REGIONAL DIGITAL TERRAIN MODEL PRODUCTION WITH LROC-NAC. S. Mattson[1], L. Ojha[1], A. Ortiz, A.S. McEwen[1], K. Burns[2]. [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA (smattson@pirl.lpl.arizona.edu), [2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA.

Introduction: The Narrow Angle Cameras on the Lunar Reconnaissance Orbiter Camera (LROC-NAC) acquire stereo images on subsequent orbits by rolling the spacecraft off-nadir [1]. A NAC observation is composed of a left and a right frame (L and R), to provide a wider field of view. Each NAC frame is 5000 samples wide by up to ~52,200 lines long. The swath width of the NACL/R observation is ~5 km (given 50 cm pixel scale from the mapping orbit altitude of ~50 km). Stereo pairs taken during the mapping orbit (~50 km altitude) are used to generate Digital Terrain Models (DTMs) with a horizontal scale (post spacing) of 2 m or better [2]. LROC-NAC DTM production is carried out at various institutions affiliated with the LROC team including Arizona State University, Astrogeology Center - U.S. Geological Survey, Ohio State University, NASA Ames, JPL, University of Arizona, DLR [3]. We describe here the production of DTMs for science use and for the Lunar Mapping and Modeling Project (LMMP) [4,5] done at the University of Arizona (UA). To date the UA has completed 7 science DTMs and 5 regional LMMP DTM mosaics.

Table 1. Constellation Program sites assigned to the University of Arizona for DTM production.

SITE	# stereo pairs	CLon	CLat
Alphonsus	4	257.85	-12.57
Humboldtianum	2	77.16	54.52
King Crater	3	119.89	6.41
Mare Moscoviense	3	150.48	26.17
Orientale 1	5	264.63	-26.16

DTM Production: Source images are downloaded from the LROC Science Operations Center data portal as Engineering Data Records (EDRs). Source images consist of geometric stereo pairs. LROC targets stereo images on different orbits, ideally closely spaced in time, that have similar incidence angles and a stereo convergence angle of 10º-25º. During DTM production with NAC images, it was determined that the optimal incidence angle range was between 30º and 70º. Some NAC images are affected by spacecraft jitter, which can result in elevation artifacts or noisy terrain data [6]. Additional data included in DTM production are LRO's Lunar Orbiter Laser Altimeter (LOLA) laser tracks [7]. Preprocessing of the image data is done with the USGS Integrated Software for Imagers and Spectrometers (ISIS) [8]. Triangulation (or bundle adjustment) of the NAC images is performed within SOCET Set (© BAE Systems, Inc.). A network of image tie points and XYZ control points to LOLA is added until the RMS of a solution is <1, elevation differences along seams between adjacent images are minimal (<2 m) and the elevation differences between the stereo model and LOLA shots are ~2 m or less. Orthorectified images are created in SOCET Set at the mapped pixel scale for science DTMs (e.g. 50 cm) or at the DTM post spacing for LMMP projects (e.g. 2 m).

DTMs with multiple stereo pairs: The LMMP sites produced at the UA (Table 1.) were selected from the NASA Constellation program 50 Regions of Interest (CxROI) [9]. Each ROI consists of a 40x40 km box with a 20x20 km and a 10x10 km box centered inside. The minimum DTM coverage requirement for LMMP is the 10x10 km box in the CxROI. In the LMMP DTMs, regional coverage was achieved by bringing contiguous stereo pairs into a single SOCET Set project and triangulating all overlapping images together. The orbit of LRO proceeds through all local times of day, therefore complete coverage of the 10x10 box typically includes adjacent sets of stereo pairs that have different incidence angles from each other. With a single pair of LROC NAC stereo images, the RMS residuals are typically ~0.25 pixels and are rarely larger than 0.4 pixels. When working with multiple

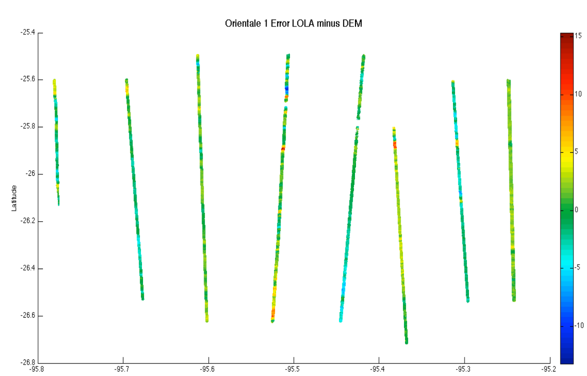

Figure 1. Comparison of LOLA tracks to Orientale 1 DTM coverage. Error is in meters, and is the color-coded according to the difference between the LOLA elevation value and the DTM value at the location of the LOLA shot.

