Radar Properties of the Proposed InSight Landing Site in Western Elysium Planitia on Mars

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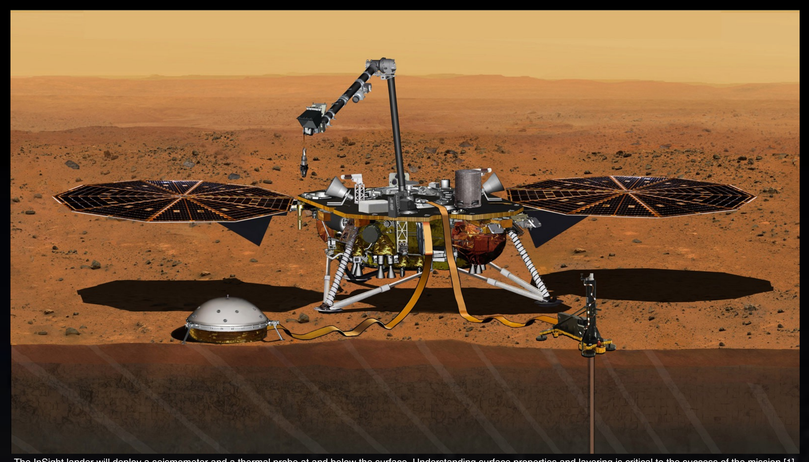
We examine near-surface properties and layering in the InSight region using radar observations from Arecibo and SHARAD.



The InSight lander will deploy a seismometer and a thermal probe at and below the surface. Understanding surface properties and layering is critical to the success of the mission [1].

Probing surface properties and layering

Both radars provide measures of dielectric properties and roughness.

Arecibo is sensitive to rocks larger than a few cm to depths of 1–3 m. Low-power returns may indicate a fine-grained mantle [8,9].

SHARAD is sensitive to broader variations in rock abundance and topography and can also detect interfaces to several 100 m depth [2].

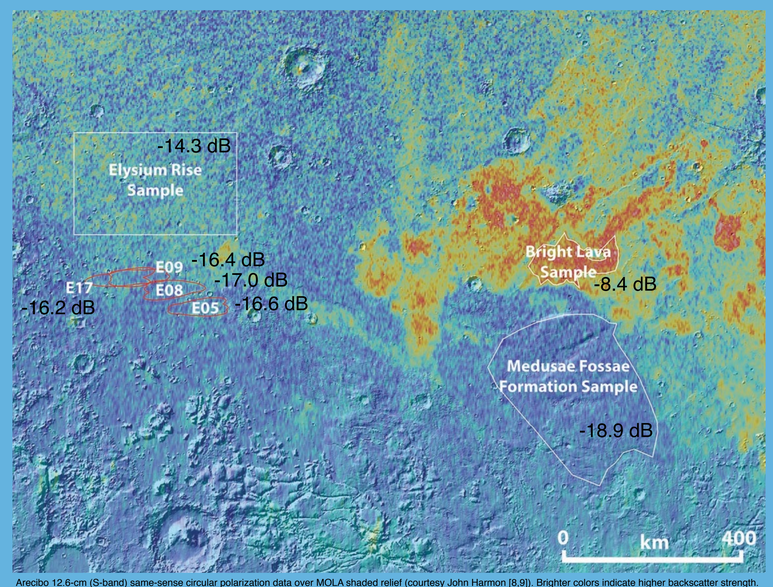
Arecibo Observatory provides S-band (12.6 cm) radar observations of Mars

SHARAD, the Shallow Radar on Mars Reconnaissaance Orbiter, emits a 25–15 MHz signal.

Findings

- Arecibo echo power indicates that 2–10 cm rock abundance in InSight region is moderate, similar to the Viking 1 site.
- SHARAD roughness measures indicate that InSight slopes are gentle, similar to the Phoenix and Opportunity sites.
- SHARAD detects faint returns from ~30 m depth south of the InSight landing site that may indicate bedrock or volcanic layering.

Arecibo radar analysis



Arecibo 12.6-cm (S-band) same-sense circular polarization data over MOLA shaded relief (courtesy John Harmon [8,9]). Brighter colors indicate higher backscatter strength.

Surface properties

Backscatter from the proposed InSight landing ellipses is moderately dark—but bright enough to rule out a surface solely composed of rock-poor, porous material [10,11]. The InSight ellipses are brighter than a large lobe of the largely "radar-stealth" Medusae Fossae Formation several hundred km to the east and are notably darker than returns from volcanic flows of nearby Elysium Rise and of Elysium Planitia further to the east.

Comparison to other sites

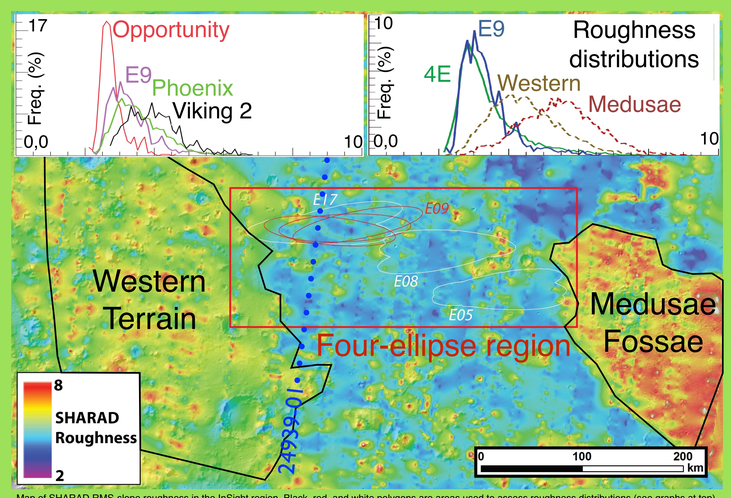
The values in the InSight region are similar to those of a field site on Kilauea [10] with a moderately rocky surface, they are only slightly higher than those of the Viking 1 site (-17 dB) but considerably higher than those of the Viking 2 site (-19 dB). Surface rock abundance in the 2–10 cm range in the InSight study area may be expected to be slightly to significantly higher than at the two Viking sites.

