THE MOON MINERALOGY MAPPER (M^3) IMAGING SPECTROMETER: EARLY ASSESSMENT OF THE SPECTRAL, RADIOMETRIC, SPATIAL AND UNIFORMITY CHARACTERISTICS.

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Introduction: The Moon Mineralogy Mapper[1] (M^3) is a high uniformity and high signal-to-noise ratio[23456] NASA imaging spectrometer that is a guest instrument on the Indian Chandrayaan-1 Mission to the Moon. The laboratory measured spectral, radiometric, spatial, and uniformity characteristics of the M^3 instrument are given in table 1. The M^3 imaging spectrometer takes advantage of a suite of critical enabling capabilities to achieve its measurement requirement with a mass of 8 kg, power usage of 15 W, and volume of 25X18X12 cm. The M^3 detector and spectrometer are cooled by a multi-stage passive cooler.

This abstract presents early M^3 performance assessment results. Early M^3 science results are present in the Pieters et.al. 2009 LPSC abstract.

Table 1. M^3 Target Mode Laboratory Characteristics

Spectral	
Range	406 to 2991 nm
Sampling	9.98 nm
Response	12.5 nm FWHM
Radiometric	
Range	0 to specified saturation
Sampling	12 bits measured,
Response	Linear to 1% (1 to 99%)
Accuracy	<10% absolute uncertainty
Precision (SNR)	>400 @equatorial reference >100 @polar reference
Spatial	
Range	24 degree field-of-view
Sampling	0.7 milliradian
Response	1.0 milliradian FWHM
Uniformity	
Spectral-cross-track	10% variation of spectral position across the field-of-view
Spectral-IFOV	10% IFOV variation over the spectral range

Early Measurements: Chandrayaan-1 was launched on the 22nd of October 2008. The first M^3 imaging spectrometer data sets were acquired on the 18th and 19th of November 2008. Both M^3 Target and Global imaging modes were exercised. Global mode is a 2X2 spatial average with selected 2X and 4X spectral averaging of Target mode sampling. Figure 1 shows a M^3 Target mode data set measured on the 19th of November rendered as an image cube.

Additional commissioning data were acquired on the 22nd and 24th of November in Global mode with the detector temperature near nominal. These measurements were calibrated to radiance by subtracting the dark signal levels and applying the laboratory radiometric calibration coefficients in the baseline calibration algorithm. Figure 2 show a set of single point M^3 Global mode radiance spectra along with a Global mode image subset and the full global mode strip.

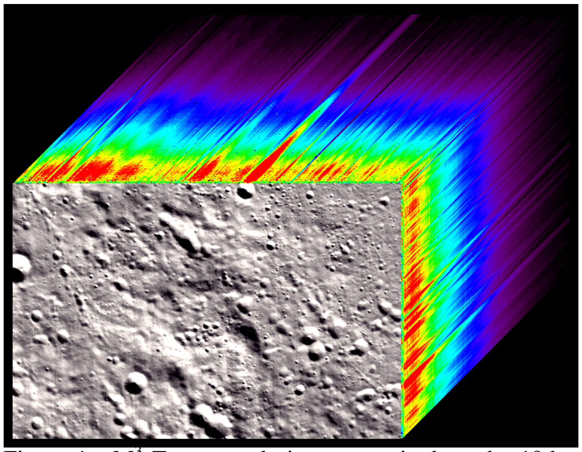

Figure 1. M^3 Target mode image acquired on the 19th of November 2008 at -43.74 longitude and +63.08 latitude. The image has 621 cross-track samples, 392 lines and 260 spectral channels measuring from 406 to 2991 nm. The spectral range is depicted in the top and side panels for the edge samples.

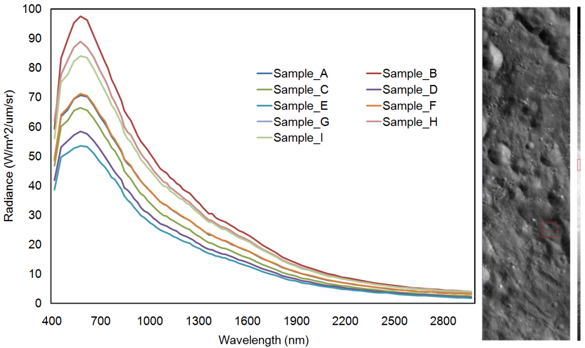

Figure 2. (left) A set of M^3 single point spectra from a Global mode acquisition on the 24th of November 2008. (Center) image from Global mode strip. (right-sliver) Full Global mode stripe from 85N over the North pole to 78.7 South latitude passing through -111.2 longitude at the equator.

