First Landing Site/Exploration Zone Workshop

Polling and Feedback Compendium

Poll Results

Session	Abstract No.	No. of Votes
Melas Chasma	1007	9
Jezero Crater	1034	8
Gale Crater	1020	6
Deuteronilus Mensae	1033	5
Acheron Fossae	1011	5
Meridiani Planum	1030	4
Hypanis	1051	4
Gusev Crater	1008	3
Mawrth Vallis	1009	3
Eastern Valles Marineris	1054	2
Apollinaris Sulci	1043	2
Deuteronilus Mensae	1044	2
Mesopotamia	1035	2
Amazonis Planitia	1018	2
Chryse Planitia	1019	1
Equatorial Vallis Marineris	1023	1
Endeavour Crater	1057	1
Apollinaris Sulci	1046	1
Hebrus Valles	1012	1
Nili Fossae	1010	1
Aram Chaos	1048	1
Huygens Crater	1032	1
Noctis Landing	1050	1
Hellas Rim	1037	1
Phlegra Dorsa	1002	1
Equatorial 1		
Coprates Chasma	1036	
Equatorial 2		
Gale Crater	1022	
Gale Crater	1040	
Equatorial 3		
Sinus Meridiani	1042	
Equatorial 4		
Hills Zephyria Planum	1016	
Equatorial 5		
Equatorial 6		
Cerberus	1017	
Southern Nectaris Fossae	1005	
Hadriacus Palus	1052	

1.

			Rationale
High-Latitude 3			
Acheron Fossae	1011	☒	**Highest likelihood of massive near surface ice for mining, but potential dust problems; Low altitude supporting EDL, radiation protection and atmospheric mining; Varied geologic points of interest**
Phlegra Dorsa	1002	☒	**Highest likelihood of massive near surface ice for mining; Low altitude supporting EDL, radiation protection and atmospheric mining; Varied geologic points of interest including volcanic, impact and periglacial landforms.**
High-Latitude 4			
Amazonis Planitia	1018	☒	**Highest likelihood of massive near surface ice for mining; Low altitude supporting EDL, radiation protection and atmospheric mining; Varied geologic points of interest**

Feedback

EZ Concept "existence proof"
1. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* **The concept is a good start given that it is embodied in the long duration buildup of a <u>permanent</u> base supported by mining of water and other ISRU activities. Extended EZ operations will then occur given increased transportation (ground and aerial) capabilities from the primary site. The primary need is a 50 year plan, not a flags-and-footprints - so "If you build it they will come."**
2. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* **The easy access and extraction (mining) of water ice should be the most important criteria. If water, the most important and versatile resource (water, oxygen, hydrogen, fuel, air), is not made the foremost important criteria, then the probability or likelihood of humans returning to Mars more than they did to the moon becomes increasingly small. Ultimately, the question comes to whether you would rather see humans on Mars in your lifetime or not.**

Reference EZs

3. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include:
    a. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?*
    b. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?*
    c. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

This question is somewhat perplexing. Should we not be looking to find a location that maximizes our ability to live and thrive on the planet so that humans will be living and learning there for the long run? This means finding a location that is the closest, in proximity, to all easily extractable resources as possible. All locations on Mars will provide planetary scientists with a <u>plethora</u> of research opportunities, across multiple sub-fields, therefore choosing sites based on science potential should not be the driving function behind site selection.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

4. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?*

    Should be Changed: Details on workshop activates need to be clear and correct. The bottom of this form says to turn in this document by “Mon Nov 30th” whereas the associated email said “Wed Dec 2nd.”

    Otherwise, there needs to be a continuous outline showing the integration between ISRU/mining interests and scientific opportunities at locations replete with ice, other resources and site hazards. These details are needed to construct the best architecture, e.g., structures, landers and systems, which will need to be developed for permanent Mars habitation.

5. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).* **Again, the primary focus should be on ice/water mining and the associated ease of extraction – this all points to higher latitude near surface permafrost type deposits. All other activities, including future mission ground data requirements, vehicle architecture designs, water storage, propellant production and surface operations will all follow in kind.**
6. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?* **Water, water, water… ice! Narrowing down the focus to short term attainable goals that have a sustainable and long term plan will increase the likelihood that humans will go to and remain on Mars regardless of all future problems and issues that will occur on Earth.**
7. *Anything else to discuss that is not covered by the previous items?* **No, see all above.**

2.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Melas Chasma	1007	☐	Best of the Valles Marineris sites: RSL, exposed stratigraphy, polyhydrated sulfates, low altitude. Valles Marineris and surrounding areas are probably my first choice for overall science interest.
Mawrth Vallis	1009	☐	Best site by far in terms of resource availability. Other great science targets as well: valley networks, ancient habitable environments and Noachian sed/strat. Already has good data coverage from rover LS characterization.
High-Latitude 1			
Deuteronilus Mensae	1033	☐	Best of the "science is the resources," esp. water ice and associated landforms. Covers both recent and ancient geology of all kinds – fluvial, volcanic, tectonic, impacts, etc.

