ENABLING SURFACE EXPLORATION AND HIGH-GRADING OF LUNAR SAMPLES WITH THE ADVANCED MULTISPECTRAL INFRARED MICROIMAGER (AMIM). J. I. Núñez[1], R. L. Klima[1], S. L. Murchie[1], H. E. Warriner[1], J. D. Boldt[1], S. J. Lehtonen[1], B. J. Maas[1], J. M. Greenberg[1], K. L. Anderson[1], T. W. Palmer[1], E. L. McFarland[1]. [1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723 (jorge.nunez@jhuapl.edu).

Introduction: To maximize scientific return, future robotic and human missions to the Moon will need to have *in situ* capabilities to characterize the geology near the landing site, prospect for lunar resources, and enable the selection of the highest value samples for analysis with other instruments and "high-grading" for potential return to Earth. In order to accomplish this task efficiently, samples will need to be characterized using a suite of compact instruments that can provide crucial information about elemental composition, mineralogy, volatiles and ices. Such spatially-correlated data sets, which place mineralogy into a microtextural context, are considered crucial for correct petrogenetic interpretations for improving our understanding of the Moon and for prospecting for potential lunar resources.

We have developed a prototype of the Advanced Multispectral Infrared Microimager (AMIM), a compact microscopic imager, for future robotic and human missions to provide *in situ* spatially-correlated mineralogical and microtextural information of rocks and soils at the microscale to support traverse characterization, geologic mapping, and facilitate the selection of samples for onboard analysis with other instruments and potential return to Earth (Figure 1) [1-3].

Background: Over the past decade, microscopic imagers such as those on the Mars Exploration Rovers [4], Phoenix lander [5], Mars Science Laboratory [6], and ROSETTA missions [7], have played such critical roles in those missions that microscopic imagers are considered essential tools for landed planetary missions [e.g., 8-9]. While these microscopic imagers have provided valuable microtextural information, they lack the ability to robustly discriminate mineralogy, essential for assessing petrogenesis.

Spatially-correlated microscale texture and mineralogy are essential for properly identifying rocks and soils *in situ* and interpreting their geologic histories. Combining microscopic imaging with visible/near-infrared reflectance spectroscopy provides a powerful *in situ* approach for obtaining mineralogy within a microtextural context. The approach is non-destructive, requiring minimal sample preparation, and provides data sets that are comparable to what geologists routinely acquire in the field using a hand lens and in the lab using thin section petrography. This approach also provides essential information for interpreting the primary formational processes in rocks and soils as well as the effects of secondary (diagenetic) alteration processes. Such obervations lay a foundation for inferring geologic histories and provide "ground truth" for similar instruments on orbiting satellites; they support astronaut EVA activities and provide basic information about the physical properties of soils required for assessing associated health risks, and are basic tools in the exploration for *in situ* resources to support human exploration of the Moon.

Instrument: AMIM features compact, low-power multispectral LED arrays coated with narrow-bandpass filters (> 20 wavelengths with FWHM ≤ 50 nm), an adjustable focus mechanism capable of focusing from a distance of few cms (spatial resolution ≤ 30 µm/pixel) to infinity with z-stacking and high depth of field, and an infrared camera capable of imaging from the visible/near-infrared to the shortwave-infrared (VNIR/SWIR, currently 0.4 - 2.6 µm) [1-3]. This wavelength coverage has wide applicability for the detection of minerals and ices. However, specific wavelengths and spectral range (up to 4 µm) can be easily tailored to address specific engineering requirements and enable lunar exploration.

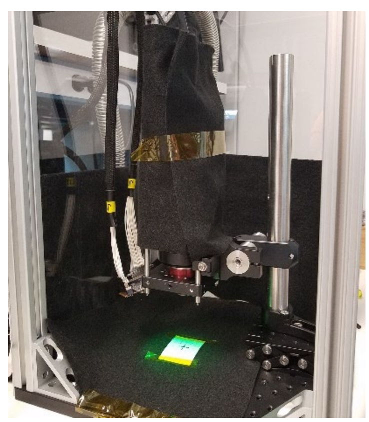

Figure 1. Image of prototype of AMIM instrument shown with green (525 nm) LEDs turned on. For scale, holes on optical base plate are ~1 inch apart.

