Workshop Statement

Summary and Background

The First Landing Site/Exploration Zone Workshop for Human Missions to the Surface of Mars was held October 27 to 30, 2015, at the Lunar and Planetary Institute (LPI) in Houston, TX. The purpose of this Workshop was to identify and discuss candidate locations where humans could land, live and work on the martian surface. These candidate locations are referred to as Exploration Zones (EZs). Candidate EZs will be used by NASA's Human Exploration and Operations Mission Directorate (HEOMD) and Science Mission Directorate (SMD) as part of a multi-year process to determine where and how humans will explore Mars. In the near term, this process includes: (a) identifying locations that would maximize the potential science return from future human exploration missions; (b) identifying locations with the potential for resources required to support sustained human presence; (c) developing concepts and engineering systems needed by future human crews to conduct operations within an EZ; and (d) identifying key characteristics of the proposed candidate EZs that cannot be evaluated using existing data sets, thus helping to define precursor measurements needed in advance of human missions. Existing and future robotic spacecraft will be tasked with gathering data from specific Mars surface sites within the representative EZs to support these HEOMD and SMD activities. Presentations and discussions at the Workshop focused primarily on items (a), (b), and (d); information derived from these presentations and discussions will be used by several NASA groups to carry out analyses associated with item (c).

A total of 47 EZs were proposed in 45 abstracts submitted to the Workshop. Presentations for 44 of these 45 abstracts were made during the Workshop. Copies of these presentations can be found at: http://www.nasa.gov/feature/mars-human-landing-site-workshop-presentations. The location of these EZs spanned most of the range of latitude, longitude, and elevation allowed in the call for proposals. The location and distribution of these EZs is shown in the figures below. A more detailed version of the map can be found at: http://www.nasa.gov/sites/default/files/atoms/files/exploration-zone-map-v10.pdf. A diverse range of exploration objectives (scientific and resources) were described in these abstracts and associated presentations, all of which are posted at the previously mentioned location. Participants were asked to characterize their recommended EZs using a Rubric developed to explicate the science and resource objectives that would be met. In addition, each presentation included a section describing the current best estimate of additional data needed for these assessments.

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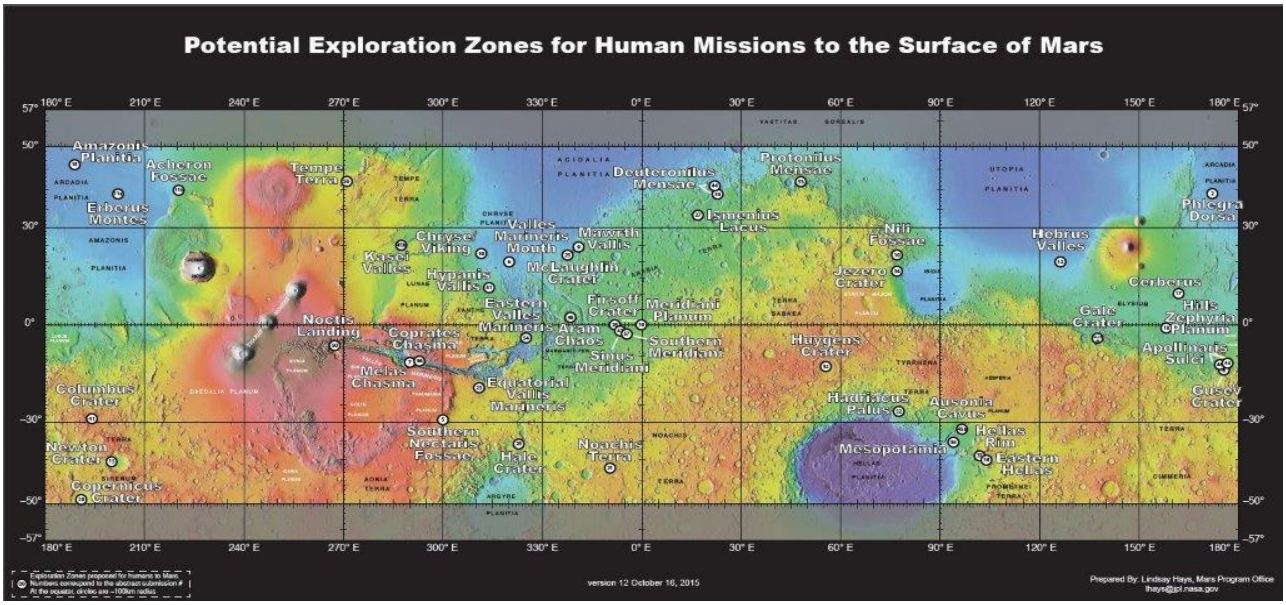

