

NEW LUNAR CARTOGRAPHIC PRODUCTS REGISTERED TO THE UNIFIED LUNAR CONTROL NETWORK 2005 (ULCN 2005). B. A. Archinal, T. M. Hare, T. L. Becker, L. A. Weller, E. M. Lee, M. R. Rosiek, L. R. Gaddis, and R. L. Kirk, U. S. Geological Survey, Astrogeology Team, 2255 N. Gemini Drive, Flagstaff, AZ 86001, USA, barchinal@usgs.gov.

Introduction: We are in the process of registering a number of lunar cartographic products to the Unified Lunar Control Network 2005 (ULCN 2005). See the USGS Open-File Report [1] for information on the ULCN 2005 itself. The primary purpose for the creation of that network was to remove the large horizontal errors known to be present in the Clementine Lunar Control Network (CLCN) [2], and thus allow for the possible generation of an improved Clementine Basemap Mosaic (CBM) [3] and the other Clementine mosaics [4, 5]. The generation of a geometrically corrected CBM is now underway. However, in the interim several products of interest have been created that are either “corrected” or explicitly tied to the new network. This includes interim “warped” (see below) versions of the Clementine mosaics, the USGS shaded relief airbrush mosaic [6], the Lunar Orbiter global digital mosaic, selected high-resolution Lunar Orbiter frames, an improved version of the ULCN 2005 topographic model, and the NASM-USGS 1 km “planet-wide” lunar DEM. The ULCN 2005 itself is being updated and we hope to tie its images to new lunar datasets as they become available over the next few years, so that all lunar cartographic products – new and old – can eventually be connected to each other at the sub-pixel level of accuracy.

Updated (“Warped”) Clementine Mosaics: As described previously [7], we have created improved versions of the CBM and other Clementine mosaics (UVVIS [4] at 100 m/pixel and NIR [5] at 500 m/pixel) by warping the mosaics based on the change in point coordinates from the CLCN to the ULCN 2005. We used a 6 parameter polynomial warp on forty-eight 30° x 30° tiles and two 31° latitude coverage polar tiles (buffered on all sides by 0.2°), with RMS errors at less than the 200 meter level. The tiles are clipped back to 30° x 30° size before merging and blending them into global mosaics. Joint lines between the tiles are only faintly detectable in the output products. This process was completed using the ESRI® Arc/Info Workstation warping routines. The most difficult part of this task was merging the tiles back together. Note that because of the residual distortions that are introduced (even if only at the 200 m level) and particularly because this product is *not* orthorectified to topography, such as that of the ULCN 2005, these versions are not intended to replace a full “redo” of the mosaics, but simply to provide a product with substantially improved geometry that can be used for interim instrument targeting and other near-term applications where more accurate coordinates are required. More detailed information on this process is provided by Hare, et al. [8].

The warped mosaics and all of the other products described below are available or will be available via the USGS PIGWAD [9] website (<http://webgis.wr.usgs.gov/>), either for viewing (Figure 1) in GIS style applications or for downloading from the lunar data ftp area. The “warped” CBM is also being used as the basemap for the Google Moon website (<http://www.google.com/moon/>).

USGS Airbrush Shaded Relief: The popular USGS shaded relief global map of the Moon [6] has been used in many applications since its creation in the early 1980s. Using an ad-hoc tie-pointing and warping process it was matched to the CLCN in the early 1990s and polar areas where data was missing was filled in based on Clementine images. Since that mosaic therefore ended up matched to the Clementine mosaics and has similar geometric errors, the polynomial warping process described above was applied to it as well, resulting in a geometrically improved version of this global map, also again matching the improved

Clementine mosaics. This is available along with the mosaics as noted above.

Lunar Orbiter Global Digital Mosaic: This mosaic [10] is nearing completion and should be released by March 2008. It has been created with direct ties to the ULCN 2005, by locating tie points from the original ULCN [11] and ULCN 2005, and doing a new Lunar Orbiter control solution with the coordinates of those points fixed to their ULCN 2005 values. This mosaic has been delayed for a number of reasons, most recently as we discovered the unforeseen need to solve for the spacecraft positions for each image as part of the control solution. The ULCN 2005 topographic information is also used to obtain a priori radii for points in the LO control solution, and is being updated in a simple iterative process, before fixing the radii of control points and orthorectifying the images onto the then defined final topographic surface.

A preliminary near side version of this mosaic is currently available, and the global mosaic will be available both via the PIGWAD site and also the USGS Map-a-Planet website (<http://www.mapaplanet.org/>).

