

LOCALIZATION OF THE INSIGHT LANDER. T. J. Parker¹, M. P. Golombek¹, F. J. Calef¹, N. R. Williams¹, S. LeMaistre², W. Folkner¹, I. J. Daubar¹, D. Kipp¹, E. Sklyanskiy¹, H. Lethcoe-Wilson¹, and R. Hausmann¹, ¹Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, (tparker@jpl.nasa.gov), ²Royal Observatory of Belgium, av. Circulaire 3, Brussels 1180, Belgium.

Introduction: On Nov. 26, 2018 at 11:52:59 a.m. PST, the InSight lander touched down on Mars at 4.502384°N, 135.623447°E (planetocentric, IAU 2000) with an elevation of -2613.426 m with respect to the Mars Orbiter Laser Altimeter (MOLA) geoid.

Base Map: During landing site selection and preparation for EDL, a base map was compiled from a carefully georeferenced pyramid of MOLA, HRSC, CTX, and HiRISE images and DEMs [1], in a manner similar to that employed to localize all our previous landed assets from Viking through all end-of-drive locations for the MER and MSL missions. [e.g., 2-5]

Initial Results from EDL and RISE: InSight landed 12 km west-northwest from the last Orbiter Determination (OD) (post Trajectory Correction Maneuver, TCM-6) and 1.38 km from the surface location indicated by the Inertial Measurement Unit (IMU).

Fig 1 shows the reference ellipse E9 (blue) [1] as well as the last OD solution (od133) and the appropriate ellipse to go with it (LaRC, green). The TCM-5 target is where the first HiRISE and CTX images were targeted (neither showed the lander). The Dec. 6 images were targeted to the RISE (Rotation and Interior Structure Experiment) [6] location determined after tracking on sol 1. Figure 2 shows a closer up view of the IMU location, and the RISE location determined after tracking on sols 1, 3 and 4, and the location of the lander (see below).

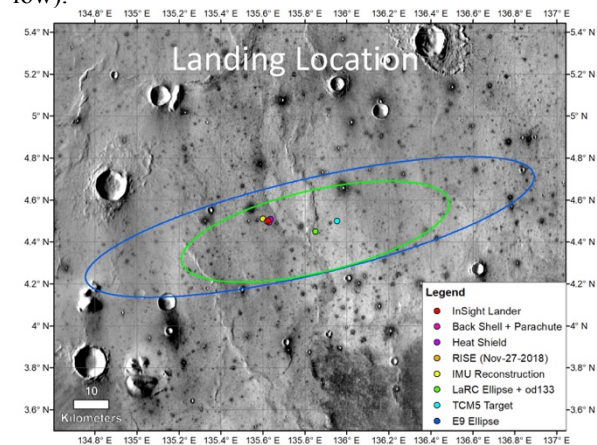


Figure 1: Progression from the reference E9 landing ellipse (dark blue, 130 km x 27 km), through TCM5 course adjusted target, the last OD solution and ellipse (LaRC green, 77.4 km x 23.2 km), the extrapolated IMU surface location, the RISE estimate from Sol 1 (4.49751° ± 0.00471°N, 135.6178693° ± 0.000337°E),

and CTX/HiRISE-based localization from December 6th.

CTX and HiRISE Image the Lander: Images acquired by HiRISE and CTX on Dec. 6 captured the InSight lander, backshell/parachute and heat shield (Fig 3).

