MICROTOPOGRAPHY OF THE MARS INSIGHT LANDING SITE: GEOLOGICAL IMPLICATIONS.
J. B. Garvin,[1] R. Dotson[2], N. Williams[3], J. Maki[3], R. Deen[3], H. Abarca[3], N. Ruoff[3], A. Trebi-Ollennu[3]; [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771 [james.b.garvin@nasa.gov]; [2]Fireball LLC, Reno, NV; [3]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109.

Introduction: The Mars *InSight* lander touched down in *Elysium Planitia* on 26 Nov. 2018 and soon thereafter began a comprehensive arm-based imaging campaign with the Instrument Deployment Camera (IDC) to support geophysical instrument deployment [2,3,10]. By means of IDC imaging in a geometry favorable for tailored Structure-from-Motion (SFM) computation [1,6] of very local scale topography at scales finer than 1 mm, we have produced and analyzed Digital Elevation Models (DEM) that offer insights into the geology of the local landing site, with implications for this region of Mars as described in Golombek and other papers in this issue [4,5,7,8,11].

Thanks to the IDC camera viewing geometry facilitated by the Mars *InSight* Instrument Deployment Arm (IDA), we were able to use the Sol 12 IDC workspace imaging campaign of ~58 frames to map the nearfield on one side of the lander at 2 mm ground scale distance (GSD) with a vertical error on the order of ~0.3 mm per grid cell (binned at 1 cm). This landing site DEM (**Figure 1**) facilitates geological terrain analysis at very local scales, as has been demonstrated on the *Curiosity* rover via MARDI sidewalk imaging and MAHLI quantitative relief model analysis [1,6]. Here the IDC imaging geometry allows for multi-frame overlap via the motions of the IDA [10,11] permitting highly-favorable multi-pose viewing for SFM computation of DEM's from an effective height above the local surface of 1.5m (and 1.2m for "high res"). Using the SFM-derived DEM, controlled by JPL tie-point based stereogrammetry for the landing site [11], we have evaluated the mm-scale texture of the immediate landing area, including the effects of the *InSight* lander pulsed descent engines in three dimensions. Results have bearing on the ultimate geophysical interpretations of the mission, but also for the multi-temporal dynamics of mm-scale relief at the surface of Mars [4,5,7,8].

Ongoing work with the available *InSight* IDC images from Sol 12 to present enables further refinement of the SFM-based DEM's, and improved vertical control and precision [11]. We anticipate repeat imaging of the workspace after sensor deployment to begin DEM time-series analysis at ~ 2-3 mm spatial scales and evaluation of dV/dt.

Here we focus on what can be measured at finest scales in the near-field workspace, as we continue to refine our SFM-DEM analysis of the lander mid-field (See **Figs. 1,2**) using multiple techniques [10,11].

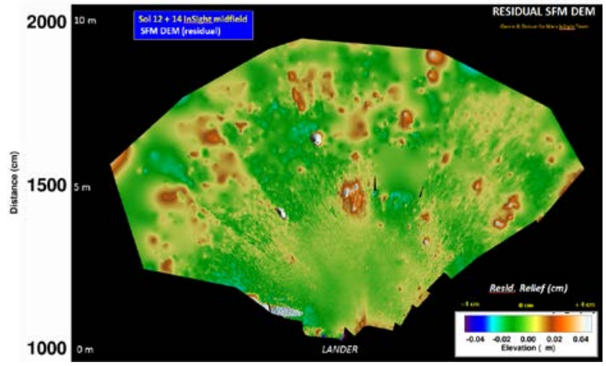

Figure 1: SFM-based DEM of the Mars *InSight* landing site from Sol 12 &14 IDC images from 1.5 m above the surface (3 mm GSD). This wide-area *residual* DEM includes sensor-deployment workspace and first panoramic IDC imaging out to ~ 10 m (Sol 14).

