FINAL THREE LANDING SITES FOR THE MARS 2020 ROVER. M. P. Golombek[1], J. A. Grant[2], K. A. Farley[3], K. H. Williford[1], R. E. Otero[1], 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: Three landing sites (Jezero crater, NE Syrtis, and Columbia Hills) remain under consideration for the Mars 2020 Rover mission following the 3rd Landing Site Workshop and subsequent meeting by the Mars Landing Site Steering Committee and the Project Science Group. This abstract describes the results of these meetings.

Third Landing Site Workshop: The third Mars 2020 Landing Site Workshop was held in Monrovia, CA, from February 8-10, 2017. The meeting was very well attended, with over ~200 participants including members of the science community and the Mars 2020 project and instrument science teams. The workshop was broadcast via the web, attracting an additional ~50 participants per day.

The workshop objective was strongly focused on discussion of the science merits of the eight candidate landing sites under study since the downselection following the Second Landing Site Workshop [1, 2]. The goal of the workshop was to provide a community assessment of five science criteria (Table 1) as all landing sites appear acceptably safe. The website marsnext.jpl.nasa.gov displays the workshop program, workshop presentations and workshop assessments. Attendees voted on the merits of each criteria for each site.

Table 1: Science criteria used to assess landing sites.

1: The site is an astrobiologically relevant ancient environment and has geologic diversity that has the potential to yield fundamental scientific discoveries when it is: a) characterized for the processes that formed and modified the geologic record; and b) subjected to astrobiologically relevant investigations (e.g., assessment of habitability and biosignature preservation potential).

2: A rigorously documented and returnable cache of rock and regolith samples assembled at this site has the potential to yield fundamental scientific discoveries if returned to Earth in the future.

3: There is high confidence in the assumptions, evidence, and any interpretive models that support the assessments for Criteria 1 and 2 for the site.

4: There is high confidence that the highest-science-value regions of interest at the site can be adequately investigated in pursuit of Criteria 1 and 2 within the prime mission.

5: The site has high potential for significant water resources that may be of use for future exploration—whether in the form of water-rich hydrated minerals, ice/ice regolith or subsurface ice.

Two of the candidate sites (Jezero crater and NE Syrtis) were consistently assessed higher relative to criteria 1 and 2 and were as high or nearly as highly ranked as any other sites relative to criteria 3 and 4. By contrast, two of the candidate sites (Holden crater and SW Melas) were consistently assessed the lowest relative to criteria 1 and 2 and were ranked lower or nearly as low as any other site relative to criteria 3 and 4.

Assessment of the remaining four sites (Columbia Hills, Eberswalde crater, Mawrth Vallis, and Nili Fossae) revealed them to be intermediate to the other sites and led to fairly similar values relative to each criterion. Nevertheless, Nili Fossae was assessed slightly lower relative to criteria 1 and 4, all four intermediate sites had nearly the same value for criterion 2, and Eberswalde crater was slightly higher for criterion 3.

Committee Meeting: Following the workshop, the Mars Landing Site Steering Committee and the Mars 2020 Project Science Group, and several Mars 2020 engineers met to make the site down-selection. Key inputs that informed committee deliberations were the discussions and assessments from the workshop, the science team's Landing Site Working Group, and engineering factors related to predicted operational efficiency (for some sites).

Mars 2020 has a distinct and diverse set of goals centered on in situ investigations, preparation of a scientifically worthy sample cache for possible Earth return, seeking signs of ancient life, and investigating non-biological aspects of Mars geology, climate, and planetary history. Accomplishing these objectives depends on the efficiency of engineering and science operations including drive distance, traversability, and temperature extremes. Extreme temperatures affect in situ exploration by limiting time available for driving and for the use of scientific instruments under optimal performance conditions. High surface temperatures may also lead to some sample degradation as the cache awaits potential Earth return on the martian surface.

Holden – relative to the other sites, especially broadly similar crater lake settings, Holden was found to lack a diversity of compelling scientific targets. Holden is also the site most challenged by temperature extremes and long traverse distances over potentially difficult terrain.

Melas – like Holden, Melas was found inferior to broadly similar lake sites. In particular, the lack of evidence for mineralogical and lithologic diversity, especially the absence of compelling igneous rocks, were notable weaknesses. Melas is thought to be the youngest of the lake sites under consideration, which may make

it less interesting from the perspectives of astrobiology and planetary evolution.

