FIELD-TESTING LOW-COST REMOTE SENSORS FOR UTILITY IN ANALYSING MARS ANALOGUE MATERIALS.

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Introduction: Can commercially available sensors provide comparative results with Mastcam and Mastcamz instruments operating on the surface of Mars? The latest US rovers sent to Mars, Curiosity and Perseverance, have incorporated multispectral cameras, the Mastcam and MastcamZ (hereafter termed 'Mastcam/z') [1]. These cameras provide band-pass information at between 400–1000 nm to enable the construction of 12 channel multispectral data [2] In this research, pushbroom sensor designed around a readily-available ZWO 120mm mini camera [3] were used to determine their utility for Mars remote sensing. Two trials were conducted: the first entailed imaging minerals previously identified on the Martian surface [4, 5], and the second imaged minerals in situ at geologically distinct sites in New South Wales (NSW), Australia. Results were then compared against spectra returned from a Spectral Evolution SR-3500 spectro-radiometer and qualitatively compared with those returned from Mastcam/z.

The pushbroom sensor was constructed using dispersive optics and a commercially available monochrome camera. Spectral calibration was performed through obtaining spectral lines from a compact fluorescent lamp (CFL) and correcting for spectral smile [3]. To assist in radiometric correction, a series of colour and greyscale swatches were mounted on a flat board for imaging under direct sunlight in a near-field test. This practice of including colour targets has been used in Mars surface missions for decades to provide a source of known spectral properties for image calibration [6].

Additional materials representative of what has been identified on Mars were also included in the near-field test. These included Olivine, Gypsum, Hematite, Mudstone and Serpentine [4, 5]. An iron oxide (Rust) sample was also included for analysis. The purpose of this was to provide guaranteed sampling of Mars analogue materials, as well as determine the utility of each sensor in sampling of these minerals in ideal conditions.

The SR-3500 spectro-radiometer was used to sample the chosen materials, including those returned from field site testing. Absolute difference between the outputs of this instrument and the custom sensor was used as a metric to determine performance.

Colour swatch and Mars analogue comparison results for the pushbroom and SR-3500 are shown in Table 1. The pushbroom spectra were in close agreement with the SR-3500 results with average differences ranging from less than 0.01 to 0.07 (High Alert Yellow).

Material	Average Fit Value
Majestic Purple	0.029
Hot Pop Red	0.055
James Blue	< 0.01
Hot Pop Green	<0.01
High Alert Yellow	0.07
Limeleaf Green	<0.01
Worldly Yellow	0.03
Hematite	0.03
Mudstone	0.05
Rust	0.01
Olivine	0.01
Gypsum	0.04
Serpentine	0.03
Vegetation	0.03

Table 1: Average fit values between the pushbroom sensor and SR-3500 for sampled colour swatches.

The Mars analogue materials and representative vegetation showed similar agreement between the pushbroom and SR-3500 spectrometer Table 1). Average fit values ranged from 0.01 (Rust, Olivine, Fig. 1b, d) to 0.05 (Mudstone, Table 1).

Geologically distinct field sites in New South Wales, Australia, were chosen to trial the sensors. The sites were chosen as they presented minerals with spectral properties that the sensors would be sensitive to in the VIS/NIR portion of the spectrum. Additionally, iron oxide-rich minerals were present at these sites, offering an analogue for Mars materials to supplement the test material samples described above. A converted quarry near Karabar, New South Wales, dubbed "Scar 2", and "Scar 3" were selected for sampling. The geology of "The Scar" is the Ordovician Pittman Formation, consisting of originally quartz-rich sandstone, siltstone and shale, now steeply dipping and regionally metamorphosed to quartzite and phyllite [7]. The exposure has been strongly weathered with secondary clays partly replacing feldspars and micas and is mottled with secondary hematite and goethite staining. Scar 2, of which eight samples were imaged, comprised a rock garden of pebbles and stones ranging from 1 to tens of centimetres on a loosely consolidated sandy matrix. Scar 3 was located 15 m south of Scar 2 and comprised a small water carved gully wall.

The spectral responses from the pushbroom sensor and SR-3500 were in close agreement (average 0.02) for the Scar 2 Red Siltstone sample (Fig. 1a, c). Reflectance values increased to a rounded curve at 610 nm and a maximum reflectance at 760 nm in a similar manner to iron oxide [8]. The Red Siltstone sample reflectance curves were similar and closely agreed to the SR-3500 spectrum (blue line, Fig. 1c), suggesting similar mineralogy.

