NGRADAR: THE HIGHEST RESOLUTION IMAGES OF THE MOON EVER TAKEN FROM THE GROUND.
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Introduction: The National Radio Astronomy Observatory (NRAO), Green Bank Observatory (GBO), and Raytheon Intelligence & Space (RIS) are designing a high-power, next generation planetary radar system for the Green Bank Telescope (GBT) dubbed ngRADAR. As a pilot project, a low-power, Ku-band transmitter (up to 700 W of output power at 13.9 GHz) designed by RIS was integrated onto the 100-meter GBT at GBO, and radar echoes were received with NRAO's ten 25-meter Very Long Baseline Array (VLBA) antennas. These observations generated the highest resolution, ground-based, synthetic aperture radar (SAR) images ever collected of select locations on the Moon, enabled size and spin-state characterizations of defunct satellites (space debris), and detected a potentially hazardous near-Earth asteroid 2.1 million kilometers (~5.5 lunar distances) from Earth [1, 2]. Here, we focus on the lunar radar imagery.

Observations: The GBT/VLBA pilot radar system illuminated the Apollo 15 landing-site region and Tycho crater with its ~0.9-arcminute beam as a technology demonstration. Using advanced focusing algorithms, SAR images of the Apollo 15 landing site (Fig. 1) and Tycho crater (Fig. 2) show tremendous detail, each with 5-m resolution (30 MHz) from 40-minute integrations. The inset in Fig. 2 shows several linear and polygonal features along the crater floor. These high-resolution images are sensitive to motion at the mm/sec scale, roughly the fidelity of the dynamical models used for radar ephemeris prediction. Work continues refining the data processing techniques required for such long integration times and such precise motion compensation. These observations suggest this radar system can provide meter-scale resolution radar imagery in cislunar space as well.

Future Work: Pilot observations demonstrated the capability of obtaining meter-scale radar imagery of the lunar surface. Design work continues toward the final objective of a 500 kW, Ku-band planetary radar system for GBT using the VLBA and the future Next Generation Very Large Array (ngVLA) as receivers. A high-power system would have nearly 1000 times the output power and several times the waveform bandwidth (up to 600 MHz). These properties will deliver a highly capable radar system for physical and dynamical characterization of solar system objects for planetary science and planetary defense as well as for space situational awareness in the cislunar domain. A next step in the near term could include integration of a medium-power transmitter (of at least 10 kW) to develop the end-to-end system at GBO/NRAO for real-time radar observations.

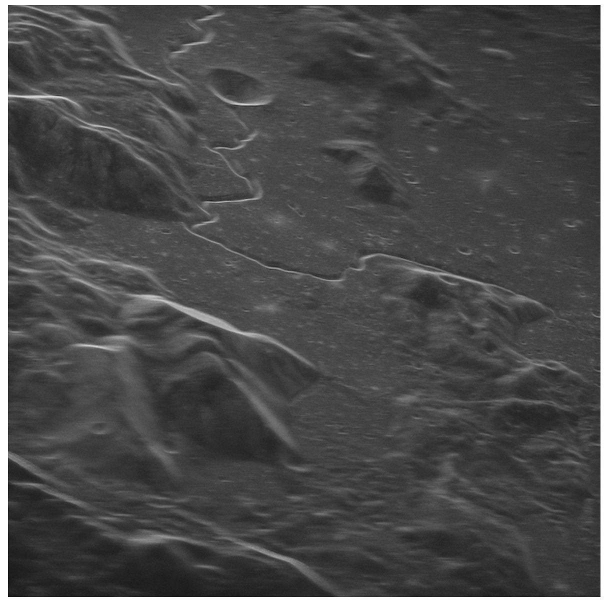

Figure 1. The Apollo 15 landing-site region at 5 m/px resolution with the GBT/VLBA pilot radar system.

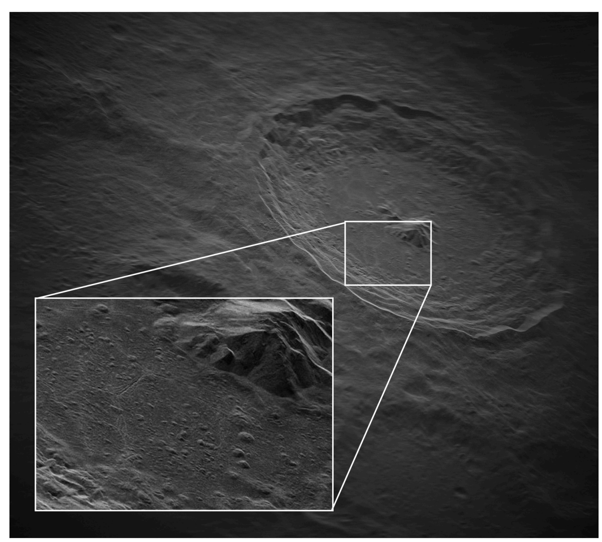

Figure 2. Tycho crater (~85 km) with 5 m/px resolution with the GBT/VLBA pilot radar system.

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References: [1] Wilkinson S.R. et al. (2022) *Microwave Journal*, *65*, 1. [2] Taylor P.A. et al. (2022) *Proceedings of the Advanced Maui Optical and Space Surveillance Conference*, 2252.