DESIGN AND PROCESSING OF THE LUNAR NORTH POLE MOSAIC. R. V. Wagner, M. S. Robinson, and the LROC Team. School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287-3603 (rvwagner@asu.edu).

Introduction: The Lunar Reconnaissance Orbiter Narrow Angle Camera (NAC) consists of two line-scan cameras aimed side-by-side with a combined 5.7° FOV. The NAC acquired images with a pixel scale of 0.5 m from a 50 km near-circular orbit from 2009 through 2011, and pixel scales ranging from 0.5-2 m from a 30×180 km orbit since December 2011 [1].

In the northern hemisphere, where the orbit is highest, the relatively large size of NAC footprints allows for complete coverage at consistent, moderate incidence angles and high resolution to a extraordinary distance from the pole. In 2014, we used this coverage to produce the first version of the 681 gigapixel Lunar North Pole Mosaic (LNPM), a 2 m/px mosaic from 60°N to the pole (Figure 1), currently released on the internet at lroc.sese.asu.edu/gigapan/ [2,3]. We are currently finishing an update of this mosaic with more uniform illumination, and are working on expanding the covered area out to 40°N, which will include just over 2 terapixels of image data.

Processing: The processing method for the LNPM was driven by the final tiled format required by the website we used to host the LNPM, Gigapan.com. Their web viewer requires that the image be split into 256x256 pixel jpeg tiles at each zoom level. Thus, the LNPM was processed in square tiles 16,384 pixels on a side, the largest multiple of 256 that could be processed on our systems without excessive memory usage. The tiling was based purely on pixel coordinates, not on geodetic coordinates. Most of the processing was done using the USGS ISIS software [4].

To minimize file size used by non-image (null) data, individual NAC images, which are usually long strips with a ~10:1 length:width ratio, were map-projected in square segments. The X/Y pixel bounds (in the map space of the final mosaic) of each segment were calculated during processing, and stored in a database that was used to select only the segments that overlapped a mosaic tile for use in creating that tile. The images are not controlled to each other; rather, we are relying on the high accuracy of cross-over controlled SPICE files [5] and NAC geometric model (absolute positional accuracy better than 19m [6], with images taken at similar times having similar errors) to minimize image-to-image offsets.

The final processing step used a combination of ISIS and ImageMagick to scale the tiles to all required resolutions, optionally add resolution-dependent feature name and latitude/longitude grid annotations, and split each tile into numerous 256x256 pixel subtiles.

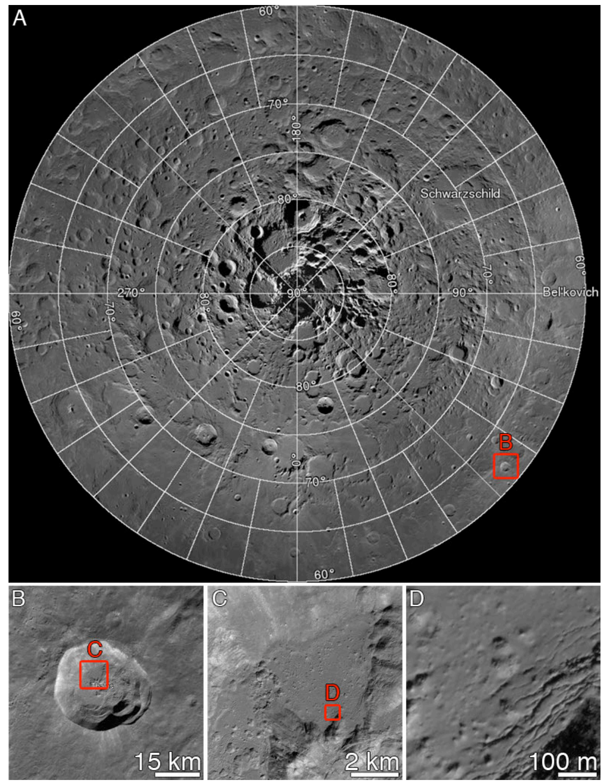

Figure 1: Panel A shows a zoomed-out view of the annotated version of the current Lunar North Pole Mosaic. Panels B-D show increasing zoom levels of a portion of Thales crater. Panel D is a single full-resolution tile from the final product.

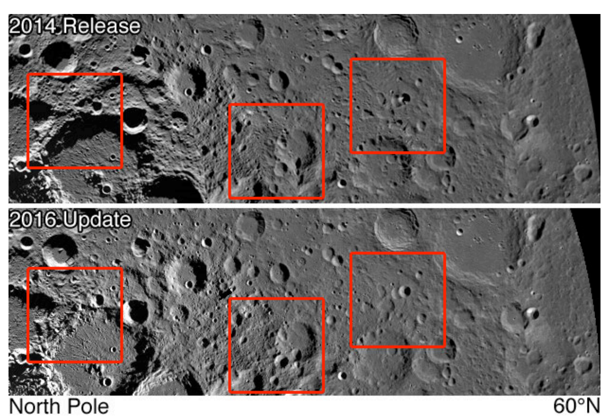

Figure 2: Improvements to the LNPM. Top panel is the original release, bottom panel is the updated version. Red boxes mark some areas of improved lighting.

Image Selection: Images for the LNPM were selected in three different ways, depending on the latitude range.