Feedback

EZ Concept "existence proof"
8. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* I think the basic EZ concept is solid. There were a few suggestions, like using traverse distances instead of absolute ones, and other more site-specific aspects that might be taken into account during the actual selection process, but as a mechanism for assessing overall scientific and engineering potential, and for making sensible comparisons between many different EZs, I think it works quite well.

9. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?*

The criteria themselves are all ones I would continue to use; however, the means by which the criteria are applied/assessed on the EZs could be modified. There was definitely a consensus among the workshop participants on the lack of necessary expertise in all areas for assessing the viability of a landing site by a single person who is often only a specialist in one or a few areas. I think this could be solved in part by using some combination of the prototype and reference EZs to make a sort of "tutorial" that shows the desired attributes in context. I also suggested the idea that instead of having simple "yes/no" criteria, a landing site could be assessed with sliding scales that could indicate confidence, e.g. very unlikely, somewhat unlikely, unsure, somewhat likely, very likely. It would be really nice to see all of this combined into some kind of web form or Java-based applet, such that the submission process could be done easily and uniformly (thinking along the lines of Galaxy Zoo, obviously with a bit more rigor and detail).

Reference EZs

10. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., "stressing" situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include:
    d. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?*
    e. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?*
    f. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

1. **The latitude/ice trade-off:** One issue we heard discussed was the potential for significant water ice resources at high latitudes where solar insolation could be significantly lower, which could strain our ability to keep machinery running and astronauts warm. It is crucial that we know the constraints on energy consumption and power production as a function of latitude, and how much of this would be used for processing water ice resources. A good Reference EZ of this type would contain significant water ice potential but have poor solar insolation. I think it was Paul Niles who emphasized how we should be developing new technologies to meet these challenges instead of basing our assumptions on current limitations.

2. **Challenging topography (crater rims, steep cliffs, rough terrain, etc.):** Stan Love's comment about driving a truck into Meteor Crater served well to remind us that we should think long and hard about what kinds of parameters are realistic for rover traverses, human EVAs, and any supplementary land- and air-based robotic exploration (e.g. rovers and drones). The suggestions we heard regarding human-robotic synergy should be given serious consideration. I'd like to see a list of criteria that outlines the limitations of rovers (most limited), humans (less limited), and remotely controlled robotics (least limited) and perhaps give a Reference EZ that shows where/how each of these assets could be used in tandem for maximum scientific return.

3. **Realistic constraints on ISRU and long-term habitability:** If we're really going to be living and doing research on the Martian surface for long periods, we have to know what kinds of resources can be utilized and how efficiently it can be done. This has to be our first priority if we're going to have a sustainable presence on Mars, even before science considerations. Perhaps instead of delving into what a particular EZ might offer in terms of these resources, a more general approach could be taken by characterizing the utilizability of the major resources we think we might find at these sites: we need comprehensive analyses on ease and methods of access, potential yield, and efficiency and energy requirements for processing, especially for the different kinds of hydrated minerals that could have varying chemical properties. (Much of this could be accomplished with an ISRU workshop.)

4. **Planetary protection:** While RSL are certainly something to keep in mind, I think the recent buzz should be taken with a grain of (hydrated perchlorate) salt as we look to all instances where planetary protection could become a problem in the course of scientific exploration. Where do we draw the line between potential contamination and limiting the amount of science we obtain? Once humans land on the surface, there will be irreversible and ultimately unavoidable forward contamination in and around the habitation zone; perhaps our focus should instead be on protecting remote ROIs where forward contamination could adversely affect science results. While we shouldn't be focusing solely on RSL in the long term, a Reference EZ that has them could be useful in developing a comprehensive planetary protection policy that could then be applied more generally to other sites.

5. **Role of precursor missions:** Just a quick note on this one – are there any particular EZs/types of EZ that would benefit most from a robotic precursor mission? What are the advantages of looking at a site that's already been visited by a rover or lander vs. ones that haven't?

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

11. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?*

I think it worked this first time to have everyone get up and talk about his/her own EZ, but it seems logical that each subsequent workshop would take a more centralized approach by having more detailed characterizations of fewer landing sites (this an obvious eventuality but it certainly wouldn't hurt to start moving in that direction soon). This is coming from someone who hasn't ever been involved in landing site "down-selections," but I can see a general progression as follows:

- First workshop: initial overview of EZs, figure out what still needs to be learned
- (Do the things listed in #5)
- Second workshop: Reassess EZs having filled in knowledge gaps and make better critical assessments, start talking in terms of which ones might be serious candidates
- Third+ workshop: Begin individual EZ evaluation and down-selection

12. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).*

As mentioned above, a workshop focused on resolving some of the outstanding engineering and ISRU issues should be held very soon; this will be crucial to providing a realistic framework for our science goals. This could and should involve both the science and engineering communities. Otherwise there are specific topics that will be covered by research related to the AO. Both will help us come up with better means of assessing EZs in future workshops.

13. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?*

We should definitely make the best use of our current and future orbital assets. We should have equally comprehensive data coverage for all potential landing sites before choosing to keep or eliminate any of them, particularly for resources. There were suggestions for gamma-ray and neutron spectrometers and ground-penetrating radar that should definitely be taken into consideration for an MRO successor.

14. Anything else to discuss that is not covered by the previous items?

Just to summarize a list of action items that I can think of to do before a second workshop (in approximate chronological order):

- Obtain the data on EZs that we can from MRO and other current assets
- Detailed assessment of resource potential and engineering constraints/TBD items
- The above in conjunction with additional AO-funded "homework"

Also let's continue to emphasize geoscience, atmospheric science, and astrobiology equally as we move forward, especially for public outreach!

3.

Session	Abstract No.	Pick 3	Rationale
Equatorial 2			
Gale Crater	1020	☒	Major ROI < 5 km from LZ. Extensive insitu characterization. Confirmed Martian organics and past habitability. Known dateable igneous crustal rocks.
Equatorial 3			
Meridiani Planum	1030	☒	Well characterized insitu data. Very safe LZ.
Gusev Crater	1008	☒	Insitu data. Safe landing zone. Science ROI concentrated.

Feedback

EZ Concept "existence proof"
15. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? *The idea of an EZ is viable.*
16. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)? *The 100 km radius EZs are so big that they are not functional for the first few missions if the ROI are very far apart. The EZ should have a staged approach of being not greater than the walk-back distance for the first mission or two, then doubling that range for the next few, etc. A realistic traverse plan must be delineated to properly assess ROI reachability across the EZ.* *The latitudinal constraint was too open. While I understand increasing latitude constraints allows access to ice, the increased burden from thermal and other operational considerations (e.g. low light angles) and less surface-to-orbit performance for return vehicles make sites >30 non-viable from a practical mission stand-point, especially for the first 5 missions where astronauts will just be learning to deal with nominal surface operations versus a stressed condition.*

Reference EZs
17. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: g. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* h. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?* i. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?* High latitude sites are too thermally difficult for the first set of human missions. Relying on ISRU production of all or significant water for the first few missions is dangerous and shouldn’t be the driver of any initial human landing site; waiting for such capability for the first mission will doom the whole process and result in a human mission to Mars never happening. The first few missions should be completely reliant on water and resources brought to the surface. Future mission gains can be made from reuse of habitats and other equipment from previous missions, as well as experience on the surface, not from expendables. Mining rock for ISRU like water and metals likely requires a significant amount of energy; what will the energy source be? Can ISRU productions be done with sufficient solar panels or is a nuclear reactor necessary? Energy generation will be a significant hurdle for a long duration mission. Solar panels tuned to Mars’ EM environment will be critical to assess for energy needs.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

18. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?*

    The rubrics were too complicated and sometimes duplicative in their queries. Adding up the number of rubrics responses by ROI didn't make sense. I'd suggest grouping together all the science ROI into one rubric line versus one for each ROI; same for ISRU ROI; e.g. we just need to know if you can 'check the box' for say, organics, or you can't.

    Nest workshop should have some form of voting for the sites (online, anonymous), so at the end of the workshop we can see which sites are more interesting for the whole group and which ones we could talk more about as a whole towards the end of the workshop.

19. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).*

Assessing traverse distance between ROI was greatly overlooked at the workshop; a better understanding about surface operations would help inform site selection and ROI viability.

20. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?*

At least one workshop a year and a few guided telecons or meetups at major meetings like LPSC, AGU, DPS, etc.

Feedback

Reference EZs

- Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., "stressing" situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include:
  - *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?*
  - *A hydrated mineral site—how would the ISRU community acquire and process the raw material?*
  - *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

4.

Session	Abstract No.	Pick 3	Rationale
Equatorial 2			
Gale Crater	1020	☐	I pick this example purely because it is the first of the three Gale Crater talks, of which I use it as a representative. Gale Crater is a very diverse and interesting zone which meets all of the engineering criteria with many SROIs, many which will not be examined by the MSL. Many of these occur outside the crater rim, giving opportunity for extended traverses out to 100 km. RROIs are somewhat fewer, however. Thanks to MSL we have ground truth, which I think will be important for any future mission from an engineering and safety perspective, and because of the need to provide some ground truth of orbital science. The presence of decades-old hardware also allows for long-term assessment of planetary protection and material science questions.
Equatorial 3			
Endeavour Crater	1057	☐	I pick this example as a representative of the four talks from the Meridiani region, some of whose zones overlap with this one. It is also my favourite of these because it is mine. However, personal preference, aside, the southern Meridiani zones on Mars appear exceptionally attractive from an engineering perspective and are proven to be very trafficable It is a very diverse and interesting zone with many SROIs, only a handful of which will have been examined by the Opportunity rover and (all being well) the Schiaparelli lander. Many of these occur well beyond the initial landsite point, but are accessible because of the proven high trafficability of the plains. RROIs are also diverse, with potential ice, brines and hydrated minerals. Thanks to Opportunity (and hopefully Schiaparelli) we have ground truth, which I think will be important for any future mission from an engineering and safety perspective, and because of the need to provide some ground truth of orbital science. The presence of decades-old hardware also allows for long-term assessment of planetary protection and material science questions.
Meridiani Planum	1030	☐	
Gusev Crater	1008	☐	I pick this example because it is the first of the four talks from the region of Gusev Crater, of which I use it as a representative. Gusev Crater is a very diverse and interesting zone which meets all of the engineering criteria with many SROIs,