APPROACH : Using SFM techniques pioneered with Mars *Curiosity* rover imaging via MARDI and MAHLI [1,6], we have extended these methods using the IDC camera mounted on the IDA arm of the *Insigh*t Lander, with emphasis on the near-field workspace where sensor deployments (SEIS, HP3) are underway (sols 26-50+). The approach takes advantage of the IDC frame overlap geometry developed by the JPL MIPL team (Abarca, Dean, Maki, Ruoff [2,3,11]) which provides excellent coverage for SFM computations of mm-scale topography as DEM's, with vertical noise at cm scales of 0.3 mm (and finer locally).

The interpretation of the sensor deployment workspace DEM is enhanced by computing a series of "residual" DEM's from the original or "total" area. These residual relief models (RRMs) are computed by removing polynomial surfaces that best-fit the total DEM from degree 3 to 8, until only small-scale relief remains (**Figs. 2,3**). This approach essentially filters out most of the longer-wavelength tilts at scales from ~8 cm to over 100 cm, while enhancing sub-cm textures at spatial scales of 0.5 to 5 cm. We have evaluated this method using *Curiosity* SFM-DEM datasets for revealing shallowly-buried topography along the rover's traverse in some areas with demonstrated detection of buried rocks otherwise invisible [1]. At the Mars *InSight* nearfield and mid-field (**Figs. 1,2**), the evaluation of buried clasts and other features is of interest to the overarching geophysical goals of the mission [9,4].

Thus, we have produced three different SFM-based DEM's each covering areas at specific spatial scales:

(1) wide-area FOV out to ~ 10 m using IDC frames from Sols 12 and 14 (**Fig. 1**); (2) sensor deployment workspace area using only IDC frames from sol 12; *and* (3) local area viewed at 1.2m via IDC on sol 16 for finest resolution (< 1 mm GSD) (**Fig. 2**). These SFM-based DEM's were delivered to the *InSight* Project rapidly during pre-deployment activities. From these, the local (1 cm grid) vertical roughness is ~ 1.9 mm.

Methods: Residual relief models were computed for each of the SFM-DEM's and then merged with ortho-image mosaics using the IDC images. The resulting ortho+RRM products were then analyzed statistically for texture, clast spacing, and periodic relief using classical methods, including *Radial Power Spectra*, *Delaunay Triangulation*, and *Morishita* Index analysis. Here we focus on unique observations from the highest resolution products for the immediate near-field (sol 16 sub-mm GSD SFM-DEM and ortho+RRM: **Fig. 2**), while we wait to fill in higher resolution wide-area SFM-DEM coverage.

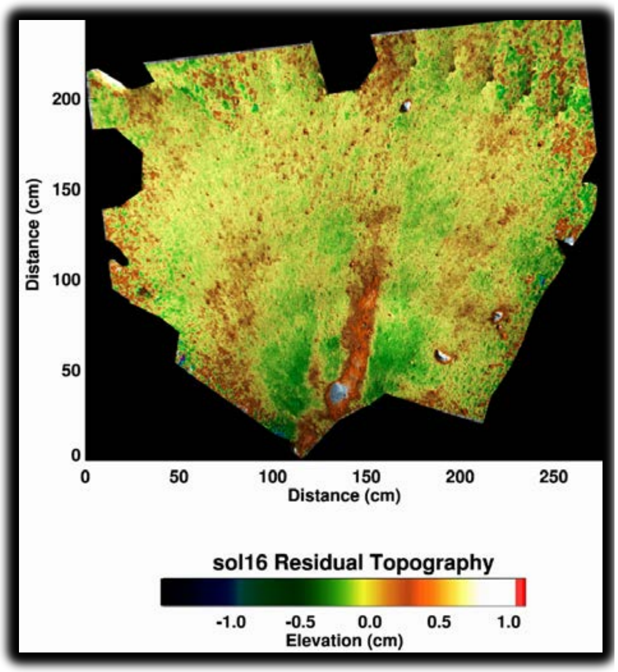

Figure 2: High resolution residual relief model (RRM) merged with ortho-image mosaic (of IDC frames) from sol 16 high-resolution survey with the IDC at 1.2m above local surface in the near-field.

