SURFACE ALTERATION FROM LANDING INSIGHT ON MARS AND ITS IMPLICATIONS FOR SHALLOW REGOLITH STRUCTURE. N. R. Williams[1], M. P. Golombek[1], N. H. Warner[2], I. J. Daubar[1], R. B. Hausmann[1], E. Hauber[3], V. Ansan[4], J. A. Grant[5], C. M. Weitz[6], S. Wilson[5], C. Charalambous[7], T. Pike[7], R. D. Lorenz[8], J. N. Maki[1], H. E. Abarca[1], N. A. Ruoff[1], R. G. Deen[1], J. B. Garvin[9], T. J. Parker[1], F. J. Calef[1], H. A. Lethcoe[1], L. M. Berger[1], A. DeMott[2], M. Kopp[2]. [1]Jet Propulsion Laboratory, California Institute of Technology, M/S 183-301, 4800 Oak Grove Dr., Pasadena, CA 91109, nathan.r.williams@jpl.nasa.gov; [2]SUNY Geneseo, NY; [3]German Aerospace Center (DLR), Institute of Planetary Research; [4]University of Nantes, Laboratory of Planetary and Geodynamics; [5]Smithsonian National Air and Space Museum, Center for Earth and Planetary Studies; [6]Planetary Science Institute; [7]Imperial College, London, Department of Electrical and Electronic Engineering; [8]Johns Hopkins Applied Physics Lab, Laurel, MD; [9]NASA Goddard Space Flight Center, Greenbelt, MD.

Introduction: The Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight) mission landed successfully at Homestead hollow in Elysium Planitia on Mars on Nov. 26, 2018, at 4.502384°N, 135.623447°E [1,2]. InSight used retropropulsive pulse thruster rockets to slow the lander's descent and perform a safe soft landing [3]. Rocket exhaust from previous landings on Mars [4-7] and Earth's Moon [8] modified the near surface by redistributing primarily fine-grained materials. This surface alteration is most easily identified as "halos" of albedo and/or color variations in visible images, especially from orbit. For Mars landing sites, alteration halos have appeared dark in orbital images because the relatively brighter dust has been blasted away – leaving behind the larger, relatively darker grains [4-7]. For lunar landings, multiple halos appear due to macroscopic disruption of regolith resulting in either increased or decreased surface roughness [8]. The pattern of surface alteration around the InSight landing site can be compared to the patterns at previous landing sites and impacts to assess the surface properties and very near surface structure of the regolith.

Data: Two primary datasets are available for assessing surface alteration around InSight: images taken from orbit and images taken *in situ* by the lander itself. The High Resolution Imaging Science Experiment (HiRISE) [9] camera onboard the Mars Reconnaissance Orbiter (MRO) acquired ~25 cm/pixel infrared/red/blue (IRB) color images of the InSight lander and surrounding terrain on Dec. 6, 2018, and again on Dec. 11, 2018 (Fig. 1a). Additionally, InSight's Instrument Deployment Camera (IDC) located on the lander's robotic arm acquired red/green/blue (RGB) color images [10] from a height of ~1.5m above the surface, including a panorama of mid- and far-field terrain around the lander on sol 14 or Dec. 11, 2018 (Fig. 2a), as well as may more images of the surface directly south of the lander over several days [1].

Results: HiRISE images reveal a high-reflectance inner halo extending up to 8-11 m from the lander that has an 18% lower relative albedo compared to unaltered background, surrounded by a low-reflectance outer halo extending from the edge of the high reflectance halo out to 15-21 m (~990 m^2 area) from the lander that has up to a 35% lower relative albedo compared to unaltered background. The low-reflectance outer halo also extends more weakly much farther to the southeast along the expected prevailing wind direction [11]. Additionally, a discontinuous pattern of low-reflectance rays (showing up as dark-blue in Fig. 1a) extends primarily towards the north up to 5 m from the lander. The IDC mosaic shows a slight darkening of the mid-field (up to 20 m away) relative to the far-field, approximately coincident with the edge of Homestead hollow (Fig. 2a, arrows).

The boundaries of the halos can be difficult to define, so we performed a decorrelation stretch (DCS) on the HiRISE images (Fig. 1b) and IDC panorama (Fig. 2b). The DCS is a principal component analysis that enhances color separation in a multispectral (3-band) image that has significant band-to-band correlation. Lander hardware and the sky were clipped from images prior to performing the stretch to emphasize areas that might exhibit surface alteration. The HiRISE (IRB) DCS images exhibit a strong spectrally bluer inner halo. The IDC (RGB) panorama DCS shows a spectrally relatively green zone close to the lander, along with more clearly delineating the low-reflectance halo which appears red in this DCS, in contrast with the more distal unaltered background terrain appearing speckled with red and lime-green. Illuminated surfaces of rocks also appear green in the IDC color panorama DCS.

Discussion: The quasi-circular disturbed zone of 15-21 m radius (~990 m^2) around InSight is remarkably consistent with the disturbed zone measured around Phoenix (same lander system) of 18 m mean radius (1020 m^2) [7]. Darkening of the surface by up to 35% is consistent with the expected removal of a thin layer (microns) of dust during landing, similar to previous Mars landing sites [4-7] including a ~20-40% darkening by Phoenix [5], an average 35% darkening around fresh impacts [6], and analogous to the formation of typical dust devil tracks [12]. Although much brighter than the outer halo, the higher-reflectance inner halo is still darker than unaltered background and likely also had a veneer of dust removed. The blue inner halo in the HiRISE (IRB) DCS and the green proximal zone in the IDC (RGB) panorama DCS consistently demonstrate that the exposed inner halo material has a relatively stronger reflectance at shorter visible wavelengths compared to surface materials nearby.

