DEMONSTRATING THE GEOLOGICAL APPLICATIONS OF A THREE DIMENSIONAL EXPLORATION MULTISPECRAL MICROSCOPE IMAGER (TEMMI). A. B. Coulter[1], G. R. Osinski[1], P. Dietrich[2], L. L. Tornabene[1,3], M. Daly[4], M. Doucet[5], A. Kerr[2], M. Robert[5], M. Talbot[5], A. Taylor[2], M. Tremblay[5], [1]Centre for Planetary Science and Exploration, Western University, London, ON, Canada N6A 5B7, [2]MDA Space Missions, 9445 Airport Road, Brampton, ON, Canada L6S 4J3, [3]SETI Institute, Mountain View, CA 94043, USA, [4]Centre for Research in Earth and Space Science, York University, Toronto, ON, Canada M3J 1P3, [5]INO, 2740 Einstein, Quebec, Canada G1P 4S4.

Introduction: High resolution microscopic imagers have been deemed a valuable and necessary component in most surface missions to Mars and the Moon [1-5]. The Curiosity rover in Gale Crater currently carries the Mars Hand Lens Imager (MAHLI) which is a high-resolution two dimesnsional (2D) microscopic imager with a spatial resolution of 14.5 µm/pixel [1]. The following abstract summarizes the capabilities of the Three Dimensional Exploration Multispectral Microscope Imager (TEMMI), a prototype instrument for future missions. In addition, we demonstrate TEMMI's imaging capabalities on various geological materials that are analogous to geologic materials that could be found in a Martian and/or Lunar environment.

TEMMI Design and Specifications: The Canadian Space Agency designed and developed TEMMI in association with two industrial partners, MacDonald, Dettwiler and Associates Ltd. (MDA) and the National Optics Institute (INO) along with three investigative academic partners: Western University, the University of New Brunswick and York University [7,8]. TEMMI was built and tested for rover-mounted operation in analog field trials. Offering three modes of operation: a 2D colour, a 3D colour, and an ultraviolet mode.

In the 2D colour mode, images are acquired using illumination from eight different Light-Emitting Diode (LED) lights, covering the wavelength range spanning the visible and near infrared (VNIR) from 455 nm to 850 nm. Calibrated reflectance images at the LED wavelengths can be used to extract 8-point spectra and also combined into RGB colour images. In the 3D mode, a number of images are taken using a digital light processor to project a Moiré pattern from which the shape model of the sample is calculated with a lateral resolution of 5 µm and vertical resolution of 2 µm. Colour composite images in 3D are derived by overlaying their corresponding 2D colour image on the shape model. The fluorescence mode uses a LED light at 365 nm that may excited visible fluorescence in biomolecules or minerals that are sensitive to ultraviolet wavelengths.

Two imaging modes are implemented for colour and fluorescence imaging, the low-resolution mode providing a field of view (FOV) of 5.7 x 4.3 mm with optical resolution of ≤ 10 µm (4.4 µm pixel resolution) while the high-resolution mode provides a FOV of 5.7 x 2.1 mm with ≤ 5 µm optical resolution (2.2 µm pixel

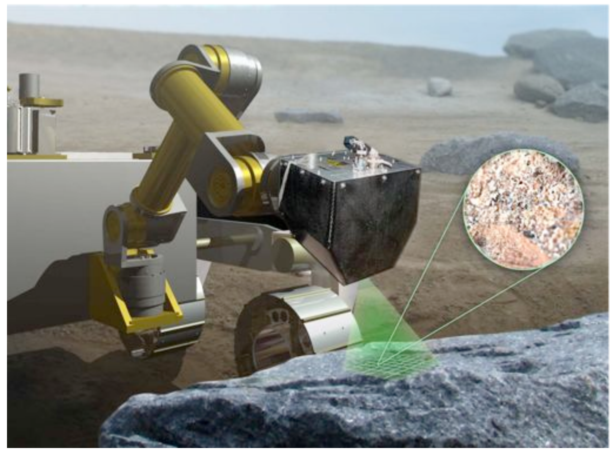

Figure 1. An artists interpretation of TEMMI imaging an outcrop from a rover platform [9].

resolution). An internal focusing stage is used to position the microscope about its nominal working distance of 25 mm (range +5/-20 mm).The native depth-of-field (DOF) is less than 20 µm but TEMMI implements focus stacking to provide extended DOF of up to several millimetres.

Demonstration: The goal of this study is to validate TEMMI's design on relevant geological materials in its various modes of operation.