			only a small number of which were examined by the Spirit. Many of these occur outside the crater rim, giving opportunity for extended traverses out to 100 km. RROIs are also present, although ice is somewhat speculative. Thanks to Spirit we have ground truth, which I think will be important for any future mission from an engineering and safety perspective, and because of the need to provide some ground truth of orbital science. The presence of decades-old hardware also allows for long-term assessment of planetary protection and material science questions.

Feedback

EZ Concept "existence proof"
21. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* I think it is a very viable and valuable approach.
22. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* I would add engineering criteria (latitude, elevation, trafficability, etc.) to the rubric.

Reference EZs
23. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., "stressing" situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: j. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* k. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?* l. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?* In addition to the three above, I would add lava caves. These were not discussed at the workshop but have often been proposed as having considerable scientific interest (potentially radiation sheltered habitats with microclimates that trap ice, perhaps warmed by geothermal heat), resource potential (ice), and as potential shelters with equitable temperatures and radiation shielding. My own experience with lava caves

	is that in reality they are often very difficult to access, may have rubble-strewn floors, and roofs of uncertain stability. They also may but occur in areas where you would want to put a station or land a mission. But they pose many interesting science and engineering challenges, including how to access their interiors, which need to be critically evaluated. With respect to ice, I would point out that there is significant geomorphic evidence for low latitude ice, although at depths too great (>1 m) and areas to small (<300 km) to be detectable from orbital neutron data. While such ice may well not be stable very long term, it will be renewed by cyclic periods of high obliquity every few million years. Regarding RSL, before people even begin to worry about planetary protection issues (which are not unique to RSLS but applicable to all sites with potential liquid water), the biggest challenge is accessing them. They occur on steep slopes, typically 30 degrees, and often at elevations 100s or 1000s of m down or up a slope. They would be impossible to access with vehicles, astronaut access would require climbing aids including ropes and winches, as would "cliff bots". Possibly drone helicopters or quadrotors would be the best way.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
24. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?* I think follow up to the workshop is very important, and am looking forward to the promise of facilitated accesss to new data, e.g. HiRISE, CRISM , over proposed zones. Perhaps working groups assigned to the most favoured zones, although this may be premature. People should be encouraged (and perhaps aided) to publish extended versions of their studies. A special issue of an appropriate journal perhaps? I am looking forward to the next workshop. My only disappointment was that some of the evening talks were not available for viewing online.
25. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).* Largely missing from this workshop was a European perspective. Many sites were considered for the ExoMars rover and, as this workshop showed, landing sites proposed for rover missions are also highly attractive for crewed missions. People involved with the ExoMars landing site selection process should be invited and encouraged to present at the next workshop. I am therefore looking forward to nearing proposals about Coogoon Vallis and Oxia Planum next time. The same applies to the 2020 rover mission, the NE Syrtis and Holden Crater sites offer significant potential to crewed missions, especially as a landing in Holden would also allow

access to Eberswalde crater and Uzboi Vallis, the longest and possibly deepest drainage system on Mars. Could a historic perspective he helpful? I don't recall any previous specific studies for crewed missions, but Greeley's 1990 survey lists many sites for unmanned missions, almost none of which have been chosen or even considered or actual missions, because new knowledge has changed the focus and the parameters. Such historical analysis may be useful in future-proofing our site selection again the possibility of being rendered irrelevant by new knowledge. Lastly, there is a planned Chinese rover mission for 2020. Chinese scientists and engineers should be invited to attend and present their perspectives. Even if they are unable to physical attend, they could present online.
26. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?* None
27. *Anything else to discuss that is not covered by the previous items?* None

5.

Equatorial 5			
Hypanis	1051	☒	SECOND CHOICE: Scientific diversity, ISRU possibility and temperate climate.
Jezero Crater	1034	☒	FIRST CHOICE: Scientific diversity, ISRU possibility and temperate climate.

Feedback

EZ Concept "existence proof"
28. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* I think this is a good and viable concept. When I do habitability assessment on Earth, I make a grid and systematically explore it to ensure that I do not bias my assessment by letting some feature of interest draw my attention to the exclusion of more cryptic yet possibly equally as interesting territory. This is ideally adaptable for human exploration.
29. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* There must be a reconciliation of science, ISRU and planetary protection interests. The ISRU community is less familiar with PP constraints, and PP needs input from them so a workable solution can be achieved. Also we must be mindful about using the term "water" as a criterion because we sometimes mean "OH-bearing minerals" and other potential sources, and this creates a communication issue.