Collars (60-82°N): The LNPM is largely made up of "collars" of NAC images: for one-month periods, the NACs would image a specific latitude band on every orbit or every other orbit. Due to the high orbital altitude in the far northern hemisphere, NAC footprints on adjacent orbits overlap, so this imaging sequence produces seamless mosaics with consistent lighting at a given latitude. There are some lighting discontinuities between collars, but where possible we have minimized these by obtaining collars during the months where the Sun is closest to the zenith in the images.

Polar Region (82-90°N): The central section of the LNPM does not use collars. Instead, it uses images taken throughout the mission during northern summers (sub-solar latitude north of the equator) to maximize the amount of illuminated terrain. Image mosaicking order was based on the 85.5-90°N 50 cm/px polar mosaics [2,7,8]: Images were sorted into bins by sub-solar latitude, and sorted within each bin by the image's beta angle (angle between the orbital plane and the Sun-Moon vector), with highest-Sun images on top. Pole-crossing images were trimmed to remove the part of the image on the night side. The image order was then manually adjusted to clean up areas with inconsistent lighting, comparing the results to a low-resolution preview mosaic created using pixel-by-pixel, lowest-incidence-angle ordering (a very slow algorithm, which leaves some artifacts at image boundaries, so it couldn't be used for the final mosaic) to identify where improvement was possible.

Southern Expansion (40-60°N): Below 60°N, the ground tracks of adjacent orbits are farther apart than a single NAC pair can cover, so it is no longer possible to create continuous collars. In this region, we are selecting images from the large existing image data set and targeting new observations to fill gaps in the high-Sun coverage, restricting image selection to those with a beta angle less than 50°. Over 60,000 images fit this restriction in this region. For comparison, the updated 60-90°N LNPM only uses 15,780 source images

The ordering criteria have not yet been finalized for this expansion. While a simple "minimum incidence angle" approach may work, it will likely lead to many locations where adjacent images are lit from opposite directions. We are currently testing ordering criteria similar to the 80-90°N images, with additional controls for lighting direction, and are also considering algorithms to find clusters of images with similar lighting direction, so that while the mosaic as a whole may not have uniform lighting, there will be near-uniform regional lighting.

A note on sampling scale: This extended mosaic is sufficiently large that distortions from the polar stereographic projection will produce a significant difference in pixel scale between the center (2 m/px) and edges (~1.6 m/px) of the map. Fortunately, due to LRO's elliptical orbit, the native resolution of NAC images improves from north to south, and is usually slightly better than 1.6 m/px at 40°N. Thus, even at the edges of the map, the source data is not oversampled. The crossover point between polar stereographic map resolution and average image resolution is ~35°N, however, so any equatorial expansion would require a different map projection. We excluded all potential source images with pixel scales worse than 2 m/px.

Publication: The current 60-90°N version of the LNPM is viewable at lroc.sese.asu.edu/gigapan/. The updated version of the same region should be released by March 2016. Imaging for the extended mosaic from 40-90°N is still ongoing, but that 2 terapixel version should be released in late 2016 or early 2017.

References: [1] Robinson et al. (2010) *Space Sci. Rev*. DOI: 10.1007/s11214-010-9634-2. [2] Wagner et al. (2015), *LPS XXXXVI*, Abstract #1473. [3] http://lroc.sese.asu.edu/posts/738 [4] Anderson et al. (2004), *LPS XXXV*, Abstract #2039. [5] Mazarico et al. (2013) *LPS XXXIV*, Abstract #2414. [6] Speyerer et al. (2014) *Space Sci. Rev*. DOI: 10.1007/s11214-014-0073-3. [7] Henriksen et al. (2013), *LPS XXXXIIII*, Abstract #1676. [8] Waller et al. (2012), *LPS XXXXIII*, Abstract #2531.

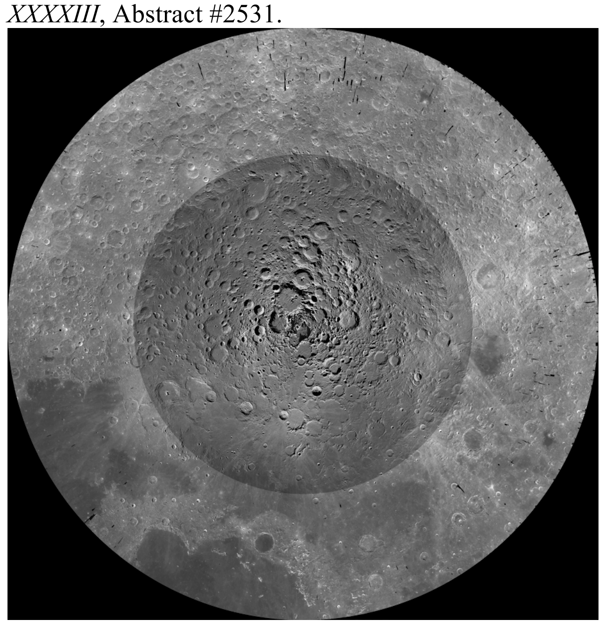

Figure 3: Images available for the expanded LNPM as of January 2016. The dark region in the center is the 40-60°N LNPM. Close inspection of the top and right edges show gores where we do not yet have complete coverage with appropriate lighting.