THE MOON AT 12.6 CM: LEGACY OF ARECIBO/LRO MINI-RF PARTNERSHIP

G. A. Morgan¹, G. W. Patterson² and the Mini-RF team ¹Planetary Science Institute, Washington DC, gmorgan@psi.edu, ²Johns Hopkins Applied Physics Laboratory, Laurel, MD,

Figure 1. Portion of LROC WAC mosaic covering the Aristarchus Plateau [left] and a Mini-RF S-band (12.6 cm wavelength) bistatic, S1 radar data (equivalent to total backscattered power) mosaic [right] consisting of 4 observations. The radar bright region delineated by the red dashed line correspond to lava flows below a locally thin region of the pyroclastic deposit. Red arrows point to examples of secondary crater chains from Aristarchus (the rim of which can be seen in the lower left corner.

Arecibo - Mini-RF Partnership: Mini-RF, a hybrid-polarized, dual-frequency Synthetic Aperture Radar (SAR) that operates at wavelengths of 12.6 cm (S band) and 4.2 cm (X/C band) [1] was designed to operate as a monostatic system – i.e., the antenna operated as a transmitter and receiver. In December of 2010 the transmitter experienced a malfunction and ceased to operate, precluding further monostatic data collection. Fortunately, through leveraging the powerful Arecibo Observatory (AO) in Puerto Rico, Mini-RF was able to return to science as a bistatic experiment. Under this architecture AO would transmit a circularly-polarized S-band signal to illuminate a portion of the lunar surface, and Mini-RF would receive the backscattered signal from lunar orbit. For observations of the surface, the incidence angle varies as a function of the observation geometry and the data have a spatial resolution of ~100 m. Varying the incidence angle allows for wavelength-scale scattering properties of the surface and subsurface to be measured over a range of bistatic angles.

Full Earth-based S-band measurements: S-band observations of the lunar surface were being conducted by Arecibo (in conjunction with the Green Bank Telescope in WV) prior to the beginning of the Mini-RF bistatic experiment. Analysis of the Arecibo data provided important insights regarding the search for ice within the permanently shadowed regions of the poles [2], mare flow units [3] and impact melt flows [4].

Why Conduct Bistatic Measurements? Studying the variations in the power returned over a range of bistatic angles can impart important information about the geology of the near surface, including regolith structure, maturity and composition. Critically, signatures diagnostic of the presence of ice can be detected, providing a means to address long contested questions regarding the existence and quantity of shallow buried ice at the lunar poles [5].

S-band analysis of the Moon: At LPSC we will present a range of Arecibo-Mini-RF studies focused on different lunar geologic processes. Here we highlight the initial results of investigations of the Aristarchus Plateau and Mare Imbrium.

The Aristarchus Plateau: on the lunar nearside is a region of ancient highland crust uplifted during the formation of the Imbrium Basin [6] and is surrounded by flood basalts of Oceanus Procellarum. The plateau is host to diverse volcanic features including a large pyroclastic deposit (~20-30 meters thick [7]) that is dominated by low-Ti glass spheroids [e.g., 8] and a prominent rille, Vallis Schröteri which cuts through the pyroclastic blanket (Fig. 1). The plateau is named after the 40km diameter Copernican impact crater situated along its southern edge.

Four bistatic S-band observations were acquired of Aristarchus between 2012 – 2020. A mosaic of the radar data products derived from these collects provides a wealth of insights into the nature of the upper ~1m of the plateau (Fig. 1).
Initial Results: Previous, fully Earth-based S-band studies revealed variations in the thickness of the pyroclastic deposits [3]. Enhanced backscatter returns (over the otherwise radar dark pyroclastic blanket) were interpreted to be caused by small impacts that have excavated blocky material from lava flows where the pyroclastics are locally thin. Mini-RF/AO S-band bistatic data show similar variations in backscatter, at larger bistatic angles, and can be used to further our analysis of the physical properties of the pyroclastic blanket (Fig. 1). In addition, the Mini-RF/AO bistatic data provide insights into impact related process. For example the location of secondary impact chains formed by the Aristarchus impact can be clearly delineated (Fig. 1) and their relative roughness quantified via measurements of their circle polarization ratio (CPR).

Mare Imbrium: The aim of the Imbrium project is to delineate individual volcanic flow fields that comprise the surface of the mare. Previous efforts to map the eruptive units and investigate the associated stratigraphic relationships have used: image/topographic data to map flow margins [9] (Fig. 2a), exploited mineralogical variations inferred from ultraviolet-near infrared (UV-NIR) spectral data [e.g. 10-12] and more recently Earth-based P-band (70 cm) radar data to map flow units based on TiO₂ content [13-14] (Fig. 2b).

Some of the sharpest topographically defined mare flows are found in Mare Imbrium. The basin is also filled with basaltic flows that display a wide range of TiO₂ content [e.g. 15] and thus represents an excellent site to explore bistatic radar mapping techniques built off prior P-band mapping. Using the Morgan et al [14] P-band map as a guide to targeting units that display sharp contrasts in radar backscatter, we undertook multiple Mini-RF/AO S-band data collects of Mare Imbrium (Fig. 1).

Initial Results: The S-band data show evidence of a flow boundary within northwest Imbrium. The boundary is delineated by a distinct contrast in radar backscatter (Fig. 2) which displays digitate like forms we interpret to be flows. There is no topographic signature associated with the flow units but the NW flow boundary does show good agreement with previous albedo and radar based mapping (fig. 2). In contrast, the SE boundary is not visible in the non-Mini-RF datasets including ground based radar observations. At LPSC we will consider the reasons why the SE boundary is uniquely seen by Mini-RF.