The Moon Mineralogy Mapper Data Set Delivered to the Planetary Data System and Calibration and Validation Status. R. O. Green[1], C. M. Pieters[2], J. Boardman[3], S. Lundeen[1], M. Staid[4], and the M[3] Team; [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109 (Robert.O.Green@jpl.nasa.gov), [2]Brown University, [3]AIG, [4]PSI

Introduction: The NASA Discovery Moon Mineralogy Mapper (M^3)[123456] was launched as guest instrument on the Indian Space Research Organization (ISRO) Chandrayaan-1 Mission to the Moon on the 22nd of October 2008. M^3 is an Offner-type pushbroom imaging spectrometer designed to return global coverage of the lunar surface in Global resolution mode as well as selected area mapping with Target resolution. The key characteristic of M^3 is measurement of the contiguous spectrum from 430 to 3000 nm at 10 nm sampling. The high level spectral, radiometric, spatial and uniformity science measurement requirements are given in Table 1.

Table 1. Key science measurements requirements.

Spectral	
Range	430±50 to 3000±50 nm
Sampling	10±2 nm constant
Response	FWHM* <1.5 X sampling
Accuracy	≤ 1 nm
Radiometric	
Range	0 to specified saturation
Sampling	12 bits measured
Accuracy	≥90% (≤10% uncertainty)
SNR	≥400 at equatorial reference radiance ≥100 at polar reference radiance
Spatial	
Range	24±2° field-of-view
Sampling	0.7±0.7° milliradian
Response	FWHM* < 1.5 X sampling
Uniformity	
Spectral-cross-track	≥90%
Spectral-IFOV	≥90%

*Full-Width-at-Half-Maximum (FWHM) of response function

The flight mission ended early on the 27th of August 2009 with loss of communication to the spacecraft. However, as a result of exceptional support from ISRO more than 95% of the lunar surface was measured in Global Mode and a range of Target Mode data sets were acquired. Global Mode is a 2X2 spatial and selected 2X and 4X averaging of full resolution Target Mode measurements. With the return of the first data set from lunar orbit on the 19th of November 2008 the M^3 team has been focused on calibration, science validation, and delivery of the M^3 Level 1b data set to the Planetary Data System (PDS). In June 2010 the complete optical period 1 data set was delivered to PDS. In December 2010 the complete optical period 2 and Target Mode data set were delivered to PDS.

M^3 Data Set: The coverage of the Moon for the full mission is shown in Figure 1. This is a composite Global Mode coverage. Many areas have more than one measurement from M^3.

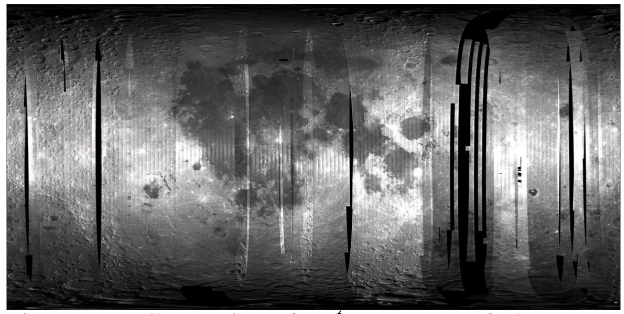

Figure 1. Composite of M^3 coverage of the Moon acquired during the operational mission.

Calibration: Generation of Level 1b includes spectral, radiometric, and spatial calibration as well as determination of location and observation parameters for every spectrum measured. Calibration involves use of the full set of laboratory characterization measurements as well as compensation for non ideal characteristics such as anomalous detector array elements and spectrometer scattered light. Figure 2 shows a portion of a M^3 data set that includes Harpalus Crater located near located near 52° 36′ North latitude and 43° 24′ West longitude. Four calibrated radiance spectra are shown as well. The current best available calibration processing has been applied to the M^3 data set delivered to PDS[7].

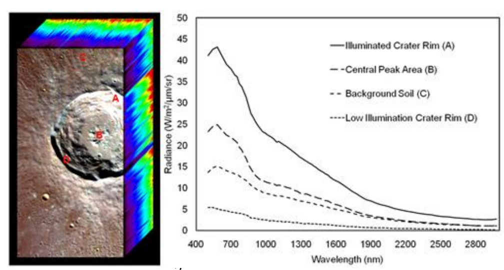

Figure 1. M^3 Global Mode image and calibrated radiance spectra from the PDS delivery.

Validation: The prime focus of the M^3 science team has been the calibration and validation of M^3 data set. An assessment of the radiometric calibration has been pursued through a range of methods including comparison of M^3 measurements with RObotic Lunar Observatory (ROLO)[8] measurement for the Mare Serenitatis region. For this comparison the radiance measurements have been converted to apparent surface reflectance and are shown in Figure 2. The agreement is good over the spectral region of overlap. Further refinement and quantification of radiometric calibration validation are being pursued by the M^3 team.

