MARS 2020 LANDING SITE EVALUATION: SLOPE AND PHYSICAL PROPERTY ASSESSMENT. R. L. Fergason[1], T. M. Hare[1], R. L. Kirk[1], S. Piqueux[2], D. M. Galuzska[1], M. P. Golombek[2], R. E. Otero[2], and B. L. Redding[1], [1]U.S. Geological Survey, Astrogeology Science Center, Flagstaff, AZ, USA, rfergason@usgs.gov, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.

Introduction: The Mars 2020 rover will explore a region of Mars where the ancient environment may have been favorable for microbial life, and will investigate martian rocks for evidence of past life. Throughout its investigation, it will collect samples of soil and rock, and cache them on the surface for potential return to Earth by a future mission. A diverse set of 8 candidate sites is currently being considered as potential landing sites, including Columbia Hills/Gusev, Eberswalde, Holden, Jezero, Mawrth, NE Syrtis, Nili Fossae, and SW Melas. Columbia Hills/Gusev was the location where the Mars Exploration Rover Spirit landed and operated from 2004 to 2010 [1-2]. Three sites (Eberswalde, Holden, and Mawrth) were previously evaluated as candidate Mars Science Laboratory (MSL) sites [3-4].

Like MSL, the Mars 2020 mission initially had a nominal landing ellipse of about 25 km by 20 km, oriented roughly east-west. Smaller ellipses are now possible using range trigger, which would allow landing within an ellipse 18 km by 14 km to 13 km by 7 km, depending on atmospheric conditions. In February 2017, there will be a landing site workshop with the goal to reduce the number of candidate sites remaining under consideration to three or four. To aid in the selection of a final landing site, we are generating Digital Terrain Models (DTMs) and Thermal Emission Imaging System (THEMIS)-derived thermal inertia data, and are objectively evaluating each candidate landing site in terms of the slopes present in the proposed landing ellipse and the physical nature of the surface materials.

Digital Terrain Models (DTM): High-resolution DTMs provide critical information regarding the topography of the landing site region, and allow engineering criteria to be evaluated and certified. The Mars 2020 engineering requirements that are addressed using DTMs include: 1) MOLA elevation below -0.5 km for sufficient atmosphere to slow the spacecraft during Entry, Descent, and Landing (EDL), 2) less than ~100 meters of relief at baseline lengths of 1-1,000 meters to ensure proper control authority and fuel consumption during powered descent, and 3) less than 25°-30° slopes at length scales of 2-5 meters to ensure stability and trafficability of the rover during and after landing.

The needs described above are addressed by: 1) generating DTMs at lander scales (1-meter baselines using HiRISE images) and for EDL simulations (20-meter baselines using Context Camera (CTX) images); 2) producing maps of adirectional slope (i.e., a measure of the steepest slope in any direction) at 1-, 2-, 5-baselines for HiRISE DTMs and 20-m baselines for CTX DTMs; and 3) identifying steep slopes to be avoided by Terrain Relative Navigation (TRN) and included in hazard maps. The data products produced to evaluate topography include CTX DTMs at 20 m/post and orthoimages of both images in the stereopair at 20 and 6 meters/pixel, and HiRISE DTMs at 1 m/post and orthoimages of both images in the stereopair at 1 and 0.25 meters/pixel. These products are produced in Equirectangular projection equally sampled in planetographic latitude, with elevations referenced to the MOLA-defined areoid [5].

DTM Generation Methods: To generate a DTM, the methods used for the evaluation of the InSight mission landing site [6-7] were also employed, and are summarized here. The USGS Astrogeology Science Center has adopted the commercial software system SOCET SET® from BAE Systems [8] for DTM production from planetary images. After a series of preprocessing steps in the USGS ISIS software system, the images, trajectory, and pointing data are transferred to SOCET SET® where matching software correlates features in each image and uses the known camera orientation to determine topography. The images are controlled and bundle adjusted using the SOCET SET® program Multi-Sensor Triangulation (MST), and then DTMs are produced by automated matching with the Next Generation Automatic Terrain Extraction (NGATE) module, which performs high-density area- and feature-based matching for robust results [9]. DTMs produced using NGATE usually have a low rate of serious errors, but can be blocky, so we also perform, as needed, a single high-resolution pass of the Adaptive Automatic Terrain Extraction (AATE) algorithm [10] to smooth the DTM without allowing it to depart significantly from the NGATE solution. We then perform manual editing as required to correct errors and remove artifacts (determined by visual inspection) from the automated matching process and typically significantly improve the quality of the DTM.

Thermal Inertia: THEMIS-derived thermal inertia enables the quantification of physical surface characteristics, such as the distribution of surface dust and aeolian deposits, and allows these physical properties to be correlated to morphologic features. The derivation of accurate thermophysical properties, with well quantified uncertainties, has proven essential for selecting scientifically interesting and safe landing site locations [e.g., 11-15], and has been used to evaluate and certify the Mars Pathfinder, Mars Exploration Rover, Phoenix, MSL, and InSight landing sites. For the Mars 2020 landing sites, surfaces must have thermal inertia values greater than 100 J m^{-2} $s^{-0.5}$ K^{-1} to avoid surfaces dominated by dust that may have extremely low bulk density and may not be load bearing. Surfaces with thermal inertias less than ~150 J m^{-2} $s^{-0.5}$ K^{-1} with high albedo may also be dusty and are noted for further investigation. In this work, thermal inertia is derived using the improved method developed by [16-17].

The primary improvements to this method include the use of the most updated KRC thermal model [18], a more robust interpolation scheme that significantly reduces error during local times where thermal inertia is generally calculated (early morning) [19] and allowing for user-defined base maps used as input parameters for increased flexibility. In the case of Mars 2020, two new datasets were employed in the derivation of thermal inertia: 1) When available, CTX DTMs were used to derive slope and slope azimuth information, and 2) a combination of Thermal Emission Spectrometer, THEMIS, and Mars Climate Sounder dust opacity information [20] was incorporated. These enhancements result in a significant improvement in the accuracy of the resulting thermal inertia values.

Future Work: With the launch of the Mars 2020 lander still 2.5 years away, significant work to fully evaluate and certify a final landing site still remains. Specific plans for future work include the following:

1) Supporting the development and generation of orthoimage mosaics and hazard data needed for TRN, which can be used to avoide areas that exceed the relief and rock constraints.

2) Complex thermal modeling of the rockiness and fine component thermal inertia of the final 3-4 landing sites to provide more robust interpretations of the physical characteristics of the surface at meter-scales. Similar to work performed for InSight landing site evaluation [7], we will model the mixtures of 2-component heterogeneous surface (i.e., rock and fine-component) to approximate the amount of rocky material at the surface and provide an improved evaluation of the non-rocky material thermal inertia (i.e., fine-component). In addition, we will model seasonal variations in thermal inertia to identify the possible presence of subsurface layering and constrain the thickness of dust, eolian deposits, and buried rocks.

3) Detailed analysis of physical properties and potential traverse paths for the downselected sites by fusing thermophysical, imaging, and topographic datasets. This analysis helped discriminate terrians in the MSL landing sites [11,14]. This effort will aid the Mars 2020 Rover project in understanding the trafficability of terrains and how far and how long the rover must traverse at a prospective landing site in order to fulfill the science objectives.

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