TARGETING FOR THE MOON MINERALOGY MAPPER (M^3) INSTRUMENT ON THE CHANDRAYAAN-1 MISSION.
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Background: The Chandrayaan-1 spacecraft is India's first mission to the Moon and is developed and launched by the Indian Space Research Organization (ISRO). Chandrayaan-1 will carry a set of 11 instruments, one of which is the Moon Mineralogy Mapper (M^3) that has been funded by NASA under PI Pieters (Brown University) and built at JPL. The M^3 instrument is a high uniformity and high signal-to-noise-ratio imaging spectrometer that operates across the solar-dominated portion of the electromagnetic spectrum from 0.7 to 3 micrometers [1, 2]. The effectiveness of imaging spectroscopy at these wavelengths for mapping the mineralogy of the Moon is reflected in the diversity of the spectral signatures of Apollo and Luna samples and lunar meteorites.

Because M^3 has a very high data rate, mapping the entire surface of the Moon at both high spatial and spectral resolution would exceed the nominal operational lifetime of the mission. Therefore, the M^3 instrument has been designed to operate in two distinct modes: target mode and global mode. The target mode captures the high spectral and spatial resolution data desired for science applications. And while the global mode captures data with lower spatial and spectral resolutions than target-mode data for the sake of lower data rate, the spectral resolution of global-mode data will still be higher than that of any previous global lunar dataset. The use of either mode during the mission is dependant on the optical period of the mission, the available data rate, and the coverage required.

Here we describe these operational modes, how they will vary during the optical periods, and how the M^3 science team is prioritizing surface coverage for targeted-mode operation.

M^3 Operational Modes: The global and targeted modes of M^3 will provide important hyperspectral data for scientific studies of the lunar surface at different scales. All data will be acquired from the nominal 100 km polar orbit of Chandrayaan-1 yielding a 40 km wide field of view.

Global-mode data will be acquired in 145º latitudinal swaths at a spatial resolution of ~140m/pixel and a will measure spectra from 86 of the available 260 spectral channels. The targeted data will be acquired at ~70 m/pixel using the full spectral range of the instrument. Targeted data can be acquired in ~12º swaths per orbit and the coverage need not be continuous. The target mode thus requires the definition of science regions along each operational orbit. The definition of science targets for this operational mode is described below.

M^3 Operational Timeline: The timeline for M^3 operations is divided into four optical periods during which illumination conditions are optimal [1]. The first optical period will be dedicated to mapping the Moon in global mode, which will be used to optimize the subsequent optical periods that will primarily focus on the higher resolution measurements.

First optical period: During the first optical period M^3 will acquire measurements over the entire surface of the Moon in lower-resolution global mode. With the current limitations of downlink and onboard memory, it is anticipated there will be sufficient capacity to initially achieve full coverage of the Moon during this time. Illustrated in Figure 1 is an example of global coverage using ~334 optimally placed sequential orbits during the first month of the first optical period. If remaining orbits are available during this period, M^3 will begin the science prioritized high-resolution target-mode coverage. The global data measured during the first optical period will be used to identify and prioritize regions for acquiring subsequent M^3 high-resolution data targeted along each degree of longitude during the remainder of the mission.

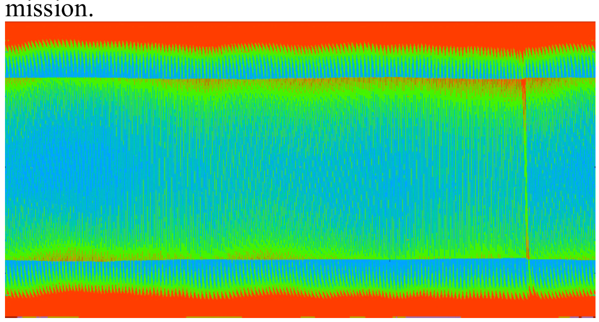

Figure 1. Possible coverage for data-takes in lower-resolution global mode of ~334 optimally placed sequential orbits in one month. Cool colors indicate no overlapping data, warm colors a larger number of coverage overlaps. The apparent discontinuity in coverage at ±55° is due to the alternating orbits of continuous data in 145° latitudinal swaths in global mode [Image centered at 0° longitude extending ± 180°; cylindrical projection ± 90° latitude.]

Optical periods two through four: Once the entire surface of the Moon has been measured successfully in global mode during the first optical period, the remainder of the mission will be utilized for high-resolution observations. Should there be any gaps in global-mode coverage remaining after the first optical period, they will be covered during the second optical period.

Target-mode measurements will be made using equivalent downlink to that available in the first optical period. Target-mode measurements along each orbit will be based upon science targets defined either prior to the mission or from rapid analysis of the initial M^3 global-mode measurements collected in the first optical period.

Priority high-resolution data: A major effort by the M^3 science team in preparation for orbital operations has been the continuing definition and organization of prioritized global science regions along each degree of longitude. The science team has been using the Rapid Environmental Assessment Composition Tools (REACT) software created by Applied Coherent Technologies (ACT) to define science targets.

