PLANET-WIDE LUNAR DIGITAL ELEVATION MODEL. A. C. Cook[1], M. S. Robinson[2], and T. R. Watters, [1]Center for Earth and Planetary Studies, National Air and Space Museum, Washington D.C. (tcook@ceps.nasm.edu), [2] Department of Geological Sciences, Northwestern University, IL. (robinson@eros.earth.nwu.edu).

Introduction: ~700,000 Clementine UVVIS [1] stereo pairs are being processed to generate a 1 km/pixel planet-wide Digital Elevation Model (DEM) of the lunar surface. We present two selected areas to illustrate the kind of data product that will be available and the expected lunar morphological structures that will be visible.

Method: A largely autonomous Digital Terrain Model (DTM or file of lon/lat/ht points) tile generation system has been produced to generate DTM tiles from Clementine stereo pairs on each given orbit. The work involved has been distributed over a Sparc 670MP, three 10s, a 20, an Ultra 1, and an Ultra 60, at the Center for Earth and Planetary Studies (CEPS) and was started in mid-November. The manual component involves loading raw Clementine images from CDROM read only disk, managing the software and archiving the results to CDROM write-once disk.

The stereo matching software uses a patch-based correlation stereo matcher [2]. The matcher software normally requires some tie-points (a few common points in each image pair) to be found manually in order to define an approximate geometric transformation from one image to the other, and to act as seed-points for the matching algorithm. However, because the Clementine images were taken systematically in a nadir pointing mode and suffer little viewing distortion between images, the tie points can be found automatically. Images are matched for every other pixel in the overlap region in each stereo pair - matching every pixel would unfortunately quadruple the expected processing time of four months. Unlike our stereo matching of Mariner 10 [3] and Viking Orbiter [4] images, we match each stereo pair just once using a fixed correlation patch radius of 7 pixels. The sampling spacing of matched points, every 2x2 pixels, although smaller than a final 1 km DEM pixel size, can provide ~50-100 height measurements per DEM pixel for a single stereo pair since the UVVIS image pixel size is 100-150 m/pixel. The DEM pixel size of 1 km, although lower in resolution than the original UVVIS images, is useful for two purposes: 1) it compensates for most gross navigation errors in camera pointing, and 2) it allows the averaging of many height points contained within each 1x1 km pixel, thus improving the topographic signal to noise ratio over that of a single stereo matched point.

The Clementine UVVIS camera was programmed [5] to take 10 images (through 5 filters with two exposures) in rapid succession (Fig 1). Then a time delay occurred during Clementine's orbit such that the field of view of the image drifted approximately two thirds of an image height before the next rapid image sequence was taken. When stereo matched, the resulting DTM tiles for each ten-image sequence overlap by about one third of a frame width and can be combined to form an interpolated DEM tile with 1 km pixels. DEM tiles can then be fitted iteratively to absolute height Clementine laser altimeter points, or to each other, to form larger area DEMs.

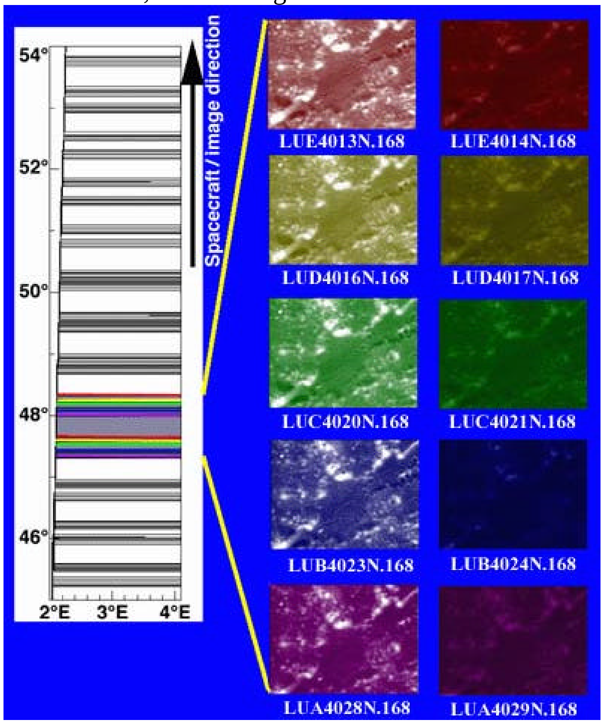

Figure 1. Clementine UVVIS camera filter/exposure image sequence: (left) image footprints, (right) five filters and two exposure settings.

Coverage: Due to the image sequencing [5] designed for global color mapping, repeated gaps in stereo coverage occur on each orbit, and when DEM tiles are combined, this results in a chess-board type of pattern over much of the lunar surface. Nevertheless these DEMs can still provide a great deal of useful information. For instance it is possible to identify previously suspected impact basins (Figures 2 and 3). The DEMs can also be used to measure crater depth to diameter ratios in areas of the Moon that were never imaged with sufficient shadow, to enable shadow measurement of heights.