Reference EZs
30. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., "stressing" situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: m. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* n. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?*

o. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

The hydrated mineral scenario is the best compromise between the PP considerations, the availability of water source and the operational requirements of hardware (not to mention humans). We should do a full-blown scenario because of its potential to address the concerns of all three communities. I am volunteering to participate.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

31. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?*

    I think that we needed more basic community conversation before we began advocating specific sites, but that is immaterial now. We came up to speed quickly enough that we can begin painting the picture with enough detail that we have a better chance of securing funding through a combination of directorates.

32. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).*

We need to talk more about com and navigation infrastructure, about organic cleanliness as distinct from planetary protection, about renewable food sources and the requirements for aquaculture or gel hydroponic agriculture. We also need to understand the requirements for inert materials.

We should discuss architecture for shallow subsurface habitat and laboratory facilities.

33. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?*

HiRise and CRISM will quickly be oversubscribed. We need a good handle on the orbital imagery and spectroscopy as well as required precursor missions that will be enabling. But first and foremost, next gen DSL and the rapid planetary communication and positioning network must be designed and deployed.

34. *Anything else to discuss that is not covered by the previous items?*

Yes—we need to come to terms with the necessity for funding so that soft money members of the scientific, ISRU and technical communities are not shut out of the process.

6.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Eastern Valles Marineris	1054	☒	Excellent Potential. Access to multiple geologic age formations; access to Marineris outflow channel, and possibly moderate chaos terrain.
Equatorial 5			
Hypanis	1051	☒	Excellent Potential. Similar to Deuteronilus Mensae, but with perhaps better access to ancient ocean shoreline and seabed.
High-Latitude 1			
Deuteronilus Mensae	1033	☒	Excellent candidate site all around, wth high potential ROIs. Terrain well characterized, and the science rationale has been thoroughly vetted and is well presented. Abundant water ice is attractive.

Feedback

EZ Concept "existence proof"

35. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?

The EZ approach appears to be ideally suited for comprehensive vetting of potential landing sites. With such diverse science rationales driving a selection solution, the 'EZ – multiple ROI' approach fosters objective discussion and cumulative assessment of each EZ. ROIs can bound the comparison of competing goals by breaking down subsets of science rationale into manageble discussions. The process enables competing or conflicting priorities to be decomposed, identified for each ROI, developed as necessary and then ranked against each other to provide a cumulative summary for the entire EZ.

This methodical consideration and vetting of ROI sites, will tend to produce objective and evolvable rankings readily competed against mission objectives, requirements and current architecture concepts. No changes seem necessary to make the current process more effective.

36. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?

Realistic access paths to RSLs should probably be identified where possible so as to characterize the 'realistic benefit' of RSLs being there. Just because RSLs may be observed in an EZ, if they cannot be readily accessed then they offer little potential for true ISRU. Such access could be a significant discriminator in realistic assessment of candidate EZ potential.

It may be too soon, but perhaps even minimal discussion of how mission architecture development can be influenced by characteristics of the site, might provide some 'ground truth data' to the discussion of ROI practicality and the EZ in general.

Reference EZs

37. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include:
    p. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?*
    q. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?*
    r. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

While extraction of water from hydrated minerals may be possible, heavy equipment and power needed for harvesting separating materials, in addition to crew time to handle materials, would drive ISRU cargo and crew time consumption to levels disproportional compared to harvesting of water ice.

Obviously, sites with water ice reserves have much more immediate feasibility, than those holding hydrated minerals, at least in terms of crews getting over the earliest ‘sustained presence’ threshold. While it is true that some proportion of delivered mass will be dedicated for hydrated ISRU over the long term, being able to skew those deliveries in deference to early water ice ISRU would go quite a ways toward mitigating risk toward achieving that initial presence threshold.

Allocating time and early cargo to establish the ‘sustained presence’ threshold early as possible, would allow more focus on generating science results sooner, and even enable mission planning for a solid 50/50 mix of activities between early science and baseline establishment.

As for hydrated minerals, subsequent missions or stations would be better suited to perfect harvesting methodology once the threshold presence has been baselined, and crews have more time available to marshal necessary systems.

RSLs may offer liquid water, but water extraction from the mix requires operations beyond that of ice sheet extraction. Until the seasonal mechanism by which RSLs appear is fully understood, the scale of equipment and infrastructure necessary to harvest them cannot be known with certainty sufficient to justify dedicating elements of mission architecture for harvesting.

If RSLs can be investigated without the immediacy of building water supplies, they can be researched in a methodical process readily confirmable as being compliant with challenging Planetary Protection protocols. An RSL located kilometers from the habitat or other visited ROI sites could help ensure the RSLs remain untouched and pristine, except during precisely planned investigation. Access could be from one direction only, at a controlled, safeguarded point deemed least risky for contamination. Points 'upstream' could be identified and proximity-access controlled, establishing controlled sampling points.