Observations: *High-Res (***Fig. 2***).* Clasts and clods with residual relief of 2-3 mm are visible in the **Fig. 2** ortho+RRM dataset, with distinctive radial patterns, and apparent spatial clumping. Radial Power Spectral (RPS) analysis of the central portion of this FOV (1024 x 1024 patch with no edges) showcases an apparent systematic pattern of relief at the shortest wavelengths measurable. **Figure 3** illustrates this set of significant wavelengths, which have been suggested to be at least partially a consequence of the Lander's pulsed descent motor exhaust in terminal landing. Larger clasts (*white & brown* in **Fig. 2**) are sparsely distributed in this ~ 2 m^2 area, where vertical roughness is ~ 1.7 mm.

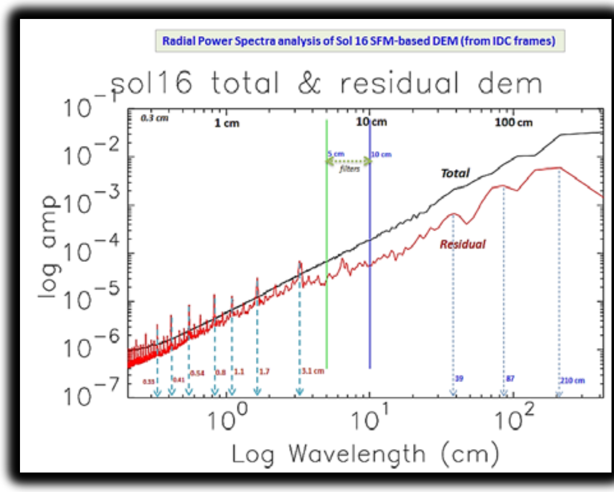

Figure 3: Radial Power Spectrum (RPS) of the central area of **Fig. 2** showing significant wavelengths of residual relief, as discussed above. Some of the sub-cm features may be due to rocket exhaust.

Wide-Area (Sols 12, 14 IDC). Although still in work, the widest-area SFM-based DEM we have computed reveals more about the surface and shallow subsurface of the immediate landing site, and supports the geologic assessments by Golombek, Ansan, and others [4-5, 7-9]. Our preliminary interpretation is that buried clasts up to 20-30 cm are very near the surface in the mid-field, extending ~ 10 m from the lander. Further quantitative analysis is underway using this DEM to evaluate burial. The vertical roughness is ~ 8.5 mm (binned at 1 cm across the **Fig. 1** area).

Discussion: The Mars *InSight* mission offers an unprecedented opportunity to carefully measure mm-scale local relief on Mars over time. During the course of the mission, we hope to produce a time-series of DEM's that document the site as part of the primary geophysical monitoring phase. Our aim is to quantify local dV/dt and other effects during a martian year.

Acknowledgements: The support of the entire *InSight* Project has greatly facilitated the SFM DEM analyses, with contributions by Dr. J. Frawley (HBG).

References: [1] Garvin J. B *et al.* (2015) *LPSC 46, #2522*; [2] Maki *et al.* (2018) *SSR 214*; [3] Abarca H. *et al.* (2018) *SSR 215*; [4] Golombek, M. *et al.* (2019), *LPSC 50th*, this issue; [5] Ansan, V. *et al.* (2019), *LPSC 50th*, this issue; [6] Garvin *et al.* (2016) *Microscopy and Microanalysis 23, 2146*; [7] Weitz C. *et al.* (2019) *LPSC 50th*, this issue; [8] Grant J. *et al.* (2019) *LPSC 50th*, this issue; [9] Banerdt B. *et al.* (2017) *SSR* 211; [10] Trebi-Ollennu A. *et al.* (2018) *SSR 214*. [11] Deen R. *et al.* (2019) this issue.