QUANTIFYING ROCK DETECTABILITY AND REFINING CANDIDATE LANDING AND SAMPLE TUBE DEPOT SITES FOR MARS SAMPLE RETURN. C.L. Brooks[1,2], E.A. Romashkova[1,3], M.C. Deahn[1,4], N.R. Williams[1], M.P. Golombek[1], F.J. Calef III[1], S. Do[1], A.K. Nicholas[1], M.M. Morris[1,5], [1]Jet Propulsion Laboratory, California Institute of Technology, [2]Department of Geology, Kansas State University, [3]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, [4]Department of Earth and Environmental Sciences, Wesleyan University, [5]Department of Geosciences, Stony Brook University.

Introduction: Following the Mars 2020 *Perseverance* Mission, the Mars Sample Return Sample Return Lander and Sample Fetch Rover (MSR SRL/SFR) would be sent to collect rock and soil samples from the Martian surface. As a collaboration between NASA and ESA, this campaign contributes to the long-term science goals in NASA's Mars Exploration Program to determine whether life arose on Mars, characterizing the climate and geology of Mars, and preparing for human exploration [1]. Members of the Mars Sample Return team collaborated to identify candidate landing and sample tube depot sites throughout Jezero crater and Nili Planum [2].

As part of refining candidate landing and sample tube depot sites, quantification of rock detectability in orbital imagery [3] was completed using images taken by the Mars Helicopter. To detect potential hazards (such as rocks) more accurately in the orbital imagery in and around Jezero crater, the higher-resolution Mars Helicopter images taken during its flights are used to identify potential hazards and measure rocks in High-Resolution Imaging Science Experiment (HiRISE) images (25 cm/pixel) within the landing area of the Mars 2020 rover.

Due to new notional rover traverses and recent engineering updates to the MSR SRL/SFR, the areal extent for landing and sample depot sites has increased and must be identified in the HiRISE imagery. The objective of this research is to further refine and add additional candidate landing and sample tube depot sites by integrating the latest engineering constraints and newest data from the Mars 2020 rover and Mars Helicopter.

Data and Methods: A basemap was created using orbital data from the (HiRISE) at ~25 cm/pixel [3]. Other layers on the map included digital elevation models and associated slope maps, a map of untraversable hazards such as aeolian bedforms, and a map of notional traverses developed by the M2020-MSR team.

For the rock detectability analysis, Mars Helicopter and HiRISE imagery over helicopter flights 5-8 were analyzed. In each area, every potential rock down to one pixel in size was marked in HiRISE and independently measured in helicopter images. Three observers independently did the analysis to reduce observer bias. The data sets were then compared to determine which rocks visible in helicopter imagery were accurately detected in HiRISE imagery.

The landing site analysis study area consisted of the Jezero crater ellipse, Nili Planum, and the inter-ellipse region. Landing site selection criteria were based on engineering constraints, including rocks, slope, aeolian features, ellipse size, and proximity to traverse. The previously listed data sets were each examined in order to find potential landing and sample depot sites that are smooth, flat and rock free along notional traverses.

Rock Detectability: When detecting rocks in the HiRISE imagery, many rocks were often visible as areas of several light pixels, since many rocks in this region were light-toned compared to the darker regolith. Other rocks often appeared as light-dark pixel pairs with the sun illuminating one side of the rock and a shadow cast on the opposite side.

Figure 1 shows a graph of the detection accuracy of rocks as a function of rock size over the Flight 8 zone. In all four flights, rock detectability was approximately linear up to ~0.8 m and near 100% for rocks larger than ~1 m. The linear relationship indicates that rocks with a diameter of ~40 cm that would be hazardous to landing are detected accurately ~40% of the time in HiRISE imagery. About 20% of rocks at HiRISE pixel scale are detected. Because rock size-frequency distributions follow a steep slope [4], the absence of visible rocks in HiRISE imagery implies there are few smaller rocks that could be a hazard. A similar percentage of rocks at HiRISE pixel scale are identified in InSight landing site surface panoramas [4]. Based on this, the safest candidate sites should have little to no rocks visible in HiRISE imagery.

