M3 ON CHANDRAYAAN-1: STRATEGY FOR MINERAL ASSESSMENT OF THE MOON Carlé Pieters[1], Joe Boardman[2], Bonnie Buratti[3], Roger Clark[4], Robert Green[3], James W. Head III[1], Sarah Lundeen[3], Erick Malaret[5], Thomas B. McCord[6], Jack Mustard[1], Cassandra Runyon[7], Matt Staid[8], Jessica Sunshine[9], Larry Taylor[10], Stefanie Tompkins[11], Padma Varanasi[3] [1]Department of Geological Sciences, Brown University, Providence, RI 02912 (Carle_Pieters@brown.edu), [2]AIG, [3]JPL, [4]USGS, [5]ACT, [6]Sp. Sci. Inst. Bear Fight Center, [7]College of Charleston, [8]PSI, [9]Univ. MD, [10]Univ. Tenn., [11]SAIC.

The type, composition, and distribution of minerals on a planetary surface are a direct result of the initial composition and subsequent thermal and physical processing active over its history. Lunar mineralogy seen today is a direct record of the early evolution of the lunar crust and a variety of subsequent geologic processes common to terrestrial planets. Due to both its proximity to Earth and its role as the small endmember of differentiated terrestrial bodies, the Moon is a central element in understanding how planets work. A detailed characterization of the mineralogy of the Moon and documentation of the geologic context in which specific rock types occur are thus fundamental data to understand the geologic evolution of this important planetary body.

The Moon Mineralogy Mapper (M3, or "m-cube"). M3 is a state-of-the-art imaging spectrometer that is a guest instrument on Chandrayaan-1, the Indian Space Research Organization (ISRO) first mission to the Moon be launched in early 2008. M3 is a NASA Discovery program Mission of Opportunity led by PI Pieters and is designed and built at the Jet Propulsion Laboratory. An overview of initial science goals is provided in [1] and updated instrument characteristics are summarized in [2]. Implementation is currently on schedule for delivery of M3 to ISRO in the spring of 2007 for integration onto the Chandrayaan-1 spacecraft. Presented here is a description of the measurement plan developed by the M3 Science Team (see authors above) that is designed to provide high quality data to the community within the expected scope of the two-years of Chandrayaan-1 operation.

There are two important constraints on the amount and type of data to be returned by Chandrayaan-1. First, physics prohibits a 100 km sun-synchronous polar orbit. The natural evolution of the Chandrayaan-1 lunar polar orbit includes two full cycles of illumination geometry as over a year's operation. This is illustrated in Figure 1 where the colored zones indicate when the zenith beta-angle (phase angle at the equator) is less than 45°. There are thus two three-month periods each year of operation when this optimal illumination geometry is available for M3. Second, there are, of course, limits to downlink capacity and all instruments must naturally share this constraint and plan the best science return within mission limits. M3 is one of three very high-data-rate optical instruments that will all need to be gathering important science data during the same optical periods. The mission science data downlink is planned using the ISRO DSN receiving station in Bangalore.

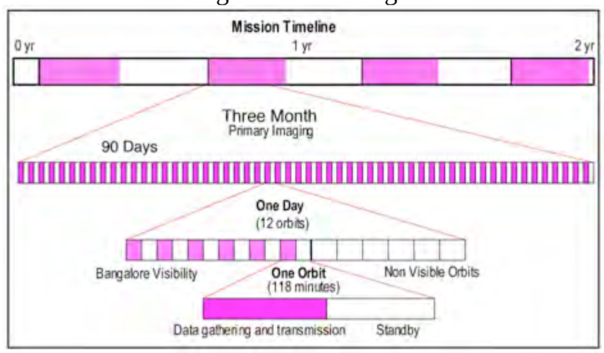

Figure 1. Schematic of prime optical periods over a two-year mission. For any given day of operation, downlink normally occurs during the 12 hours when Bangalore receiving station is visible.

As discussed in [1] and [2], to meet science requirements the overall science measurement design capabilities of the M3 imaging spectrometer are:

- 40 km FOV (allows contiguous orbit overlap)
- 600 spatial pixels (+ 40 dark under mask)
- 70m/pixel IFOV from 100 km altitude
- 0.7 - 3.00 µm (0.43 baseline lower limit)
- 260 spectral channels (10 nm/pixel)
- 12 bit/pixel

=> 44.4 Mbps operation
=> Pole to Pole = 157 Gb/orbit

The high data-rate for M3 precludes obtaining global coverage of the Moon using the full science capabilities of the instrument during Chandrayaan-1 operations. Since a large portion of the Moon is covered by well-mixed "mature" regolith, however, little science is lost if the full capacity of M3 is used in a more selective mode. The M3 Science Team thus developed two modes of operation to fit within the original downlink estimates as summarized below:

Targeted 40 km FOV:
600 spatial pixels (70m/pixel)
260 spectral channels (0.43 to 3.00 nm)
1 GB /orbit: 10 - 12° longitude swath

Global 40 km FOV:
300 spatial pixels (140m/pixel)
86 spectral channels
1GB/orbit: 135° longitude swath (alternating poles)

Based on the original estimated time available per orbit (when Bangalore is visible) allocated for M3 downlink, the M3 operation plan is to use approximately one of the four optical periods acquiring Global mode data in order to provide a lower spatial and spectral resolution context and the three remaining optical periods for full resolution science data acquired with Target mode for a prioritized sequence of science regions for each orbit (longitude ground track). With this strategy, the original estimates of M3 downlink available should allow near global coverage at the lower resolution Global mode and 10 to 25% coverage at the desired full resolution Target mode for science areas that are likely to exhibit mineral diversity (fresh craters, large central peak craters, basin massifs, mare basalt boundaries, etc.).

