CHARACTERIZATION OF MARS ROVER 2020 PROSPECTIVE LANDING SITES LEADING UP TO THE SECOND DOWNSELECTION. M. P. Golombek[1], R. E. Otero[1], M. C. Heverly[1], M. Ono[1], K. H. Williford[1], B. Rothrock[1], S. Milkovich[1], E. Almeida[1], F. Calef[1], N. Williams[1], J. Ashley[1], A. Chen[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109.

Introduction: The Mars 2020 Rover project has been characterizing eight prospective landing sites to better understand landing safety, traversability, and sample acquisition since the 2nd Landing Site Workshop and downselection (August 2015) [1]. High-resolution images have been processed into Digital Elevation Models (DEM), rock abundance and size-frequency distribution maps, and terrain maps to identify potentially hazardous terrains and evaluate their traversability. This activity along with Entry, Descent and Landing (EDL) simulations using region specific mesoscale atmospheres of the sites have defined the landing ellipses and the hazardous areas that need to be avoided using Terrain Relative Navigation (TRN). Supervised machine learning algorithms using neural networks have defined different terrains in the ellipses, whose rock abundance and slope distributions determine the type of driving required, and how long it will take to traverse. In addition, the highest priority science Regions of Interest (ROI) have been defined at each site, with members of the science community who proposed them, to define which ROIs and how many samples must be acquired at each. This information is then used to determine the probability of successful landing using TRN and the probability of acquiring all the samples at each site for the distribution of landing points within each ellipse. This information thus allows a comparison of the science value of the samples acquired versus how long it will take to acquire them. This abstract reviews these studies in advance of the 3rd Landing Site Workshop and downselection planned for February 2017.

Imaging and Data Products: Ellipses for the eight landing sites (Table 1) have been covered by nearly continuous High Resolution Imaging Science Experiment (HiRISE) stereo images at ~25 cm/pixel. These stereo images have been made into 1 m elevation posting DEMs [e.g., 2,3,4] that cover 77%-100% of each ellipse. The ellipses also have Context Camera stereo images at 6 m/pixel, which have been made into 20 m elevation posting DEMs [e.g., 4]. All are also covered with High Resolution Stereo Camera (HRSC) stereo images and DEMs at around 100 m elevation postings [5]. Slopes >20° over 1 m baselines were extrapolated in areas without DEMs from adjacent areas with DEMs using stereo anaglyphs.

Measurement of rocks in HiRISE images for the Mars 2020 landing ellipses utilized the rock shadow segmentation, analysis, and modeling method that was successfully developed for the Phoenix landing site selection [6] and improved upon for the Mars Science Laboratory and InSight landing site selections [7,8]. The process includes blind deconvolution, sectioning the images for shadow enhancement, shadow segmentation, fitting ellipses to shadows and cylinders to rocks to derive rock height and diameter, elimination of non-rocks, and fitting to model size-frequency distributions for rocks 1.5–2.25 m in diameter in 150 m tiles. Model cumulative fractional area covered by rocks versus diameter fits for different rock abundance over 150 m tiles were spaced every 30 m to subsample the areas with the highest rock abundance.

Inescapable hazard maps were produced from HiRISE DEMs and images. Inescapable hazards are defined as locations were the rover might land safely, but could not traverse out of [e.g., 7]. The most common types of such features are fresh craters in which the rover might land safely on the relatively flat floor, but would be unable to traverse up steep interior crater walls and/or dense networks of large eolian bedforms.

Terrain maps of the ellipses were produced by a machine vision algorithm using neural networks that segment HiRISE images via pattern recognition into regions with similar textures [e.g., 7]. The algorithm utilizes a deep convolutional network that provides a direct mapping from the image pixels to the terrain classification map [9]. The deep network structure allows the classifier to better discriminate complex tex-

Table 1. Ellipse center locations, elevations and ellipse size (length oriented east-west and width) of the eight landing ellipses under consideration for the Mars 2020 Rover.

Landing Site	Latitude °N	Longitude °E	Elevation (km)	Ellipse Size (km)
Colombia Hills	-14.548	175.626	-1.93	9.6 x 8.7
Eberswalde	-23.775	-33.515	-1.49	8.6 x 7.7
Holden	-26.613	-34.817	-2.18	9.5 x 8.1
Jezero	18.439	77.503	-2.64	10.7 x 8.3
Mawrth	23.969	-19.061	-2.24	11.9 x 9.8
NE Syrtis	17.889	77.160	-2.04	11.1 x 8.2
Nili Fossae	21.030	74.349	-0.65	9.7 x 7.7
SW Melas	-9.813	-76.468	-1.92	9.7 x 8.7

tures and patterns over conventional hand-designed filters. The filter weights are learned by training the network end-to-end from terrain annotations provided by human experts [9].