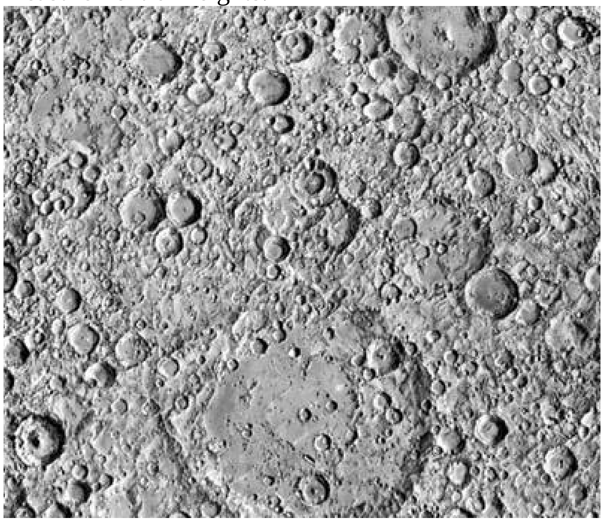

Figure 2. Airbrush map (175°W-140°W, 20°N-10°S) of Korolev basin (lower half of map) and region to the north.

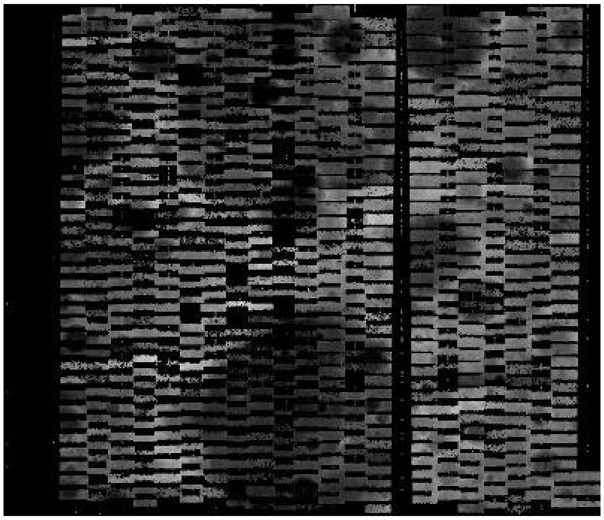

Figure 3. Grey-scale DEM of Korolev region shown in figure 2. Black=-6.4 km, white = +6.4 km (black also indicates no stereo coverage). Note the presence of the previously suspected [6,7] shallow basin, now referred to as Dirichlet-Jackson basin, to the north of Korolev.

Within 30° of the lunar poles [8-10], where the tracks of the Clementine polar orbit stereo converge, the stereo coverage that we utilize (nadir pointing images) improves such that 89% of the lunar north pole and 76% for the south pole are complete. Other regions of the Moon imaged, on the 3rd month or where the camera was tilted intentionally for special stereo imaging purposes, can also be used to produce DEMs with fewer gaps (e.g. sections of Mare Orientale, Figure 4).

Conclusions: To date three basins have been discovered using existing Clementine derived DEMs of one fifth of the lunar surface, and three suspected basins have been confirmed (Table 1). At the time of writing, 138 orbits out of 348, had been processed (40% of all available data). It is anticipated that all orbits will have been processed by April 2000, and after some extensive iterative global DEM tile fitting, a final planet wide coverage DEM will be released mid-2000 and made available from the following web site:

http://www.nasm.edu/ceps/research/cook/topomoon.html

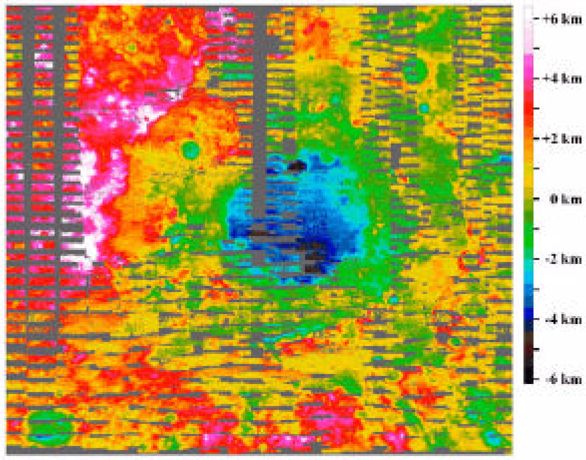

Figure 4. Color-coded DEM of Mare Orientale (120°W-75° W, 0°S-40°S) [11].

References: [1] Nozette S. *et al.*, (1994) *Science*, *266*, 1835-1839. [2] Day T. *et al.* (1992) *Int. Archiv. Photogram. Rem. Sens.*, *29-B4*, 801-808. [3] Cook *et al.* (2000a) *LPSC 31*. [4] Cook et al., (2000b) *LPSC 31*. [5] McEwen A.S. and Robinson M.S. (1997) *Adv. Space Res.*, *19*(10) 1523-1533. [6] Spudis P.D. (1999) *private communication*. [7] Konopliv A.S. and Yuan D.N. (1999) LPSC 30 #1067. [8] Cook et al. (1999) *LPSC 30*, #1154. [9] Cook et al. (1999) *Vernadsky-Brown 30*, 11-12. [10] Cook et al (2000) *JGR (planets) in press*, manuscript #1083. [11] Cook A.C. and Robinson M.S. (1999) *New Views of the Moon-II*, #8056.

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Basin	Center	Diam1	Diam2
Amundsen-Ganswindt	(120E, 81S) 122E,81S	(355km) 360km	
Bailly-Newton	57W, 73S	330km	
Dirichlet-Jackson[6,7]	158W, 14N	470km	
Schrödinger-Zeeman	165W, 81S	150km	250km
Sikorsky-Rittenhouse	(111E, 68.5S) 110E, 68S	(310km) 270km	
Sylvester-Nansen	45E, 83N	300-500km	

Table 1 Impact basins discovered or confirmed (in italics), using the Clementine DEMs. Brackets indicate previously accepted values.