Lunar Orbiter High-Resolution Images: Over the last several years, USGS has scanned and geometrically and cosmetically restored a number of high resolution Lunar Orbiter images [12]. These, too, are being controlled either one image at a time or in sets (if they overlap each other) to the ULCN 2005 network. These will be made available in orthographically projected (onto the improved topography just described) versions from the USGS Lunar Orbiter website and via links from the PIGWAD website.

ULCN 2005 topographic model: A global topographic model of the Moon, both in point and various gridded formats is already available as part of the ULCN 2005 solution [1] (and also displayable via Google Moon). We have pointed out since its release that this model is difficult to work with, mostly due to the wide variation in accuracy and precision of the included points (as opposed to many types of topographic data, where the height information is commonly all of nearly the same accuracy). We have undertaken two steps to improve the ease of use and likely the accuracy of this model. First, we filter the points in various ways, including eliminating all points that (1) have poor expected vertical precision (EVP), (2) appear to be outliers in radius compared to nearby points, and/or (3) have only one image measurement and therefore a suspect radius based on the original ULCN solution [11]. This reduced the number of points globally from 272,931 to about 260,000. Further the model is now being improved by correcting the radii of ULCN 2005 points that are better determined in the LO solution, and adding about 2,000 new LO to LO image tie points. Points whose radii are determined from the LO solution will likely have better radii than previously, and the EVP from the LO images are generally much lower than they were in the ULCN 2005 (i.e., the LO images provide better stereo coverage by far than that available from the Clementine images). The improved point set and a gridded version of the topography is currently available by request from the authors and will soon be available at the PIGWAD website.

NASM-USGS 1 km “planet-wide” lunar topographic model: We have previously described our plans to register some of the NASM (Cook, Robinson, and Watters) [13] Clementine stereo tiles to the ULCN 2005. This effort is almost complete, and the gridded 1 km resolution dataset should be released soon via the PIGWAD website. Note that this is called a “planet-wide” rather than a global data set

since it has many holes, and yet for a significant portion of the Moon there will be radii estimates with 1 km spacing. The absolute accuracy will still be that of the ULCN 2005, and therefore still difficult to estimate [1], although likely in the range of hundreds of meters. However, the relative accuracy of the radii should be much improved based on the stereo EVP of the Clementine images used to create the tile information. About 30,000 tiles total will be used as part of this model. The model will be made available both with and without fill-in information interpolated from the UCLN 2005 topography.

Future Products and Plans: An effort is currently underway to improve the ULCN, creating a new version (possibly to be called the “ULCN 2008”). As has been described previously [1, 7], this network would include direct tie point measurements from LO, Mariner 10, and Galileo images. This should provide some interim improvement of the overall horizontal accuracy, primarily due to the increased geometric strength provided by the very large LO and large Galileo images relative to the small Clementine images. More importantly though it will tie these legacy image datasets directly into the “ULCN” series of network solutions. This is an incredibly important step as when the ULCN networks are tied to the currently arriving new and future mission datasets, it will assure that all of these datasets are tied together (as recommended by the NASA Advisory Council to NASA [14]).

A “redo” of the Clementine Basemap mosaic is also underway, to control it to the ULCN 2005 (or if available in time, the improved ULCN) network, and to orthorectify it to one of the improved topography models (or if available in time, an altimetry model from one of the new missions). This will finally provide for a rigorous correction of the geometric errors in the Basemap. This mosaic will also be produced using the improved and current USGS ISIS 3 [15] software package, so that the mosaic can be very quickly updated in the future, either based on further improvements in the network or improved photometric or radiometric modeling. Since the Clementine dataset includes images with wavelength bands and emission angle coverage that will NOT necessarily be duplicated by upcoming missions, this processing will assure that this valuable dataset remains usable far into the future.

Of course, other critical work to control past lunar datasets and to begin the incorporation of new lunar datasets remains (e.g., [16]). This includes, but is certainly not limited to: (1) the control of the incredibly valuable and significant Apollo metric and panoramic camera images, covering about 16% of the Moon in 7 m and 1-2 m resolution (respectively) multicoverage stereo. Some of this coverage will still provide the highest resolution imagery and stereo imagery of given areas for likely decades to come; (2) the measurement of ties to the LRO LOLA (or international mission altimetry) in order to substantially increase (and quantify) the horizontal accuracy of the networks, and use such altimetry for orthorectification; (3) the measurement of ties to all of the upcoming significant image datasets, so all the data, past and present, can be properly intercompared; (4) the interim re-“warping” of mosaics (Clementine, airbrush, and Lunar Orbiter) to LOLA for use over the next few years, and (5) the final redo of these significant mosaics once a stable (sub-pixel level) network has been achieved.

