which rover traversing and observations follow as much of a pre-planned schedule as possible and "late" phase, during which more real-time decision making is implemented and reactions to "early phase" findings are enabled. Both phases take advantage of the near real-time communications with the rover and real-time geostatistical analysis methods to maximize observation effectiveness.

Unlike Mars rover missions, VIPER's operations demand real-time decision support in order to make progress in a challenging and dynamic lighting and communications environment. Operators and scientists will have access to up-to-the-minute measurements and rover and instrument status. A team in VIPER's Mission Science Center (MSC) will advise and support real-time operations in order to maximize science return. For example, TRIDENT drill hole placement and subsequent sample analysis activities will be guided by both the MSC and Mission Operators.

References:

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