Prioritization: The science team has primarily used geologic context along with the Standard Color Composite from Clementine UVVIS data, the Clementine 750nm albedo mosaic, and Lunar Prospector elemental data to define the spatial extent of regions for high-resolution targets. Targets are assigned a priority value of one through three. Priority one targets are expected be measured at the earliest possible opportunity and are defined as those targets that have high spectral contrast and probable high science return, are necessary for calibration or public outreach, or are part of the Lunar International Science Co-ordination/Calibration Targets (L-ISCT) [3].

For example, the central peaks of craters previously identified as containing distinct mineral spectral signatures [4] are all defined as priority one targets as these regions will have high spectral contrast and a high science return. Additionally we have defined the polar regions as priority one targets. These targets extend poleward of 80º and will be measured at every opportunity. Illustrated in Figure 2 is possible coverage of the polar regions during the first optical period.

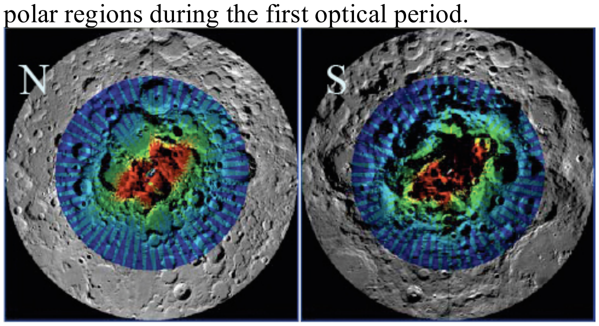

Figure 2. Predicted targeted-mode coverage of the polar regions during the first optical period. The colored areas cover the surface poleward of 80º. Blue indicates that the surface will be measured once while red indicates 4 or more measurements.

Targets assigned a priority of two or three will be measured at any time when downlink is available or when there are no other priority one targets to be measured along a given orbit. These targets typically cover larger regions and require multiple orbits or cover scientifically interesting areas with more mature surfaces (low spectral contrast). For example, Figure 3 shows two targets encompassing Giordano Bruno. The smaller target, covering just the crater, is a priority one target and is ~20 km in diameter. This smaller target is approximately half the 40 km field of view of the M^3 instrument and can be measured in a single, well-placed, orbital pass. The larger target is a priority three target that requires multiple passes to cover the entire region.

Large regions, such as the entire South Pole-Aitken Basin, have been defined as a priority three target so that as downlink is available data will be gradually collected over these important regions. These large areas are clearly visible in Figure 4, which illustrates the locations of all current targets. Priority one targets embedded in larger regions will normally be measured only once. However, exceptions occur for a few areas that are specially designated for calibration and instrument testing purposes. With this targeting approach, it is expected that M^3 high-resolution data will be acquired for 25% to 50% of each lunar longitude, accumulated over the four optical periods of nominal Chandrayaan-1 operations.

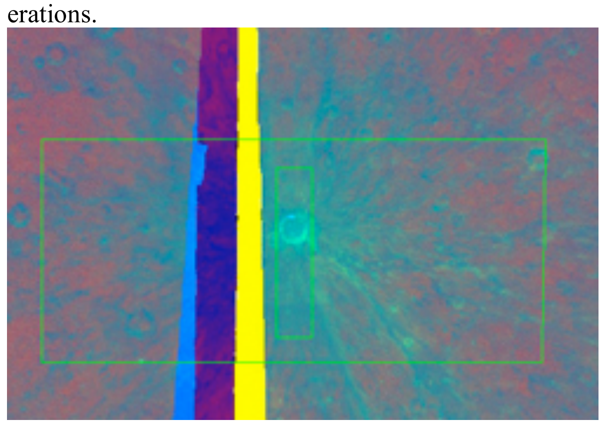

Figure 3. Target coverage over Giordano Bruno as seen with the Standard Color Composite using Clementine UVVIS data. The small target centered on the crater is priority one and ~20 km across while the larger ~400 km target is priority three, requiring multiple orbits.

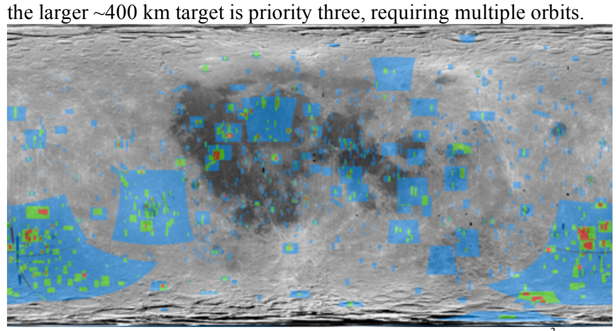

Figure 4. Map of presently defined priority regions for M^3 high-resolution data. Projection is the same as in Figure 1. Small regions embedded in lower priority targets appear as green or red.

References: [1] Pieters, C.M., et al. (2007) *LPSC XXXVIII* #1295. [2] Green, R.O., et al. (2007) *LPSC XXXVIII* #2354 [3] Pieters, C.M. et al., (2007) *J. Adv. Space Res.* [4] Tompkins, S. and Pieters, C.M. (1999) *MAPS 34*, 25-41.

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