Capabilities: AMIM advances beyond the capabilities of current microscopic imagers in the visible such as MER's MI [4], Phoenix' RAC [5] and MSL's MAHLI [6] or multispectral imagers in the VNIR (0.4-1.0 µm) such as ROSETTA's ROLIS [7], which are limited to detecting Fe-bearing minerals. The expanded coverage in the SWIR and narrow bandpasses (FWHM ≤ 50 nm) enable AMIM to discriminate both iron and non-iron bearing mineralogies with greater fidelity compared to these instruments or similar imagers with wider bandpasses (> 100 nm). Compared with microscopic hyperspectral imaging spectrometers, this approach provides simplicity by eliminating the need for complex optics, scanning. or electronically tunable filters, and flexibility by allowing data to be collected at a variety of distances under a variety of illumination conditions.

AMIM is particularly well-suited for investigating the composition of rocks and soils *in situ* at the grain scale, especially Fe-bearing igneous and oxide minerals (ex. olivine or hematite), OH/H_2O-bearing minerals (ex. altered minerals), glasses, agglutinates, and ices (ex. H_2O and CO_2) as well as effects of space weathering (Figure 2). These materials are of cross-cutting importance for understanding the geology of the lunar surface and prospecting for resources [e.g., 8-10]. Deployed in the field or in a glovebox in a lunar rover/lander, AMIM would play a critical role in characterizing rocks and regolith near the lander/rover enabling astronauts to quickly characterize collected samples during EVAs and carefully select the most valuable samples (i.e. “high-grade”) for potential return to Earth [11].

Thus, AMIM would provide many of the capabilities that are commonly associated with orbital instruments such as CRISM on the Mars Reconnaissance Orbiter (MRO) [12] or M3 on Chandrayaan 1 [13], but at a size and mass comparable to current microscopic imagers for landed science while also requiring little to no sample preparation - a powerful tool for future human exploration of the Moon .

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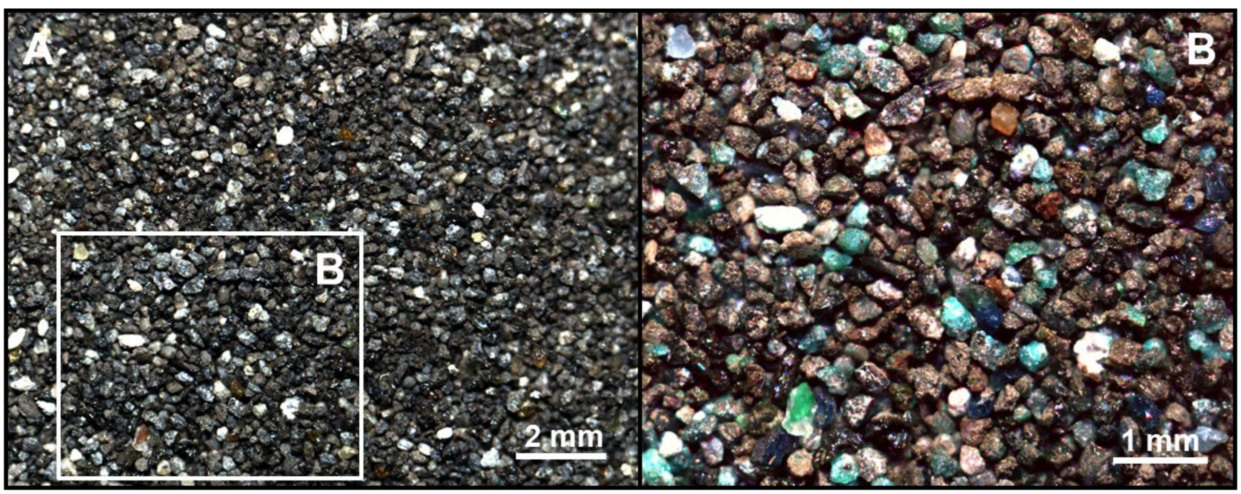

Figure 2. Results of imaging data collected with AMIM prototype of lunar regolith sample 14259 (mature regolith sample), collected approximately 100 meters west of the Apollo 14 Lunar Module (Lunar Sample Compendium). (A) Natural-color image of regolith sample composed of RGB bands (630, 525, 450 nm) respectively with white box shown in (B), FOV is approximately ~14x11 mm, Image linear stretched to enhance color variation between grains; (B) Zoom of false-color image composed of RGB bands (935, 770, 525 nm) respectively showing individual grains of different shapes and compositions in different colors in the infrared bands: Brown = Agglutinates; Blue = Olivine; Turquoise = Low-Ca Pyroxene; Green = High-Ca Pyroxene; White = Plagioclase Feldspar; Grey = Black Glass. Lunar regolith sample 14259 was contributed by Dr. Brett Denevi (JHU/APL).