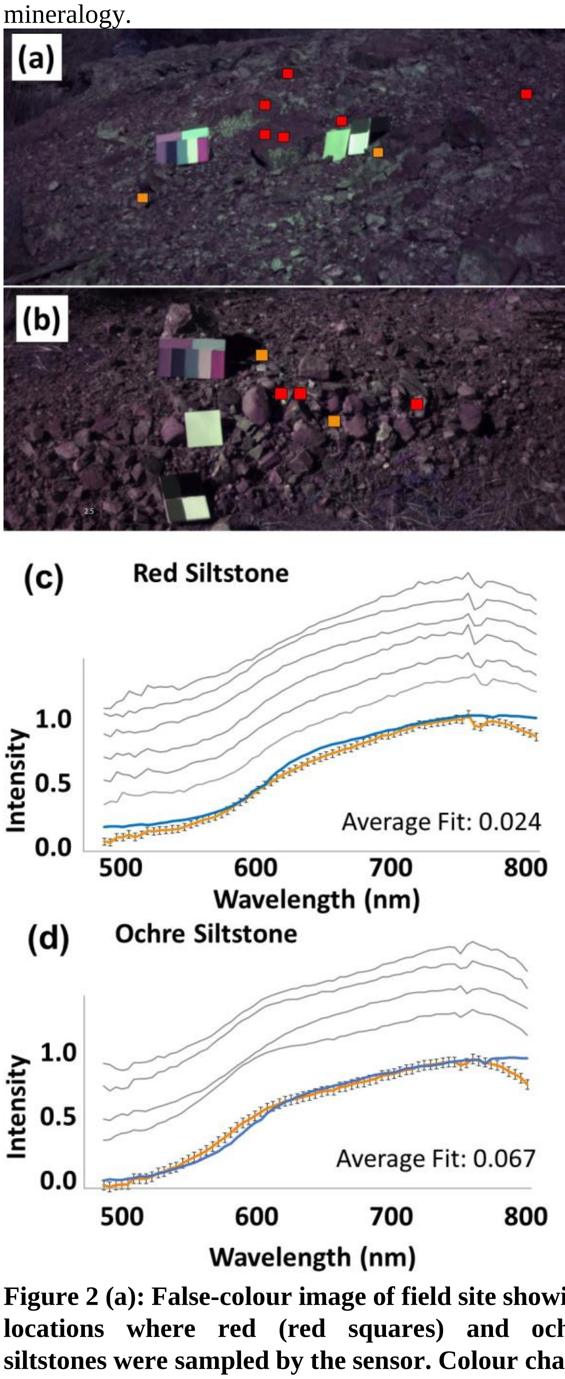

Figure 2 (a): False-colour image of field site showing locations where red (red squares) and ochre siltstones were sampled by the sensor. Colour charts and the diffuse reflector are also visible. (b) Additional siltstone sample area with radiometric targets to assist with calibration. (c) Red siltstone average sensor graph (orange) compared with SR-3500 (blue) and individual readings (offset by 0.1 in intensity) in grey. (d) Ochre siltstone measurements. Error bars are across 50 distinct pixels/frame.

The iron-oxide rich sandstone is likely the dominant material in the regolith comprising the Scar sites. The Ochre Siltstone samples showed greater brightness deviations compared to the SR-3500 though they exhibited similar rounded double peaks near 590 nm and maximum reflectance at 760 nm (Fig. 1d). The reflectance values from 500–590 nm were higher for the Ochre materials than the Red Siltstone materials (Fig. 1c).

Discussion: Mars-analogue material and field trials of the pushbroom sensor revealed a useful spectral range between 450–800 nm. This was less than the 400–1000+ nm spectral range of the Mastcam/z. Secondary spectral peaks of some Martian minerals such as hematite and jarosite would not be identifiable from this sensor, and also are beyond the spectral range of the sensor. Despite this limitation, the 700–750 nm spectral peaks of Jarosite and hematite, respectively, and the 650 nm peak of hematite are within the spectral range of the pushbroom. It was found that these peaks were readily identifiable in the pushbroom data. Within the wavelength constraints, the pushbroom possessed a higher spectral sensitivity than Mastcam/z and was able to return spectra comprising hundreds of bands, binned to 70 bands for this work. The pushbroom Mars-analogue results also closely agreed with the laboratory SR-3500 results, indicating its ability to return information on spectral phenomenology of these minerals.

Future pushbroom configurations will incorporate additional processing power to accommodate 12-bit spectral capture. This would increase the dynamic range of the sensor, particularly when co-imaging high contrasts between dark and light materials.

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