THE ADVANCED MULTISPECTRAL INFRARED MICROIMAGER (AMIM) FOR THE *IN SITU* EXPLORATION OF PLANETARY SURFACES.
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Introduction: Future planetary missions to the surfaces of the Moon, Mars, asteroids, comets, and Ocean Worlds will need instruments that can maximize scientific return, but maintain low mass, size, and power so they can be accommodated on mass and power-constrained landers or rovers. In order to accomplish this task while maximizing science return, planetary surfaces will need to be characterized by robotic instruments that can provide crucial information about elemental composition, mineralogy, volatiles and ices in spatially-correlated data sets, which place mineralogy and chemistry into a microtextural context, crucial for correct petrogenetic interpretations.

Microscopic imaging has long been an essential tool for field geologists, as it is now in the robotic exploration of planetary surfaces. Spatially correlated microscale texture and mineralogy are essential for properly identifying rocks and soils *in situ* and interpreting their geologic histories. Over the past decade, the microscopic imagers on the Mars Exploration Rovers [1], Phoenix lander [2] and the Mars Science Laboratory [3] have played critical roles in those missions. Microscopic imagers are now recognized as essential tools for landed planetary missions [e.g., 4 - 7]. While these microscopic imagers have provided valuable microtextural information, they lack the ability to robustly discriminate mineralogy, essential for assessing petrogenesis.

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 and requires minimal mechanical sample preparation. This approach 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, and provide 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 past environmental conditions; provide "ground truth" for similar instruments on orbiting satellites; and provide information about potential fossil biosignatures [8, 9]. For the astrobiological exploration of Mars, such observations are key for creating scale-integrated paleoenvironmental interpretations to assess the nature and persistence of past habitable zones and their potential for supporting life.

Instrument: The Advanced Multispectral Infrared Microimager (AMIM) is a prototype microscopic imager being developed for future planetary missions as an arm-mounted instrument 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 [10].

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, nominally 0.4 to 2.6 µm) [10]. This wavelength coverage has wide applicability for the detection of minerals and ices. However, specific wavelengths and spectral range (up to 4.5 µm) can be easily tailored to address specific mission science and engineering requirements.

Capabilities: AMIM advances beyond the capabilities of current microscopic imagers in the visible such as MER's MI [1], Phoenix' RAC [2] and MSL's MAHLI [3] or multispectral imagers in the VNIR (0.4-1.0 µm) such as ROSETTA's ROLIS [11], 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*, especially Fe-bearing igneous and oxide minerals (ex. olivine or hematite), carbonates, OH/H_2O-bearing minerals (ex. clays or sulfates), and ices (ex. H_2O and CO_2) (Figure 1). These minerals are of cross-cutting importance in planetary science, because some or all of them are found on the surface of the Moon, Mars, asteroids, comets, and Ocean Worlds, and are indicative of past and/or present geologic processes [e.g., 4 - 7]. By mapping these minerals up-close and in survey-mode, AMIM would play a critical role in characterizing the regolith near the lander/rover and identifying targets for sampling for further study with onboard instruments or potential return to Earth. Furthermore, data collected by AMIM would provide ground truth to globally mapped datasets collected from orbit.

By employing a compact, low-power illumination system, AMIM eliminates the need for mechanical or complex systems such as a filter wheel, grating system, scan mirrors, multiple detectors, or tunable filters. This reduces the mass, size, power consumption and complexity of AMIM compared to larger imaging spectrometers, enabling it to be deployed at the end of a robotic arm on a compact rover/lander, or small asteroid lander/hopper.

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 - a capability unmatched by any current microimaging instrument developed for flight.

