AVAILABILITY OF LRO MINI-RF AND CHANDRAYAAN-2 DFSAR DATA FOR ARTEMIS LANDING ZONE CHARACTERIZATION. G. W. Patterson[1], S. S. Bhiravarasu[2], C. I. Fassett[1], B. J. Thomson[3], J. T. S. Cahill[1], T. Chakraborty[2], D. Putrevu[2], G. A. Morgan[4], A. M. Stickle[1], E. G. Rivera-Valentin[1], C. A. Nypaver[3], P. A. Taylor[5], M. C. Nolan[6], M. Slade[7] and the Mini-RF and DFSAR teams, [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD (Wes.Patterson@jhuapl.edu), [2]Space Applications Centre, Ahmedabad, Gujarat, India, [3]University of Tennessee, Knoxville, [4]Planetary Science Institute, [5]NRAO, [6]University of Arizona, [7]NASA JPL/Caltech

Introduction: NASA's Mini-RF instrument on the Lunar Reconnaissance Orbiter (LRO) is a hybrid-polarized, dual-frequency synthetic aperture radar (SAR) that operates at S- (12.6 cm) and X/C-band (4.2 cm) [1]. Mini-RF initially operated as a monostatic system – i.e., the instrument antenna transmits and receives – at a fixed incidence angle of 47.6°. A transmitter anomaly led to Mini-RF transitioning to a bistatic architecture – i.e., transmitting from Arecibo Observatory (AO) or the Goldstone deep space communications complex antenna DSS-13 and receiving at the LRO spacecraft. In this architecture, the incidence angle varies as a function of the observing geometry.

ISRO's Chandrayaan-2 Dual-Frequency SAR (DFSAR) instrument [2] is also a monostatic system, operating at L- (24 cm) and S-band (12 cm) with standalone (L or S) and simultaneous (L and S) modes of imaging. DFSAR can collect data in both hybrid and linear full (quad) polarimetric modes over a wide range of incidence angles (~10° to 37°).

Combined, these instruments can characterize the radar scattering properties of the lunar surface and near subsurface at depth scales < 1 cm to > 3 m. These data are valuable for identifying landing hazards and constraining the dielectric properties (including volatile content) of regolith within the Artemis landing zones.

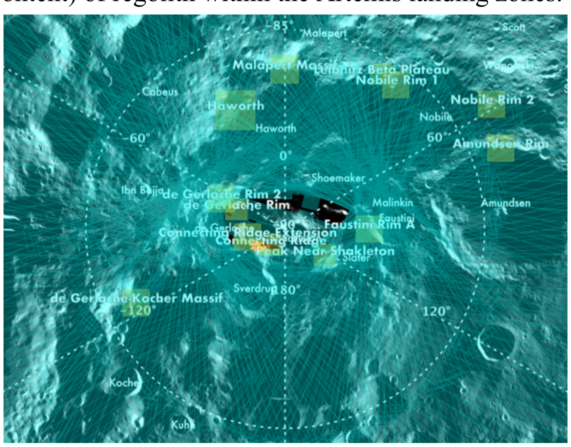

Fig. 1. Mini-RF S-band zoom image footprints overlain on WAC global mosaic. Artemis landing zone locations denoted with yellow squares.

Available Data (Mini-RF): Mini-RF monostatic data includes both 150 m (baseline) and 30 m (zoom) resolution modes. The majority of these data were collected at S-band in zoom mode and cover >95% of the poles (Fig. 1, Table 1). Controlled mosaics of derived Stokes products for both poles have been produced by the USGS [3] and provide access to permanently shadowed regions (PSRs) at a resolution of 30 m. Where available, monostatic coverage of the Artemis zones in X-band zoom and S- and X-band baseline modes (Table 1) provide additional wavelength coverage and sensitivity, respectively.

Bistatic data includes both S- and X-band observations and has a processed resolution of ~100 m in range and 2 m in azimuth. The range resolution can vary from one observation to another, as a function of the viewing geometry, and the data are averaged in azimuth to provide a spatial resolution of 100 m, yielding a 50-look average for each pixel. This architecture allows examination of the scattering properties of a target surface for a variety of bistatic angles. Laboratory data and analog experiments, at optical wavelengths, have shown that the scattering properties of lunar materials can be sensitive to variations in bistatic angle [4-6]. Although Mini-RF is not currently collecting S-band bistatic data, X-band acquisition is ongoing.

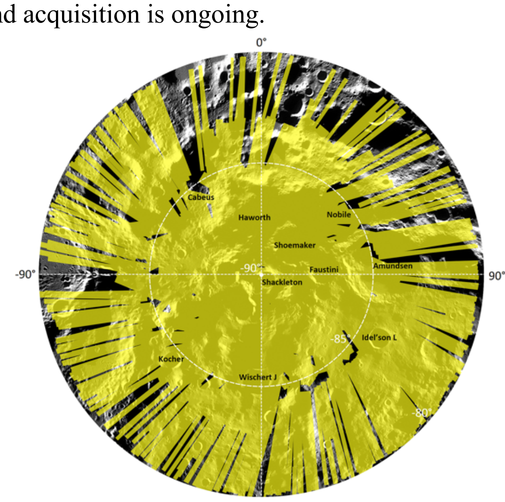

Fig. 2. DFSAR L-band image footprints, overlain on LROC WAC global mosaic.

