**MULTI-WAVELENGTH BISTATIC VIEW OF THE LUNAR MARE USING MINI-RF.** G. A. Morgan[1], B. A. Campbell[2], G. W. Patterson[3] and the Mini-RF team [1]Planetary Science Institute, Washington DC, gmorgan@psi.edu. [2]National Air and Space Museum, Smithsonian Institution, Washington DC, [3]Johns Hopkins Applied Physics Laboratory, Laurel, MD.

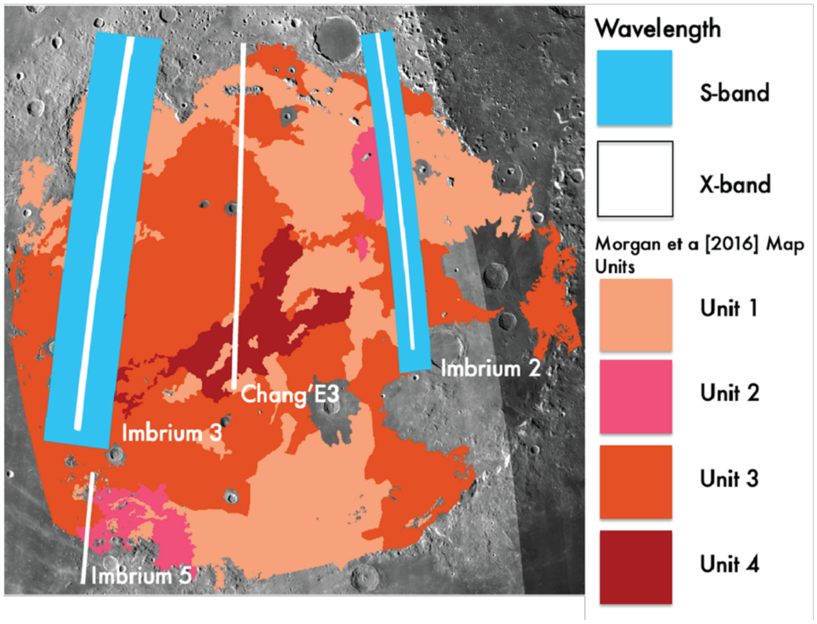



***Figure 1****. Mare Imbrium bistatic Mini-RF targets for both S and X-band collects. The map units are from P-band radar mapping work conducted my Morgan et al. [1]. The four units represent a stratigraphic framework from oldest (Unit 1) to youngest (Unit 4) surfaces and form the bases for comparing the biostatic Mini-RF collects.*

**Introduction:** The Lunar Reconnaissance Orbiter (LRO) Cornerstone Extended Mission has seen the revival of the Mini-RF radar in order to conduct bistatic observations of the lunar surface. Working in conjunction with S-band (12.6 cm) and X-band (4.2 cm) signals transmitted by Arecibo (Puerto Rico) and Goldstone (southern California) observatories, respectively, enables dynamic viewing geometries through which backscatter angles from 0 - > 50º can be achieved.

*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 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 [2].

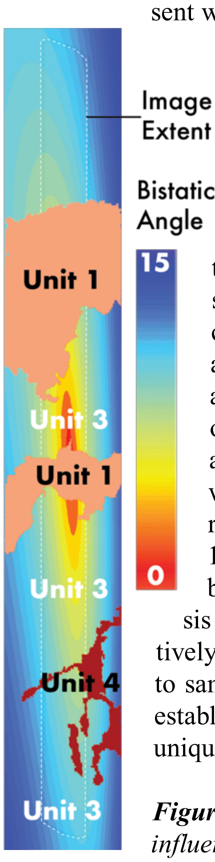
Bistatic radar experiments also offer a viable strategy to study small bodies with spacecraft. For example, the first orbital mission to a comet, Rosetta, utilized bistatic observations via the CONSERT instrument. Transmissions made from the spacecraft were received by the *Philae* surface platform enabling the internal composition of comet 67P/Churyumov–Gerasimenko to be constrained [3]. Similar studies of near-Earth asteroids could be undertaken which leverage Earth-based observatories as either the transmitter or receiver. Mini-RF results could therefore serve to advise future mission design and data interpretation.

*50^th^ LPSC:* During the meeting the Mini-RF team will follow up on a range of presentations made during the last LPSC that explain the diverse geological applications that can pursued with bistatic radar. Over the last 12 months we have been able to undertake new observations and take large strides in data processing to account for an observation strategy that Mini-RF was not initially designed for. Here we present our ongoing targeting campaign to investigate the composition of the lunar mare, the aim of which is to better constrain the titanium content of individual flows.

