The Volatiles Investigating Polar Exploration Rover (VIPER) Near Infrared Volatile Spectrometer System (NIRVSS).

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Introduction: NASA's VIPER mission is planned for delivery to the lunar surface in late 2023 [1]. VIPER's science objectives are to: 1) characterize the distribution and physical state of lunar polar water and other volatiles in lunar cold traps and regolith to understand their origin and 2) provide the data necessary for NASA to evaluate the potential return of relying upon in-situ resource utilization from the lunar polar regions [1]. The NIRVSS instrument, matured through several R&D programs to TRL 6 [2,3,4], has been chosen as part of the VIPER science payload [5].

NIRVSS Scientific Objectives: NIRVSS is a multi-component system enabling observations that characterize lunar surface composition, morphology, and thermophysical properties during rover traverse, throughout areas of targeted volatile investigation (called science stations), and during drilling activities.

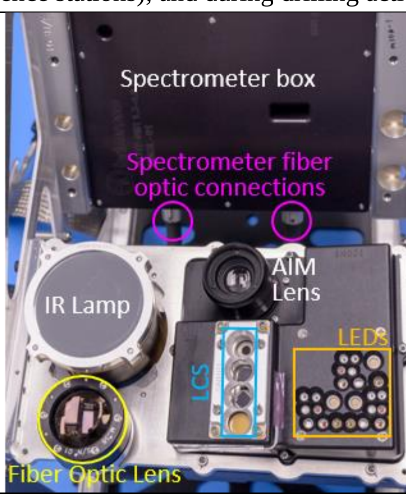

Figure 1. CLPS Mission 1 NIRVSS unit spectrometer (top) and bracket assembly with several components labeled (bottom, see text for their description).

Figure 1 shows a precursor to the VIPER NIRVSS payload represented by the two CLPS Mission 1 NIRVSS units: the bracket assembly (bottom) and spectrometer box (top). These are connected via electronic, data communication, and fiber-optic cables and will be reconfigured and attached bottom of the VIPER rover payload deck. The system total mass is ≈ 3.6 kg and draws ≈ 30 W when all subsystems are powered.

The Spectrometer Box contains two commercially modified spectrometers with their controlling electronics (Brimrose Corporation of America). The independent, fiber-optic fed, short-wave (SW) and long-wave (LW) spectrometers cover 1300-2500 and 2200-4000 nm with a minimum of 1 nm spectral sampling and spectral resolutions of <20 and <50 nm, respectively. Each spectrometer has two gain settings. On board spectral subsampling and spectral binning provide additional flexibility in data management. Figure 2 illustrates the compositional capabilities of NIRVSS for ices (top) and minerals, as well as, organics (bottom).

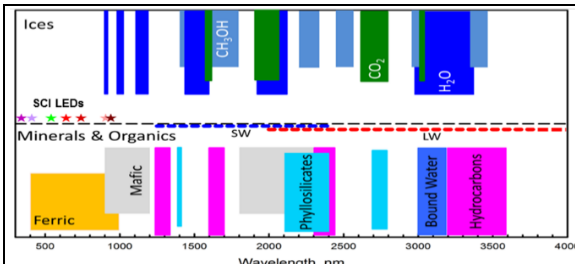

Figure 2. NIRVSS LEDs (stars) and spectrometers (blue and red dashed lines) spectral coverage. The top and bottom panels show spectral features associated with ices and minerals/organics, respectively.

The Bracket Assembly includes 1) the Ames Imaging Module (AIM) is a 4 megapixel CMOS sensor using multiple LEDs, (Fig. 1, orange rectangle) for wavelength discrimination between 348 and 940 nm (Fig. 2, stars) provides context for the spectrometer and LCS observations and document the morphological characteristics of the surface; 2) the Longwave Calibration Sensor (LCS) with 4 thermopiles and associated filters (6-25, 10, 14, and 18 μm, Fig. 1, blue rectangle), monitors surface temperature variations down to ≈ 100 K and provides an independent capability for thermal contribution removal from the observed NIR spectra; 3) a dual filament tungsten IR Lamp, filtered to transmit only ≈1150-5000 nm, provides illumination when needed and to enables simultaneous imaging and spectral measurements; and 4) a fiber optic lens (Fig. 1, yellow oval) that is connected to the fiber inputs on the spectrometer box (Fig. 1, magenta ovals).