Available Data (DFSAR): DFSAR is currently acquiring monostatic data from a nominal 100 km circular polar orbit. Since its first imaging season in 2019, DFSAR has been collecting L-band, full polarimetric, high-resolution (25 m/pix) data of the lunar poles from ±75° to 90°. To date, ~95% coverage poleward of 85° and ~65% coverage in the latitude range from 80° to 85° has been achieved (Fig. 2, Table 1). Simultaneous dual-frequency (L- and S-band), hybrid-pol (to complement

Mini-RF data), and radiometeric data are planned for key targets identified in the polar regions (e.g., PSRs and Artemis zones). Very high resolution DFSAR hybrid-pol acquisitions (4 m/pix ground resolution) are also planned to target landing sites of existing and future missions, similar to those obtained for the rocket booster impact event in March 2022 [7].

Summary: Mini-RF and DFSAR radar data provide fundamental information on the structure and dielectric properties of the lunar surface and buried materials within the penetration depth of the system(s) [e.g., 8-10] and have the advantage of being sensitive to the physical form of water ice [11-13]. Radar data characterize wavelength-scale scatterers (e.g., size-frequency distribution, morphology), provide insights into subsurface structure, and constrains bulk density and composition (i.e., dielectric permittivity), all values relevant for characterizing landing hazards (e.g., Fig. 3 and 4). The continued operation of Mini-RF and the addition of DFSAR in orbit around the Moon provide both complementary and unique capabilities for measuring these properties and for addressing science and engineering objectives of the Artemis and CLPS programs.

References: [1] Raney R. K. et al. (2011) *Proc. IEEE, 99*, 808–823; [2] Putrevu et al. (2016), ASR, 57, 627-646; [3] Kirk R. L. et al. (2013) *LPSC XLIII*, Abstract #2920; [4] Hapke et al. (1998), *Icarus*, 133, 89-97; [5] Nelson et al. (2000), *Icarus*, 147, 545-558; [6] Piatek et al. (2004), *Icarus*, 171, 531-545; [7] Chakraborty et al., this LPSC volume; [8] Campbell et al. (2010), *Icarus*, 208, 565-573; [9] Raney et al. (2012), *JGR*, 117, E00H21; [10] Campbell (2012), *JGR*, 117, E06008; [11] Slade et al. (1992), *Science* 258, 635-640; [12] Black et al. (2001), *Icarus* 151, 167-180 ; [13] Rivera-Valentín, E. G. et al. (2022) PSJ 3, 62.

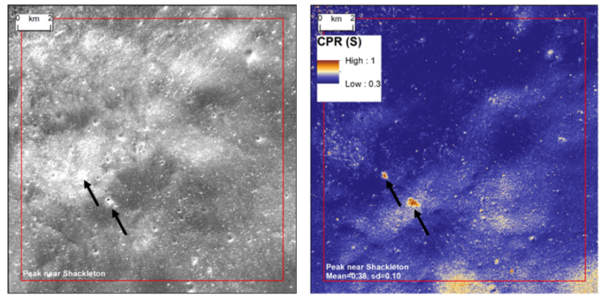

Fig. 3. Mini-RF S-band zoom S_1 (left) and CPR (right) coverage of the landing zone Peak Near Shackleton. CPR data indicates overall low cm-scale surface roughness for the landing zone, with the exception of several prominent fresh craters.

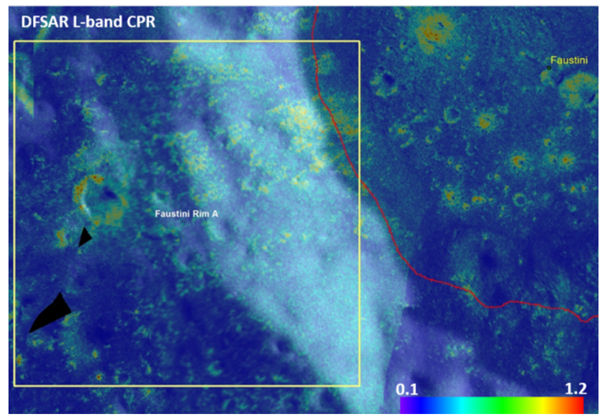

Fig. 4. DFSAR L-band CPR overlain on LROC WAC global mosaic. Artemis landing zone indicated in yellow and boundary of Faustini floor PSR in red. Crater ejecta and mass wasting features are clearly observed.

Table 1. Mini-RF and DFSAR coverage of Artemis landing zones

Radar Architecture		Monostatic					Bistatic	
Wavelength		24 cm*	12.6 cm		4.2 cm		12.6 cm	4.2 cm
Spatial Resolution		25 m	30 m	150 m	30 m	150 m	100 m	100 m
Artemis Zones	Amundsen Rim	✧	✦	✧		✦		
	Connecting Ridge	✧	✧				✦	✦
	Connecting Ridge Extension	✧	✧				✦	✦
	de Gerlache Rim	✧	✧			✧	✦	✦
	de Gerlache Rim 2	✦	✦			✧	✦	✦
	de Gerlache-Kocher Massif	✧	✦	✦	✦			
	Faustini Rim A	✦	✦	✦		✧		✧
	Haworth	✧	✦		✧	✦	✦	
	Leibnitz Beta Plateau	✧	✦			✦	✦	
	Malapert Massif	✦	✦			✦	✦	
	Nobile Rim 1	✧	✦			✦	✧	✧
	Nobile Rim 2	✧	✦		✧	✦		
	Peak Near Shackleton	✧	✦	✦			✧	✧

*Opposite look direction coverage is available for DFSAR (24 cm) data but not shown in Fig. 2

✦Denotes complete coverage of zone

✧Denotes partial coverage of zone