Mineralogical, Elemental, and Tomographic Reconnaissance Investigation for CLPS (METRIC)

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METRIC is a robotic science laboratory that can determine the mineralogy, elemental chemistry, micromorphology, and thermophysical properties of planetary regolith. The METRIC suite comprises METRIC XRD/F, an X-ray diffraction/X-ray fluorescence instrument that can determine the mineralogical and elemental chemistry of regolith samples; METRIC XCT, a micro X-ray computed tomography instrument that can be used to evaluate grain/crystallite sizes and textures; METRIC IRS, an imaging spectrometer mounted on a rover that can determine mineralogy and thermophysical properties at the landing site; and a pneumatic sample collection, processing, distribution system developed by Honeybee Robotics. The payload elements could be deployed on a static lander or a rover. Data returned from the METRIC payload would inform origin, formation, and evolution of rocky planetary bodies.

METRIC XRD/F draws on heritage from the CheMin instrument on the Mars Science Laboratory (MSL) Curiosity rover [1], with a few important improvements. Like CheMin, METRIC XRD/F operates in transmission geometry and uses piezoelectric actuators on sample cells in a tuning fork geometry to induce convective grain motion of the regolith to create a randomly oriented powder. MSL CheMin uses an energy-sensitive CCD to collect XRD patterns and XRF spectra simultaneously from the same sample cell, resulting in qualitative XRF data. METRIC XRD/F uses two different sample cells, one optimized for XRD and one optimized for XRF, and a silicon drift detector to detect fluoresced X-rays. This improvement to the XRF capabilities provides quantitative geochemical data of major elements down to Z = 11 and allows for the detection of minor and trace elements that are critical for evaluating geologic evolution of the Moon (e.g., P and Th). Modest improvements to the XRD geometry and hardware allow for better angular resolution and the ability to distinguish between members of the pyroxene group.

METRIC XCT uses the same geometry and much of the same hardware as METRIC XRD/F, where a CCD would capture images of a regolith sample in a 3 mm diameter sample tube that is rotated 360° in steps <1°. Image brightness can be used to infer compositional data, where brighter materials indicate a higher Z, much like scanning electron microscopy. Data from METRIC XCT complement those from METRIC XRD/F. Particle size, shape, and texture can provide petrologic and provenance information, whereas vesicle size and morphology in volcanic or impact melt lithologies can inform cooling rates.

METRIC IRS is a hyperspectral thermal imager that can be mounted on a lander or rover to provide mineralogical data from the broader landing site and help determine whether the samples analyzed by METRIC XRD/F and XCT are representative. The METRIC IRS spectral range (8–14 μm) and resolution (10.8 cm−1) allow for quantitative mineralogy from modelling Reststrahlen bands of major rock-forming minerals (e.g., silicates, phosphates). Radiance cubes can be processed and modelled with an onboard high-performance computer to determine mineral abundances of plagioclase, high-Ca pyroxene, pigeonite, orthopyroxene, olivine, and glass.

Regolith samples can be acquired, processed, and delivered to the X-ray instruments via multiple sample handling systems, but the pneumatic sampling systems developed by Honeybee Robotics [e.g., 2] are best suited for relatively low-cost missions that are being competed for the Moon (e.g., NASA’s Payloads and Research Investigations for the Surface of the Moon program). There are pneumatic sampling systems that collect surface material and other systems that pneumatically drill up to ~1 m below the surface, providing material that has not been space weathered and has not been affected by the lander’s exhaust.

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