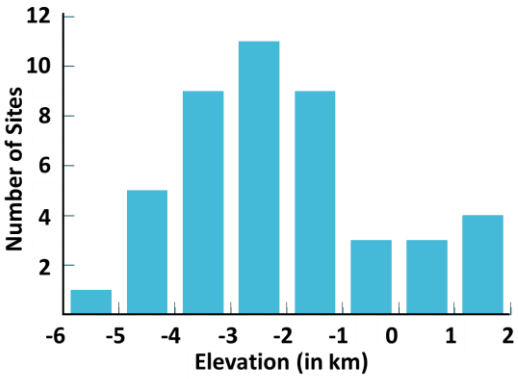

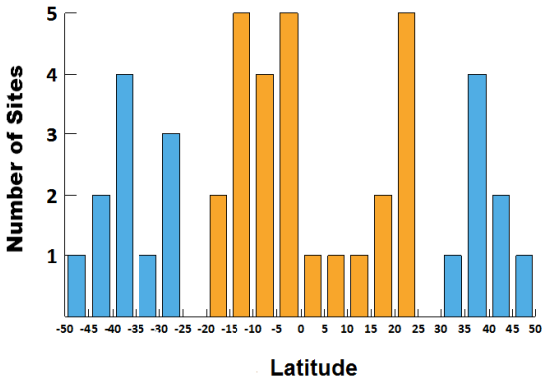

Blue represents primarily ice-based ISRU.
Orange represents primarily mineral-based ISRU.

Approximately 175 people – including scientists, engineers, technologists, industry representatives and the press – attended the Workshop in person. An additional approximately 280 people from around the world watched the Workshop via a Ustream connection.

On the final day of the Workshop time was set aside for the organizers and participants to discuss impressions based on the previous days of presentations with a focus on how to build on the process started at this Workshop. During this discussion Dr. James Green, director of the Planetary Science Division in NASA Headquarters' Science Mission Directorate, called the Workshop "historic." Dr. Green

added that the results of this Workshop are "… really the start of making Mars real … identifying the real locations for us to be able to land, work and do our science."

The participants were also invited to answer several questions and submit additional comments regarding this Workshop via email for a period of several weeks. The comment period closed in mid-December and the comments received are still being reviewed and discussed by the Workshop Steering Committee. An update to the Human Landing Sites Study (HLS2) Plan Forward (included later in this document) will be prepared reflecting these email comments and distributed to the Workshop participants. However, a preliminary review of participant responses indicates the following:

- More than half of the presentations were considered by the attendees to have made a strong case for the merits of sending multiple crews to the EZ; only about one-sixth of the presentations were considered to have presented insufficient data to make an assessment.
- Slightly more than one third of the EZs presented should reconsider their requested highest priority data – most often by requesting data from a different instrument, but potentially also selecting a different ROI to target.

Feedback provided during the workshop on specific EZ proposals will be provided to individual EZ presenters to help them improve their proposals.

Questionnaire feedback provided by email after the workshop (with respondents names removed) is available at:
http://www.nasa.gov/sites/default/files/atoms/files/post_hls2_workshop_polling_and_feedback_compendium.pdf

The viability/value of the EZ concept in describing and assessing human exploration on Mars.

The concept of an Exploration Zone made up of multiple regions of scientific interest plus regions containing potentially exploitable resources plus a centrally located site for launch and landing operations along with permanent surface infrastructure, was considered a useful construct for this point in determining a location for future human missions.

An EZ was defined as a group of ROIs located no more than 100 km from a central landing site (the 100 km value having been based on previous engineering studies indicating that small pressurized rovers could reach these distances within a reasonable period of time for a reasonable vehicle size, mass, and power system; this was not intended to be a constraint) and should be located between 50 degrees north and south latitude.