Holding RSLs back for investigation only, rather than immediate harvesting, could ensure sustainment of their original state until they are fully understood, sized and their underground sources mapped.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

38. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?*

Combined group discussion realtime is crucial to the depth and effectiveness of the selection process. This approach effectively uncovers subtle dependencies or impacts between the science, ISRU, CE, Bio and engineering goals, concerns and perceptions of risk.
I see no other way to ensure such comprehensive and thorough vetting of EZ potential (and potential limitations). It may be slow and at times cumbersome, but it is probably a necessary process to ensure solid progress.

39. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).*

A future consideration could include initial assessment of terrain trafficability, or 'practicality of access' to the rest of the Martian surface external to the EZ. It would be a plus to identify land routes leading from an EZ to broader areas of the surface. This could become more important later on, as expeditions start roving ever further from the field station, perhaps even to ROIs in other EZs.

One example of this might be the cluster of EZs on Hellas' eastern rim. Although of substantial interest, it is possible these locations may be 'landlocked', surrounded by terrain not easily traversable by wheeled vehicles, essentially isolating the Field Station from the rest of the surface.

40. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?*

There may be some benefit to a different method of how sites within ROIs are considered, which can build on results of the first workshop.

Rather than identifying ROIs within a model circle (like some presentations in which 'some' ROIs were included only as a matter of content) the intent would be to initially emphasize quality of specific sites within the ROIs first.

Consider one or more of the richer ROI sites as a model, and then look for analog sites elsewhere at the same latitude or region. Once similar quality ROIs sites have been located and reviewed, they would be numerically 'graded' to understand the occurrence of higher quality sites.

Distribution would then be considered on a larger scale, to see if 'clustering' appears which might mandate a wider and more distributed EZ, with more and richer ROI sites, even if they exceed the 100 km radius distance. In this way, it could be easier to develop 'trade values' to compare site content value against access effort.

For this to work, establishing the field station near water ice reserves within the EZ could enable early establishment of the sustainability threshold, so emphasis could be shifted toward exploration of multiple specific sites. Target sites would then be accessed by extended travel over paths (evolving roads) that would have to easily traversable, as described in #5 above (re: surface trafficability) about availability of access to the rest of the surface.

This could lead to specifically outfitting mission excursions as dedicated expeditions to multiple ROI sites (i.e. a Bio mission, a Geo mission, Noachian mission, etc.,) in which multiple sites of the same interest and value are accessed along the way.

This process is intended only as a suggestion for subsequent assessments, not a rework of any previous efforts.

41. *Anything else to discuss that is not covered by the previous items?*

Aspects of site that can influence Mission Architecture

One aspect to consider may be the ability for communication line of sight between the landing site and location of the habitat.

Aspects of 'field crew navigability' may be enhanced by presence of terrain features conducive to deployment of field repeaters for a local comm and data network, especially when teams enter low elevations and canyons.

Multiple vehicles or scattered crew members would benefit from such a local network under their control, and bolster assurance of an uninterrupted local data transport capability.

Reliance on a synchronous relay satellite may be part of the mission baseline, but the crew would likely want to be able to establish a comm network among field teams and the base, as a backup capability, accessible and serviceable by themselves in case the comm link does go down.

Such a land based network could also allow recording of all field activities at the field station even if the main earth comm path were unavailable.

This is not to say that easy path access to elevated terrain features should be a site requirement in itself, but this as possible discriminator may be useful when assessing multiple sites of otherwise equivalent appeal.

Establishment of such a network could also be a key early enabling capability, should the budget not allow for a dedicated comsat sufficiently early in the Mars program. Understanding where nodes could be located would certainly aid the discussion when the time comes.

Finally,

Might it be possible to obtain specific daily and seasonal temperature range profiles for a handful of the leading contender sites? This could help establish an understanding of 'Day in the Life' environmental experience to be had.

Thanks for the opportunity to provide input.

Thomas Cave

Palmdale, CA

7.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Melas Chasma	1007	☐	#1 polyhydrated sulfates at surface for ISRU, RSL, ancient and modern habitability, equatorial, low elevation, tremendous geologic diversity
High-Latitude 3			
Jezero Crater	1034	☐	#3 polyhydrated sulfates for ISRU, great mineral diversity and ancient habitability.
Acheron Fossae	1011	☐	#2 Site with known shallow ice, at lowest latitude and N hemisphere for relatively constant temperatures (compared to same latitude in the south). If ISRU from hydrated minerals or RSL doesn't work, they will require shallow ice. Ancient and modern habitability.

Feedback

EZ Concept "existence proof"
42. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? That seemed to work, although somewhat arbitrary
43. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)? Drop anyplace above 45 N and S latitudes—seasonal CO2 frost and polar hoods would be a nightmare, and there is shallow ice from 39-45 N latitude.

