NEW 70-CM RADAR MAPPING OF THE MOON. B.A. Campbell[1], D.B. Campbell[2], and J. Chandler[3], [1]Smithsonian Institution, MRC 315, PO Box 37012, Washington, DC 20013-7012 (campbellb@si.edu), [2]Cornell University, Space Sciences Bldng, Ithaca, NY 14853-6801 (campbell@naic.edu), [3]Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138 (jchandler@cfa.harvard.edu).

Introduction: We are using the Arecibo and Greenbank radio telescopes to collect a new 70-cm wavelength radar map of the entire lunar nearside. These data have a spatial resolution as fine as 450 x 320 m near the limbs, and ~900 m for areas at 30^o incidence. A patch-focusing method is used to preserve the best possible resolution across the illuminated area. Each region is mapped in both senses of reflected circular polarization, and the complex-valued data permit determination of the linear-polarized component of the echo. These data represent the highest-resolution synoptic radar coverage of the Moon, and have applications to a variety of geologic and cartographic problems.

Data Collection and Reduction: We collect 70-cm wavelength, dual-circular polarization backscatter maps of the Moon by transmitting a 3 μs un-coded pulse from the 305-m Arecibo telescope, and receiving the echoes at the 105-m Greenbank Telescope (GBT) in West Virginia. The surface horizontal resolution along the range axis is a function of the pulse length and radar incidence angle: resolution is ~900 m at 30^o incidence and ~450 m at the limbs. Spatial resolution along the frequency axis is a function of the integration time for each look and the angular offset of any point from the apparent spin axis of the Moon. Our best spatial resolution along the frequency axis is ~320 m. All maps are resampled at 400-m pixel spacing, and represent averages over 3 or more independent looks to reduce speckle and thermal noise.

Each radar look is normalized to the off-Moon noise level, so we can calibrate the power ratio between the same-sense (SC) and opposite-sense (OC) circular polarization states. We also correct for the variation in antenna beam sensitivity across the images. No effort at absolute calibration has yet been made.

The raw data (Fig. 1) are projected to a latitude-longitude format by a 3x3 matrix transform that links the apparent coordinate system created by the Moon's spin and libration with the cartographic framework. At any given instant, the Moon's apparent motion may be described by a (1) sub-radar point location, (2) apparent limb-to-limb bandwidth, and (3) spin axis orientation angle. We solve for these parameters by an iterative fit to ephemeris data for four or more locations on the lunar surface. The ephemeris data are updated for each minute, so we create a polynomial fit for the variation of the Moon's spin state as a function of time.

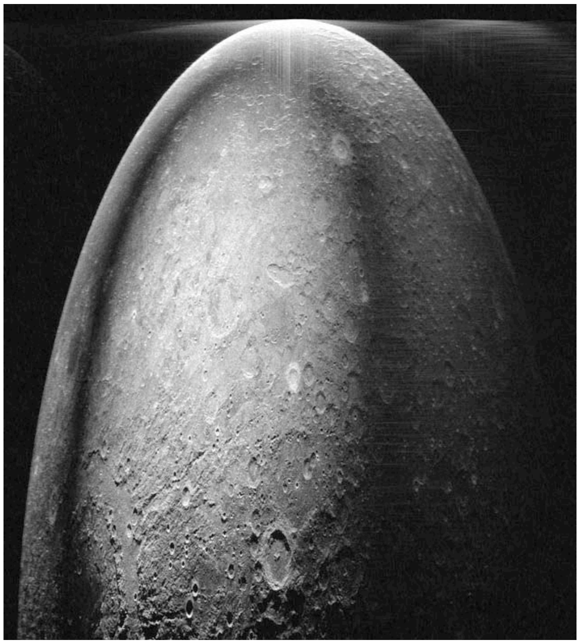

Fig. 1. Raw delay-Doppler image of the region from the center of the Moon (top) to the western limb. Note Orientale at lower left. Dark ring is first null of antenna beam pattern. Bright ringing at top is an artifact of the strong return from the front cap.

The radar is "pointed" by tracking a particular location on the Moon's surface, such that the transmitted signal is adjusted to maintain the target at zero apparent Doppler shift and delay. Other points on the Moon's surface are translating, at varying rates, with respect to the target. With the fits to the Moon's spin state, we may calculate this time-dependent differential delay and frequency shift for any chosen point, and remove it from the raw complex data array. When mapped, the resulting image is "focused" for an area around the chosen location. We map the region illuminated by the antenna beam in small patches to obtain a focused image with the best possible spatial resolution. To date, we have collected data for much of the southern hemisphere (Fig. 2). Once the full nearside map is completed, we will also collect higher-resolution (150 m/pixel) 70-cm data for areas of interest.