References: [1] Herkenhoff K. E. et al. (2008) *J. Geophys. Res.*, 113, E12S32. [2] Keller et al. (2008) *J. Geophys. Res.*, 113, E00A17. [3] Edgett K. S. et al. (2009) *LPSC XL*, Abstract 1197. [4] NRC (2007) *An Astrobiology Strategy for the Exploration of Mars*. [5] NRC (2011) *Vision and Voyages for Planetary Science in the Decade 2013-2022*. [6] Mars 2020 SDT (2013) *Report of the Mars 2020 Science Definition Team*, 154pp, posted July, 2013, by the Mars Exploration Program Analysis Group (MEPAG). [7] Europa Lander SDT (2013) *Report of the Europa Lander Science Definition Team*, 264pp, posted February, 2017. [8] Farmer J. D. and Des Marais D. J. (1999) *J. Geophys. Res.*, 104, 26,977–26,995. [9] Farmer J. D. (2000) *Palaeobiology II*, Eds. D. Briggs and P. Crowther, Blackwell, Oxford. [10] Núñez et al. (2017) *LCPM-12*, Abstract SESS04A-09. [11] Mottola et al. (2007) *Space Sci. Rev.*, 128, 241-255. [12] Murchie et al. (2007) *J. Geophys. Res.*, 112, E05S03. [13] Green et al. (2011) *J. Geophys. Res.*, 116, E00G19.

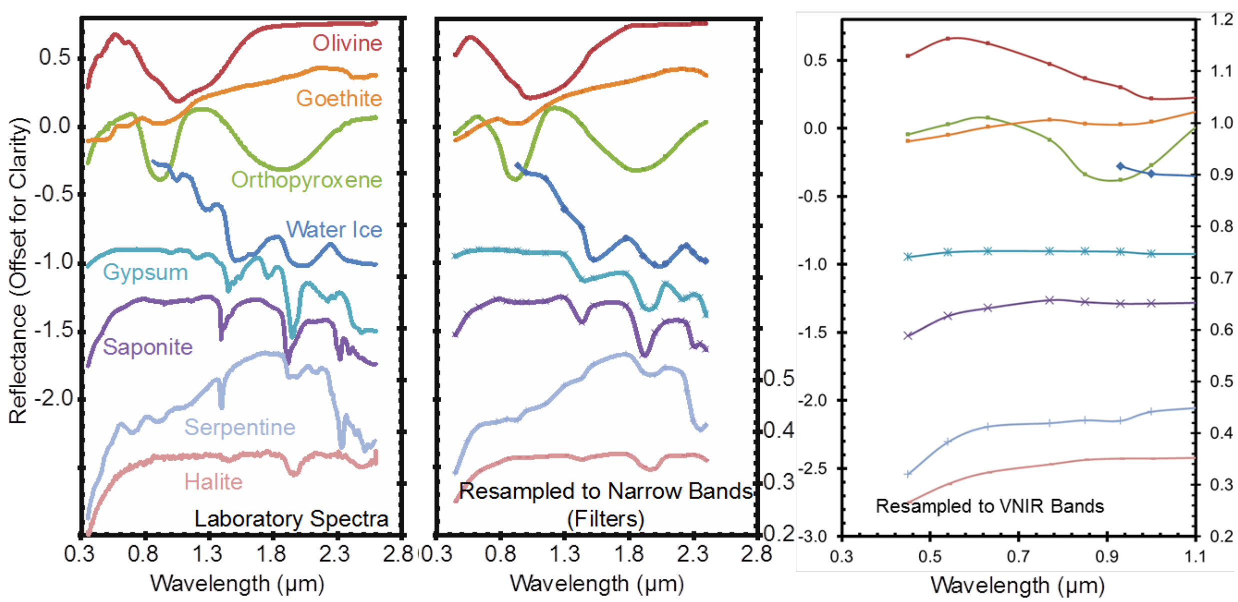

Figure 1. Laboratory spectra of minerals relevant to planetary surfaces (Left) convolved to AMIM's narrow bandpasses (Middle) and an instrument with bands in the VNIR range (Right). Minerals have been offset for clarity; Serpentine and Halite values are on the right, others are on the left. AMIM's bands (Middle) enable the instrument to discriminate both iron and non-iron bearing mineralogies with greater fidelity compared to an instrument with bands in the VNIR range (Right).