FINDING #1: *There was strong consensus that at a scale of 100 km (radius), multiple places on Mars exist that have both sufficient scientific interest to sustain multiple crews of exploring astronauts, AND potential resource deposits for In-Situ Resource Utilization (ISRU). At this point in the process of identifying the preferred EZ there is no rationale to change this dimension (e.g. to 150 km radius)*. The concept of recurring visits to the same site (as opposed to landing in multiple different places) was a Workshop assumption that was not discussed.

FINDING #2: *Very few sites were proposed poleward of 45 degrees, even though by the rules of this Workshop, sites up to 50 degrees both north and south were allowed.* However, a number of important candidate sites were proposed in the latitude range 40-45N and 40-45S. Within these belts, ice is going to be the most continuous, and the overburden that needs to be removed will be thinnest.

Data and Data Analysis.

There was general agreement that the addition of accessible resources to traditional scientific objectives as criteria for a desirable Exploration Zone expanded the need for new data types and new data analyses. Those participants who count themselves among the traditional science community acknowledged a need to better understand the kinds of raw materials, and properties of those materials, that are sought after by the ISRU community. Similarly, the ISRU community acknowledged a need to better understand the kinds of raw materials found on Mars and their distribution across the surface (and subsurface).

Both communities acknowledged that there is a substantial, but not complete, overlap between the data sets needed by each community among the data currently being gathered as part of scientific investigations at Mars. In some cases additional data of the type that can currently be acquired is needed for EZs proposed in areas that have not been studied in detail. In other cases additional data of the type that can currently be acquired is needed at higher resolution (e.g., imagery). In a substantial number of cases new data is needed that has never been gathered before (e.g., radar at shallow depths) and require new instruments in orbiting spacecraft or may require data acquired from the surface or subsurface. **FINDING #3**: *There was agreement that these new data types argued strongly for a new orbiter mission, and possibly one or more surface missions, to obtain these data*. The need for surface missions(s) targeted for candidate EZs (and possibly for specific ROIs with the EZs) was particularly apparent for resources-related questions associated with determining the quantity of the target feedstock (e.g., what is the vertical distribution of the feedstock of those materials for which only surface data are available) and the quality of the feedstock (i.e., verifying, or refining, estimate based on remote sensing data).

Presenters generally acknowledged that additional analyses of existing data, plus new data when it is available, will be required to improve their assessment of features within their proposed EZs relative to the criteria distributed with the call for proposals. Each of the presentations included a section describing the current best estimate of additional data needed for these assessments.

During the Workshop presenters were informed that they could each request data for up to three targets per EZ proposal for future MRO imaging. These requests will be identified and tracked as HLS2 requests. Data will be collected on an as-possible basis, which implies, realistically, that the first choice for each proposer could be acquired. Details on how to enter the requests for MRO data acquisition will be sent to all the EZ proposers by the telecon in January.

The Next Workshop(s).

Dialog between science and ISRU/Civil Engineering (CE) communities was generally acknowledged as one of the major benefits of this Workshop. Finding means to continue and expand this cross-communities dialog was also encouraged but there were many different approaches suggested for accomplishing this. Additional workshops, perhaps focused on different aspects of selecting an EZ, is one approach that could address these interests. Allowing more than approximately one year to pass between workshops was seen as detrimental to maintaining interest and focus on the EZ topic. Give the likely amount of time until MRO data requests could be fulfilled, those proposing EZs generally thought that another workshop focused on EZ proposals should not be attempted for approximately two years. However, there was broad interest in a series of workshops occurring on a more frequent basis. Perhaps the most frequently mentioned topic for one of these workshops was a more detailed discussion of ISRU-related site criteria as well as descriptions of candidate processing technologies.

The rubric.

All of the EZ proposers were invited to do a self-assessment using the rubric provided by the organizers. These self-assessments were not evaluated in a systematic way by the organizers, and inconsistencies in degree of optimism/pessimism, as well as in conclusions that are well-accepted vs. speculative, became clearly apparent during the course of the presentation sessions. Consequently, the data from these self-assessment cannot be directly compared in their present form.