An example of coverage possible during the first month of operation in Global mode is shown in Figure 2 (assuming equivalent downlink time for all orbits Bangalore is visible). Although Global Mode data will not have full spectral resolution, as the downlink gaps are filled with later measurements, the M3 Global mode data will provide direct context for the M3 full resolution data from Target mode and will also provide a basemap to allow valuable integration of other important lunar spectroscopy data (HySI & SIR2 of Chandrayaan-1 and LISM of SELENE).

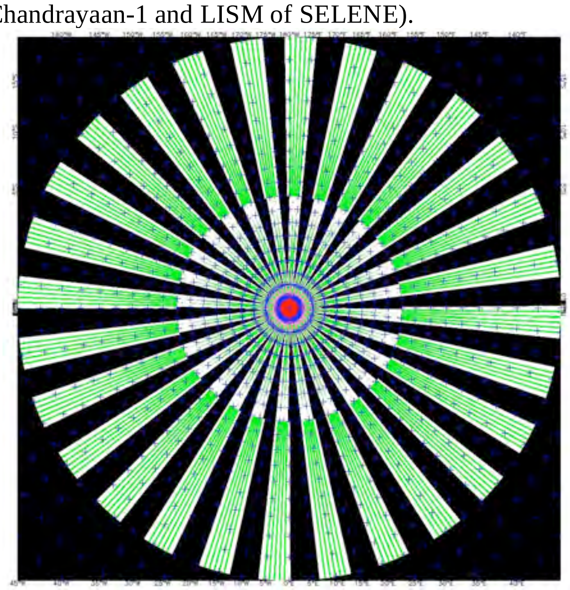

Figure 2. Equator to pole idealized coverage of M3 Global mode data during first full month of operation, assuming equivalent downlink time for each orbit. White is single coverage, green overlap area, purple to red >5 pass coverage; black are periods when Bangalore is not visible.

When M3 operates in the full resolution Target mode, targets must be prioritized for each orbital overpass. An example of Target mode coverage for the two-year+ mission is shown in figure 3. Over the next year the M3 Science Team will be identifying and prioritizing lunar regions to be included in these observations. Recommended priority targets from the science community are always welcome.

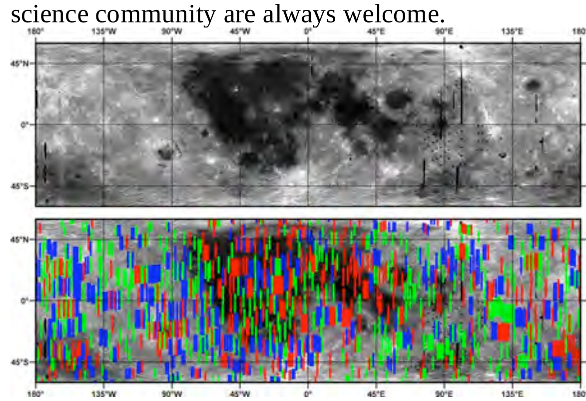

Figure 3. Schematic overview of M3 full resolution Target mode. Red: nominal 15% coverage; Green optimistic 30% coverage; Blue: extended mission 45% coverage. For any given orbit 10-12 degrees longitude of data can be acquired in order to fit within anticipated downlink constraints.

The bulk of M3 data will be delivered to PDS for community use one year after production (as stipulated in the US-India MOU). The M3 team is committed to outreach and international coordination and will also prepare data for the Lunar International Science Calibration/Coordination targets [3] for early release to the community. M3 calibrated data will appear in two principal forms, all of which are ENVI compatible imge cubes. Level 1 (produced at JPL) will be calibrated to be radiance at sensor including geometric corrections at the pixel level. No data will be resampled, but each pixel will include selenographic coordinates (based on spacecraft data and the standard lunar reference frame used by the mission). Level 2 data (produced at Univ. MD and ACT) is based on Level 1 data but includes phometric corrections (including wavelength dependence) and conversion of the data to reflectance. Again, the data will not be resampled in order to maintain the full integrity of the measurements. Although no standardized mosaicing of the data is planned, all data will have seleneographic coordinates for each spatial pixel. All spectral data are coregistered (within 0.1 pixel).

Acknowledgment: We thank NASA Discovery Program for supporting M3 development and implementation. The dedication of M3 team members at JPL has resulted in an extraordinary spectrometer. We are honored to be part of ISRO's Chandrayaan-1 mission.

References 1. Pieters C. M. et al. (2006) LPS37 #nnnn; 2. Green R. et al. (2007) these volumes; 3. Pieters et al., (2006) COSPAR proceedings submitted.