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Dear Michael and John:

This letter summarizes the outcomes and findings of the fourth Mars Science Laboratory (MSL) Landing Site Workshop held in Monrovia, CA, from September 27-29, 2010. The meeting was well attended, with well over 150 participants from the science community and the MSL science teams on all three days of the workshop. The workshop objective was strongly focused on discussion of the science merits of the four remaining candidate landing sites. The goal of the workshop was to develop summary statements regarding their science merits as measured against major science objectives of the MSL mission. These statements include aspects of the sites that remain uncertain and may benefit from additional work in the coming months.

Workshop presentations were grouped into an introductory session followed by individual sessions for each of the four sites remaining under consideration. A final session on the morning of the last day related to ongoing characterization of the candidate sites. Ample time was provided for discussion at the end of each session and on the final day of the workshop and was focused on the science opportunities afforded at each site. All discussion sessions were lively and involved and we thank all of the participants for their effort in preparing for the workshop. Supporting materials related to all aspects of the workshop, including all presentation materials, were posted in real time at http://marsoweb.nas.nasa.gov/landingsites/ and http://webgis.wr.usgs.gov/msl. These workshop presentations provided an additional means for participants to review each site.

All four remaining sites clearly possess high science merit and were deemed to be generally safe for landing by the MSL project. There was unanimous agreement from workshop participants that all four of the sites represent acceptable science targets for exploration by MSL and that all four should remain under consideration leading up to the fifth and final workshop to be held in the Spring of 2011. The four sites include in order of presentation:

Gale Crater (4.5S, 137.4E), Mawrth Vallis (24°N, 341°E), Holden crater (26°S, 325°E), and Eberswalde crater (23.9°S, 327°E).

A lunch meeting of the Landing Site Steering Committee was held on the final day of the workshop and yielded broad support for the ongoing process for selecting the MSL landing site. In addition, the luncheon was used to kick off the process of developing summary statements for the sites as a means of focusing subsequent workshop discussions.

The summary statements emerging from the workshop follow below and represent strong community consensus on the science merits of the sites. They are not intended to be comprehensive, however, and will be posted at the MSL landing site websites. The science community is encouraged to review and comment on the summary statements, thereby allowing for additions and revisions over the coming weeks that will be vetted by the Steering Committee. A common theme that emerged for each site was the need to develop specific sets of targets for exploration within and outside of the proposed landing ellipse. Such efforts should include a statement on why each target is important and what tools on MSL would be used in the target interrogation. Such a set of targets and proposed measurements can help to define the mission resources required to complete the science investigation at each site. These targets will help inform integrated traversability and science evaluation studies conducted by the MSL Project, LSWG, and community over the coming months that will be discussed at the next workshop.

We continue to appreciate the opportunity for the science community to contribute to the MSL landing site selection process. We hope that NASA will continue to support analysis of potential future landing sites in order to achieve the most comprehensive evaluation of their relative merits.

Sincerely,

John Grant

Matt Golombek
Co-Chairs, MSL Landing Site Steering Committee
On behalf of the MSL Landing Site Steering Committee

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Gale crater:

Over-Arching Hypothesis –

Strata forming the mound within Gale crater reflect a sequence of aqueous habitable environments over an extended time period.

Setting -

Diverse stratigraphy in the 5 km mound and adjacent stratigraphy, including hydrated minerals, are well defined and the lower mound likely reflects deposition during changing environmental conditions, with some contributions by fluvial processes.

The landing ellipse contains alluvial materials whose form and distribution record hydrologic conditions when they were emplaced and provides the opportunity to sample materials weathered and eroded from the crater walls.

Diversity -

Multiple mineralogical and stratigraphic units within the 5 km thick mound sequence with alternating inter-bedded phyllosilicate and sulfate bearing beds in the lower mound. Stratigraphy comprising the mound is continuous over many km and well characterized in places.

Preservation –

The phyllosilicate bearing units in the lower mound and moat appear well preserved and may contain and help preserve organics. Biosignatures may be preserved in the sulfate bearing strata in the mound.

Future Efforts and Remaining Questions –

The depositional provenance of the mound strata remains uncertain relative to dominant processes responsible for their emplacement. If deposited in a lake, the relative paucity of associated valleys suggests groundwater as opposed to meteoric sources.

Additional stratigraphic characterization should refine properties relative to chemistry and sedimentology. Can a more detailed evaluation of the strata and mineralogy result in a refined understanding of depositional setting? Can a mass balance of pristine vs. degraded crater morphology relative to lower mound volume be used to help resolve the source of the lower mound sediments?

The original extent and timing of processes responsible for the current mound form need better definition and the regional and global stratigraphic context of the mound is not firmly established, but may be better resolved by measurement of crater statistics. Crater statistics may help establish whether the mound is part of a larger deposit and similar to deposits seen elsewhere on Mars and help define how much of Martian history is recorded in the mound.

There is the need to define where MSL would go in Gale to look for preserved organics based on geology and the specific distribution of science targets within the ellipse should be better defined.

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Mawrth Vallis:

Over-Arching Hypothesis -

Mawrth Vallis records the geologic processes during early Martian history, when aqueous phyllosilicate-forming processes were pervasive and persistent, and provides the opportunity to understand early habitability on the planet.

Setting -

Exposes the oldest preserved layered stratigraphic section of the four candidate sites and provides an opportunity to explore Noachian crust to capture the processes that were active on early Mars. This stratigraphic sequence may be among the oldest preserved on Mars and may be from a period not recorded in the rock record on Earth.

