Assessment Of The Complete Moon Mineralogy Mapper Data Set And On-Orbit Validation Of The Spectral Calibration. R. O. Green, C. M. Pieters[2], J. Boardman[3], M. Eastwood, P. Mouroulis, S. Lundeen, and M. White; 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

Introduction: The NASA 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. The flight mission ended on the 27th of August 2009.

Over the course of the mission M^3 returned 856 gigabytes of uncompressed imaging spectrometer measurements covering more than 95 percent of the Lunar surface. This is a unique data set that was measured over a range of different acquisition conditions and will remain important for Lunar scientific investigations and research into the future.

M^3 measures the spectral range from 406 to 2991 nm with 9.98 nm sampling. The radiometric sampling is 12 bits with a signal-to-noise ratio of 400:1 for the benchmark equatorial reference radiance and 100:1 for the corresponding polar reference radiance and nominal instrument conditions. From an altitude of 100 km the nominal field of view is 40 km with 70 m spatial sampling. The M^3 instrument achieved this performance with a mass, power and volume of 8 kg, 15 W and 25X18X12 cm. M^3 was designed with two acquisition modes: (1) Target Mode at full spectral and spatial sampling; and (2) Global Mode with 2X2 spatial averaging with proscribed spectral averaging of adjacent channels to equal a 3X compression. Figure 1 shows a Global Mode image cube and selected radiance and apparent reflectance spectra from an M^3 data set acquired on 5 February 2009 that includes the Apollo 15 landing site near Hadley Rille (26° 26' N, 3° 39' E).

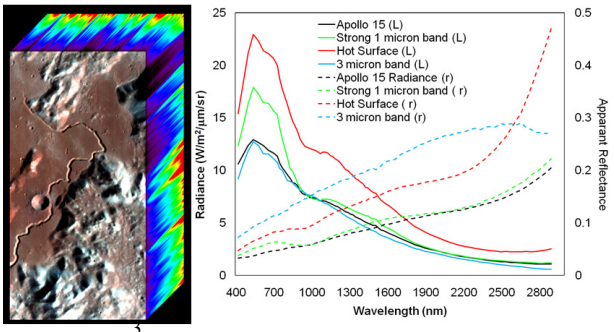

Figure 1. M^3 image of the Apollo 15 landing area including the Hadley Rille is shown along with selected radiance and apparent reflectance spectra.

On the 22nd of July 2009 a unique data set for spectral calibration validation was measured of the Earth from Lunar orbit. A image of this data set is shown in Figure 2. With the presence of strong atmospheric gas absorption bands, this data set provides a strong basis for on-orbit spectral calibration validation.

This abstract presents results from the ongoing assessment of the full M^3 data set and acquisition conditions as well as results of M^3 spectral calibration validation based upon the Earth data set.

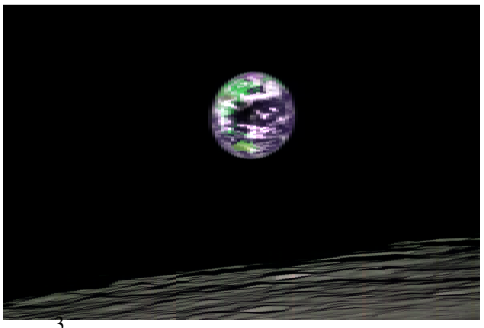

Figure 2. M^3 spectral calibration validation data set of the Earth from Lunar orbit. The image is centered on the western Pacific with Australia visible in the lower center of the image.

The M^3 Data Set: The first M^3 data set acquired from Lunar orbit was measured on the 18th of November 2008. The final data set was measured on the 16th of August 2009. A total of 1534 data sets were collect with the vast majority in Global Mode spatial and spectral resolution. During the spaceflight mission these data were collected during two optical illumination periods that are defined by the solar beta angle. The beta angle is the angle between the orbital plane and the vector to the sun. The first optical period (OP1) was centered on a 0° beta angle on the 17th of December 2008 and second optical period (OP2) was centered on the 0° beta angle on the 17th of June 2009.

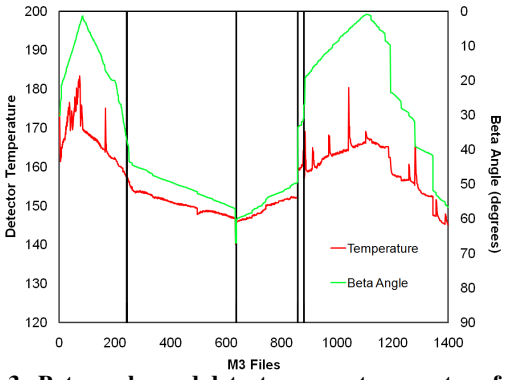

Figure 3. Beta angles and detector array temperature for the Global Mode data sets acquired. The vertical dividers identify different elements of the two optical periods of the M^3 Mission.

