**PREPARING TO SCOUT THE NEXT FRONTIER: HARDWARE AND OPERATIONAL CONSTRAINTS ENCOUNTERED DURING TARGETING OF THE LUNAR RECONNAISSANCE ORBITER CAMERA NARROW ANGLE CAMERAS.** S. J. Lawrence[1], M. S. Robinson[1], B. L. Jolliff[2], E. Bowman-Cisneros[1], T. Tranh[1], J. D Stopar[1], B. R. Hawke[3], S. D. Thompson[1], S. Koeber[1], and the LROC Targeting Action Team [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ (sjlawren@asu.edu) [2]Department of Earth and Space Science, Washington University, St. Louis, MO [3]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, Honolulu, HI

**Introduction:** The Lunar Reconnaissance Orbiter Camera (LROC) is one of six instruments aboard the NASA Lunar Reconnaissance Orbiter (LRO), scheduled for launch in Spring 2009. LRO will obtain scientific measurements of the Moon to enable future lunar human and robotic exploration. LROC investigation goals include landing site identification and certification, mapping of polar permanently shadowed and sunlit regions, meter-scale polar region mapping, global multispectral imaging, a global morphology basemap, characterization of regolith properties, and the determination of current impact hazards to enable the safe design and operation of lunar human habitats [1,2]. LROC has two imaging subsystems: the multispectral Wide Angle Camera (WAC) and the high-resolution Narrow Angle Camera (NAC). Only the LROC NAC requires active targeting.

**NAC Target Selection:** The ambitious science goals of the LROC investigation require an equally ambitious targeting strategy. NAC images targeted by the LROC Science Team will address multiple objectives, including the LROC proposed measurement objectives, research objectives proposed by the LROC participating scientists, and targets requested by the NASA Constellation Project to support human lunar exploration. A companion abstract [3] discusses LROC Science Team NAC target sources and rationale in detail. Here, we summarize important operational constraints on LROC NAC targeting. We also introduce the LROC NAC public targeting submission system, which will allow members of the general public and outside scientists to directly participate in the United States' first steps back to the Moon.

**NAC Targeting Constraints:** LROC NAC observations are affected by LROC hardware capabilities, LRO pointing, LROC NAC data transfer rates, and the location of the target on the Moon. These factors place important constraints on LROC operations during the nominal mission which must be considered when planning NAC observations.

*Hardware Constraints:* The two NACs are monochrome linescan imagers with a resolution of 50cm/pixel. The NACs are designed to have a combined downtrack footprint of 5×25km (or 125 $km^2$) from the nominal 50-km LRO orbit. The NACs can also operate in a 2x summed mode (where exposure time is doubled) with a combined downtrack footprint of 5×100km. Immediately after image collection, the data is transferred from the camera buffer to the spacecraft recorder, requiring approximately ~220 seconds (or 11.9° of downtrack latitude). No images can be collected during the data transfer. Figure 1 shows the effects of the buffer read-out time. Up to 14 images will be acquired per orbit, for a theoretical maximum daily total of approximately 180 images. Depending on the LROC downlink allocation and acquisition parameters, at least 50,000 NAC images should be acquired during the nominal mission, which theoretically enables high-resolution coverage of approximately 9% of the lunar surface.

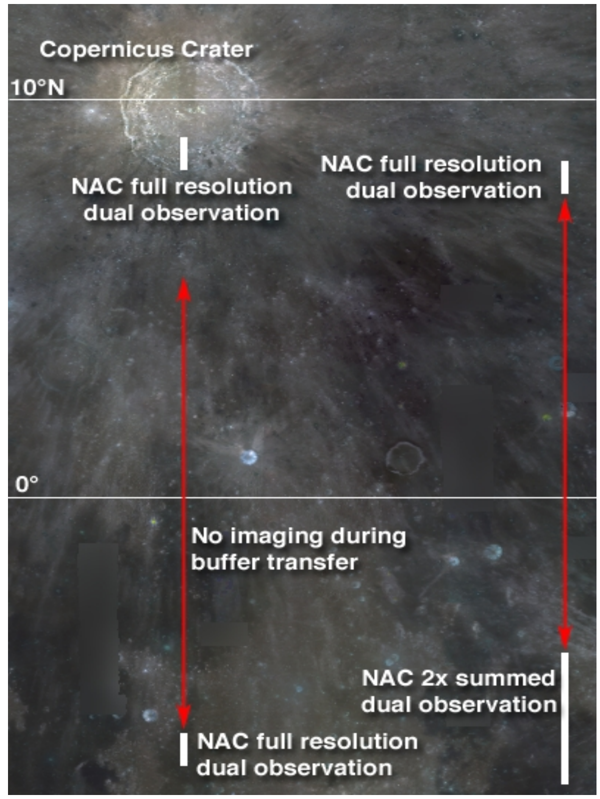


*Figure 1: Relative sizes of LROC NAC Nominal dual observations (5x25 km), 2x summed images (5x100km), and the data transfer "shadow zone."*

*LRO Pointing and Positioning:* The LROC imaging subsystems (NAC and WAC) are body-fixed pointing instruments. The position of the LRO with respect to the lunar surface and the Sun is therefore the most important driver for LROC NAC targeting. LROC NAC observations requested by the LROC Science Team must be planned in advance using LRO ephemeris data, and viewing opportunities for any one region on the lunar surface during the nominal mission are limited. In the nominal mission, the LRO itself will be in a 50km ±15 km circular mapping orbit. As the orbital height decays over time, the NAC footprint will increase or decrease in size accordingly.