NIRVSS to rover communication is via RS-422 and NIRVSS data is time synchronized and forwarded by the rover avionics for relay to Earth. The NIRVSS instrument will typically be operated via established sequenced commands. However, the ability to change instrument modes in near-real time is available.

NIRVSS VIPER Concept of Operations: During pre-launch NIRVSS will be powered to confirm system health and functionality. NIRVSS will not be powered during launch, orbital, or landing phases of the mission. During cruise, NIRVSS will perform a full functional check and instrumental bakeout. After landing, NIRVSS will observe a calibration plate prior to the rover leaving the lander. For surface operations NIRVSS will be continuously collecting imaging, spectral, and surface temperature measurements during rover traverses between science stations. Imaging capabilities can use windowing (subarray) and pixel binning if required during lower-bandwidth surface operations. At each drilling site NIRVSS will collect a full suite of LED, spectral, and LCS observations prior and subsequent to drill activities. During drilling NIRVSS will acquire continuous spectral and LCS observations and imaging, at selected LED wavelengths, of the location where the drill cuttings pile will accumulate. These observations will document the morphology, temperature, and compositional behavior of the subsurface materials as it is exposed at the surface. A calibration target attached to the drill foot is observed in each AIM image.

There is significant overlap between the NIRVSS spectrometer and MSolo [5] instrumental fields-of-view (FOVs, Fig. 3) providing synergy between measurements of gaseous (MSolo) and solid (NIRVSS) species before, during, and after TRIDENT drilling activities, as well as during traverses.

Summary: NIRVSS observations during VIPER will provide the ability to monitor variations in surface reflectance properties throughout the mission duration. NIRVSS will observe drill cuttings as they are emplaced on the surface to document the morphology, temperature, and composition of subsurface materials. These observations can be used to address surface composition and any variation of volatiles including water, carbon dioxide, and methane, if present, with time. The spatial context of the spectral observations is provided by the simultaneous imaging sequences. The surface thermophysical response of the surface under the rover and during drilling will be measured. Data will be delivered to the Planetary Data System (PDS) after end of mission.

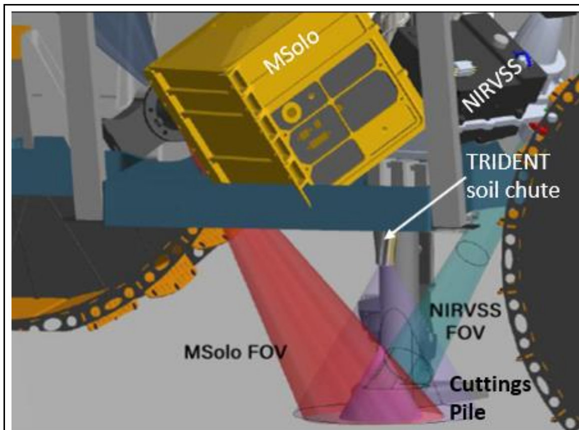

Figure 3. CAD model (courtesy of Honeybee Robotics) showing the intersection of the FOVs of MSolo (red) and NIRVSS spectrometer (green), when mounted below the VIPER rover, relative to the TRIDENT cuttings pile (purple cones). The small and large purple cones represent the cuttings pile with a 60° angle of repose after 10 cm and 100 cm of drill cuttings, respectively.

Acknowledgments: NIRVSS was originally developed for the former Resource Prospector mission. We thank NASA's Advanced Exploration Directorate, and Human Exploration and Operations Mission Operations Directorate for continued support of NIRVSS. The CLPS version is funded by NASA Provided Lunar Payloads (NPLP).

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