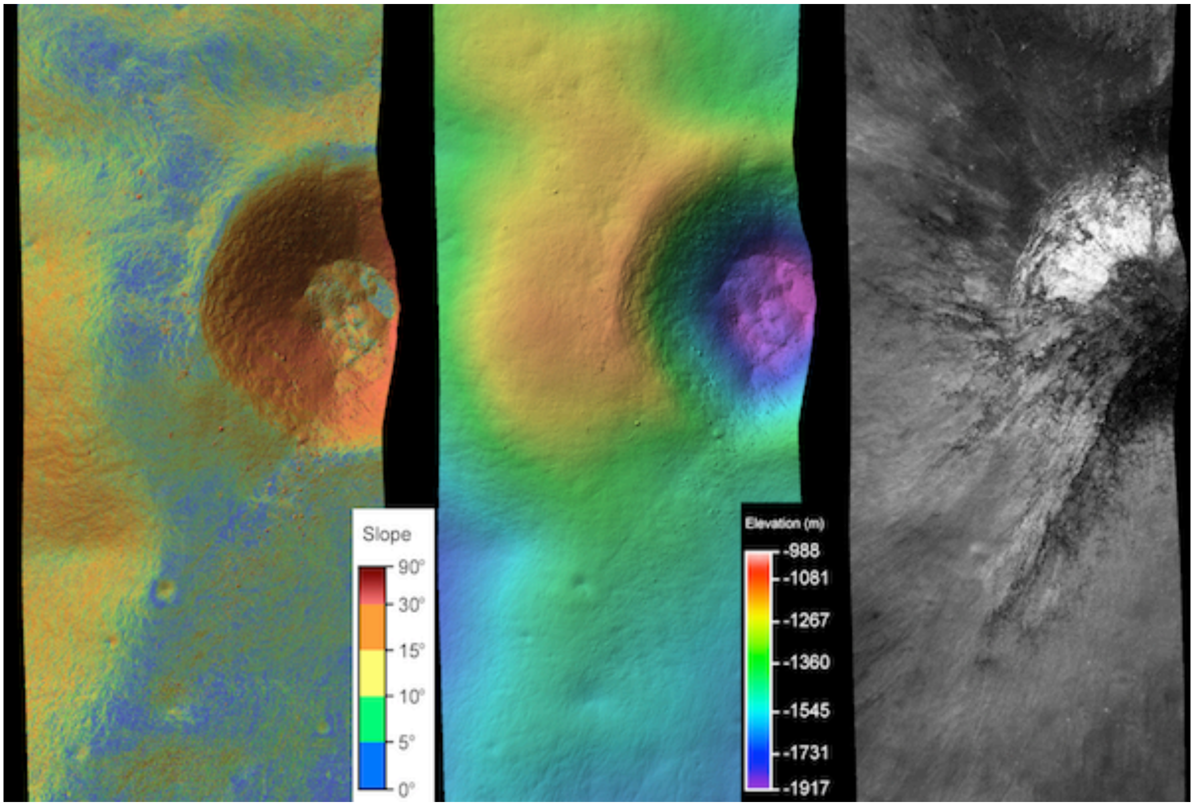

Figure 2. Detail of examples of output products for a DTM of a fresh impact crater generated from NAC frames M141932532 and M141939317. Slope map draped over shaded relief image (left); colorized elevation map over shaded relief (middle); orthomosaic of M141939317L/R (right).

sets of stereo images of the same region, there may be points with larger residuals, but the overall solution RMS is typically less than 1 pixel. The higher RMS from tying multiple stereo pairs together is due to errors propagated from measuring tie points through images with different incidence angles. Each input NAC frame is orthorectified to the DTM and exported for post-processing in ISIS.

Error Analysis: Positional accuracy values are reported in the SOCET SET triangulation solution for X (longitude) and Y (latitude) in units of meters. The final RMS value is also reported. The RMS is in units of image pixels. The elevation error for the entire DTM is determined by comparing the final DTM to the LOLA tracks used to control the model with XYZ points (Fig. 1). The average difference, minimum and maximum difference (absolute values) and standard deviation of the error are reported.

Output products: The final DTM is exported from SOCET Set and converted to ISIS format to apply the correct mapping labels. In addition, a hillshade image, color shaded relief image (color hillshade), slope map, and confidence map are provided in GeoTIFF format (Fig. 2). These products are made using GDAL routines. Orthoimages from the L and R frames are tone matched using ISIS *equalize* and mosaicked together. For LMMP, the nadir-most half of each stereo pair used for the orthomosaic. The orthomosaic is then converted to GeoTIFF format.

Conclusion: High resolution DTMs are essential for identifying potential landing sites, landing site hazard assessment, and surface operations and navigation. Site-specific science DTMs also serve as a foundation for orthoprojection and control of local/site mosaics. Access to LMMP products generated at the UA and other participating institutions will be available freely to the public through the LMMP Portal, http://www.lmmp.nasa.gov. The LROC team releases DTMs and associated products to the public on a regular basis at http://wms.lroc.asu.edu/lroc/dtm_select. We encourage use of these products for science analyses.

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