The contiguous areal extent of LROC mosaics and LROC's ability to obtain the image sets required for the creation of stereo products (see following section) is heavily dependent on target latitude. Above 57°N and below 57°S, off-nadir imaging can view regions from directly adjacent orbits, and above 85°N and below 85°S, NAC observations begin to overlap adjacent orbits. In contrast, at the equator the LRO orbit-to-orbit offset is ~31 km, meaning that a 30° off-nadir roll (beyond LRO's operating constraints) would be required to collect cross-track images from adjacent orbits. However, off-nadir observations can be used to image locations centered between orbits.

*Stereo Observation Constraints*: Topographic information at spatial scales of 1-5m allows detection of potential small-scale hazards (e.g., craters), that could present challenges for future lunar expeditions and affect the surface trafficability of the site. Small shallow craters can be assessed both from images with extreme incidence angles (>80°) and derived meter-scale topographic products. LROC will provide stereogrammetric and photometric stereo observations (within the pointing constraints of the mission) for high-priority sites, but lacks the funding profile to produce more than a handful of test stereo products.

LROC stereo observations are operationally challenging. The LROC team can request up to three off-nadir (1°-20°) spacecraft rolls for each 24-hour period, enabling cross-track stereogrammetric observations. However, the spacecraft roll itself creates a 60°-latitude zone (30° above/below target) that sacrifices nadir-pointing observations. Due to the limited availability of off-nadir observations, a typical stereogrammetric dataset will consist of one nadir and one off-nadir observation. Many of the available off-nadir roll opportunities will have to be used to increase the areal coverage of non-stereo mosaics of important lunar regions, thus further limiting the number of off-nadir rolls available for stereogrammetric observations and the areal coverage of stereo datasets.

The slow rotation of the Moon precludes a Sun-synchronous orbit for LRO, presenting problems for creating large areal mosaics with consistent lighting conditions but providing opportunities for repeat coverage under different lighting conditions. LROC will collect repeat nadir observations under different solar illuminations and solar azimuths to enable the eventual future production of photometric stereo products (e.g., [4]). At least four repeat observations with different solar illumination conditions and solar azimuths will be required to produce photometric stereo products. The LROC Science Team will produce several test photometric stereo products to validate the dataset.

*LROC NAC Targeting Opportunity Example*: Using an early version of the LRO predict ephemeris, the LROC Team has performed basic targeting simulations of select sites to evaluate operational constraints on NAC targeting. For example, Figure 2 shows a simulated image campaign for the Constellation design reference landing site near Peek Crater (2.5°N, 86.5°E) in Mare Smythii. The

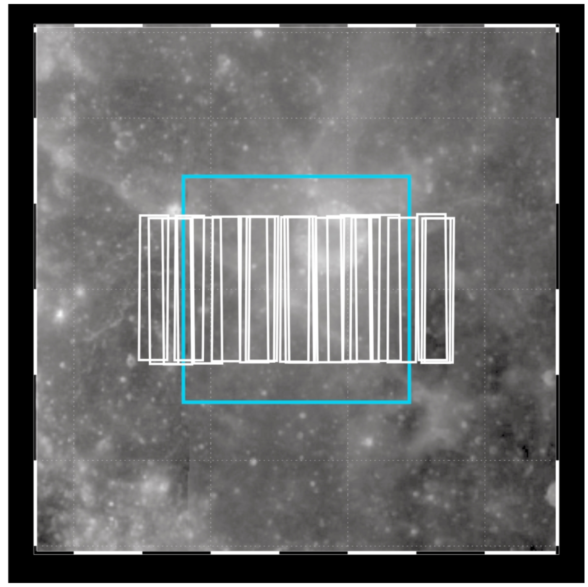

*Figure 2: Simulated LROC NAC observation opportunities for the Mare Smythii design reference landing site. Blue square represents the size of the desired mosaic; the white rectangles are NAC footprints. Note the "bunching" effect of the NAC footprints due to the near-equatorial location of this site.*

goal of the analysis was to determine the number of standard NAC observation opportunities falling within a 40x40km region centered on the design reference landing site. This analysis does not consider missed opportunities due to spacecraft activities or readout time from preceding NAC observations along the orbital track. A total of 23 standard NAC observations are available for this region during the nominal mission. The creation of photometric stereo data products would require successfully obtaining all of these observations. This example illustrates the potential difficulties associated with acquiring areally-large stereo datasets during the 1-year nominal mission, and stereo image sets will be a relatively minor component of the total LROC data volume.

**LROC Public Targeting Website:** The general public and outside scientists will be able to propose NAC targets using the LROC public targeting interface, which will be accessible through the main LROC webpage shortly before LRO launch:

http://lroc.sese.asu.edu

Users will be able to view existing target requests and, after launch, see regions where images have already been collected. Up to five point targets per day can be submitted, and users will be notified when their images have been released to the NASA Planetary Data System.

**References:** [1] Chin G. et al. (2007) Sp. Sci. Rev. 129:4, 391-419 [2] Robinson M. S. et al. (2005) LPSC XXXVI, #1576 [3] Jolliff B. L. et al. (2009) LPSC XXXX, this volume. [4] Gaskell R. W. et al. (2007) LPSC XXXVIII, #1333