EARTH-BASED RADAR MAPPING OF THE LUNAR NEARSIDE AT 12.6-CM WAVELENGTH. B. A. Campbell[1], D. B. Campbell[2], L. M. Carter[1], J. Chandler[3], R. R. Ghent[4], M. Nolan[5], and R. F. Anderson[1], [1]Center for Earth & Planetary Studies, Smithsonian Institution, Washington, DC 20560 (campbellb@si.edu); [2]Cornell University, Ithaca, NY 14853; [3]Smithsonian Astrophysical Observatory, Cambridge, MA 02138; [4]Dept. of Geology, University of Toronto, Toronto, ON M5S 3B1; [5]Arecibo Observatory, Arecibo, PR 00612.

Introduction: We are collecting a dual-polarization radar backscatter map of the lunar nearside at 12.6-cm (S-band) wavelength and 40-m single-look horizontal spatial resolution. The observations use the Arecibo Observatory radar system as a transmitter, and receivers at the Green Bank Telescope (GBT) to measure the echoes in both senses of reflected circular polarization. A focused processing method is employed to obtain high resolution over the full illuminated area. These data are calibrated, based on measurements of the antenna beam patterns, receiver system thermal noise, and transmitted power to best estimates of the radar backscatter coefficient. Data averaged to four looks per pixel at 80-m spatial resolution, and mosaics for large regions, will be archived with the PDS, following up the nearside 70-cm map [1].

Mapping Technique: We transmit a circular-polarized 2380-MHz radar signal from Arecibo Observatory, and receive the reflected echo in both senses of circular polarization at the GBT (the Moon is too close for Arecibo to switch from transmit to receive). We modulate the outgoing signal with a pseudo-random code with 0.2-μs baud and length of 65535 samples. The reflected signals are sampled in quadrature (complex voltage) at 5 MHz rate with 4-bit A/D conversion for high dynamic range. The integration period for each observation of a particular illuminated area (Fig. 1) is 29 minutes. We need about 120 such observations to produce a complete mosaic of the near side (with the exception of a region near the center of the Moon that does not allow useful radar mapping geometries).

Because the Moon is moving relative to the two telescopes throughout the integration period, any given point will have a varying round-trip delay and Doppler shift over time. These shifts would cause a radar image to smear in resolution. We compensate for the Moon's motion first by adjusting the repetition rate and frequency of the transmitted signal to match the predicted behavior of the chosen target as seen from the GBT. To fully focus the image, we use a technique similar to synthetic aperture processing that determines a range and phase history for each small patch within the illuminated area, applies these corrections, and maps the resultant focused patch onto the lunar latitude-longitude grid [2]. We have a suite of programs to perform these operations on each observation, including a step that estimates residual errors in the ephemerides via an image-entropy autofocus technique.

Our goal is to produce data calibrated to values of the dimensionless backscatter coefficient, σ^0. This value can be compared with data for the Moon at other wavelengths and with AIRSAR and other data for terrestrial analog sites. We also calibrate the relative signal strength in each polarization to permit an accurate estimate of the circular polarization ratio (CPR).

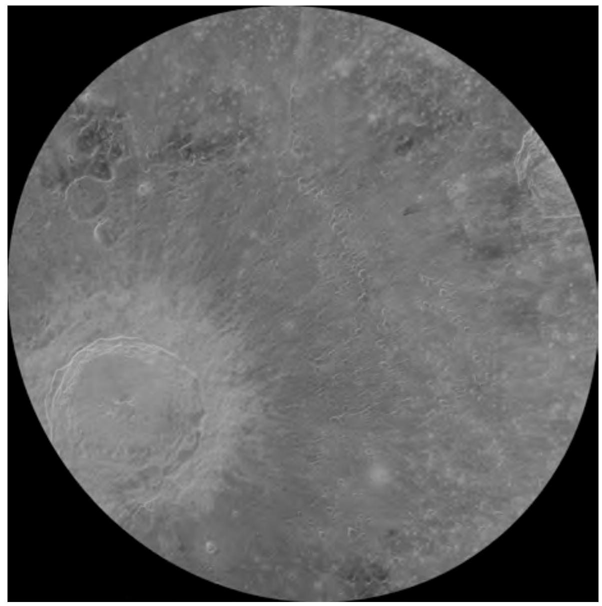

Fig. 1. Radar image of Copernicus crater (93 km) and region to the NE. Same-sense circular polarization.

The steps include normalization of each image to the thermal noise measured during the ~1.5 ms of each interpulse period when no signals from the Moon are present. Channel isolation is on the order of -30 dB, so we expect little impact of crosstalk on the polarimetric analysis. We measured the thermal noise as a function of the GBT beam location on the lunar disk (the combination of "cold sky" and lunar thermal emission), and calibrated this curve against a source (3C48) of known brightness. Knowing the transmitted power, the gain of the two antennas, the range to the Moon, and the resolved area of each map pixel, we can define a value for σ^0 with an estimated uncertainty of 1-2 dB. We also compensate for the decrease in antenna gain away from the center of an illuminated area. Speckle induced by coherent interference among reflections from objects within a resolution cell can be reduced by averaging over multiple looks, and we will deliver to the PDS 80-m resolution, 4-look images.

