FINAL FOUR LANDING SITES FOR THE INSIGHT GEOPHYSICAL LANDER. M. Golombek[1], N. Warner[1], N. Wigton[1,2], C. Bloom[1,3], C. Schwartz[1,4], S. Kannan[1,5], D. Kipp[1], A. Huertas[1] and B. Banerdt[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [2]University of Tennessee, Knoxville, TN 37996, [3]Occidental College, Los Angeles, CA 90041, [4]Mt. Holyoke College, S. Hadley, MA 01075, [5]California Institute of Technology, Pasadena, CA 91125.

Introduction: InSight, the Discovery Program lander designed to determine the interior structure of Mars to better understand terrestrial planet formation and differentiation [1] has downselected to four landing sites in Elysium Planitia. This abstract discusses the characterization and rationale in downselecting to these four and the plans for selecting the landing site.

Downselection Chronology: In the Fall of 2012, the InSight project defined 16 ellipses on Hesperian lava plains in Elysium that appeared to meet the engineering constraints in remote sensing data (dominated by latitude and elevation) [2]. Acquisition of nearly complete coverage by Context Camera (CTX) images with a few HiRISE images allowed mapping of terrains in the region of interest (2°S-5°N, 134°-145°E) and the definition of 6 more prospective ellipses [3]. Additional HiRISE coverage allowed the initial characterization of rocks and slopes and the estimation of potential hazards for the 22 ellipses. Following a landing site workshop, the project downselected to four final landing sites in the summer of 2013.

Terrains and Hazards: Mapping of terrains in CTX images along with a small number of HiRISE images allows the definition of a number of terrains based on morphology and likely slope and rock hazards [3]. The five main terrains are Smooth, Rougher Smooth, Gradational, Patchy Etched, and Etched. Slope hazards (Crater Rim and Highland Scarp) and Dense Crater Rays/Swarms were also defined.

Initial characterization of slopes at the 2-5 m length scale in two HiRISE stereo Digital Elevation Models and measuring rocks from measurement of shadows, indicated that the smooth terrain was exceptionally safe with low slopes and very low rock abundance (0-3%). Etched terrain appeared least safe with higher slopes and rock abundance (~20%) with the other terrains in between. Analysis of along track MOLA data show that large crater interior walls and highland scarps exceeded the 15° slope constraint at ~300 m length scale.

Two other hazards in the ellipses were recognized: rocky ejecta craters and fresh secondary craters. THEMIS thermal images showed craters between 40-2000 m diameter have high thermal inertia ejecta blankets. CTX images show many of these ejecta blankets are light-toned. HiRISE images show the ejecta had large rocks and bright eolian bedforms. The limited diameter range for these craters indicates a strong coherent layer of rock at 4-200 m depth and broken up regolith above [4], thereby conducive to penetration by the heat flow probe. Rock counts were used to estimate the rock abundance in these ejecta blankets, CTX images were used to measure the area covered by the blankets, and thermal images were used to extrapolate across an entire ellipse.

HiRISE images also showed virtually all of the ellipses had a population of small secondary craters. Dense secondary swarms covered 20-45% of the surface of three ellipses. Tracing the azimuth of these dense secondary rays showed they originated from a fresh, impact crater called Corinto (16.95°N, 141.7°E) about 800 km to the north [5]. Dense crater rays show up as dark elongate forms in nighttime THEMIS images, similar to other fresh rayed craters, and radiate ~1400 km to the south [5]. Targeted HiRISE images in the ellipses indicate all dark rays in the InSight ellipses are composed of dense secondary craters. The density and size-frequency distribution of secondaries in these dense rays were measured and their geometry estimated from morphometric measurements of secondary craters [6] that indicate the depth and width of each steep interior wall is ~10% and ~25% of their diameter, respectively.

Estimation of Hazards: The relative safety of all 22 candidate ellipses was estimated by measuring the areal extent of different terrains in the ellipses [3], by ascribing failure probabilities due to slope and rock hazards, and then summing the proportion of terrains and their risk for each ellipse. The main contributors to failure in this analysis are 300 m slope hazards and rock hazards. Slopes >15° were considered as 100% failure because the seismometer cannot level itself on steeper slopes. Slopes that exceeded 15° at 300 m length scale were assumed to be at least that steep at 2 m length scale.

Measurement of rock size-frequency distributions in HiRISE images, their validation by comparing with landed rock measurements, and their probabilities of failure were documented for the Phoenix landing in the northern plains [7]. Because InSight is a reflight of the Phoenix lander, we used the same technique for measuring the rock diameter and height by automated segmentation of shadows and all rocks larger than 1.5 m diameter were counted in 150 m square bins for several HiRISE images with different terrains. We then used the relationship between number of rocks in each bin and the derived fractional area covered by rocks (or rock abundance which varied from 0-20% for the different terrains) to calculate the risk to landing on a rock higher than the base of the lander or that would impede the opening of the solar panels [7]. We took average rock density for each terrain and ascribed respective failure rates for each rock abundance and then summed the risk based on the fractional coverage of each terrain. The risk of landing on rocky ejecta was estimated in a similar way based on rock counts, measurement of ejecta blankets in CTX images, and estimates of the total area covered by ejecta from thermal images.

