RADAR PROPERTIES OF THE PROPOSED INSIGHT LANDING SITE IN WESTERN ELYSIUM PLANITIA ON MARS. N. E. Putzig[1,†], G. A. Morgan[2], B. A. Campbell[2], C. Grima[3], I. B. Smith[1], R. J. Phillips[1], and M. Golombek[4]. [1]Southwest Research Institute, Boulder, CO, [2]Smithsonian Institution, Washington, DC, [3]University of Texas, Austin, TX, [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA. [†]Email: nathaniel@putzig.com.

Introduction: As part of a broader study [1], we carried out an assessment of surface and subsurface properties based on radar observations of the region in western Elysium Planitia selected as the landing site for the InSight mission prior to the cancellation of its 2016 launch. We used observations from Mars Reconnaissance Orbiter's Shallow Radar (SHARAD) and Arecibo Observatory to examine near-surface properties, including roughness and layering. Each radar data set offers unique constraints for landing-site safety considerations and instrument operations.

Methods: SHARAD has been used to assess the nature of volcanic deposits a few 100 km east of the InSight landing area [2], detecting interfaces at depths up to several 100 m. For each SHARAD track in the InSight study region, we produced radargrams (along-track profiles of returned power vs. delay time in an image format; see Fig. 1). We compared radargrams to simulations from digital elevation models (DEMs) to determine whether late returns (i.e., delayed relative to surface returns) are from subsurface interfaces or off-nadir topography (clutter). We then mapped the extent of likely subsurface interfaces and provided an interpretation of material properties. At past landing sites, subsurface detections were confined to the Phoenix site, where returns from ~25 m depth extend over 2900 km^2 and may represent the base of ground ice [3].

SHARAD also offers a view of surface roughness (RMS slope) on horizontal scales of 10–100 m and in footprints of 500 m to 3–4 km, depending on local topographic variability [4]. In this method, a roughness parameter is computed from the ratio of echo power integrated over a range of incidence angles to the peak echo power. This measure of roughness is independent of surface reflectivity and dominated by the RMS slopes of the surface. We then map results and compare them between proposed landing ellipse, surrounding terrains, and other landing sites. At past landing sites, SHARAD roughness estimates are consistent with landed observations and other data [3]. Alternatively, a model-based statistical analysis may be applied to SHARAD returns to estimate material properties and roughness in terms of RMS heights [5]. Here, the SHARAD data are separated into coherent and incoherent components by fitting the amplitude distribution with a probability density function. One may then extract dielectric permittivity (ε') and RMS height using a backscattering model applicable over a range of conditions and a calibration zone of known or assumed properties. For this study, we chose a smooth region atop the south polar layered deposits as a calibration zone and assumed water-ice properties (ε'=3.1).

These SHARAD techniques complement larger-scale roughness from Mars Orbiter Laser Altimeter (MOLA) data [6] as well as smaller-scale roughness from MOLA pulse-width measurements [7] and Arecibo data. The Arecibo S-band radar [8,9] provides information on near-surface dielectric properties and roughness relative to its 12.6-cm wavelength for the InSight study region. The radar has a spatial resolution of ≥3 km at Mars but is sensitive to small-scale surface roughness and rocks larger than a few cm within the signal's penetration depth (1–3 m). Low-power returns may also indicate a fine-grained mantling material. In addition to estimating the maximum surface roughness or rock abundance [10,11], we compared the Arecibo echo patterns to the geology to assess possible changes in surface density or mantling cover.

Results: We mapped late returns in SHARAD radargrams across the InSight region and produced corresponding MOLA DEM simulations. In most instances—including within all landing ellipses for the four finalist sites—we found that late returns correspond to surface clutter in simulations. On four adjacent radargrams, low-power, late returns extend ~50 km southward from the southern edge of the 2016 final ellipse (E9) [1] and do not appear in simulations (e.g., Fig. 1). Delayed 0.40–0.85 µs from the surface, these returns correspond to depths of ~20–43 m in basaltic regolith (ε'=9). We interpret them as an interface with an abrupt density contrast, perhaps a contact between regolith and bedrock or layers of volcanic rocks.

Our map of SHARAD-derived RMS-slope roughness parameter (Fig. 2) shows that the four finalist sites are in one of the smoothest areas of the region. These sites have a narrower roughness distribution relative to areas to the east and west (Fig. 2 inset). The study area has a similar distribution of roughness to that of the Phoenix and Opportunity landing sites. The power of surface returns at InSight is similar to that of Phoenix but larger by several dB than that of Opportunity. The Phoenix site has a shallow ice table extending from a few decimeters to ~35 m depth [3], and large dielectric contrasts presumably contribute to the surface-return power. In contrast, the Opportunity site has stacked sediments up to a few 100 m thick with no evidence of

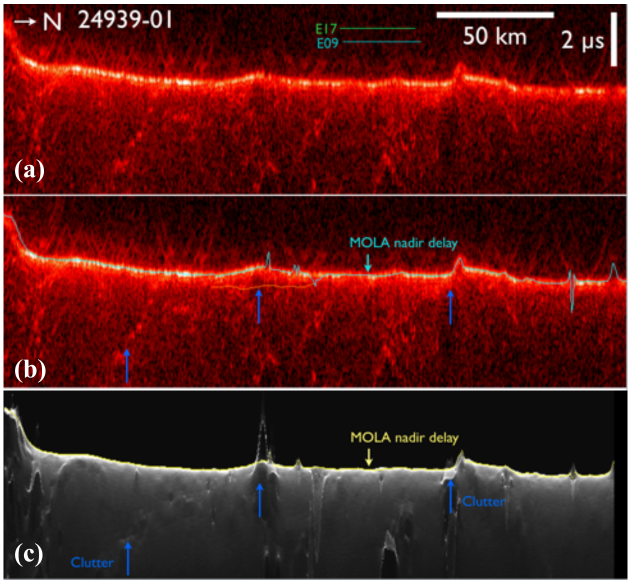

Figure 1. (a,b) SHARAD radargram with power in shades of red. Putative subsurface return (marked in (b) with orange line and middle blue arrow) does not appear in MOLA simulation in (c). Extents of InSight ellipses E9 and E17 shown at top of (a).

