IDENTIFYING LANDING AND SAMPLE TUBE DEPOT SITES AND CHARACTERIZING TRAVERSE TERRAINS FOR MARS SAMPLE RETURN. M.C. Deahn[1,4], M.M. Morris[2,4], C.L. Brooks[3,4], N.R. Williams[4], M.P., Golombek[4], F.J. Calef III[4], S. Do[4], A.K. Nicholas[4], [1]Department of Geological Sciences, State University of New York College at Geneseo, [2]Department of Earth, Environmental, and Planetary Sciences, Rice University, [3]Department of Geology, University of Hawaii at Manoa, [4]Jet Propulsion Laboratory, California Institute of Technology.

Introduction: NASA and ESA are jointly planning a potential Mars Sample Return (MSR) campaign that would retrieve selected samples of martian rocks and regolith collected by the Mars 2020 *Perseverance* rover for possible return to Earth. Members of the Mars Sample Return team collaborated to map terrains and potential mobility challenges in the *Perseverance* Jezero crater landing ellipse and along a traverse to the southwest in Nili Planum on Mars. Candidate MSR landing sites, sample depot sites, and rover traverse paths are identified and characterized to help plan the Sample Return mission.

Data and Methods: A basemap was created using orbital data from the High-Resolution Imaging Science Experiment (HiRISE) [1,2] at ~25 cm/pixel. The map also includes a 1 m per elevation posting Digital Elevation Model (DEM) and slope map [2]. Other layers referenced during classification are inescapable landing/traversal hazards such as aeolian bedforms [3] and a set of notional traverse paths developed during M2020-MSR joint operations concept studies. Data was loaded, viewed, and mapped in a geographic information system (GIS).

Our study area encompasses the Jezero crater ellipse, “Midway” candidate M2020 ellipse in Nili Planum, and inter-ellipse regions [4]. We mapped landing and sample tube depot sites within ~500 m of the notional rover traverse paths and terrain and rock cumulative fractional area (CFA) classifications within 50 m of the paths. Candidate landing and depot sites are identified and classified based on average slope; lack of visible rocks, craters, and bedforms; region size; and distance to notional rover traverse paths. Potentially safe regions include: smooth regolith, smooth outcrop, and mildly rough outcrop terrains. Other terrains mapped are: rough outcrop/regolith, layered/stepped outcrop, heavily fractured outcrop, partial ripples on smooth regolith/outcrop, partial ripples on rough regolith/outcrop, or untraversable. Rock CFA was binned into ~5%, 10%, and 15% abundance based on counts of the frequency of rocks large enough to be resolved in orbital images per unit area.

Results: *Landing and Depot Sites (Fig. 1).* About 250 candidate MSR landing and sample depot sites were identified along the notional traverse paths. A majority of sites have a radius >20 m, to account for an anticipated 20 m landing precision of the spacecraft using terrain relative navigation. Smooth regolith is the dominant terrain of landing/depot sites, due to ease of traverse and sample retrieval on smoother terrains. Outcrop sites tend to appear rougher and potentially less benign than regolith, and thus were less commonly mapped as potentially safe, while mildly rough outcrop sites are only identified in regions deficient of preferred smoother terrain.

Terrain and Rock Densities (Fig. 2). The morphology of mapped paths tends to be predominantly smoother and more frequently regolith-comprised terrains that avoid rougher/fractured outcrop and aeolian bedforms, although rougher terrain is frequently within 50 m. Terrains across the region are highly heterogeneous and typically vary on scales of tens to hundreds of meters, often transitioning abruptly. Rock CFA near traverses is typically ~5% as expected for paths preferentially drawn in locally smoother terrains, although several locations with higher rock abundances of ~10% to ~15% could not be avoided, and often transition more gradually. Rocks appear to be predominantly eroding in place on the Jezero delta, and likely as ejecta or lag deposits across Nili Planum.

Discussion: The large number and widespread distribution of candidate landing/depot sites provides flexibility in where the MSR would land and retrieve M2020’s sample cache. The average spacing of potentially safe regions is only a few hundred meters, although few are large enough to both drop samples and land. Nearby sites with short, benign traverses would significantly reduce the time needed to retrieve and deliver samples back to the lander within the same year, in the time for launch and planetary alignment for subsequent return to Earth. All of the preliminary notional paths appear traversable based on our orbital assessment, although often heterogeneous on scales of tens to hundreds of meters. The majority of paths evaluated have very few if any rocks detected in HiRISE images, although some rocks below the resolution limit are expected. Additional possible routes and science targets may also be feasible but have not yet been evaluated. Final selection of sites will be partly contingent upon future system engineering of MSR, post-landing performance of Mars 2020, refined rock CFA calculation, and further interpretation and correlation between images taken by HiRISE and from the rover after landing.

