ROVER-BASED RECONNAISSANCE WITH AN INFRARED SPECTRAL MAPPER AND REAL-TIME DATA PROCESSING. C. I. Honniball[1], K. E. Young[1], A. D. Rogers[2], P. G. Lucey[3,4,5] D. Piquero[5], B. Wolfe[5], and T. D. Glotch[2], [1]NASA Goddard Space Flight Center, Greenbelt, MD, USA (casey.i.honniball@nasa.gov), [2]Department of Geosciences, Stony Brook University, Stony Brook, NY, USA, [3]Hawaii Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, Honolulu, HI, USA, [4]Department of Earth Science, University of Hawai'i at Mānoa, Honolulu, HI, USA, [5]Spectrum Photonics, Inc., Honolulu, HI, USA

Introduction: During the Apollo missions, astronauts conducted experiments and geologic field work on the lunar surface. Of the twelve astronauts to set foot on the Moon, only one (Harrison Schmitt) had formal training in geology and field work. It was his keen-eye that spotted the orange soil that would later lead to revolutionary discoveries about the Moon [1-3]. The finding of the orange soil, however, relied upon a visual difference between the orange soil and the surrounding material and the expertly trained eyes of the crew. Unlike the orange soil, many compositionally interesting materials do not show unique colors in the visible or the variation with respect to its surroundings is so subtle that it cannot be detected by the unaided human eye [4].

Traditional field geology begins with large scale preliminary observations using aerial or orbital imagery from drones, airplanes, and satellites. In planetary science this remains true. Before Apollo astronauts landed on the Moon, maps of the lunar surface were created using satellite and telescopic images. These meter scale data sets are used prior to arrival to assess potential areas of interest, landing sites, and hazards. From orbit, however, it is not possible to have a local scale level of understanding of the site as these data are limited to meter scales and can be affected by viewing geometry and possibly complications due to nature (e.g. the atmosphere of Mars makes observations of the surface difficult during dust storms).

At a local scale, field geology is conducted using the unaided eye. However, to the unaided eye, many compositional variations are subtle or impossible to detect. The addition of spectral imaging instruments aims to complement the human perception of the scene by providing information of spectral features outside the human visual capabilities. Spectral images allow for faster definition of units in a quantitative manor in terms of relevant compositions. After unit definition, remote sensing at finer scales can provide context on individual grains and textures and may explain units.

Localized Infrared Spectral Imaging: There are three main advantages for implementing infrared spectral imaging into field work: 1) documentation of major compositional variations, 2) enhancement of visibly subtle or concealed variability in (sub) units, and 3) characterization of inaccessible outcrops [5]. Work conducted by Ito et al. (2018) [5] demonstrates ground-based spectral mapping of local terrain and its use during field analog work with the RIS[4]E (Remote, In Situ and Synchrotron Studies for Science and Exploration) SSERVI (Solar System Exploration Research Virtual Institute) team. They conclude that spectral mapping of the local area from the surface of a planetary body provides a critical link between orbital imaging and in-situ measurements and samples.

One such example could be a spectral imager on board a rover [5]. The imager would be automated to scan the surrounding area and process the data to create maps prior to astronauts setting foot outside for an EVA. The maps produced could be used to identify spectrally interesting samples and lithologies and may influence sample triage and traverse execution.

The Use of Spectral Mapping: Remote sensing of minerals and volatile components on planetary bodies plays a large role in understanding their interiors, surface processes, and potential resources. The infrared region from 2 to 14 µm is particularly useful for the detection of olivine, garnet, and volatile components including carbon dioxide, hydroxyl, molecular water and many other compounds. The RIS[4]E project has demonstrated the use of an imaging spectrometer operating in the thermal infrared in the field [5,6]. They have shown that crews can react in real-time to spectral anomalies and react appropriately. To expand on this work, and apart of RISE2 (a follow-on to RIS[4]E), we need to develop and test near real-time data processing and visualization.

During the RIS[4]E team field deployment to the Potrillo Volcanic Field in New Mexico a thermal infrared hyperspectral imager was deployed to simulate ground-based reconnaissance [5]. Data acquired from that field deployment are used to create spectral maps. In one scene, olivine clasts were set up next to a calibration target (Figure 1a). Post processing of the data reveal stark differences between what the unaided human eye can see in the visible wavelength region compared to thermal infrared spectral images specifically processed to show interesting spectral features.