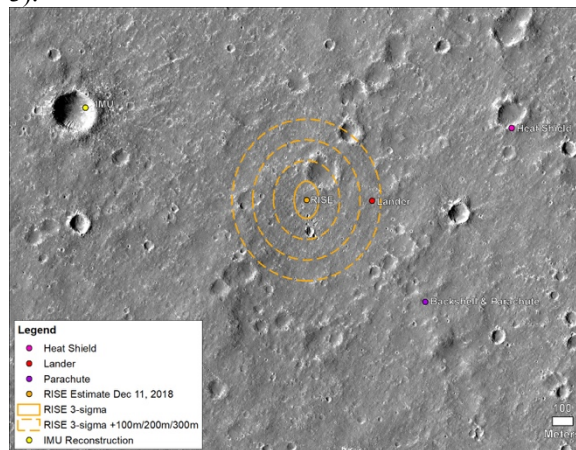


Figure 2: Enlargement of area around IMU (inside crater toward upper left) and the RISE location (4.50247° ± 0.000168°N, 135.6180843° ± 0.000009°E) from tracking on sols 1, 3 and 4 (small solid ellipse, and ~1, 2 and 3-sigma dashed ellipses). Also shown is the HiRISE-based location of the lander (red dot).

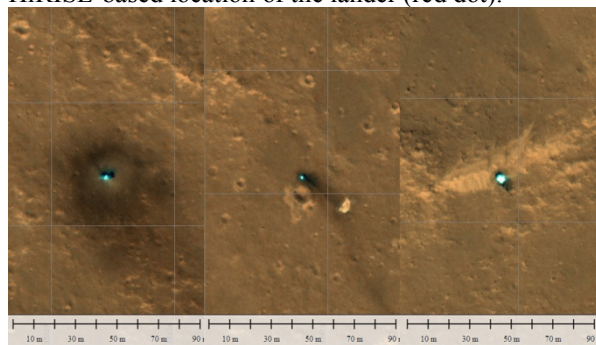


Figure 3: Color HiRISE images of the InSight Lander (left), and backshell/parachute (center) taken December 6th, and heat shield (right), taken December 11th. HiRISE images ESP_057939_1845_RGB and ESP_058005_1845_RGB georeferenced to ESP_036761_1845_RED. Grid lines are in 0.001° increments.

The lander, backshell/parachute and heatshield were localized on a carefully georeferenced HiRISE image acquired several years ago (Figs 3,4). The distance to the RISE location from Sol 4 is 320 m west, which is a measure of the cartographic map tie uncertainty with

inertial coordinates in this part of Mars. The lander is 13.78 km from od133 solution, but well within the landing ellipse (4.502384°N, 135.623447°E, Northing = 266877.460 m, Easting = 8039038.792 m, Elevation = -2613.426 m). The heatshield is located 0.762 km down-track (NE) from the lander, at an azimuth of 62.3° (4.508346°E, 135.634845°N, Northing = 267231.038 m, Easting = 8039715.141 m, Elevation = -2617.504 m). This position is visible from the lander, but the heatshield has not yet been identified. The backshell/parachute is located 0.553 km to the SE at an azimuth of 152.3° (4.49413°N, 135.627781°E, Northing = 266388.697 m, Easting = 8039296.003 m, Elevation = -2614.012 m). This position may be obscured by degraded crater rims in that direction. Neither the backshell nor the parachute have yet been identified in lander imagery.

Map Tie Error: Localizing surface features relies on our understanding of the offset between the Mars inertial and cartographic reference frames, i.e. 'map tie' error. MOLA serves as the map tie between the inertial reference frame established by Earth tracking the Mars Global Surveyor spacecraft (MGS), which the instrument was mounted on, and the ranging measurements it provided to the surface used to establish the cartographic reference frame via its derived elevation model. Absolute positional accuracy measured between MOLA and orbital images puts the map-tie error at ~300 m [3,7,8]. The RISE in InSight measures the

precession and nutation of Mars to better understand the size and state (solid or liquid) of the planet's core. It is expected that RISE will accurately locate the lander, eventually down to centimeters, providing the most precise and accurate position ever determined for a martian surface feature. Map tie error between the RISE reported lander position from data collected over 3 sols and our MOLA georeferenced HiRISE orthophoto is ~330 m in longitude and 5 m in latitude. Some longitudinal error may be explained in the difference between the J2000 definition of Airy-0, Mars' prime meridian, between IAU2000 used for the MOLA DEM inertial reference standard and the more recent IAU2018 definition used by the RISE team, in addition to errors in measuring Mars rotation rates, though the latter is expected to be <40 m. Further work is necessary to better understand and refine the longitudinal map error to provide a full assessment of mapping accuracy. Remaining uncertainties between the cartographic and inertial reference frames will be reduced with additional updates from RISE.