SHARAD analysis

Surface properties

Method 1 We derive a roughness parameter, which is independent of reflectivity and dominated by RMS slope at ~10–100 m, as echo power integrated over a range of incidence angles and scaled to the peak power [4]. By this measure, InSight's four finalist sites are in one of the smoothest areas of the region, with a relatively narrow distribution of roughness.

Roughness in the InSight region is similar to that of the Phoenix and Opportunity landing sites. Surface-return power at InSight is similar to that of Phoenix and larger by several dB than that of Opportunity. A shallow ice table at the Phoenix site likely contributes to the surface-return power, but layered sediments at the Opportunity site show no evidence for strong dielectric contrasts [3]. Ground ice is unlikely in the equatorial InSight area, but shallow (≤10–20 m) layering in regolith may contribute to return power.



Map of SHARAD RMS-slope roughness in the InSight region. Black, red, and white polygons are areas used to assess roughness distributions (see graphs at top).

Method 2 Radar statistical reconnaissance [5] of SHARAD returns allows estimation of material properties and roughness. Separating coherent (P_c) and incoherent (P_n) power, we constrain dielectric permittivity (ϵ') and RMS height (σ_h) using two backscattering models and assuming water-ice properties in a calibration zone atop the south polar layered deposits.

A small-perturbation model (SPM) [5] yields dielectric permittivity of 4.9 and RMS height of 0.28 m for Elysium Rise lava flows northeast of the InSight area, consistent with our results from Arecibo and Method 1. In the ellipses and other nearby terrains (Mesa at right), P_c/P_n is negative, precludes a quantitive assessment from SPM. However, the open, middle, and close variants of the selected landing ellipse (E9) have similar statistics, with a slight decrease in P_c and in P_c/P_n (indicative of smoothness) as the ellipse rotates clockwise with time of launch. The broader distribution of amplitudes in the close ellipse indicates slightly more variable terrain. Using an integral equation method (IEM), we can constrain RMS heights to ~1.8–2.3 m in the E9 ellipses, increasing with permittivity and time of launch, as with the SPM.

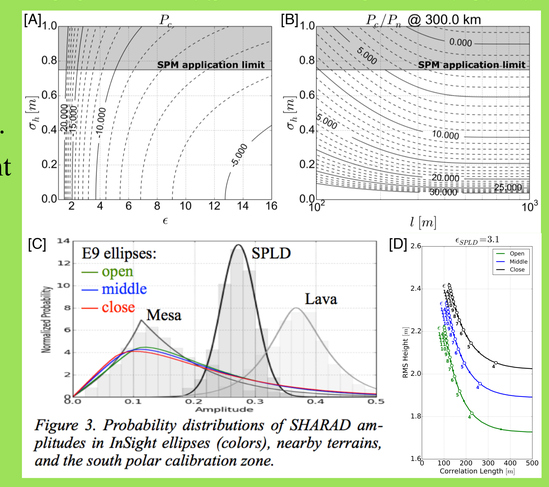
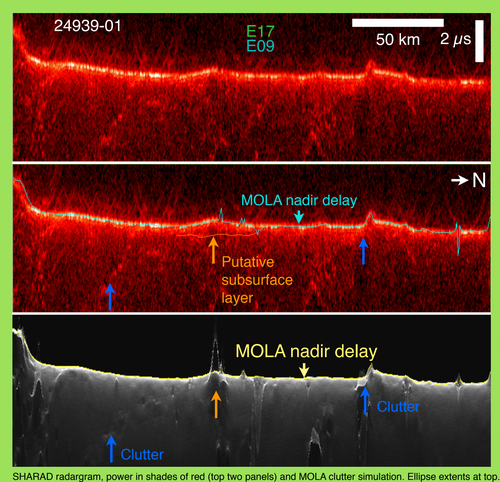


Figure 3. Probability distributions of SHARAD amplitudes in InSight ellipses (colors), nearby terrains, and the south polar calibration zone.

[A,B] Solution space for RMS height vs. permittivity and correlation length using a small-perturbation model, applicable for RMS height < 1/20 of the radar wavelength (0.75 m) and correlation lengths ≈ the radar footprint (~600 m). Under these conditions, one may fit probability distributions of radar amplitudes [C] and quantify RMS height and permittivity, given a calibration zone of known or assumed properties (SPLD). [D] The integral equation method has more relaxed conditions and thus allows constraints on RMS heights and permittivity of the InSight ellipses not possible with SPM.



SHARAD radargram, power in shades of red (top two panels) and MOLA clutter simulation. Ellipse extents at top.

Layering

Most SHARAD late returns in the InSight region correspond to surface clutter in simulations using elevation models from MOLA and HRSC (courtesy of Klaus Gwinner). However, low-power, late returns extend ~50 km southward from the southern edge of the selected ellipse (E9) and do not appear in clutter simulations (e.g., Fig. 1c). 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 to be from an interface with an abrupt density contrast, perhaps a contact between regolith and bedrock or volcanic layers.

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. **Acknowledgments:** We thank John Harmon for providing Arecibo data. We are grateful to all of the people and organizations who have helped facilitate this work, including the SHARAD Instrument Team, the Italian Space Agency, the MRO Project, and SeisWare International. This project is funded by the Jet Propulsion Laboratory Critical Data Products Program, Subcontract 1505380.