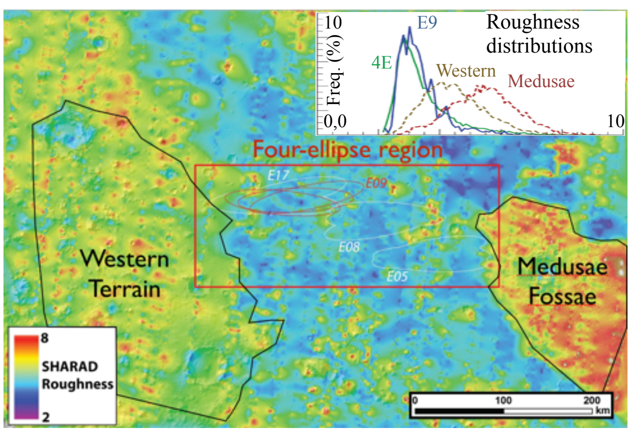

Figure 2. Map of SHARAD RMS-slope roughness in the InSight study region. Black, red, and white polygons are areas used to assess roughness distributions (inset).

large dielectric contrasts [3]. It is extremely unlikely that ground ice plays a role at the low latitude of the InSight study area, but the similarity to Phoenix could be due to layering of other materials with contacts too shallow (≤10–20 m) to produce distinct late returns.

Applying the model-based approach to assessing SHARAD roughness to data from the Elysium Rise lava flows just to the northeast of the four finalist sites, we obtained estimated values for the dielectric permittivity of 4.9 and RMS height of 0.28 m. These values are consistent with more qualitative results obtained from the Arecibo image and from SHARAD using the RMS-slope method. Within the InSight landing ellipses and in other nearby terrains (Mesa in Fig. 3), the coherent-to-incoherent power ratio is negative and thus the model limits are exceeded and no quantitive assessment in possible. Nevertheless, qualitative inferences may be made from the relative behavior. The open, middle, and close variants of the E9 landing ellipse all have similar statistics (Fig. 3), with a slight decrease in coherent power and its ratio with incoherent power (indicative of smoothness) as the ellipse rotates clockwise with time of launch. The close ellipse has a slightly broader distribution of amplitudes, indicating slightly more variable terrain.

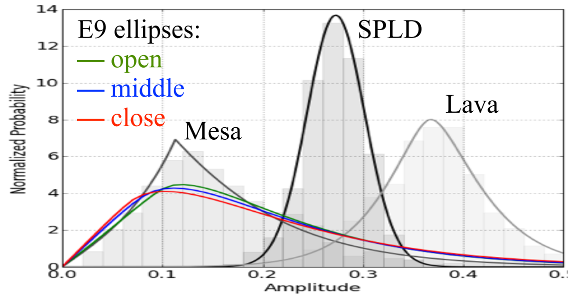

Figure 3. Probability distributions of SHARAD amplitudes in InSight ellipses (colors), nearby terrains, and the south polar calibration zone.

In the Arecibo data, the backscatter strength from the four finalist landing sites is moderately low (-17.0 to -16.2 dB). Being in the middle of the typical diffuse reflectivity range, these sites are not solely composed of rock-poor, porous material at the 12.6-cm scale. The InSight ellipses are rather brighter than a large lobe of the Medusae Fossae Formation (-18.9 dB) several hundred km to the east and are notably darker than returns from volcanic flows of nearby Elysium Rise (-14.3 dB) and of Elysium Planitia (-8.4 dB) further to the east. The values in the InSight region are similar to those of a field site on Kilauea [10] with a moderately rocky surface, they are only slightly higher than those of the Viking 1 site (-17 dB), and they are considerably higher than those of the Viking 2 site (-19 dB). Thus, surface rock abundance in the 2–10 cm range in the InSight study area may be expected to be slightly to significantly higher than at the two Viking sites.

References: [1] Golombek M. et al. 2016, *LPS XLVII* (this conference). [2] Morgan G.A. et al. 2013, *Science 340,* 607–610. [3] Putzig N.E. et al. 2014, *JGR 119,* 1936-1949. [4] Campbell B.A. et al. 2013, *JGR 118,* 436–450. [5] Grima C. et al. 2014, *Planet. Space Sci. 103,* 191-204. [6] Kreslavsky M.A. & Head J.W. 2000, *JGR 105,* 26695–26711. [7] Neumann G.A. et al. 2003, *GRL 30,* 1561. [8] Harmon J.K. et al. 1999, *JGR 104,* 14065. [9] Harmon J.K. et al. 2012, *Icarus 220,* 990–1030. [10] Campbell B.A. 2001, *Icarus 150,* 38–47. [11] Campbell B.A. 2009, *IEEE Geosci. Rem. Sensing 47,* 3480–3488.