A key factor in M^3 performance is the detector array temperature that is cooled by a passive radiator. Above 165° the noise becomes significant. A strong correlation between detector array temperature and beta angles has been determined. Figure 3 shows the beta angle and

detector array temperature for all of the M^3 Global Mode measurements. The intermittent temperature spikes are associated with spacecraft maneuvers.

In addition to beta angle variation, two other critical factors that affect the M^3 data set are the orbital altitude and platform attitude knowledge. In the period around 13 May 2009 the ability to acquire detailed information on spacecraft attitude was reduced. On 19 May 2009 the orbit of Chandrayaan-1 was raised from 100 to 200 km altitude. In combination the two optical periods, attitude information availability, and orbital altitude are used to sub divide the M^3 data set into five acquisition states. The numbers of M^3 measurements acquired in each of these acquisition states are summarized in Table 1. These values are for all M^3 data sets. A fraction of these are acquired on the unilluminated side of the Moon to provide dark signal level for calibration. Work is proceeding to enhance the attitude knowledge for OP2B and OP2C with image based coordinate mapping to the Universal Lunar Coordinate Network.

Table 1. Summary of M^3 acquired data by conditions.

Conditions	Total	Dates
OP1A "warm"	231	18 Nov 08 to 24 Jan 09
OP1B "nominal"	396	25 Jan 09 to14 Feb 09
OP2A "nominal"	306	15 Apr 09 to 27 Apr 09
OP2B (~att. 100 km)	29	13 May 09 to 16 May 09
OP2C (~att. 200 km)	572	20 May 09 to 16 Aug 09
TOTAL	**1534**	

On-orbit Spectral Calibration Validation: An important M^3 spectral calibration validation data set was acquired of the Earth from Lunar orbit in Global Mode on the 22nd of July 2009. This data set includes the western Pacific region and was acquired coincident with a solar eclipse in the center of the image. Major illuminated composition types include: ocean, land, vegetation, and clouds. A series of spectra extracted from this data set are shown in Figure 4.

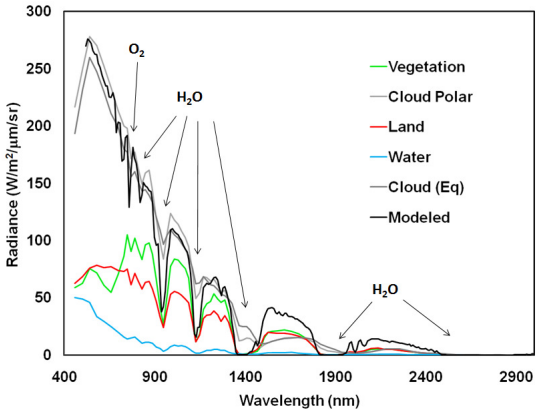

Figure 4 Spectra measured by M^3 of the Earth from Lunar orbit. The location of the atmospheric absorption bands and chlorophyll absorption of vegetation provide validation of the spectral calibration.

The Earth atmosphere gas absorptions are present in all of the illuminated spectra. Initial comparison of these M^3 spectral measurements with spectra modeled of Earth radiance show good correspondence of the position of the oxygen band at 760 nm and the water vapor absorption bands at 820, 940, 1140, 1380, 1880, and 2680 nm. The agreement between the wavelength positions of measured spectral Earth atmosphere absorption bands and modeled absorption bands in this initial analysis provides a key validation of the M^3 on-orbit spectral calibration.

Conclusion: The M^3 spaceflight mission spanned two optical periods of illuminated observations of the Lunar surface from the 18 November 2008 to 16 August 2009. During this period 1534 M^3 data sets where acquired that cover more than 95% of the surface of the Moon. Acquisition conditions varied over the course of the mission. These conditions are being documented and refined. Assessment and understanding of these conditions is essential for the calibration and characterization of the full M^3 data set for use by the research community.

A unique data set was acquired of the Earth from Lunar orbit on the 22nd of July 2009. Based upon good agreement in the measured positions of the Earth atmosphere absorption bands this data set provides a key validation of the on-orbit spectral calibration of M^3.

Over the full flight mission, M^3 has acquired a unique data set of the Moon that will remain important for future Lunar scientific investigations and understanding.

Future Work: Work in ongoing to finalize detailed characterization of the complete M^3 mission data set as a function of the acquisition conditions. In conjunction with this effort, an understanding the on-orbit M^3 spectral, radiometric, spatial, and uniformity characteristics are being assessed and validated as well. This work is focused towards release of the M^3 data set into the Planetary Data System with optimal calibration and characterization.

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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