Previous Mars landing sites have not shown high-reflectance inner halos, although they do sometimes occur near small impacts [6]. Lunar landing sites also have high-reflectance halos and are interpreted to be caused by decreased surface roughness resulting from the destruction of fine-scale "fairy-castle" structures [8]. Although such delicate structures are not expected in the Martian environment, small-scale surface roughness could have been affected during landing by redistributing sand and/or pebbles. IDC images of the surface 1-2 m south of the lander show radial linear grooves and ridges several mm in relief with many pebbles with tails extending away from the lander – suggesting scour from landing [13-15]. This indicates that landing likely removed at least some unconsolidated surface material, exposing shallowly buried material underneath. The retro rockets also excavated steep-sided pits under the lander that suggests a mildly cohesive duricrust [15]. This duricrust is relatively light-toned and appears to have a smooth top surface, which could be partially exposed as the high-reflectance inner halo. The small proximal discontinuous dark-blue low-reflectance zone in Fig. 1a has not yet been well-imaged by the lander, but we hypothesize that it represents a combination of dust removal and roughening of the duricrust by more severe rocket plume interactions.

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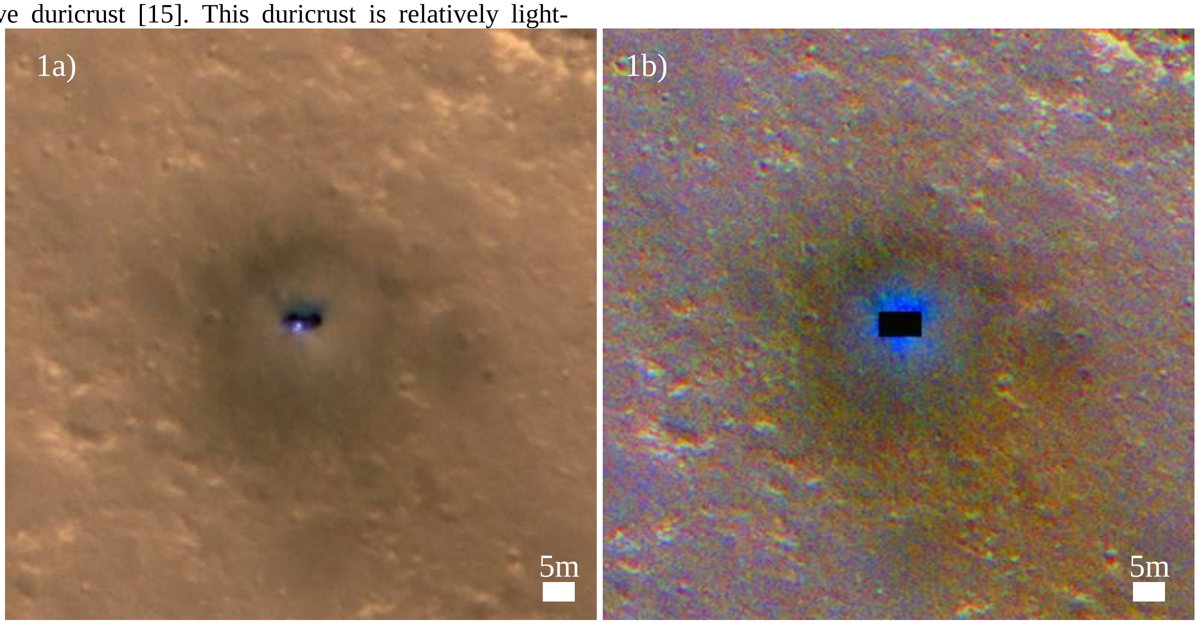

Fig. 1: a) False-color (IRB) stretch of HiRISE image ESP_057939_1845 over the InSight landing site, and b) decorrelation stretch of the image (excluding lander itself in black rectangle) to enhance surface spectral differences.

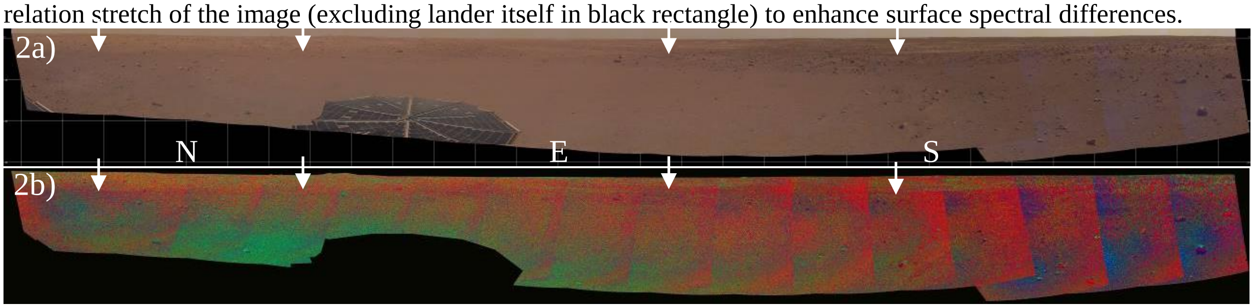

Fig. 2: a) InSight sol 14 IDC panorama of the landing site, and b) decorrelation stretch (with sky and the lander masked out) to enhance surface spectral differences. White arrows indicate the apparent extent of the alteration zone.