DOCUMENTING SURFACE AND SUB-SURFACE VOLATILES WHILE DRILLING IN FROZEN LUNAR SIMULANT. T.L. Roush[1], A.M. Cook[2], A. Colaprete[1], R. Bielawski[2], E. Fritzler[2], J. Benton[3], B. White[1], J. Forgione[1], J. Kleinhenz[4], J. Smith[5], G. Paulsen[6], K. Zacny[6], and R. McMurray[1] [1]NASA Ames Research Center, Moffett Field, CA 94035, Ted.L.Roush@nasa.gov, [2]Millennium Engineering, Sunnyvale, CA, [3]Wyle Labs, Houston, TX, [4]NASA Glenn Research Center, Cleveland, OH, [5]NASA Kennedy Space Cener, FL, [6]Honeybee Robotics, Pasadena, CA

Introduction: NASA's Resource Prospector (RP) mission is intended to characterize the three-dimensional nature of volatiles in lunar polar regions and permanently shadowed regions [1]. RP is slated to carry two instruments for prospecting purposes. These include the Neutron Spectrometer System (NSS, [2]) and Near-Infrared Volatile Spectrometer System (NIRVSS, [3]). A Honybee Robotics drill (HRD, [4]) is intended to sample to depths of 1 m, and deliver a sample to a crucible that is processed by the Oxygen Volatile Extraction Node (OVEN, [5]) where the soil is heated and evolved gas is delivered to the gas chromatograph / mass spectrometer of the Lunar Advanced Volatile Analysis system (LAVA, [6]).

For several years, tests of various sub-systems have been undertaken in a large cryo-vacumn chamber facility (VF-13) located at Glenn Research Center [7-9]. In these tests a large tube (1.2 m high x 25.4 cm diameter) is filled with lunar simulant, NU-LHT-3M, prepared with known abundances of water. There are thermocouples embedded at different depths, and also across the surface of the soil tube. The soil tube is placed in the chamber and cooled with LN2 as the pressure is reduced to ~5-6x10^{-6} Torr. Here we discuss May 2016 tests where two soil tubes were prepared and placed in the chamber. Also located in the chamber were 5 crucibles, an Inficon mass spectrometer, and a trolly permitting x-y translation, where the HRD and NIRVSS, were mounted. The shroud surrounding the soil tube was held at different temperatures for each tube to simulate a warm and cold lunar environment. Table 1 provides a summary for each soil tube.

	Table 1	
Date	17 May 2016	26 May 2016
Name	Soil Tube 1 (ST1)	Soil Tube 2 (ST2)
Shroud Temperature	223 K	93 K

Once the average soil temperature reached ~178 K, drilling operations commenced. Five holes were drilled, in 10 cm increments, with the soil from the 30-40 cm depth delivered to a crucible. For a sub-set of the holes, depths to ~70 cm were drilled. During drilling activities the mass spectrometer operated continuously and NIRVSS was alternating between obtaining spectra and obtaining images using LED illumination. Here we focus on the NIRVSS spectral data and relate these to drilling activity.

NIRVSS consists of two components; a spectrometer box (SB) and bracket assembly (BA), connected by two fiber optic cables. The SB contains separate short- and long-wavelength spectrometers, SW and LW respectively, that collectively span the 1600-3400 nm range. The BA contains an IR emitter (lamp), drill observation camera (DOC, 2048 x 2048 CMOS detector), 8 different wavelength LEDs, and a longwave calibration sensor (LCS) measuring the emissivity of the surface at four IR wavelengths. Figure 1 illustrates the nominal overlap of the various NIRVSS component fields-of-view (FOVs), the drill foot, and the top of the soil tube.

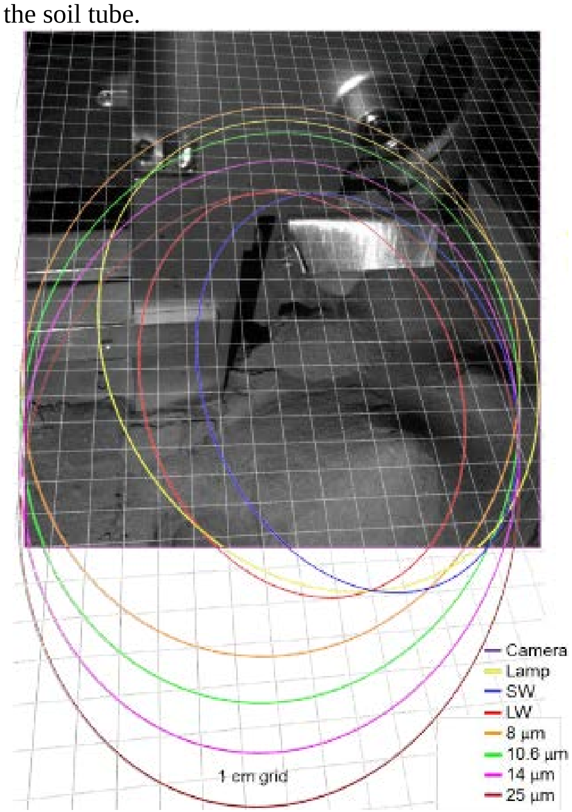

Figure 1. NIRVSS component fields-of-view using the DOC image as the reference frame.

