UNIFIED LUNAR CONTROL NETWORK 2005 AND TOPOGRAPHIC MODEL.
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Introduction: There are currently two generally accepted lunar control networks. These are the Unified Lunar Control Network (ULCN) and the Clementine Lunar Control Network (CLCN), both derived by M. Davies and T. Colvin at RAND. We address here our efforts to merge and improve these networks into a new ULCN.

The ULCN was described in the last major publication about a lunar control network [1]. See Table 1 for statistics on this and the other networks discussed here. Images for this network are from the Apollo, Mariner 10, and Galileo missions, and Earth-based photographs. The importance of this network is that its accuracy is relatively well quantified and published information on the network is available.

The CLCN includes measurements on 43,871 Clementine 750-nm images—the largest planetary control network ever computed. This purpose of this network was to determine the geometry for the Clementine Basemap Mosiac (CBM) [2]. The geometry of that mosaic was used to produce the Clementine UVVIS digital image model [3] and the Near-Infrared Global Multispectral Map of the Moon from Clementine [4]. Through the extensive use of these products, they and the underlying CLCN in effect define the generally accepted current coordinate system for reporting and describing the location of lunar coordinates. However, no publication describes the CLCN itself. See [5] for ULCN and CLCN files.

CLCN Problems: After the completion of the CBM, it was noticed that horizontal errors of 15 km or more were present in it and therefore the CLCN [6-8]. These errors seem to have arisen for several reasons, including that only a few (22) near side points were fixed to ULCN positions, the camera angles were unconstrained, and the tie points were all constrained to lie on a mass-centered sphere of radius 1736.7 km.

ULCN 2005: We are merging the ULCN and CLCN and are addressing to a large extent the horizontal accuracy problems of the CLCN, with the intent to create a new ULCN. Our new solution(s) include 3 changes. 1) The camera angles are constrained to within 0.03° of their a priori (NAIF) values. 2) The coordinates of all identifiable ULCN points are fixed to their ULCN values. 3) Rather than assuming a spherical Moon, radii of all tie points are solved for. Our current results show horizontal position changes from the CLCN on average of ~7 km with some changes of dozens of km. See Figure 1.

Topographic Information: There are various sources of vertical (radii) information for the Moon. This includes Clementine lidar [9], polar stereo [10], other stereo [7], radar [11], Apollo lidar and stereo [12] (Table 2). Connections between the horizontal and vertical systems exist, but they are only well determined regionally and locally.

In our current preliminary ULCN 2005 solutions we constrain the radii to within 1 km of values interpolated from lidar and Clementine stereo. The mean absolute average change is ~200 m, thus showing radii are being recovered at that average accuracy. See Figure 2 for our current radii model. This is the only lunar topographic model that is registered globally with horizontal control.

Future Work: In the near term we plan to finalize our ULCN 2005 solution. Removing the radii constraints and solving for independent radii directly appears feasible, and we also will constrain (at least the horizontal) positions of the existing ULCN points. Future planned versions of this network may include the direct use of Mariner 10 and Galileo image measurements, the Lunar Orbiter control network currently being developed [13], and Clementine stereo [7]. We will also add ties to the current absolute LLR and ALSEP network [14].

Table 1. Lunar Horizontal Control Net Comparison.

Name	# points	# images	Horz. Acc.	Vert. Acc.
ULCN	1478	n/a	100 m to 3 km	Few km?
CLCN	271634	43871	Few km to some>15 km	Sphere
ULCN 2005	273090	43871	Few km	~ 1 km or less

Table 2. Vertical Data Sources for the Moon.

Name	# points	Vert. Acc.	Comments
ULCN	1286	Few km?	Sparse, mostly nearside
Clem. lidar	72548	130 m	Sparse, between ±75°
Clem. polar stereo	3198240	~1-2 km absolute	Polar only
Clem. stereo	?, not released	Few km absolute	Random coverage
Earth radar	~33.8x10^6	Few km absolute	Polar and Tycho only
Apollo lidar	5629	Few km?	<20% coverage
Apollo stereo	Contour maps	As above	<20% coverage
ULCN 2005	273090	< 1 km?	In preparation