Figure 1b shows the emissivity map of the location using 8.5, 9.1, and 11.3 µm depicted as blue, green, and red, respectively. Producing the emissivity maps at these specific wavelengths highlights a difference between the olivine clasts and the surrounding terrain that is not obvious in the visible image. Also the sur-

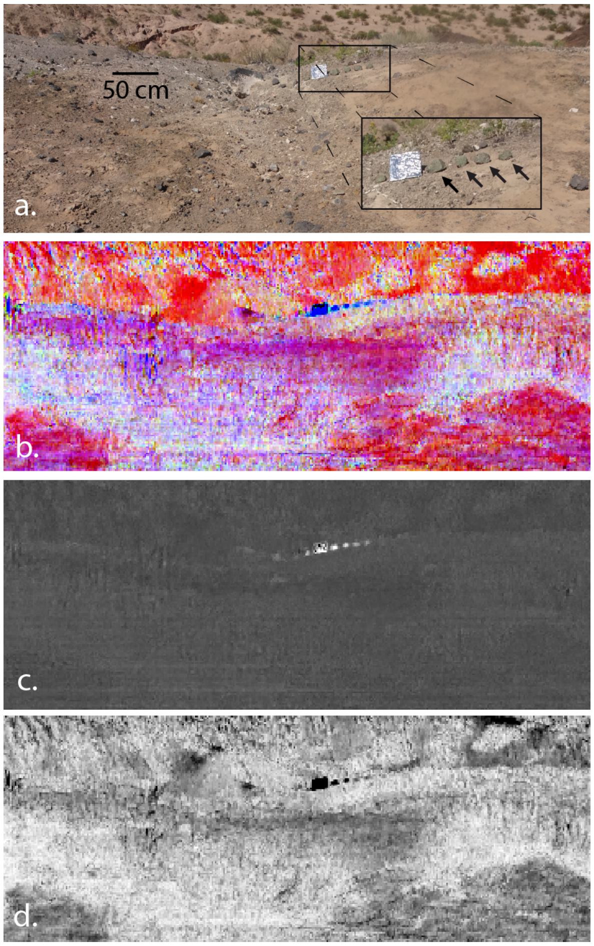

Figure 1: Data acquired at the Potrillo Volcanic Field in New Mexico with a square foil calibration target set up next to olivine clasts. a) Visible image of the scene with an insert zoomed in on the calibration target and clasts identified by arrows. b) Emissivity image using 8.5, 9.1, and 11.3 µm depicted as blue, green, and red, respectively. c) Index map specifically highlighting the olivine clasts using a band ratio of (10.01 µm + 12.11 µm)/10.88 µm. d) Image showing the first principle component analysis.

rounding terrain shows different units. A map such as this can provide initial sample collection sites, for example, the astronaut may want to collected a sample from the purple, white, red, and dark blue areas. This map also shows which areas may be similar in composition and therefore overly redundant sampling can be avoided.

Figure 1c shows an olivine index map made from the band ratio of (10.01 µm + 12.11 µm)/10.88 µm. This map specifically highlights olivine within the scene (indicted by white) but reduces all other variations in the surrounding terrain. A map such as this is useful for locating specific minerals and with different band ratios could highlight other minerals and also volatiles of interest, for example, garnet or hydration features like hydroxyl and molecular water. The last map, Figure 1d, shows the first principle component analysis over all 31 wavelengths. This map looks similar to the emissivity map in Figure 1b, however, subtle differences can be seen in the upper third of the image specifically in where the red dominates in Figure 1b.

Real-time Data Processing: The spectral maps clearly provide a means of detecting different geologic units and minerals of potential interest. However, in order for this type of instrument and con-ops to be useful in real EVA situations, the data needs to be collected and processed in real-time but also provide flexibility in which type of maps are created and displayed. Real-time processing and the flexibility to control the output requires access to a computer and necessitates more time [5].

In analog field work the time needed to set up a tripod mounted spectral imager, run calibrations, and take measurements is approximately 15 to 35 minutes [6]. A spectral imager mounted on a rover will not require physical set up by astronauts and therefore the setup time is constrained only by software set up lowering the estimated time it would take for the full procedure. Using the RIS^{4}E thermal infrared hyperspectral imager as an example of an instrument that could be mounted onto a rover and assuming a field of view of 180˚ in front of the rover, a full scan is estimated to take less than 2 minutes. Afterwards, processing the data through a pipeline streamlined to produce emissivity and spectral maps, such as those shown in Fig. 1, can be completed in real time with a few second delay. The map products would begin to be available within a minute from the start of the scan.

Conclusions: Spectral imaging on the surface of planetary bodies can provide a wealth of information about the composition and different units of a location selected for EVA's. Spectral mapping can indicate locations and samples that may be of high interest for sample triage. The maps can be produced prior to astronauts performing an EVA and aid in planning traverse paths. Maps will also provide information for inaccessible outcrops where in situ measurements and sampling is not possible and could also be used to relate more accessible samples (such as displaced rocks) to intact stratigraphy [5].

References: [1] Meyer et al. (1975). Proc. 6th Lunar Sci. Conf., 1673 1699. [2] Wasson et al. (1976) Proc. 7th Lunar Sci. Conf., 1583 1595. [3] Saal et al. (2008) Nature, 454, 192-195. [4] Hauff (2008) Spectral International Inc., 80001, 303–403. [5] Ito et al. (2018) *Earth and Space Science,* 5, 676–696. [6] Young et al. (2018) *Earth and Space Science,* 5, 697–720.