It appears that some of these efforts will start in the near future, either as part of the LPRP Lunar Mapping and Modeling Program recently established by the NASA ESMD, or under science programs, such as the LASER and PG&G Programs of the NASA SMD. However, the coming orders of magnitude increase in lunar datasets and data processing and accuracy requirements is still only slowly being recognized [16]. The floodgates of new lunar data to be registered and turned into useful products are just starting to open.

Acknowledgements: This work was funded under the NASA PG&G, LPRP, and Constellation programs.

References: [1] Archinal, B. A., et al. (2006). U. S. Geological Survey Open-File Report 2006-1367, 21 p. pubs.usgs.gov/of/2006/1367/. [2] Edwards, et al. (1996) LPS, XXVII, 335. [3] USGS (1997) USA_NASA_PDS_CL_30xx, NASA PDS. [4] USGS (1999) USA_NASA_PDS_CL_40xx, NASA PDS; Eliason, et al. (1999) LPS, XXX, 1933. [5] Gaddis, L. R., et al. (2007) USA_NASA_PDS_CL_5001-5078, NASA PDS; Eliason, et al. (2003) LPS, XXXIV, 2093. [6] E.g. USGS (2003) Color-Coded Topography and Shaded Relief Map of the Lunar Near Side and Far Side Hemispheres, Geo. Inv. Series I-2769. [7] Archinal, B. A., et al. (2007) LPS XXXVIII, #1904 (Errata: Fig. 2 arrows incorrect); Archinal, B. A., et al. (2007) ISPRS WG IV-7: Extraterrestrial Mapping Workshop “Advances in Planetary Mapping 2007”. [8] Hare, T. L., et al., this conference. [9] Hare, T. L., et al. (2003) LPS XXXIV, #1974. [10] Becker, T., et al. (2005) LPS XXXVI, #1836; Gaddis, et al., this conference; <http://astrogeology.usgs.gov/Projects/LunarOrbiterDigitization/>. [11] Davies, et al. (1994) JGR, 99, E11, 23,211. [12] Weller, L., et al. (2006) LPS XXXVII, #2143; Weller, L., et al. (2007) LPS XXXVIII, #2092. [13] Rosiek, M. R., et al. (2007) LPS XXXVIII, #2297. [14] NASA Advisory Council (2007) Recommendation S-07-C-13 of the NASA Advisory Council to NASA Administrator Griffin, p. 14. [15] Anderson, J. A., et al. (2004) LPS XXXV, #2039; Becker, K. J. et al. (2007) LPS XXXVIII, #1779; <http://isis.astrogeology.usgs.gov/>. [16] Kirk, R. L., et al. (2006) Int. Arch. Photogram. Rem. Sen. & Spatial Inf. Sci, XXXVI, Part 4, Goa.; Archinal, B. A., et al. (2007) Workshop on Science Associated with the Lunar Exploration Architecture, Tempe, AZ.; Kirk, R. L., et al. (2007) “Cartography for Lunar Exploration: Current Status and Planned Missions,” International Cartographic Conference.

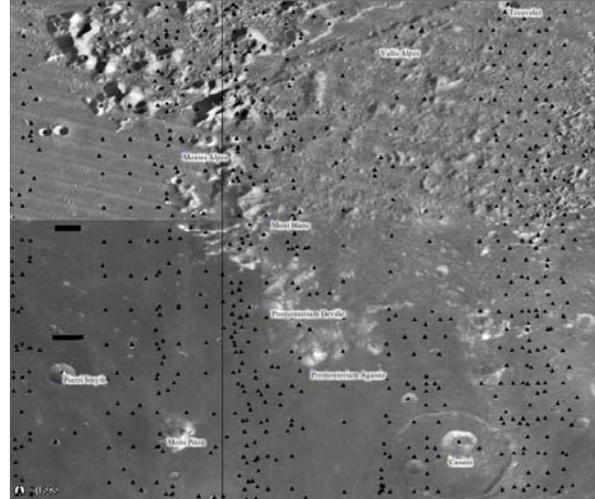


Figure 1: Sample display from PIGWAD showing some of the products described here, centered on 2° east longitude and +44° latitude with north up, using simple cylindrical projection. The north half of the image shows part of the current LO near side mosaic, the south half shows part of the Warped Clementine Basemap mosaic, and ULCN 2005 control points are also shown. Nomenclature is also displayed (but is not yet available in the ULCN 2005 frame). The vertical line at left center is the prime meridian graticule. For scale, the Cassini crater (the large subdued crater at the lower right with the name in it) is 56 km in diameter.