ROCKS AT THE INSIGHT LANDING SITE ALSO IDENTIFIED IN HiRISE IMAGES AT THE SCALE OF A PIXEL. M. Golombek[1], A. Trussell[1,2], and N. Williams[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [2]California Institute of Technology, Pasadena, CA.

Introduction: Rocks in High-Resolution Imaging Science Experiment camera images larger than 1.5 m diameter can be readily identified and accurately measured [1]. Some rocks smaller than this can also be identified and measured, but comparison of the size-frequency distribution with rocks imaged from the surface, indicates that fewer and fewer rocks can be detected in HiRISE as their size approaches the pixel scale of the images (~0.25-0.3 m), which is similar to resolution roll off in crater counts.

After the InSight (Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport) mission landed, rock counts were performed in areas around the lander that had stereo coverage [2] and their size-frequency distribution were compared with rocks measured in HiRISE [3]. In this abstract, rocks in surface panoramas that also can be identified in HiRISE are measured. Results show that some rocks down to and below the pixel scale can be identified.

InSight Rocks: After InSight landed, craters, rocks, and bedforms that could be identified in both the InSight surface panoramas and in HiRISE were identified [4]. Eleven large rocks and 15 craters (1–10 m diameter) that could be confidently identified in both were mapped on a HiRISE image georeferenced into a map view, which show the location of these features out to around 40 m distance from the lander [4]. These same rocks and craters were also identified in eight ~45° azimuth views of the surface panorama. The azimuths of these features in the panoramas matched their azimuths in the HiRISE image to within 1°, indicating the spacecraft Inertial Measurement Unit that measured the yaw, pitch, and roll of the spacecraft to determine the site frame (with respect to north on Mars) was accurate within 1° as expected [4]. Here we identify and map a total of 82 rocks that could be identified in both the HiRISE image (Fig. 1) and the InSight panoramas (e.g., Fig. 2). Because these rocks can be identified in the HiRISE image, their distance from the lander could be measured and their diameter and height could be determined from the size of the pixels in the panorama at that distance.

Method: Relatively large rocks were identified in the afternoon and evening portions of the color panoramas that emphasize shadows. The relative distance of the rock was initially estimated qualitatively in the panorama by its position and size with respect to large rocks and craters that had already been identified [4]. The azimuth of the rock was noted in the panorama and then the HiRISE image was inspected for circular to elliptical shadows that extended to the southeast, (i.e., perpendicular to the terminator), separating the illuminated rock face, at the relative distance estimated in the panorama. If a light-dark pattern of pixels (to northwest and southwest, respectively) was identified, the azimuth and relative distance were compared to that

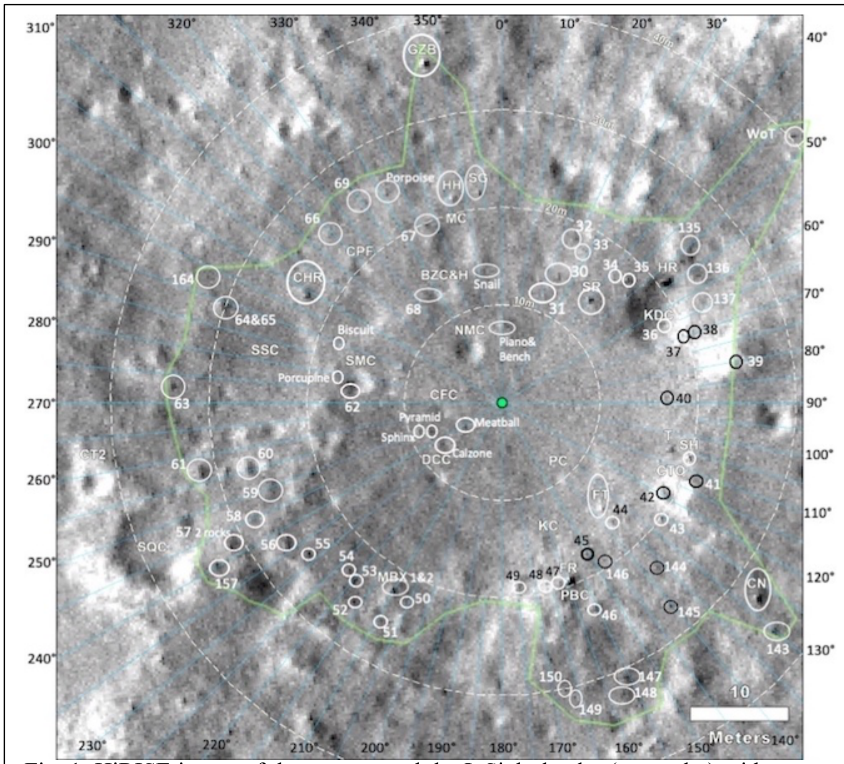

Fig. 1. HiRISE image of the area around the InSight lander (green dot) with craters and rocks that can be identified in both the surface panoramas as well as this orbital image. Rocks are circled and either numbered or named and are identified in the surface panoramas. Green line encloses area used to determine the SFDs. Outside black numbers are azimuths in degrees (blue lines every 5°) clockwise from north. Dashed white circles are distances from the lander in 10 m increments. Named rocks and craters from [4]. HiRISE image number ESP_036761_1845, is not map projected at 27.5 cm/pixel, with the Sun 54° from vertical from the northwest, azimuth 293° measured clockwise from north), but has been georeferenced into a map view and contrast enhanced to emphasize illuminated rock bright sides to the northwest and shadows in the solar azimuth to the southeast.