Nili Fossae – the presence of an undisputed igneous unit correlatable to the Syrtis lavas was a strong attraction to this site, but the astrobiological potential of the site was considered by the committee to be inferior to that available at other potential landing sites.

Eberswalde – this crater lake site was found less compelling than the broadly similar, but significantly older, Jezero site. While Eberswalde offers an attractively compact distribution of scientific targets, like Holden, it suffers from temperature extremes that reduce operational efficiency.

Mawrth – the central attraction of this site is its extraordinary accumulation of phyllosilicates, and its great antiquity. Although this site was considered favorably, strong concerns were raised about the uncertain origin of the phyllosilicates, the strong dependence on different models for phyllosilicate formation and alteration for the astrobiological relevance of the site, and the perceived degree of difficulty that the science team would have in establishing a robust geologic context at the site during surface exploration. Taken together, these concerns were deemed important enough by the committee to drop the site from further consideration.

The next two sites were ranked substantially higher than all others, and therefore are included among the final three:

1) **Jezero crater** – this site was strongly endorsed by the Mars 2020 Landing Site Working Group and by the workshop attendees. Jezero offers a well-defined delta environment including facies of fine grained clay that are most favorable for organic concentration and preservation, a large and geologically diverse headwaters region emptying into an open, deep lake, and an intriguing carbonate-bearing unit that may preserve a record of the ancient martian carbon cycle. Jezero is clearly Noachian in age and the oldest of the candidate lake sites considered. The mafic crater floor unit has a young age as estimated by crater counts (~1 Ga) and lacks unambiguous evidence for a volcanic origin, thus potentially limiting its applicability for returned sample geochronology.

2) **NE Syrtis** – this site was also ranked very highly by both the Landing Site Working Group and by workshop attendees. A key attraction of NE Syrtis is lithologic diversity spanning a broad interval of early Mars history in clear and readily accessible stratigraphic context throughout the landing ellipse. Units of scientific interest include large, well-exposed blocks of megabreccia probably emplaced by the ~4 Ga Isidis impact, abundant phyllosilicates, and a high concentration of carbonates that could harbor evidence of past climate and of possible life (e.g., in an ancient, subsurface aquifer and serpentinizing system). Similar to Jezero, a widespread mafic capping unit present in the ellipse could provide important chronostratigraphic context, but only if determined to be of igneous origin. Highly desirable Hesperian Syrtis lava flows and sulfates have been identified in the region, but at a distance of 20 to 30 km from the landing ellipse, which may be beyond the range of an extended mission.

Although ranked lower than either Jezero or NE Syrtis, the committee agreed to retain the Columbia Hills site after lengthy discussion.

3) **Columbia Hills** – this site, visited by the Mars Exploration Rover Spirit, possesses a range of potentially attractive targets for Mars 2020 to investigate. Most notable among these is a silica-rich, putative hydrothermal sinter deposit that some scientists, by analogy to Earth, suggest is an excellent target for seeking evidence of possible ancient martian life. An additional attraction is a diverse suite of previously characterized volcanic rocks, useful for returned sample science. Considerable time in the workshop was spent evaluating the evidence supporting a hot spring origin for the key target at this site, and whether a surface mission could adequately test the hypothesis. In the end, the committee agreed to retain this site to allow the nascent understanding of its geologic setting to be further developed and tested, and to allow time for the project to more deeply study the site's science value and potential engineering challenges (including sampling cm-scale sinter deposits). Unlike the sites removed from further consideration, it was believed that important changes in our assessment of this site might emerge in the coming months. Absent such revision, this site compares unfavorably to both NE Syrtis and Jezero.

The three remaining candidate landing sites are thought to represent each of the three environments most commonly considered favorable for detecting possible ancient life on Mars: fine-grained sediments and chemical precipitates deposited in lakes (Jezero), subsurface crustal settings in which water interacts with rock (NE Syrtis), and surficial hot springs (Columbia Hills).

Future Plans: The three landing sites are under further evaluation with respect to their science potential, landing safety, traverseabilty and surface operations (acquiring samples from Regions of Interest during the nominal mission). Carefully registered image and topographic base maps are being constructed to support these studies [3]. A Fourth Landing Site Workshop will likely be held sometime in 2018, which will lead to final landing site selection at least one year before launch.

References: [1] Golombek M. et al. (2016) *LPSC 47,* Abs. #2324. [2] Golombek M. et al. (2017) *LPSC 48,* Abs. #2333. [3] Williams N. et al. (2018) *LPSC 49,* this issue.