**Previous Lunar Mare Compositional Variations:** The lunar mare are the product of extensive flood volcanism which formed ~4.1 - 1.5 Ga [e.g. 4]. Despite the lack of distinct flow boundaries typical of flow fields on the Earth, Mars and Venus, variations in composition of the lunar eruptions have enabled the surface of the maria to be subdivided into individual units [5]. Such mapping work is vitally important to our understanding of the geologic history of the Moon as it enables the generation of a stratigraphic framework for lunar eruptions as well as constraining the evolution of magma chemistry. The majority of investigations into mare composition have used spectral investigations involving ultraviolet to near infrared (UV-NIR) data obtained from Earth and lunar orbit [e.g. 5 -7].

*Radar Mapping:* More recent studies comparing S and P-band (70 cm) Earth based radar data have provided an additional and complementary means to map mare flows [1,8]. Based on modelling work incorporating studies from Apollo sample returns, $TiO_2$ content was found to be the most dominant influence on the P-band return [7]. Tracking broad variations in the strength of the P-band backscatter across the surface of the lunar mare can therefore be used as a proxy for ilmenite content.

Use of the P-band mapping technique has provided a stratigraphic framework for Mare Imbrium (Figure 1) [1], which is consistent with previous studies of embayment relationships between individual flows that are present within central Imbrium [9].




**Mini-RF Study of Mare Composition:** In principle, radar mapping could be used to derive a value for $TiO_2$ content that is comparable to spectral based techniques [e.g. 10]. Such a dataset would be value to our understanding of lunar petrology, especially due to the advantages associated with radar imaging discussed above. To investigate the influence of titanium content on radar attenuation we have been collecting data with Mini-RF to measure the bistatic response across mare surfaces (Fig 1). Using the Morgan et al [1] P-band map of Mare Imbrium as a basis for identifying mare units of relatively uniform ilmenite content and thus to sample the bistatic data, we aim is to establish whether individual units exhibit unique signatures (Fig 2).

***Figure 2.*** *Sampling Strategy to assess the influence of TiO2 on bistatic response from the Imbrium* 3 S-band collect.

Through this we hope to isolate the various parameters which contribute to CPR values measured over a large range of bistatic angles, including mare surface age, regional slopes and emission angle.

**Initial Results:** To date we have collected data within five regions of Mare Imbrium. For each target we isolated the data returned exclusively from the surface of the mare - excluding all highland terrain or large craters (D > 10 km) and associated ejecta – and plot the CPR as a function of bistatic angle (Figure 3).

None of the map unit samples display an opposition effect. Though there are possible, subtle differences in CPR, similar to as was observed by [11].

At LPSC we will present a complete analysis of all available Imbrium coverage and make comparisons with S-band bistatic collects from the first LRO extended mission. As part of our analysis we will fully interrogate the parameters responsible for the variations in CPR and assess whether variations in path length of the radar signal through the regolith can be leveraged to constrain composition.

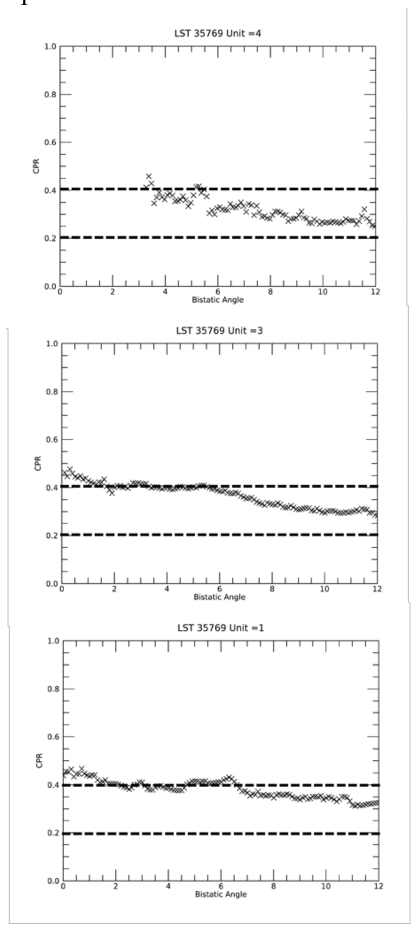



***Figure 3.*** *CPR as a function of bistatic angle for different map units within Mare Imbrium.*

**References:** [1] Morgan et al., 2016. JGR, 121, 1498–1513 [2] Hapke et al. 1998, *Icarus*, 133, 89-97. [3] Kofman et al., 2015. [4] Taylor (1982), Planetary Science: A Lunar Perspective, LPSC, TX. [4] Hiesinger, et al., 2000, JGR, 105, 29,239–29,275. [5] Soderblom, et al., 1977, Proc. Lunar Sci. Conf., 8th, 1191–1199. [6] Pieters, 1978, Proc. Lunar Planet. Sci. Conf., 9th, 2825–2849. [7] Campbell et al., 2014, JGR, 119, 313–330. [8] Schaber, 1973, Proc. Lunar. Planet. Sci. Conf., 4(1), 73–92. [9] Xiao, et al., 2015, Science, 347(6227), 1226–1229. [10] Lucey, 2000, JGR, 105, 20,297–20,306. [11] Patterson, et al. 2017, *Icarus*, 283, 2-19.