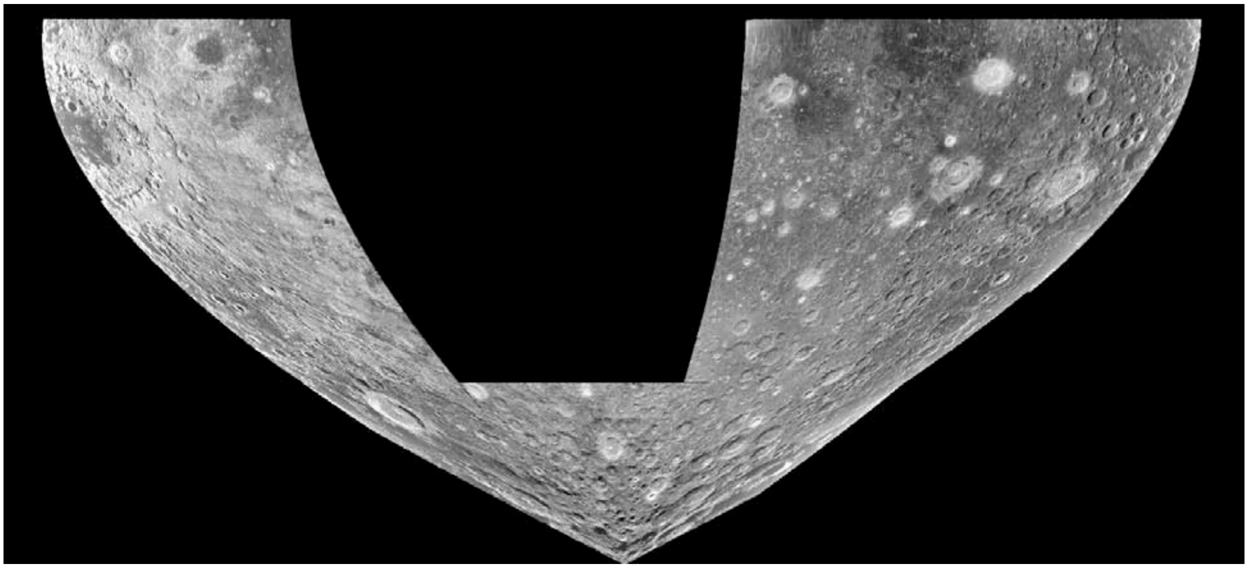

Fig. 2. Mosaic of same-sense polarized (SC) 70-cm radar data for the lunar southern hemisphere. Image resolution averaged to 4 km/pixel; sinusoidal projection for 0-90^o S. Limb areas imaged at favorable libration to view up to 7^o of the farside.

Geologic Applications: The high-resolution 70-cm radar data permit a new view of deep (up to 10's of meters) regolith rock population and mineralogy-dependent loss tangent. Recent work has used these data to determine that previously observed thermal lows around some craters correspond to a rock-poor ejecta halo that is likely ubiquitous among Eratosthenian and Copernican craters [1]. The long probing wavelength has also revealed cryptomare deposits beneath 10 m or more of highland overburden [2], and extended the search for polar ice deposits to depths below the range of orbital neutron sensing [3].

Future work will extend earlier analyses of the relationship between radar backscatter and lossy mineral (e.g., ilmenite) abundance in the maria, and explore the combined use of radar, VIS-IR, and eclipse thermal data to characterize regolith properties for possible landing sites and areas of high resource interest (e.g., polar terrain, pyroclastic deposits).

Cartographic Applications: One advantage of the 70-cm radar observations is the large illuminated region on the Moon (Fig. 1). When we re-project the data from one such illumination pattern to a cartographic grid, the only positional errors between points on the surface arise due to variations in topography from an ideal reference sphere. In general, these errors are on the order of a few pixels (1-2 km) for our 400-m resolution maps and the range of lunar nearside topography. Any such errors are also strictly local – there is no cumulative positional error across the scene.

In contrast, the base-map prepared from Clementine images of the lunar surface has cumulative positional errors due to the lack of control points away from the nearside landing sites. These errors can be on the order of 10 km at the limbs [4]. We suggest that the individual (single beam pattern) radar images provide a better reference base for regional VIS-IR image mosaics, and the full nearside radar map may be useful in correcting the Clementine base-map.

References: [1] Ghent, R.R., D.W. Leverington, B.A. Campbell, B.R. Hawke, and D.B. Campbell, *J. Geophys. Res*., in press, 2005; [2] Campbell and Hawke, LPSC XXXVI, 2005; [3] Campbell, B.A., D. B. Campbell, J. F. Chandler, A. A. Hine, M. C. Nolan, and P. J. Perillat, *Nature*, 426, 137-138, 2003; [4] Cook, A.C., M.S. Robinson, B. Semenov, T.R. Watters (2002), Eos Trans. AGU, 83(47), Fall Meet. Suppl., Abstract P22D-09.