The following sections of this extended abstract give preliminary assessments of the in-flight spectral, radiometric, spatial, and uniformity characteristics of M^3. These are early assessments based on limited commissioning phase measurements. A comment on future in-flight performance assessment and calibration validation is given at the end of the abstract.

Spectral: Early assessment of the in-flight spectral properties of M3 is based on comparing modeled spectra with measured M3 spectra. Figure 3 shows a comparison of the M3 radiance measured from an area estimated to have soil properties similar that that of the Apollo 16 landing site and the radiance modeled for the site based on the Apollo 16 soil reflectance, solar zenith angle and irradiance spectrum. The location of the solar peak and the correspondence in shape indicates the in-flight spectral range and spectral channel position is consistent with the laboratory measured values. Differences between the measured and modeled spectra are related to the use of an approximate Apollo 16 analog site and absence of correction for photometry. The first opportunity to measure data over the Apollo 16 landing site is the 8th of January 2009.

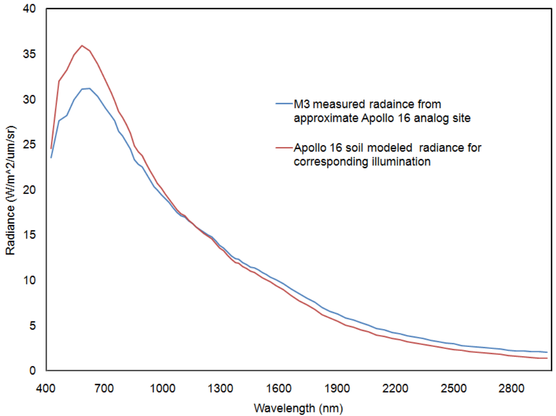

Figure 3. Comparison of an M^3 measured and modeled spectrum for a site estimated to be similar to the Apollo 16 soil.

Radiometric: At this time, the quality of the radiometric calibration of M^3 may only be qualitatively assessed based on the correspondence of the measured and modeled spectral shown in Figure 3. Early in-flight analysis confirms a known scattered light characteristic of M3 impacting the visible portion of the spectrum. This due to the light weight diamond turned mirrors that were required. A correction algorithm based upon laboratory measurements is being evaluated. Initial assessment of the dark-signal noise-equivalent-delta-radiance (NEdL) for the early commissioning phase data is consistent with the NEdL predicted for the temperature of the detector.

Spatial: Assessment of the in-flight spatial properties has commenced with simple comparison to pre existing image data. Figure 4 shows a comparison of Harpalus Crater imaged by M^3 in Global mode and by Clementine. M^3 shows higher spatial image detail even at the 140 m sampling distance of Global mode.

Uniformity: the cross-track spectral uniformity has been initially assessed by fitting a modeled spectrum in the area of the solar peak across the FOV of M^3 in an area assessed to be spectrally uniform. This analysis indicates M^3 has an in-flight uniformity consistent with the laboratory measured values. Spectral-IFOV-uniformity has been assessed by comparing cross-track profiles at different wavelengths in areas with extreme variation in brightness across the FOV. The alignment of the bright and dark feature in these profiles over the spectral range indicates the spectral-IFOV-uniformity of M^3 in the space flight environment is consistent with the laboratory determined values.

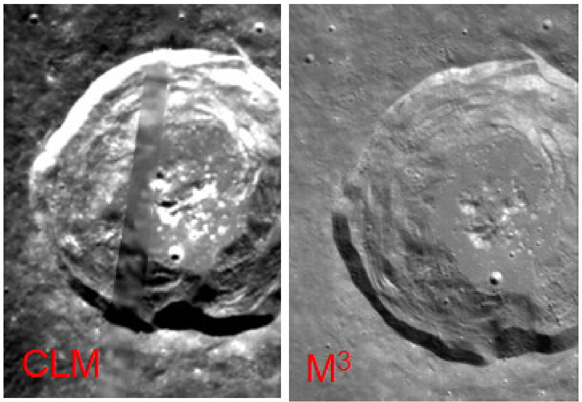

Figure 4. Comparison of single channel M^3 Global mode image (right) with Clementine image (left) for the same area. M^3 records higher spatial detail even at the 140 m sampling of Global mode.

Conclusion: Early analysis of the M^3 imaging spectrometer commissioning phase shows that the M^3 measurements are consistent with the spectral, radiometric, spatial, and uniformity characteristics measured in the laboratory.

Future Work: In-flight performance assessment and calibration validation will continue over the next year with acquisition of measurements over the Apollo sites and acquisition of data set that have common illumination and observation geometries with the Rolo telescopic observations of the moon and with the Earth orbiting Hyperion imaging spectrometer that has also viewed the Moon. There are also planned to be observations of the Earth by M^3 where the spectral features of the atmosphere will be used for detailed spectral validation.

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