Regions of Interest: A Region of Interest (ROI) is an area identified from orbit that is judged to best address the science objectives of the mission. An ROI is a ~1 km area in which detailed study conducted during multiple campaigns would lead to the collection of a number of rock and regolith samples. A waypoint is defined as an abbreviated campaign in which a single sample is acquired. Site proposers from the science community were engaged to identify and prioritize ROIs and waypoints within each site that best address the science objectives of the mission and would lead to the collection of 16 samples and four blanks.

Landing Ellipses: For each landing site, an ellipse was sited that yielded a >99% probability of landing success with the secondary objective to minimize the traverse distance and time to visit the identified ROIs and collect the samples. The size of each ellipse was derived from EDL Monte Carlo simulations using both flight system performance uncertainty models and mesoscale atmosphere models for each site at the season and time of landing (Table 1). Landing safety simulations used the DEMs, rock abundance maps, inescapable hazard maps and terrain maps to identify areas with a high risk to landing safely and used TRN to avoid them. Landing risk was assessed at all landing points by the measured slope and rock abundance and the susceptibility to failure. Two sites, Nili Fossae and Holden, do not require TRN. These simulations indicate that all eight sites are acceptably safe for landing, so that the selection can be based on the science and the traversability.

Traversability: The distance and time required to visit each ROI and waypoint for each landing site was evaluated by using the 1 m slope, rock abundance and terrain maps. The drive mode and efficiency (35-75 m/sol) as well as untraversable regions were determined throughout the ellipse. For each landing point in the ellipse, the minimum distance and drive time needed to visit the ROIs and waypoints were determined. The eight landing sites fall into ~4 main groups in terms of how far the rover needs to traverse (Fig. 1). Northeast Syrtis (Noachian clay-bearing basement, carbonates and basalt cap) and Mawrth (Noachian clays and fracture fills) have ROIs located close enough such that traverses of ~4 km are needed. Jezero (delta deposits and basin fill carbonates) and Eberswalde (delta deposits and breccias) require traverses of around ~8 km, with Southwest Melas (delta and hydrated silica deposits) at ~6 km. Columbia Hills (Home Plate silica deposits and Comanche carbonates) and Nili Fossae (Noachian valley wall and Hargraves ejecta) have one ROI each outside the ellipse, so each requires ~12 km of traverse, which is the distance that can be accomplished in the nominal mission scenario. Holden (light-toned layered deposits and megabraccia) requires a drive of ~16 km because one of the ROIs is south of the ellipse. Northeast Syrtis, Mawrth and Southeast Melas have estimated traverse times of <50 sols, Jezero and Eberswalde ~70 sols, Nili Fossae and Columbia Hills ~85 sols (the nominal mission drive duration), and Holden ~150 sols.

Plans: The 3rd Landing Site Workshop is scheduled for February 8-10, 2017 in the Pasadena, CA area [8]. Prior to the workshop a teleconference will describe the information covered in this abstract. At the workshop, the relative science merits of the eight sites will be discussed. Because all sites have <1% probability of failure on landing, the downselection to 3-4 sites for continued evaluation will be based on their science and how long it will take to traverse to the ROIs and waypoints to meet the science objectives of the mission within the nominal mission.

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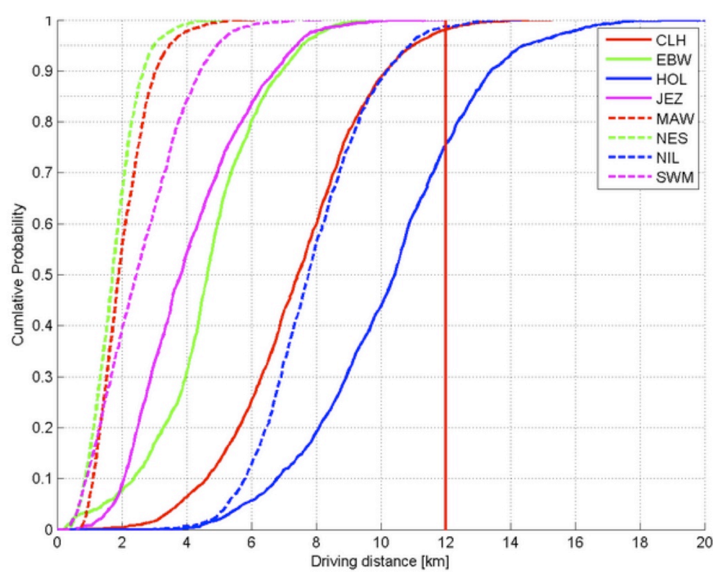

Figure 1. The probability of traversing the required distance to visit the ROIs and waypoints at each landing site within the time available for a nominal reference mission that includes the time needed to carry out science investigations and collect 16 samples.