Spectral parameters to track volatile behavior: Fig. 2 shows the laboratory spectrum of granular water ice over the region sampled by NIRVSS SW and LW. Diagnostic signatures of ice occur near 2000 and 3000 nm. Two band depths (BD2000 and BD3000) were defined to track behavior of ice as a function of time, and hence drill position, and shown in Fig. 2.

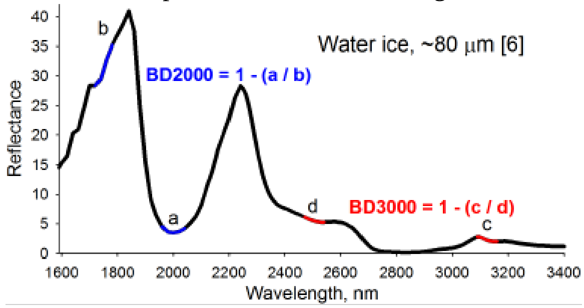

Figure 2. Ice parameters for monitoring water ice.

Results: Fig. 3 shows the drill depth (black lines), BD2000 (blue lines), BD3000 (red lines), and brush zone (dashed line) the entire drilling sequence for each soil tube.

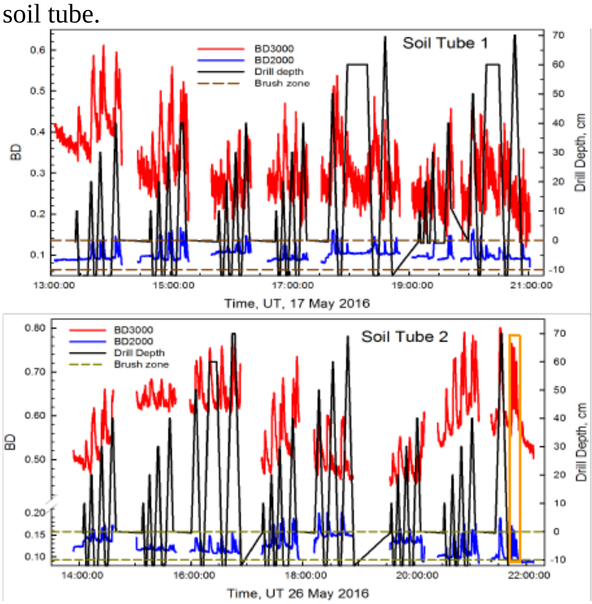

Figure 3. Volatile parameters (BD 2000 and BD3000) are shown for ST1 (top panel) and ST2 (bottom panel) along with the drill depth. Negative drill depths are above the soil surface where the bottom 10 cm of the drill stem is being actively brushed.

As shown in Fig. 3, both BD parameters increase as the drill stem is brushed and soil is deposited on the surface within the FOVs of the spectrometers. This behavior is also seen in some drill holes, as new material is encountered at depth and transported up the drill stem and is deposited onto the surface. There is a complex, repeatable, interaction between the drilling activity and soil deposition into the NIRVSS FOVs.

To characterize sublimation, we used the end of drilling in ST2. Imaging clearly showed that the funnel depositing soil to the surface was full for the last drill hole, approximately 21:45:00 UT. We requested 3, one second percussions from the drill and the BD behavior of these are shown in Fig. 4.

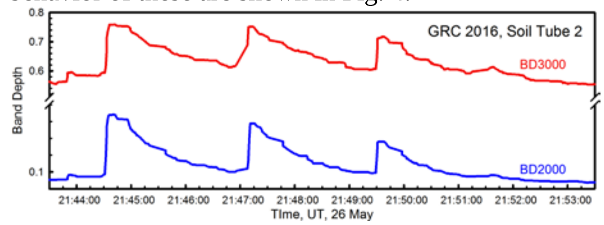

Figure 4. Enlargement of the orange rectangle in bottom of Fig. 3 showing the percussive activity.

Both BDs quickly rise with percussion and decay to near background levels in approximately 2.5 minutes.

Conclusions: BDs derived from the NIRVSS SW and LW spectrometers both document the appearance and disappearance of water ice as drilling occurs. This demonstrates the ability of NIRVSS to monitor ice as a function of depth in real time. The NIRVSS BDs also provide an estimate of the time required for exposed ice to sublime in simulated cold lunar environment and provide data for soil diffusion models.

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