Reference EZs
44. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). s. *Try not to base any studies on wishful thinking. There is no clear evidence for ice within 10 m of the surface anywhere closer to the equator than 39 N. SHARAD can only detect deeper ice. The lowest-latitude sites with known shallow ice are also rather dusty, but that may be unavoidable because the high dust albedo and low thermal inertia make shallow ice stable. Studying a dusty ice site near 40 N would be worthwhile; several were presented.* t. *I don't think you need to study a site more polar than ~40 N or S, given the extreme winters. I didn't hear any discussion of the polar hood, but sites above 45 N are cloudy most of fall and all of winter and would be terrible. The S polar winter hazes are less severe. Don't forget to consider the effects of seasonal CO2 frost, which buffers the temperatures (day and night) to the CO2 frost point of ~150 K (-123 C). Keeping people or machinery alive under those conditions is extremely challenging. I guess you could study such a site just to make the point loud and clear.* u. *Study a site with polyhydrated sulfates, which may be substantially easier for ISRU than other hydrated minerals. The water content is higher and is released at lower temperatures (150 C) than other hydrated minerals known on Mars, and the deposits are soft and friable--easy to excavate. Note that sulfates are not silicates, so the summary slide on Friday morning that said "polyhydrated silicates" was wrong. However, the sulfates are likely mixed with silicate sand.* v. *Study a site in Valles Marineris with potentially high slope winds, to address that issue, and to include an equatorial site.* w. *Study a site with RSL to address issues such as planetary protection, although difficult given the unknowns. Note that many presenters mentioned possible RSL in places where there is no evidence for RSL and appear highly unlikely to have RSL based on my experience.* x. *Study a south mid-latitude site to understand the effects of long winters, maybe E Hellas where several EZ were suggested. We do not know how deep the ice is here, so a range of assumptions is needed.* y. *Study one of the past rover sites--Gale, Gusev, or Meridiani, where a lot more is known about surface properties and compositions. Also challenging sites for ISRU for water, and includes equatorial sites.*

z. *Pick a site with lots of exposed hydrated mineral diversity such as Mawrth Vallis or Nili Fossae/Jezero, for ancient habitability, and to assess potential ISRU.*

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

45. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?*

I think we need a lot more information about ISRU—what's realistic?

46. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).*

47. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?*

I don't see a need to accelerate it, except MRO lifetime, but the current process is okay for choosing MRO targets.

48. *Anything else to discuss that is not covered by the previous items?*

8.

Session	Abstract No.	Pick 3	Rationale
Equatorial 7			
Noctis Landing	1050	☒	Intrigued me; new thoughts given; #3
High-Latitude 2			
Mesopotamia	1035	☒	Interesting; high latitude; formations; #2
High-Latitude 4			
Amazonis Planitia	1018	☒	High latitude; soil; #1 site

Feedback

EZ Concept "existence proof"
49. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* 50. *Great to have so many good ideas!!*
51. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* 52. *Material readily accessible on line and score sheet too!!*

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
53. What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed? *54. Better presentation room – be able to enter and leave without disturbing the presenter.*
55. What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop). *Workshop involving safety community and a handful of sites to look at the differential design and ops requirements for these possible sites. This would help drive the design to a tighter and better product.*
56. What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone? *57. Establish goals – what to we wish to find / discover* *58. Establish safety margins WRT environment of a landing zone* *59. Assure vehicle and launch / return systems are designed to meet margins*

9.

Session	Abstract No.	Pick 3	Rationale
Equatorial 6			
Mawrth Vallis	1009	☒	Lots of hydrated minerals
High-Latitude 1			
Deuteronilus Mensae	1044	☒	Lots of water ice
High-Latitude 2			
Mesopotamia	1035	☒	Lots of water ice, diverse geology

Feedback

EZ Concept "existence proof"
60. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? *I think the EZ concept is great so far.*
61. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?

Reference EZs
62. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: aa. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* Depth and covering of the ice, whether it is mantled by regolith or large glacial till bb. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?* cc. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
63. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?* *On site voting.*
64. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).* *Mining water and other resources.*
65. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?* *Start the deselection process at the next meeting.*
66. *Anything else to discuss that is not covered by the previous items?*

10.

1) EZ Concept "Existence Proof"

a) I believe the EZ concept is a valuable method for planning the human exploration of Mars because it emphasizes that all aspects of the mission (engineering, ISRU, science, crew safety, etc) must be taken into account when choosing potential landing sites. It also recognizes the value of developing infrastructure on the surface over multiple missions, which will be key to a long-term sustainable program.

b) I think the EZ criteria distributed prior to the workshop were good and that the rubric was very useful in organizing our assessment of the sites. However, I think many of the rubric sections should be clarified and redundancies removed before moving forward. I am also in favor of developing standardized criteria for assigning certain values to certain categories. (For example, many presenters marked their sites as "potentially habitable" simply due to evidence of past fluvial processes. While this might be an indicator of potential habitability, I think much more evidence should be compiled before actually listing a site as "potentially habitable".)

c) I think the existence of near-surface ice deposits above 30 deg, in both hemispheres, is a compelling reason for considering sites in the mid-latitudes. I have some serious doubts about the feasibility of using the water resources proposed by some of the presenters (polyhydrated sulfates, sand dunes, etc) due to the energy and equipment mass limitations of a realistic mission, and the ability to prove that those materials exist to a sufficient depth and are of a sufficient grade to provide the necessary amount of water. In my opinion, the existence of thick ice deposits in the near subsurface, which have been confirmed by radar measurements, provide a compelling reason to consider the mid-latitudes despite the additional operational concerns over an equatorial site. However, I am not sure if latitudes above 40deg are necessarily required, since near-surface ice deposits exist in the 30-40deg range.

