SCIENCE OBJECTIVES, ENGINEERING CONSTRAINTS, AND LANDING SITES PROPOSED FOR THE MARS 2020 ROVER MISSION. M. P. Golombek[1], J. A. Grant[2], K. A. Farley[3], and A. Chen[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; [2]Smithsonian Institution, Center for Earth and Planetary Sciences, Washington, D.C. 20560, [3]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.

Introduction: The Mars 2020 mission would explore a site likely to have been habitable, seek signs of past life, prepare a returnable cache with the most compelling samples, take the first steps towards in situ resource utilization on Mars, and demonstrate technology needed for the future human and robotic exploration of Mars. This abstract describes the science and engineering criteria important for landing site selection and presents the results and sites proposed at the first landing site workshop.

Science Criteria: Science criteria on potential 2020 landing sites are based on the findings of the Mars 2020 SDT [1]. All potential landing sites must meet the threshold geological criteria (below). The potential qualifying geological criteria (below) will be used to rank sites that meet the threshold criteria [1].

Threshold Geological Criteria: 1) Presence of subaqueous sediments or hydrothermal sediments, or 2) hydrothermally altered rocks or low-temperature fluid-altered rocks. 3) Presence of minerals indicative of aqueous phases (e.g., phyllosilicates, carbonates, sulfates, etc.) in outcrop. 4) Noachian/Early Hesperian age based on stratigraphic relations and/or crater counts. 5) Presence of igneous rocks of any age, to be identified by primary minerals. 6) Not a Special Region (water or ice within 1 m of the surface) for planetary protection.

Potential Qualifying Geological Criteria (in order of importance): 1) Morphological criteria for standing bodies of water and/or fluvial activity (deltaic deposits, shorelines, etc.). 2) Assemblages of secondary minerals of any age. 3) Presence of former water ice, glacial activity or its deposits. 4) Igneous rocks of Noachian age (better if including exhumed megabreccia). 5) Volcanic unit of Hesperian or Amazonian age well-defined by crater counts and well-identified by morphology and/or mineralogy. 6) Probability of samples of opportunity (ejecta breccia, mantle xenoliths, etc.). 7) Potential for resources for future human mission.

Engineering Constraints: Engineering constraints on potential 2020 landing sites are based on those derived for the MSL "sky crane" landing system [2], with some important exceptions [3]. *Elevation:* Below +0.5 km elevation, with respect to the MOLA geoid. *Latitude:* Within ±30° of the equator. *Landing Ellipse:* The 2020 mission has a nominal landing ellipse using range trigger, of 16 km long by 14 km wide ellipse. It may be possible in the future that the range trigger ellipse could become as small as 13 km by 7 km. *Terrain Relief and Slopes:* Less than ~100 m of relief at baseline lengths of 1-1,000 m to ensure proper control authority and fuel consumption during powered descent. Less than 25°-30° slopes at length scales of 2-5 m to ensure stability and trafficability of the rover during and after landing. *Rocks:* The probability that a rock taller than 0.6 m high occurs in a random sampled area of the belly pan should be less than 0.5% for the proposed sites, which corresponds to about 12% rock abundance. *Radar Reflectivity:* The radar backscatter cross-section must be >-20 dB and <+15 dB at Ka band to ensure proper measurement of altitude and velocity by the radar velocimeter/altimeter. *Load Bearing Surface:* Surfaces with thermal inertias >100 J m^{-2} $s^{-0.5}$ K^{-1} and albedo <0.25 and radar reflectivities >0.01 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 so should investigated further. Areas that are below +0.5 km and within ±30° latitude are shown in Figure 1.

Enhanced EDL Capabilities-Hazard Tolerance: Under investigation is the possible inclusion of enhancements to MSL entry, descent and landing (EDL) capabilities and the possible inclusion of Terrain Relative Navigation (TRN) technology that would allow the consideration of landing sites with some areas that exceed the relief and rock constraints. A conceptual TRN system would allow areas of <150 m radius that violate the slope and rock constraints within the ellipse so long as they are surrounded by areas >100 m radius that appear safe for the landing system (i.e., that meet the engineering constraints).

First Landing Site Workshop: The first Mars 2020 Landing Site Workshop was held in Crystal City, VA, on May 14-16, 2014 and was preceded by a request for imaging potential new landing sites (10/13). The workshop was well attended with approximately 100 participants. An additional ~30 people participated each day via web access to the meeting. Attendees included many members of the 2020 Project as well as numerous scientists unaffiliated with the mission to date.