Those participants familiar with this device generally thought that it has useful potential. But there seemed to be general consensus that individual presenters had too much latitude in the assessments they used to fill out the rubric (as noted above). Several suggestions were made to improve this process, some of which included: (a) using more precise and quantifiable criteria for each item in the rubric, (b) adding a few more gradations to the rating scale (e.g., using a 5-point scale instead of the 3-point scale used for this Workshop), and (c) provide some uniform training (e.g., a document with specific instructions and examples, or a webinar).

Standard Nomenclature.

A discussion topic related to providing uniform training for the rubric was to develop a standard nomenclature for all participants to use. An example of the different definitions of the term “dust” was cited to illustrate the point. Holding discussions of the type experienced at this Workshop was seen as one means of developing a common understanding of certain terms. But developing a document with these terms and their definition that was also easily accessible was seen as a more practical and effective approach.

Realistic appraisal of sites.

Perhaps more important than a more consistent means of populating the rubric was the concept of a more consistent (and realistic) process for evaluating sites prior to populating the rubric. Using more precise and quantifiable criteria was considered one means to improve this situation; providing some uniform training prior to the Workshop was another option discussed. But perhaps the most common comment on this topic was the need for more time and support to carry out these appraisals. Most of the work presented at this Workshop was carried out pro bono. In order to sustain and foster improved

results, some mechanism to support researchers in these appraisals was strongly recommended. **FINDING #4:** *An Announcement of Opportunity for analysis of EZs was mentioned by the Workshop organizers and was strongly endorsed by the participants*.

Building the community and maintaining momentum.

FINDING #5: *There was general consensus that this Workshop was an excellent start to identifying a place where future human missions to Mars can productively explore this planet and learn to live and work there for the long term. The participants expressed a strong desire to maintain the momentum started by this Workshop, which was understood to include more extensive analyses of the EZs presented and building the community of science and resources/engineering interests that came together to carry out these EZ analyses*. A series of workshops along the lines described above was viewed as one means to maintain momentum by setting tangible deadlines with specific objectives. The AO mentioned was also seen as a way to allow real progress to be accomplished, which could in turn be targeted at the future workshops. Other mechanisms, such as a web portal supporting a repository of analysis results and other relevant materials as well as allowing contact among interested individuals or groups, were proposed as a positive means to build a sense of community.

The breadth of the interested community itself was also recognized as an aspect of community building that will require additional effort. Other components of the aerospace community, such as those more directly involved with human spaceflight operations (e.g., the astronaut corps as well as the planners and controllers of human space missions) plus a broader sweep of the mining and materials processing industry, were recognized as possessing important experience and insight that should be incorporated into the EZ assessment process as early as possible. Mechanisms such as those discussed above represent a portion of the means to engage these prospective stakeholders but additional mechanisms are likely to be required to raise awareness that this EZ analysis effort is underway and would benefit from an expanded participation. The enthusiasm exhibited at this first Workshop indicates that this is a topic of great interest and should be easily expanded to incorporate the broad spectrum of specialized groups needed to select the first Martian Exploration Zone.

The Workshop organizers would like to thank all of the participants for their presentations and the stimulating discussion during the Workshop and their thoughtful feedback after the Workshop.

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Steering Committee Key Findings

The Workshop Steering Committee is reviewing comments made on the last day of the Workshop as well as those comments received after the Workshop. Because the email comment period has just recently closed, the Steering Committee defer populating this section until comments received have been reviewed and appropriately reflected in the Findings. However, several key findings have already been identified within these Workshop comments:

FINDING #1: There was strong consensus that, at a scale of 100 km (radius), multiple places on Mars exist that have both sufficient scientific interest to sustain multiple crews of exploring astronauts, AND potential resource deposits for ISRU. There is no rationale (at least at this point in the EZ selection process) to change this figure (e.g. to 150 km radius).

FINDING #2: Very few sites were proposed poleward of 45 degrees, even though by the rules of this Workshop, sites up to 50 degrees both north and south were allowed.

FINDING #3: There was agreement that new data types (needed for more definitive analysis of EZs) argued strongly for a new orbiter mission, and possibly one or more surface missions, to obtain these data.

