ANALYSIS OF HIGHLY ILLUMINATED ZONES NEAR THE LUNAR SOUTH POLE. E. J. Speyerer[1] and M. S. Robinson[1], [1]Lunar Reconnaissance Orbiter Camera Science Operation Center, School of Earth and Space Exploration, Arizona State University, Tempe, AZ (espeyerer@ser.asu.edu).

Introduction: The spin axis of the Moon is tilted by only 1.54° (compared with the Earth's 23.5°), leaving some areas near the south pole in permanent shadow, while other nearby regions remain sunlit for the majority of the year. Previous studies have delimited these regions using theoretical models, Clementine images, and topography from Kaguya and LRO [1-5]. Theory, radar data, neutron measurements, and Lunar CRater Observation and Sensing Satellite (LCROSS) observations suggest that volatiles may be present in cold traps in permanently shadowed regions [6-10]. Thus, areas of near permanent illumination are prime locations for future lunar outposts due to their benign thermal conditions and near constant accessibility to solar power [11-12].

One of the primary scientific objectives of the Lunar Reconnaissance Orbiter Camera (LROC) is to unambiguously identify regions of permanent shadow and near permanent illumination using its two imaging systems that provide medium and high-resolution views of the south pole [13]. Since the start of the nominal mission, LROC has acquired over 4,800 Wide Angle Camera (WAC) images and over 2,500 Narrow Angle Camera (NAC) image pairs within 2° of the south pole. We reduced a subset of these images (illumination maps, movie sequences, and high resolution maps) to delimit lighting conditions over one year. Analysis of these products reveal regions near the south pole that remain illuminated for a majority of the year (92% of the year, a 10% increase over previous studies [1,4]).

Wide Angle Camera Products: LRO's 50-km polar orbit enables images of south pole to be acquired every ~2 hours during normal spacecraft and instrument operations (average time between WAC observations is 2.3 hours including spacecraft and instrument disturbances). The WAC 90° field of view (monochrome mode) allows for a 104-km region within 2° degrees of the pole to be acquired at a resolution of 100 m/pixel. This repeat coverage enables the creation of illumination movies and multi-temporal illumination maps that can be used to delimit permanently shadowed regions and permanently (or near permanently) illuminated regions.

Illumination Movie Sequences. When LRO passes over the south pole, the WAC images from 80° to 90° S on the dayside and back to 80° S on the night side. We compiled these images into a year-long illumination movie, with time steps between frames typically ranging from 2-4 hours. The movie sequences allow us to visualize the way lighting conditions at each pole change over a calendar year.

Multi-Temporal Illumination Maps. The same WAC movie sequence frames were used to produce multi-temporal illumination maps of the south pole. First, binary images show which regions are illuminated and in shadow are made by selecting a threshold value for each WAC image. These binary images are then stacked and the percentage of time each pixel is illuminated is calculated (Figure 1 and 2).

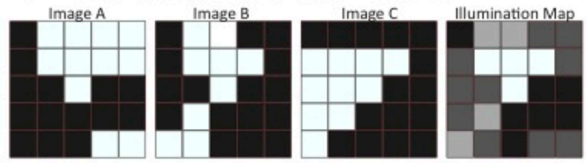

Figure 1- Example of three binary images used to create the illumination map.

Figure 2- Illumination map of the south pole (88° to 90° S) created from over 1,700 WAC images acquired over 6 lunar days.

Narrow Angle Camera Products: The two NACs provide high-resolution (0.7 to 1.5 m/pixel) images of select regions around the south pole. Due to the NAC's 2.85° field of view (5.7° combined) broad scale multi-temporal mapping is limited. However, during summertime months, when shadows are at a minimum, the NACs acquire 100s of images that are used to create meter scale maps of the illuminated terrain at the south pole. During the winter months, a majority of the region is in shadow, so NAC imaging is focused on previously identified illuminated peaks that stay illuminated for a majority of the year [1, 3-4]

Due to its high resolution, the NAC images can be used to validate previous illumination studies that used lower-resolution topographic models (200-500 m/pixel). NAC images revealed several cases where small regions of the surface were illuminated when previous models predicted they would be in shadow (Figure 3). Similarly, NAC images have also shown some regions in shadow at times in which models showed them illuminated.

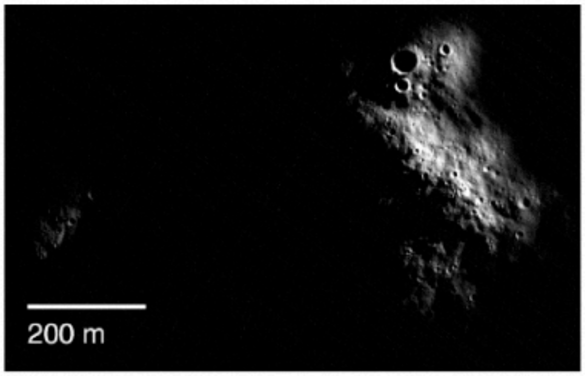

Figure 3- Small illuminated peaks in a region (Point B [1,4]) thought to be in shadow (M126688662L, sub-solar latitude = +1.45°, sub-solar longitude = 62.0° E).