Landing and Depot Sites: Two sample caches with associated sites for landing and placing sample depot(s) are needed, with at least one initial depot cache near the top of the delta. Landing and depot should be less than a few hundred meters apart to allow the SFR to traverse between them.

In Figure 2, many sites were found along the notional traverse ranging from ~40 - 300 m in diameter. Availability of site size is dependent on location along the traverse. The majority of the sites found were between ~80 - 120 m and sites >200 m in diameter are limited, especially in Nili Planum. Most sites greater than 200 m in diameter were found in Jezero crater. Some of the sites along the traverse are designated "Depot Only" due to smaller (<100 m) size or less consistent terrain.

With regard to the initial depot cache, there are very few sites located near the base of the crater rim in Jezero, and almost none of the sites identified in this area meet both the size and hazard constraints for landing. For the extended mission, there are several clusters of candidate sites throughout the study region; however, many of these are separated by large swaths of terrain that does not appear suitable. The notional traverses with the most evenly distributed sites should be prioritized when planning rover paths.

Implications: Rock detectability analysis has provided context for some of the features seen in HiRISE. It will further improve understanding of what potential hazards to a lander may look like in orbital imagery and help estimate the likelihood of hazards in HiRISE images. The limited options for landing sites >200 m diameter in Jezero and Nili Planum places constraints on accuracy of landing in the study area. Candidate landing and sample depot sites will be further developed in the future as engineering constraints are updated and the final landing sites will be chosen based on images acquired by the Mars 2020 rover along its traverse and extended mission.

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References: [1] iMOST et al. (2019) MPS 54, 667-671. [2] Deahn M. C. et al (2021) LPS LII, Abstract #1325 [3] Williams N. R. et al. (2018) 49th LPS, Abstract #2799. [4] Golombek M. et al. (2021) ESS e2021EA001959.

Figures:

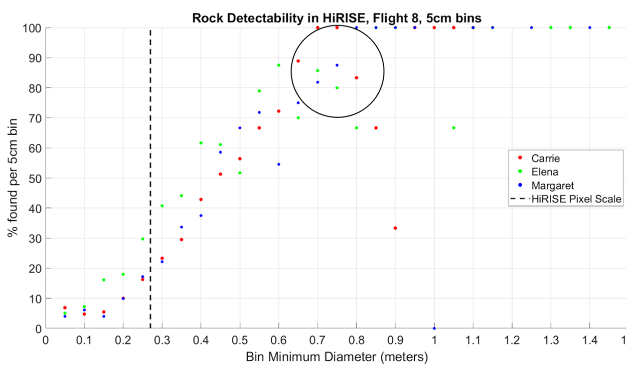

Fig 1. Detection accuracy of rocks as a function of rock diameter over the Flight 8 zone**.** Rocks detected in helicopter imagery are divided into 5 cm bins. For each bins, the percentage of rocks accurately marked in both HiRISE and helicopter imagery is plotted. Results from all three interns' analyses of the data set are shown.

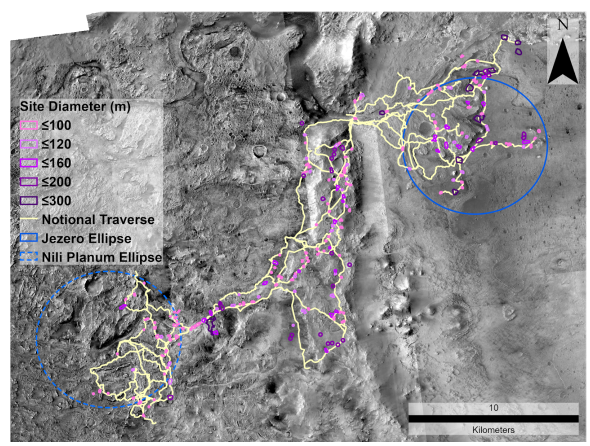

Fig. 2. Map of potential landing and sample depot sites along notional traverse within Jezero crater and along the traverse to Nili Planum. Sites are color-coded by size.