FINDING #4: Workshop participants strongly endorsed the concept of an Announcement of Opportunity to support more detailed analyses of EZs as described by the Workshop organizers.

FINDING #5: There was general consensus that this Workshop was an excellent start to identifying a place where future human missions to Mars can productively explore this planet and learn to live and work there for the long term. The participants expressed a strong desire to maintain the momentum started by this Workshop, which was understood to include more extensive analyses of the EZs presented and building the community of science and resources/engineering interests that came together to carry out these EZ analyses.

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Human Landing Sites Study (HLS2) Plan Forward

The first Mars Human Landing Sites / Exploration Zones Workshop was a great success, and a number of ideas and elements of a forward plan were identified. Many of these are still being assessed at NASA, but the following steps are being implemented:

1) Support image/data requests identified in the presentations to the maximum extent possible.
    a. Feedback from workshop on individual requests will be provided to each proposer
    b. Each EZ Proposer may submit up to three individual requests for either HIRISE or CRISM data. Instructions on how to submit requests are now available
    c. EZ proposers are asked to prioritize their requests
    d. Goal is to do as many of the requests as possible

2) We are re-assessing our Mars architectures assuming we have access to water and seeing how that would impact those architectures.

3) NASA has set up a preliminary Working Group to consider several aspects of Mars Water ISRU. One of their goals is to consider the relative science and human exploration merits of the different sources of water on Mars.

In addition, NASA is exploring the following ideas for possible follow-on activities and would like to solicit feedback:

4) Establishing a multi-directorate team to define ISRU production options for each type of feedstock.
    a. This team would be given a set of boundary conditions for each feed stock which is concurred upon by HLS2 Steering Committee (such as sheet ice is within 1 meter of surface; ice runs at least 4 meters deep).
    b. Using these boundary conditions, team would then estimate:
        i. Total mass of extraction system needed on Mars to support extraction of feed stock to support specified rate of production.
        ii. Energy required to support extraction

iii. Qualitative assessment of operational complexity of extraction system and assembly / maintenance requirements by human crewmembers. This assessment should outline the end-to-end concept of operations, including transportation of the water back to the habitation zone.

5) Conducting a Water Feedstock Options Workshop to assess whether it's possible to narrow water options down and to figure out how we might use our current fleet of robotic spacecraft at Mars (including missions soon to be at the planet) to help with this. Specifically, the team would:
    a. Building on the NEX-SAG report and ISRU Production Assessment Team (note above) results, identify specific measurements using current and soon-to-be-at-Mars instruments to better assess potential for feed stocks (overall quantities available)
    b. Use engineering common sense to assess whether any potential feed stocks can be eliminated simply because it would be impossible to assess potential of a feedstock
    c. Develop a campaign of data measurements that we want to implement (for either orbiters or rovers; M2020 should also be included) to narrow trade-space down for water types.
        i. This would include prioritizations for the MRO imaging requests submitted in the proposals.
        ii. This should include rover visiting locations and potentially proposed landing sites.

6) Proto-typing on how to collect data on EZs
    a. Want to prototype using an EZ in the equatorial region as well as in the higher latitude regions (North or South).
    b. Goal would be to do the following:
        i. Collect needed data on highest priority science and resource ROIs
            1. Data requests which help clarify water feedstock availabilities are high priority.
        ii. Image the habitation zone and primary landing site zone
        iii. Perform traverse planning to the highest priority science ROI and the highest priority resource ROI
            1. Traverse planning will assume a human class rover (details of which will be provided by HLS2).
            2. Traverse planning will make use of JPL software tools for traverse planning.
        iv. Analyze temperature profiles and weather at the EZ and provide an assessment of impacts to human operations there. Goal is to establish a "Day in the Life" understanding of what it would be like to live at the EZ.
            1. Understand dust storm profiles.

v. Study EDL ramifications of landing at that EZ
vi. Experiment with creating more integrated / interdisciplinary teams
vii. The results of these prototyping studies will
    1. Support Engineering assessments by the EMC
    2. Guide updates to HLS Landing Site/Exploration Zone selection criteria
    3. Inform efforts to create an Announcement of Opportunity (AO) to support and accelerate the overall HLS2 effort.

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