The area of dark Corinto rays were measured in THEMIS images and sample density measurements in HiRISE images along with the assumed geometry were used to estimate the probability the lander would be on a slope greater than 15° or that the solar panels would be blocked from opening fully.

The cumulative risk from all sources determined using this method varied from 1% to 7.5% for the 22 ellipses (130x27 km) [3]. Not surprisingly, ellipses that were mostly in smooth terrain without highland scarps, large fresh crater walls or dense secondary crater rays were the safest. These ellipses are all located between 3-5°N and were estimated to have ~1-2% probabilities of failure. The project downselected to 4 ellipses (E05, E08, E09, E17) for further imaging and analysis (Fig. 1) in July 2013.

Final Four Ellipse Characterization: Since selection of the final four ellipses, all HiRISE imaging has focused on them, and over 20 images returned. Mapping of terrains based on CTX images has now been confirmed in every case by new HiRISE images. Almost ten HiRISE images now have automated rock counts, with special attention to the rocky ejecta craters. Systematic measurement of the density of secondary craters has been done in the final four ellipses. Finally, the affect of a change in ellipse azimuth with launch date has been evaluated.

Table 1. Final four center ellipse (130x27 km, 90° azimuth) coordinates.

Ellipse	Lat., °N	Long., °E
E05	3.31	138.23
E08	4.09	137.37
E09	4.46	136.04
E17	4.37	135.10

The smooth terrain continues to look exceptionally benign with respect to slopes and rocks. Slopes >15° appear rare and large portions of the plains have no detectable rocks. Other areas have only 1-3 rocks per 150 m bin indicating average rock abundance of 1-3%. Measurement of rocks in rocky ejecta craters appear to indicate the risk to the spacecraft is less than previously estimated.

No dense secondary rays from Corinto have yet been found that do not show up in the nighttime THEMIS images. Further, small areas with moderate secondary density (less than 4%) do not appreciably increase the risk for an ellipse.

Finally, the azimuth of the ellipses changes with launch date, varying from 79° at the open to 93° at the close of the launch window. The azimuth for the middle and end of the launch window has little impact to the originally defined 90° ellipses because their azimuths only vary by ±3°. However for the opening of the window the ellipse centers must be moved to avoid large fresh craters and highland scarps, which appears to have the greatest impact on the placement of ellipses E05 and E08. One possibility to counteract this would be to have different ellipses certified for different times in the launch period.

These results indicate that the final four ellipses under investigation will continue to have acceptable levels of failure and that one will be suitable for landing InSight. The project plans another downslection to ~2 ellipses in the summer of 2014, with final site selection in the fall of 2015, before launch in March 2016.

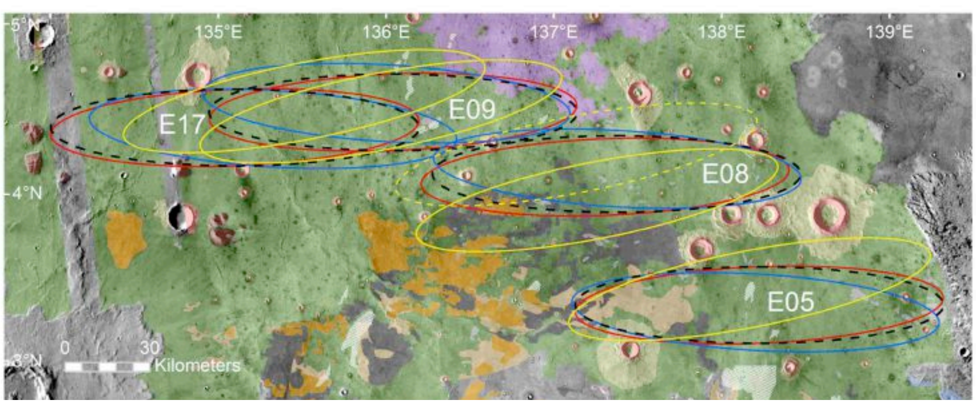

Fig. 1. Final four InSight landing ellipses in Elysium Planitia. Terrain types in different colors [3] (green is smooth, orange is etched, red are steep crater walls or highland scarp). Yellow ellipses are open, red middle and blue close of the launch window. Black dashed ellipses are reference ellipses (Table 1). Background is THEMIS thermal mosaic.

References: [1] Banerdt, W. et al. (2012) *43rd LPS* abs #2838. [2] Golombek, M. et al. (2013) 44th LPS abs #1691. [3] Wigton, N. et al (2014) this issue. [4] Golombek, M. et al. (2013) *LPS* abs #1696. [5] Golombek, M. et al. (2014) this issue. [6] Pike R.J. & Wilhelms D.E. (1978) *LPS IX*, 907-909; McEwen et al. A. (2005) *Icarus 176*, 351–381. [7] Golombek, M. et al. (2008) *JGR 113*, E00A09.