Acknowledgments: This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration (80NM0018D0004), and co-sponsored by the NASA Summer Undergraduate Program for Planetary Research (SUPPR), Caltech Summer Undergraduate Research Fellowship (SURF), JPL Summer Internship Program, and the Hawaii NASA Space Grant Consortium. Special thanks to the members of the MSR campaign teams at NASA Jet Propulsion Laboratory and the European Space Agency, and the MRO/HiRISE teams. The decision to implement Mars Sample Return will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.

References:

[1] McEwen A. S. et al (2007) *JGR* 112, E05S02. [2] Fergason R. L. et al. (2020), *LPS LI*, Abstract #2020. [3] Berger L. M. et al. (2018), *LPS IL*, Abstract #2958. [4] Grant, J. and Golombek M. (2018) https://marsnext.jpl.nasa.gov/workshops/wkshp_2018_10.cfm.

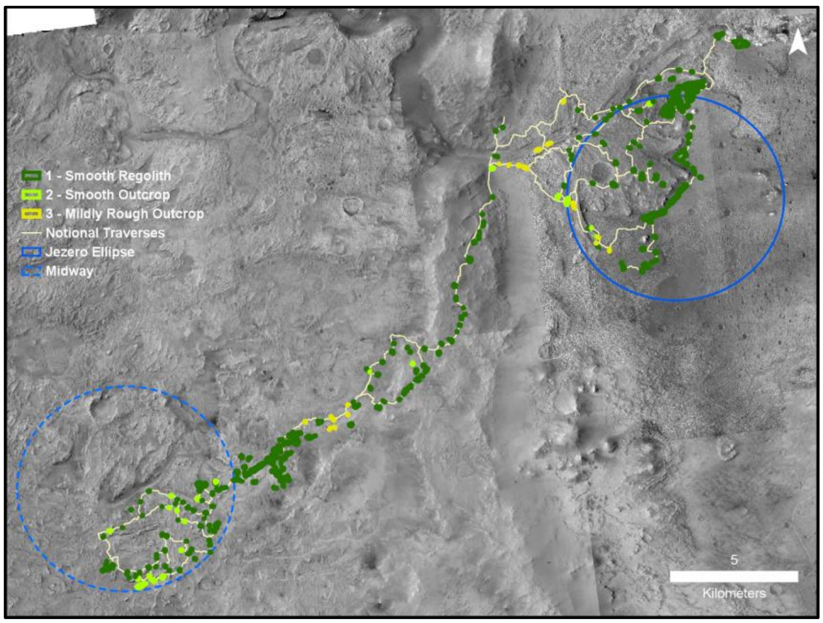

Figure 1.
Completed map of ~250 candidate areas for landing and sample depot (colored dots) along the entire notional traverse between Jezero crater and Midway landing ellipses. The average spacing between each site is only a few hundreds of meters apart, and each is classified by terrain types smooth regolith, smooth outcrop, and mildly rough outcrop (color coded).

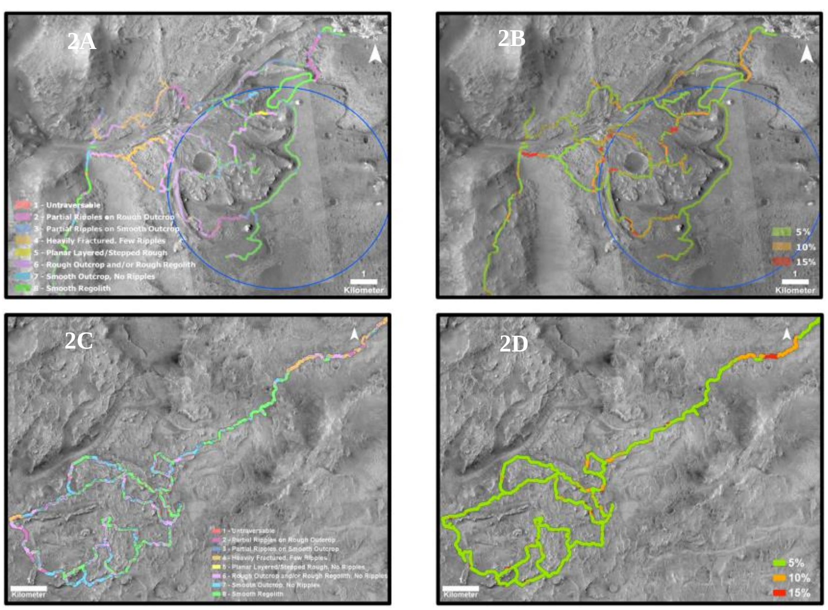

Figure 2.
Terrain and CFA classifications along notional traverses within the Jezero and Nili Planum regions. (A) Terrain classified within Jezero crater. (B) CFA classified within Jezero crater. (C) Terrain classified within Nili Planum. (D) CFA classified within Nili Planum.