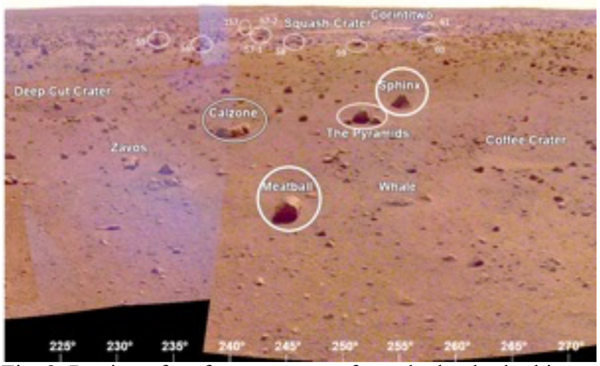

Fig. 2. Portion of surface panorama from the lander looking to the southwest-west (220° to 275°) showing measured rocks (circled, named or numbered) and craters also identified in HiRISE (Fig. 1). Meatball, Calzone, the Pyramids and Sphinx are 0.12-0.29 m in diameter as are the numbered rocks in the background. A portion of the afternoon panorama that has been stretched and is not true color.

in the panorama. Finally, the location of the rock and its size had to match the azimuth (with the shadow extending to the southeast), relative distance, and size of other nearby surface features to be considered a match. Once the rock was identified on the HiRISE image, the azimuth and distance from the lander were measured. We used a sharpened [3], not map-projected HiRISE image (NO MAP, ESP_036761_1845) with a pixel resolution of 27.5 cm/pixel to avoid resampling pixels that was georeferenced into a map view (Fig. 1).

To measure the size of the rocks, the Instrument Deployment Camera pixel scale of 0.82 mrad/pixel at the center of the image [5] was multiplied by the distance to the rock in meters to get the size of each pixel in mm. Rock height was measured by counting the number of pixels in a vertical column from the base to the top of the rock. The width of the rock was measured by counting the number of pixels across a horizontal row. The number of pixels was multiplied by the size of each pixel at that distance to get the width and height of each rock. Because the images capture only the side or sides of the rock facing the camera, independent measurements of the length and width of the rocks could not be made. However, there is no reason that the orientation of the rocks viewed from the lander would have a preferred direction, so the observed apparent width can be considered as an average sample of the actual rock diameter. This is the same assumption for rock diameter measured from shadows in HiRISE images where the solar illumination direction is constant in the image and thus, the measured width of the shadow can be considered an average sample of the rock diameter [e.g., 1]. As a result, we assume that the measured apparent width is roughly the diameter.

Results: There are 82 far-field rocks measured in this data set over a total area of 2630.4 m^2 (Fig. 1). Rocks measured range from 5–40 m away from the lander. Rock diameter varied from 0.1 m to 0.6 m and rock height varied from 0.1 m to 0.3 m [3]. Roughly, one third of the rocks have diameters below the pixel scale of the HiRISE image (~0.3 m/pixel), indicating that the signal to noise of the HiRISE camera is sufficient to produce illuminated (bright)-shadow (dark) pairs that are as small as one pixel each.

The size-frequency distribution of the rocks measured falls near the 3% exponential model Mars size-frequency distribution for diameters of 0.4 m to 0.9 m [4]. At diameters from 0.4-m to 0.15 m diameter, the slope of the size-frequency distribution flattens considerably, consistent with the expected resolution roll off. The 3% cumulative fractional area of these rocks is the same as that of all rocks measured in orthoimages within 10 m of the lander and similar to that measured in HiRISE images [3]. For rocks whose diameter is at the pixel scale of HiRISE (27 cm) or smaller, roughly 20% of the rocks expected for the 3% model distribution observed at larger diameters were detected using this method.

Discussion: The observation that 20% of rocks at the pixel scale of HiRISE have been identified at the InSight landing site is similar to experience with helicopter images at Jezero crater. The measurements of rock diameter in HiRISE and helicopter navigation camera images of ~700 m long swath beneath flights 5-8 showed that about 25% of rocks smaller than a HiRISE pixel could be identified in the HiRISE image and that all rocks with diameters greater than ~1 m diameter could be identified [6]. The ability to identify some rocks at the pixel of HiRISE has important ramifications for identifying surfaces with no (or very few) decimeter size rocks, which is important for finding airfields for the helicopter and for identifying rock free paths for future rovers [6]. Because the size-frequency distribution of rocks on Mars follows a steep slope on a log-log plot (e.g., [1,3]), areas with no rocks identified in HiRISE are likely to also not have any (or very few) rocks below the pixel scale that could be hazardous. So far 15 airfields for landing the Mars helicopter have been found by identifying smooth, flat locations in HiRISE images with no (or very few rocks) [7].

References: [1] Golombek M. et al. (2008) *JGR* 113, E00A09. [2] Golombek M. et al. (2020) *Nature Comm.* 11, 1014. [3] Golombek M. et al. (2021) *Earth Space Sci.* 8, e2021EA001959. [4] Golombek M. et al. (2020) *Earth Space Sci.* 7, e2020EA001248. [5] Maki J. et al. (2018) *SSR* 214(105). [6] Brooks C. et al. (2022) *53rd LPSC*. [7] Golombek M. et al. (2022) *53rd LPSC*.