Illumination Analysis: Previous studies have identified peaks around the south pole that remain illuminated for a majority of the year, including a massif (Point B) located ~10 km off the edge of Shackleton crater that is estimated to be illuminated for 82% of the year [4]. Using the WAC and NAC datasets, we investigated in greater detail when this massif is illuminated over a six month period.

The 100 m/pixel WAC illumination maps were used to locate regions of extended illumination to a finer scale than previous datasets and models have permitted [1,2-5]. In addition, test regions were defined to look for illumination surfaces around a particular point. Figure 4 shows how the illumination percentages increase as the size of the test region (centered at 89.4° S 223° E) is increased.

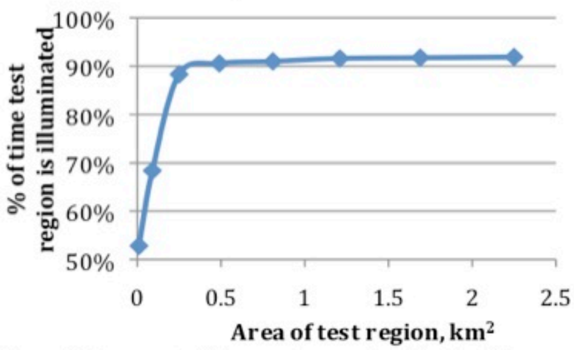

Figure 4- The percent of time a region remains illuminated increases as the size of the test region increases. This demonstrates the need for surface mobility or an array of solar panels for any future polar outpost that needs to remain illuminated for extended periods of time.

This plot illustrates that while it is difficult to fine a small region that is illuminated for a large majority of the year, a small amount of surface mobility greatly increases the time illuminated. Currently, we have not found an area with permanent illumination at the south pole. We have found a 2.25 km^2 region (centered at 89.4° S, 223° E) that remains illuminated for 92% of the year, which is 10% higher than the value previous reported in studies that examined only single points in only topographic models [4]. These percentages may change slightly as we acquire more complete dataset through the rest of the science phase of the mission.

Conclusions: The Moon's slightly tilted axis provides a unique opportunity for regions near the vicinity of the pole to be permanently shadowed while other nearby regions can have extended periods of sunlight. Illumination in these regions has been previously studied with Clementine UVVIS data and topographic models from laser altimeters. LROC compliments this analysis with higher resolution data (up to meter scale) that can unambiguously identify these regions. The WAC provides 100 m/pixel imaging for polar movies that enable the visualization on how lighting conditions change over time and multi-temporal illumination maps that illustrate regions of permanent shadow and extended illumination. The NAC's detailed view of the polar region can be used for high resolution mapping as well as locating small regions of illumination (Figure 3 and 5). This analysis can be applied to other highly illuminated areas in other regions around the south and north pole. Together, the NAC and the WAC can enhance our knowledge of the lighting conditions at the pole and provide a new dataset planning future science and exploration missions to the polar regions.

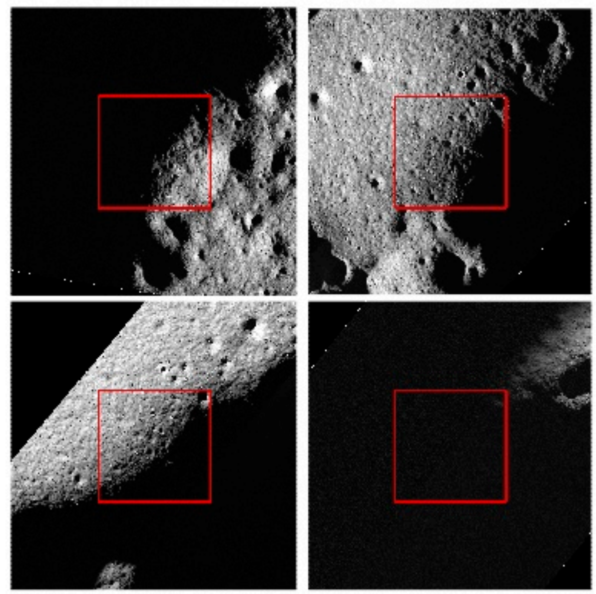

Figure 5- Detailed look at the illumination conditions of the same 2.25 km^2 region (red box centered at 89.4° S 223° E) throughout the mission using NAC images. UL) M108578776 UR) M112490681 LL) M117228165 LR) M121951177.

References: [1] Bussey et al. (1999) *GRL*, 26, 1187-1190. [2] Bussey et al. (2003) *GRL*, 30, 1278. [3] Noda et al. (2008) *GRL*, 35, L24203. [4] Bussey et al. (2010) *Icarus*, 208, 558-564. [5] Mazarico et al. (2010) *Icarus*, In press. [6] Watson et al. (1961) JGR, 66, 1596-1600 [7] Ingersoll et al. (1992) *Icarus* 100, 40-47. [8] Feldman et al. (2000) *JGR*, 105, 4175-4195. [9] Nozette et al. (2001) *JGR*, 106, 23253-23266. [10] Colaprete et al. (2010) *Science*, 330, 463-468. [11] Goddard (1920) *The Papers of Robert H. Goddard*. McGraw-Hill, New York. [12] Heiken et al. (1991) *Lunar Sourcebook*, Cambridge University Press, Cambridge. [13] Robinson et al. (2010) *Space Sci. Rev.*, 150, 81-124.