References: [1] Golombek M. P. et al. (2017), *SSR 211*, 5-95, [2] Parker T. J. et al. (1998) *LPS 30*, #2040, [3] Parker T. J. et al., (2004) *LPS 35*, #2189, [4] Parker T. J. et al. (2012) *LPS 43*, #2535, [5] Parker T. J. et al. *LPS 44* (2013), #2534, [6] Folkner W. M. et al. (2018), *Space Sci. Rev.* 214(5), 100, [7] Shan J. et al. (2005). *PE&RS 71*, 97-108. [8] Arvidson R. et al. (2004) *Science 305* & 306.

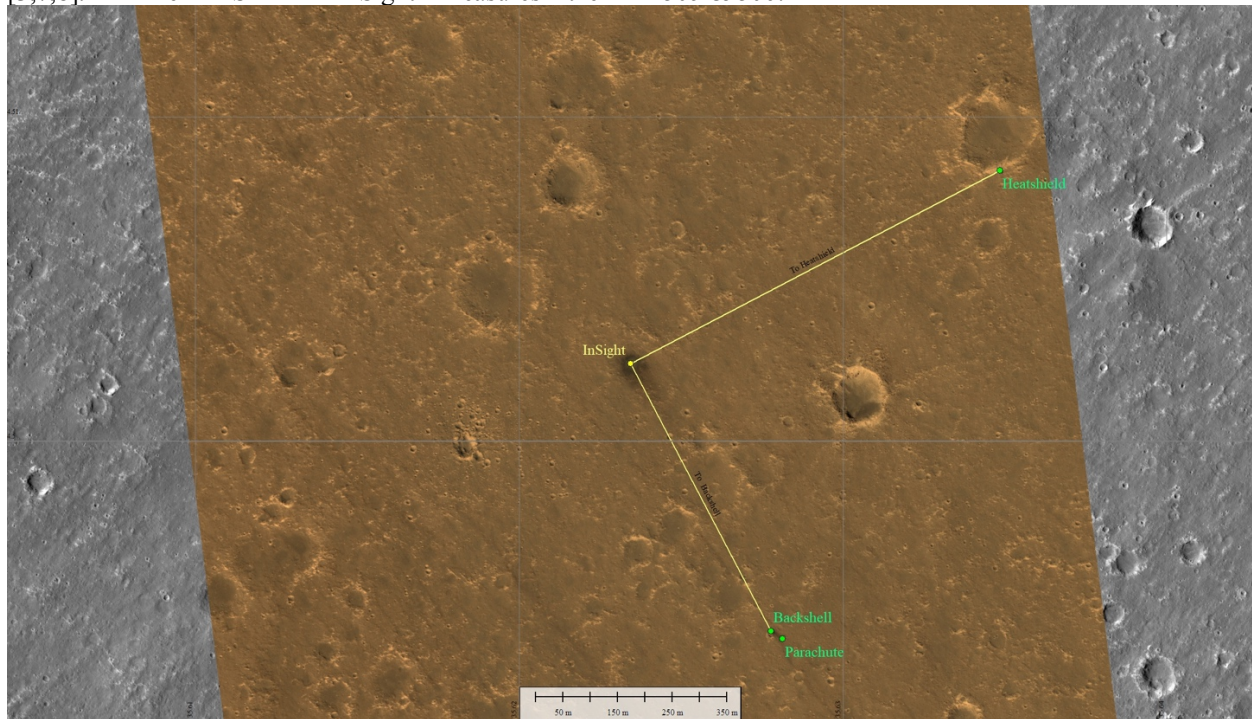


Figure 4: Relative positions of Lander, Backshell & Parachute, and Heatshield with respect to HiRISE ESP_036761_1855_RED, overlain with ESP_057939_1855_RGB and ESP_058005_1855_RGB.