The objectives of the workshop were to: 1) begin to identify and evaluate potential landing sites best suited to achieving science objectives of the 2020 Rover Mission within the constraints imposed by engineering and

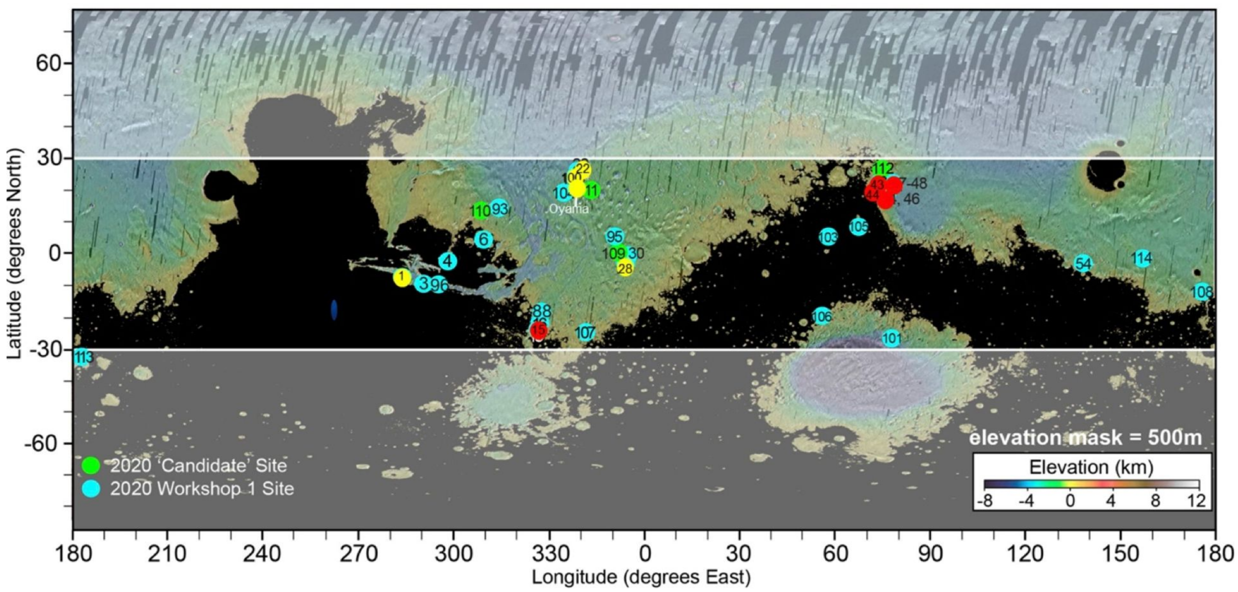

Figure 1. Landing sites proposed and discussed at the First Landing Site Workshop. The top five and next five are in red and yellow, respectively. In ranked order from highest to lowest the sites and identifying numbers are: NE Syrtis (44), Nili Fossae (43), Nili Carbonate (48), Jezero crater (46), Holden crater (15), McLaughlin crater (100), SW Melas (1), Mawrth Vallis (22), E Margaritifer (28), Oyama crater (south of 22), Eberswalde crater (16), Ladon Valles (88), Gusev crater (108), Oxia Planum (104), Nili Patera (105), Hadriaca Palus (101), Hypanis Vallis (6), Kashira crater (107), Hellas basin (106), Coprates Chasma (96), Sabrina Vallis (93), Gale crater (54), Firsoff crater (95), Melas Chasma (3), Juventae Chasma (4), and Meridiani Planum (30). Map shows topography >0.5 km elevation with respect to the MOLA geoid in black. Areas north and east of Gusev (54) and east of E Margaritifer (28) fail the thermal inertia criterion. Presentations and further information on the sites are available at [3].

planetary protection requirements, and the necessity of ensuring a safe landing; and 2) provide input to NASA and the 2020 Project on the relative importance of including any enhanced EDL capabilities on the mission.

A major outcome of the workshop is a rank ordering of the proposed sites (Figure 1) for use in future targeting for imaging by the Mars Reconnaissance Orbiter (MRO) and other orbital assets [3]. In addition, and where possible, there was an initial discussion and assessment of how enhanced EDL capabilities might improve the ability to land at a site or to improve access to a site. There was unaniomous agreement that range trigger should be used to reduce the ellipse size. All of the proposed sites will remain under consideration until or unless new data show them to be in violation of engineering or planetary protection constraints or introduce significant risk to achieving mission science objectives.

It was clear from the discussion at the workshop that sites emerging near the top of the list related to perceived science potential that goes well beyond the singular mission objectives for Mars 2020. The ability to cache samples with the possibility of eventual return to Earth clearly led attendees to consider broader science questions related to Mars that might be addressed by future analyses of returned samples. As such, sites with a broad range of science targets covering a wide range of Martian history that could be related to important events in the Mars stratigraphic system were ranked the highest.

A call has already been put out to workshop presenters for imaging targets related to their landing sites that would help to assess their safety and science potential. These targets will be entered into the queue for imaging by MRO with the goal of obtaining as many new images of the sites as possible prior to the second workshop planned for August 4-6, 2015 in the Pasadena, CA area. In addition, the proponents of all sites have been asked to identify the locations of regions of interest at prospective sites that expose materials necessary to fulfill the scientific objectives of the mission so that the Mars 2020 Rover Project can assess the trafficability, safety and operability of each site.

References:

[1] Mustard, J. F. et al. (2013) http://mepag.jpl.nasa.gov/reports/MEP/Mars_2020_SDT_Report_Final.pdf [2] Golombek, M. et al. (2012) Space Sci. Rev. 170, 641-737, DOI: 10.1007/s11214-012-9916-y. [3] http://marsnext.jpl.nasa.gov/index.cfm