Progress to Date: Our image coverage to date is shown in Fig. 2. Overlaps in beam pattern coverage allow for mosaicking. Initial science results include analyses of pyroclastic deposit thickness and substrate properties [3], and detection of very rugged lava flow surface morphology in the Marius Hills dome complex [4]. In these studies, the high-resolution 12.6-cm data, with their 1-3 m probing depth and sensitivity to 2-cm and larger rocks, provide an excellent complement to the lower-resolution but greater penetration-depth 70-cm observations. The full nearside S-band coverage will also provide a synoptic background for more localized imaging by Moon-orbiting radar systems.

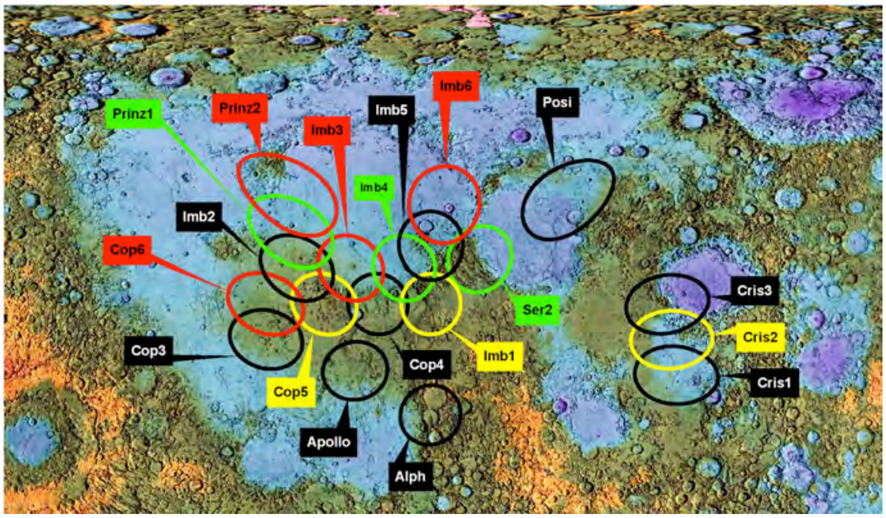

Figure 2a. Maps of 12.6-cm radar image coverage for the central lunar nearside.

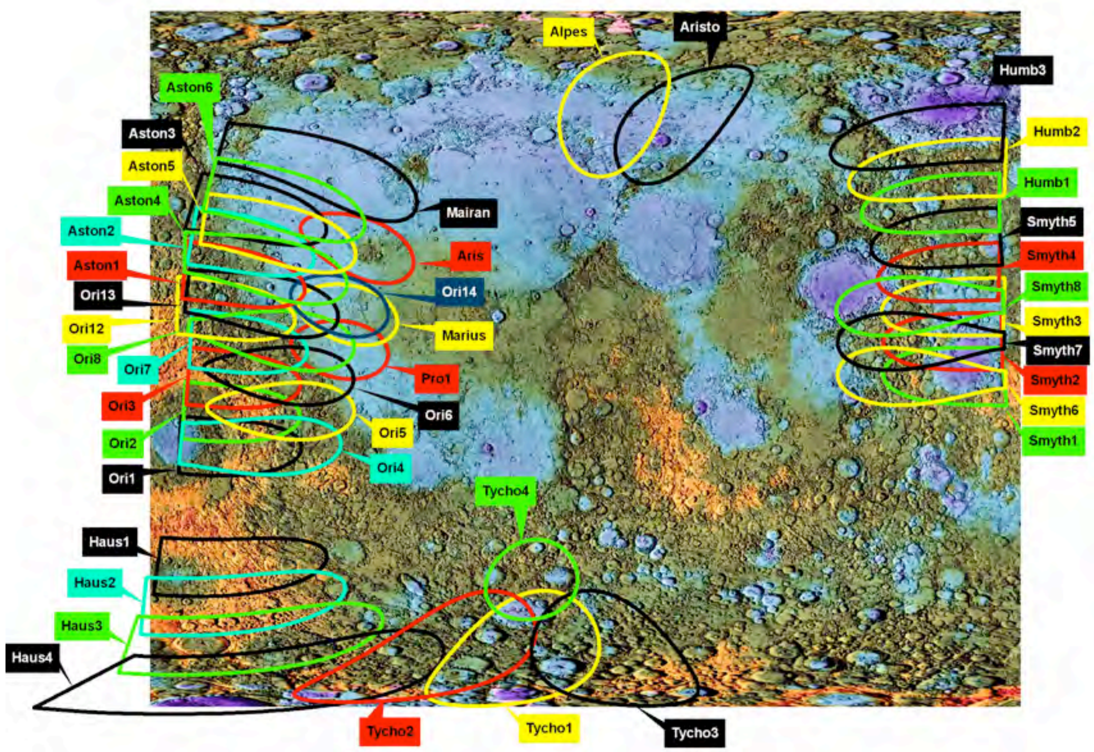

Figure 2b. 12.6-cm radar image coverage for the nearside limb regions. Images of the N and S pole also obtained, but not shown on cylindrical map. Libration brings into view areas 6-7^{o} of longitude beyond limb at equator.

References: [1] http://pds-geosciences.wustl.edu/missions/lunar_radar/index.htm; [2] Campbell et al. (2007), IEEE Trans. Geosci. Rem. Sensing, 45(12), 4032-4042, doi:10.1109/TGRS.2007.906582; [3] Campbell et al. (2008), *Geology,* 36, 135-138, doi:10.1130/G24310A.1; [4] Campbell et al. (2009), *JGR*, in press.