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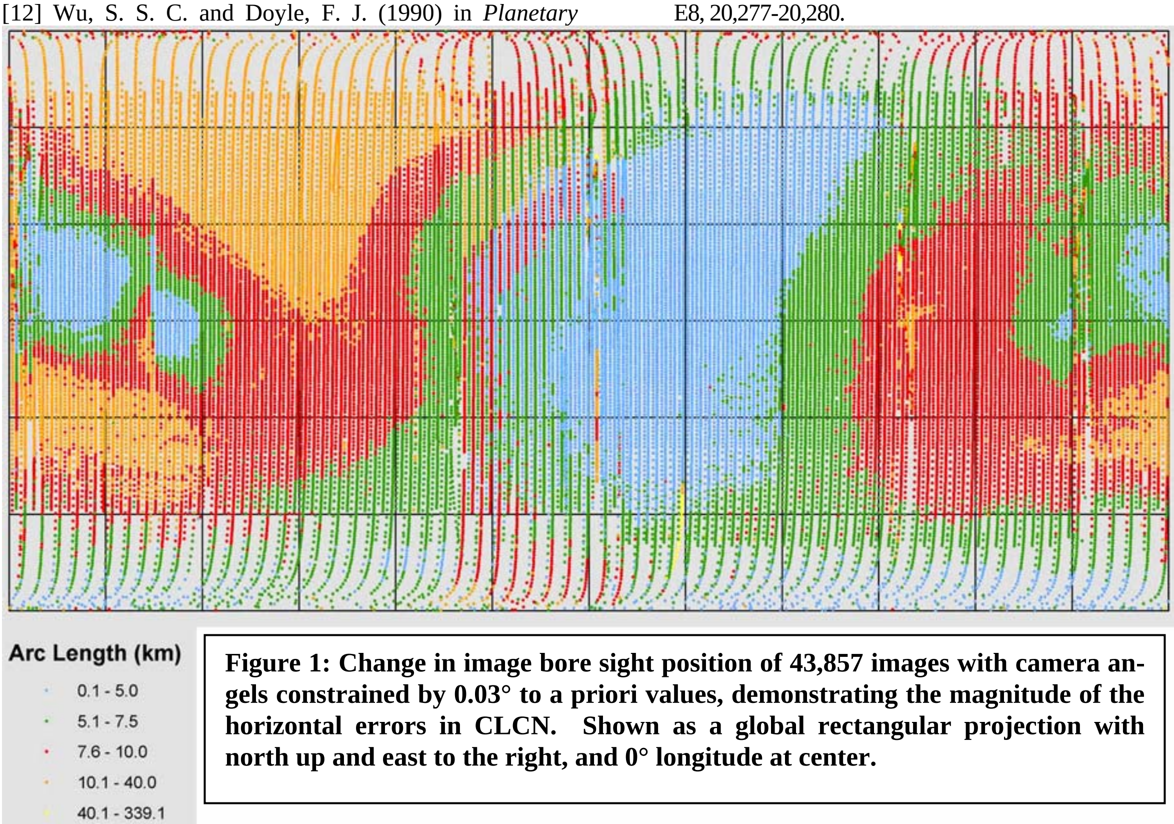

Figure 1: Change in image bore sight position of 43,857 images with camera angels constrained by 0.03° to a priori values, demonstrating the magnitude of the horizontal errors in CLCN. Shown as a global rectangular projection with north up and east to the right, and 0° longitude at center.

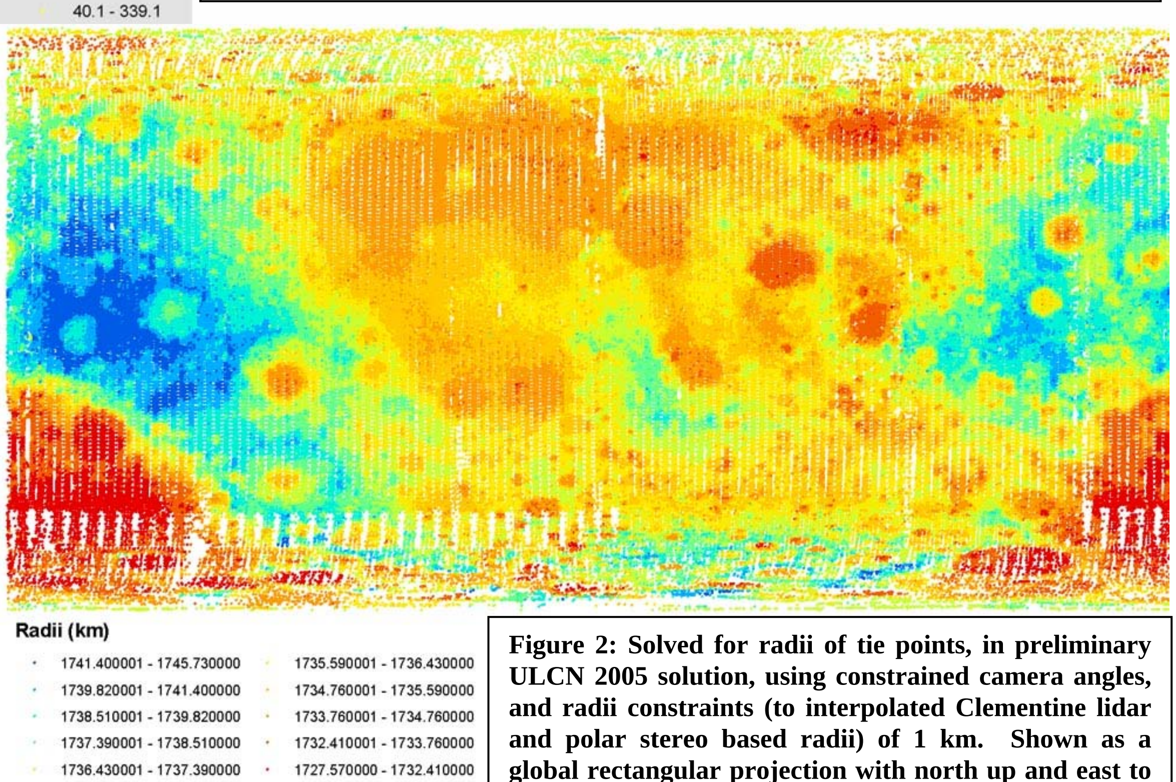

Figure 2: Solved for radii of tie points, in preliminary ULCN 2005 solution, using constrained camera angles, and radii constraints (to interpolated Clementine lidar and polar stereo based radii) of 1 km. Shown as a global rectangular projection with north up and east to the right, and 0° longitude at center. This constitutes a preliminary improved lunar topographic model, with radii uncertainties of a few hundred m to 1 km.