3D: In many cases, micromorphology may be difficult to interpret in 2D. Figure 2 shows a set of impac-

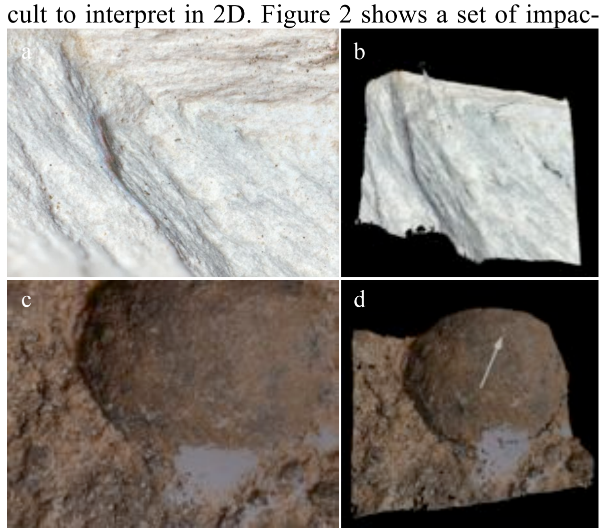

Figure 2. a and c) Low-resolution color images with a FOV of 5.7 x 4.3 mm. b and d) 3D perspectives of the same images from (a) and (c) draped on their derived 3D models.

tites: a shatter cone and a melt-bearing rock. The microtextures and micromorphologies are difficult to interpret in the low-resolution 2D image, while their micromorphology and microtexture become much more apparent when utilizing the focus stacking and 3D mapping capabilities. A shatter cone is the only macroscopic indicator of an impact event creating the characteristic conical and striated structure [10]. While the melt-bearing rock mimics the Martian 'blueberries' observed in Meridiani Planum by the Opportunity Rover [11].

Ultraviolet: The ultraviolet mode can reveal materials that will fluoresce under UV light (365 nm). Some minerals and biological molecules fluoresce under this wavelength. As seen in Figure 3, a corundum (on the right) set in a zoisite matrix (on the left) fluoresces under UV light (Fig. 3b).

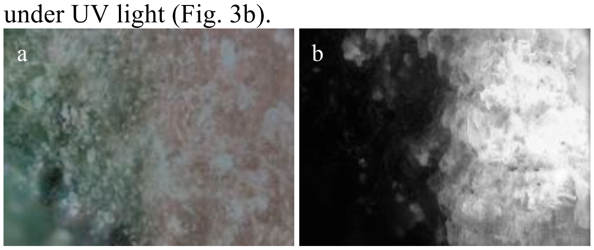

Figure 3. a) Low resolution color image with FOV of 5.7 x 4.3 mm. b) Same image taken with just the UV wavelength at 365 nm.

Reflectance Spectroscopy: The multispectral reflectance data created by TEMMI's images can be utilized to provide or supplement useful mineralogical data. TEMMI's multispectral reflectance data has success-

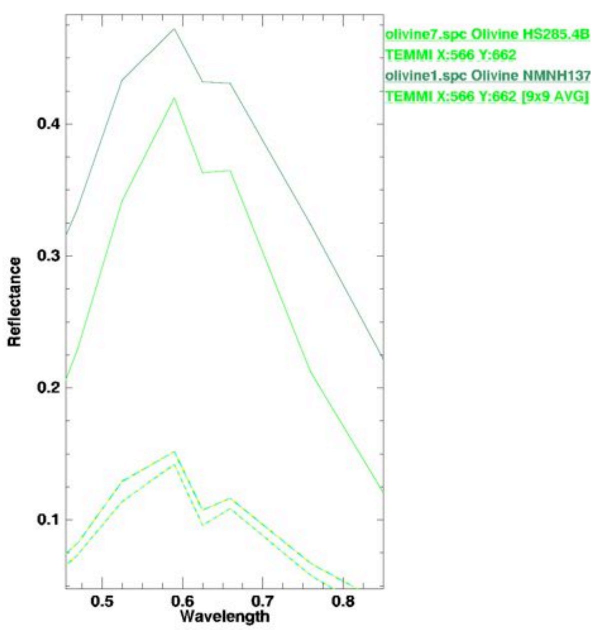

Figure 4. TEMMI's 8-point spectra (solid lines) matched with olivines from the USGS mineral spectral library (dashed-lines).

fully identified minerals when compared to known mineral spectral libraries. Figure 4 demonstrates a comparison of TEMMI's 8-point spectra with olivine spectra from the USGS mineral spectral library of 481 minerals [12]. These results were obtained via visual matching and the utilization of three different methods: spectral angle mapping (SAM), spectral feature fitting (SFF), and Binary Encoding (BE).

Future Work: Ruggedizing the mechanical design and advancing the electronic design towards flight are important steps towards a flight design. Also, image acquisition and processing are currently lengthy processes which could be improved by dedicated software and hardware. Rover-mounted operations in terrestrial analog sites are forthcoming.

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