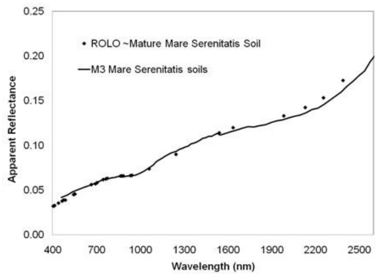

Figure 2. Comparison of M^3 and ROLO measurements for the Mare Serenitatis region.

A critical validation data set was acquired with M^3 viewing the Earth from lunar orbit on the 22nd of July 2009 shown in Figure 3. The spectral features of the Earth's atmosphere were used to validation the on orbit spectral properties of M^3. Figure 4 shows a comparison of the M^3 measurements of the Earth's atmosphere from a cloud target in the Pacific Ocean and a MODTRAN radiative transfer code[9] modeled spectrum for a cloud like reflectance.

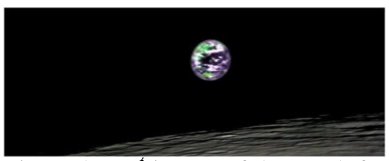

Figure 3. M^3 image of the Earth from lunar orbit.

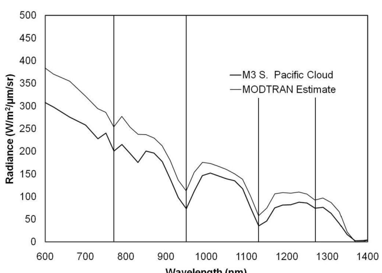

Figure 4. M^3 measured and MODTRAN modeled spectra of the Earth's atmosphere showing agreement in the position of the atmospheric absorption features.

To assess the cross-track spectral uniformity of M^3 in orbit, cloud spectra were extracted from the lowest and highest available cross-track samples in the Earth view data set. Figure 5 shows a plot of different cloud spectra from sample 131 and sample 230 showing the positions of the atmospheric absorption features and confirming good on-orbit cross-track spectral uniformity.

To assess spectral instantaneous field-of-view (IFOV) uniformity an illuminated subsample peak in the polar region was identified M^3 data set. The cross-track profile across the illuminated lunar peak was extracted for a set of wavelengths from 750 nm to 2736 nm and normalized. These cross-track profiles are shown superimposed in Figure 6. The close agreement in the cross-track profiles across this wide spectral range demonstrates good spectral IFOV uniformity of M^3 on orbit.

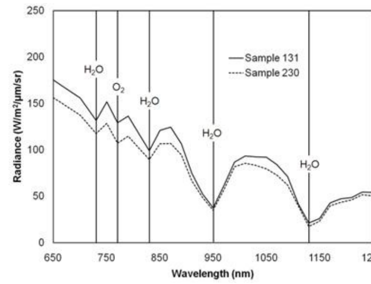

Figure 5. Comparison Earth atmosphere absorption features in different portions of the M^3 field-of-view demonstrating cross-track spectral uniformity.

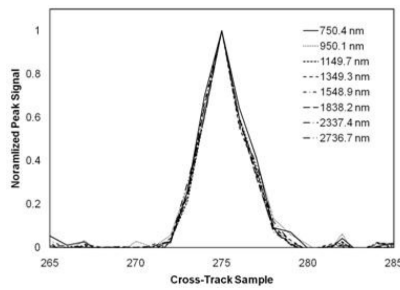

Figure 6. Normalized cross-track profile for multiple wavelength of an illuminated sample in the polar region showing spectral IFOV uniformity.

Summary and Conclusion: The initial complete delivery of the M^3 data set has been delivered to PDS. This data set provides Global Mode coverage for the > 95% of the Surface of the Moon. The current Level 1b product includes spectral, radiometric, spatial calibration as well as location and observation parameters for each spectrum measured. Considerable effort has focused on validation of the M^3 measurement acquired in lunar orbit. The results presented here provide initial validation of key aspects of the radiometric, spectral and uniformity calibration properties of M^3 in the challenging orbital environment.

Work is ongoing to further enhance the calibration of the M^3 data set. As improved calibrations are validated they will be included in updated deliveries to the PDS.

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References:

[1] Pieters, C.M., et al. LPSC07 #1295; [2] Mouroulis et al., APPLIED OPTICS 39 (13) 2000*;* [3] Green et al., LPSC07*;* [4] Mouroulis et al.., OPT ENG 46 (6): No. 063001 2007*;*[5] Green et al., IEEE, 10.1109 / Aero.2008.4526382*;* [6] Green et al., LPSC08,09; [7] Green et al., JGR-Planets, 2011 submitted; [8] Kieffer H. H. et al., J. Atmospheric and Oceanic Technology,1996; [9] Berk et al., MODTRAN Users Manual, 1999