Numerous minerals are present that formed in aqueous environments and the section in and near the landing ellipse appears to be mineralogically representative of other Noachian crustal sections in Arabia Terra, thus allowing an understanding of what may have been widespread processes. Overlying (capping) materials appear unaltered and may record changing conditions during the Hesperian and younger times on Mars.

Diversity -

MSL would land on a diverse, complex mineralogical and stratigraphic sequence that records changing processes and environmental conditions. The sequence was likely emplaced by multiple geologic mechanisms that probably included diagenetic, impact, fluvial, and/or pedogenic processes.

Preservation -

Several locations in close proximity with one another and within the ellipse may allow interrogation of a variety of rocks that will help define the early period of time when water was present and determine whether the environment was habitable.

Future Efforts and Remaining Questions –

The timing and depositional setting(s) associated with emplacement of the stratigraphy and mineralogic units at Mawrth may be better refined using crater statistics and additional careful mapping. The relative importance of impact versus alternate processes in emplacement of the stratigraphy and timing of mineralogical units relative to the observed global stratigraphic column remains unclear. Is the Al-phyllosilicate unit the same age or younger than the stratigraphy it is associated with? Can the relationship of the Al-unit to Oyama crater ejecta be determined to help refine the timing?

An important step in resolving the above points involves definition of prioritized targets for interrogation within the ellipse as well as definition of the highest-priority science targets outside of the ellipse (e.g., for an extended mission). Identification of targets most likely to contain organics is also needed.

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Holden:

Over-Arching Hypothesis -

Holden crater preserves evidence of a fluvial-lacustrine system that provides the opportunity to apply a geomorphic systems approach to evaluating a sustained, habitable environment.

Setting -

Fans flanking the western wall of Holden crater (and in the ellipse) and light-toned layered deposits comprise one of the largest and best preserved alluvial systems on Mars. The diverse and potentially weathered sediments record the conditions responsible for their formation during the Late Noachian and (more likely) the Early Hesperian. This sequence is bounded by the crater floor/walls and overlying Uzboi flood deposits that enable the age of the fans and light-toned layered deposits to be related to global stratigraphy.

Diversity -

Diversity is represented by fan sediments, phyllosilicate-bearing light toned layered deposits, Uzboi flood deposits, and mega-breccias in the crater walls/floor.

The mineralogical diversity in the light toned layered deposits and crater walls/floor include both altered and primary compositions.

Preservation -

Strata comprising the light toned layered deposits may be the equivalent of bottom set beds emplaced in a lacustrine setting, which may preserve organics for interrogation by the MSL payload.

Future Efforts and Remaining Questions –

Origin of light toned layered deposits as lacustrine versus alternate depositional processes remains uncertain. Are there shorelines, stratal geometries, or other properties of the light toned layered deposits and fan deposits whose distribution can be mapped and used to more confidently define their origin and genetic relationships?

A search for additional evidence within the mega-breccias in the crater walls and floor that can support or refute an impact-induced hydrothermal system would be useful.

Better definition of targets for interrogation by MSL is needed within the landing ellipse.

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Eberswalde:

Over-Arching Hypothesis -

Eberswalde Crater stratigraphy, geomorphology, and mineralogy record the evolution of a crater lake and associated fluvial-deltaic systems, and additionally represent a sedimentary, potentially habitable environment that is favorable to the preservation of organic materials.

Setting -

Eberswalde shows excellent preservation of what is highly likely to be a fluvial-deltaic deposit emplaced into a standing body of water that integrates sedimentary material from a broad source region.

The landing site provides the opportunity to quantitatively reconstruct the sedimentary and hydrologic conditions during deposition and specific formation models allow prediction of locations to target for exploration with MSL.

Diversity -

In addition to the delta-associated deposits, and sinuous ridges in Eberswalde, hills of Holden crater ejecta megabreccia occur in the landing ellipse and provide an exploration target. Collectively, the materials in the ellipse and nearby delta include two distinct clay minerals whose distribution is associated with different outcrop characteristics.

Preservation -

Clay minerals have been found near the bottom of the delta front, maybe in bottom set deposits that form a well-defined target for exploration. There are also potential lake deposits within the landing ellipse that offer exploration targets. Such deposits may concentrate and preserve organics and evidence for habitability and life.

Future Efforts and Remaining Questions -

Is there evidence of a shoreline/bench in Eberswalde crater corresponding to the elevation of the delta surface and the spillway to the eastern basin? How confident is the interpretation that there are exposed lacustrine sediments and/or bottom set beds in and near the ellipse, and what is their distribution? Could the putative lake in Eberswalde crater have been ice-covered?

What time interval is recorded in the deposition of the delta? Could its emplacement be consistent with delivery of water and sediment by the Holden impact? Could the bulk of the sediments forming the delta be Holden ejecta that have been eroded and transported and therefore less likely to record accumulation of organics? Can bottom set beds from each lobe of the delta be defined and identified for exploration? Careful mapping of Eberswalde tributaries and characteristics of incision will help answer these questions.

Careful definition of science targets and additional detailed study of mineralogical diversity within and outside of the ellipse are needed to help define the exploration strategy for MSL. What specific targets within the delta are available for exploration that allows evaluation of conditions during delta emplacement? What are high-priority long-term targets for exploration?

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