2) Data Collection

a) I think the conference organizers should compile, and distribute to the presenters via email, a clear procedure for requesting data from the various existing assets. HiRISE targeting via HiWish was mentioned at the workshop, but the procedures for requesting data from other instruments, especially CTX and CRISM, were much more vague.

b) I would recommend that MSL perform additional measurements to better constrain the availability of water in sand dunes. Specifically, how predictable are the abundances quoted by some of the presenters? How does that percentage change with depth? with lateral variations in surface features? with time of day/year? And are there ways we can predict these abundances using orbital datasets? I have doubts about the feasibility of sand dune water being the sole source of water for a human mission, but more data should be collected/analyzed in order to conclusively determine this.

c) The ability to observe thermal IR wavelengths beyond 25μm would be very helpful in determining the exact compositions and abundances of chloride deposits, which would improve our ability to characterize them and to assess their potential for preserving biosignatures.

3) Data Analyses
I think one of the clear outcomes of the workshop is that the Mars science community has not spent much time studying locations that would make good exploration zones, since so much work over the last decade has focused on potential rover landing sites, which have very different requirements. I believe many of the sites presented at the workshop, especially those that have not been previously proposed as rover landing sites, would benefit greatly from additional analysis of existing datasets. However, due to realistic funding and time constraints, it will be difficult for many of the presenters to perform that additional analysis without financial support from funding opportunities specifically focused on the analysis of potential exploration zones, such as the proposed AO.

4) EZ Selection Process
I think the general format of the EZ selection process as currently planned, which appears to be closely modeled on the Mars rover landing site selection process, should be kept more or less intact. However, I believe there are some important decisions/trades that need to happen sooner rather than later in order to maximize the efficiency of the process. The selection of a final exploration zone will be significantly driven by available resources, particularly water. I think the community needs to come to a consensus relatively soon about what water resources are feasible/reliable/demonstrable enough to be considered further. For example, if the extraction of water from hydrated minerals is not going to be a feasible primary source of water for the planned series of missions, then it would be best to decide that early so that the science community can focus its efforts and resources on investigating other types of sites.

5) Reference EZs
a) Mid-latitude site with shallow ice potential
If the primary goal of this reference EZ is only to consider how the ISRU community would access/process near subsurface ice, I think either of the Deuteronilus Mensae EZs (Head et al. and/or
Plaut) would be good reference sites because the water resources have been confirmed by SHARAD and the sites provide access to the gently sloping lobate debris aprons via relatively flat ground.
However, if the primary goal is to "stress" the scenario of accessing subsurface ice, the Western Noachis Terra EZ would be a good reference site because it will require accessing lineated valley fill or concentric(-ish) crater fill on potentially steeper slopes and approaching the deposits from more challenging topography. (Full disclosure: I was the primary author on the Noachis Terra abstract.)
b) Hydrated Mineral Site and/or RSL Site
I think the Melas Chasma EZ (McEwen et al.) would be a good reference site for assessing both the feasibility of using hydrated minerals as the primary water source and for assessing the science constraints of an EZ near an RSL, since that sites contains good examples of both.

6) Next Workshop
I think the next workshop should be held approx. one year from now. Waiting any longer would make it difficult to build a cohesive community. However, since the AO is still a couple months out, and the awarding of any research support even further out, I don't think the science community will be able to allocate enough resources to make significant progress analyzing the existing sites within the next year. So I would suggest the next workshop focus on the non-science aspects of the EZs. Let the science sub-community learn details about the technologies the ISRU community have developed and/or are currently developing. Let's all hear from the Entry, Descent and Landing (EDL) community, which didn't seem to be represented at this workshop, to learn how they're planning to deliver all this payload to the surface, etc, etc.

Then, approximately two years from now, once the additional research funded through the AO has been completed, we can gather for a third workshop and present the results of that research.
And since it was brought up at the end of the workshop, I think the next EZ-focused workshop is still going to be too soon to start any sort of downselect process. Ideally, I think you would want to see the results of the research conducted under the awards made from the upcoming AO, put out a second AO to fund follow-up research based on those results, review the results from the research conducted under the second AO, and THEN I think we'll be realistically able to start a meaningful downselect process.
I know, that's going to be a long process, which is going to make it hard to “push the ball down the field” as a community. But we should have in-depth analyses of these sites, conducted by researchers who have the resources necessary to do that level of analysis, before we start downselecting.

7) ISRU/Civil Engineering Analysis Group

Yes, I agree that there should be a MEPAG-like analysis group dedicated to Planetary ISRU/Civil Engineering. I believe it would be a good way of reaching a consensus among that community on various issues, which the other members of the EZ analysis community could use to make more significant progress.

8) Improve/Accelerate EZ Selection

I think the best way to accelerate the EZ selection process would be to accelerate the awarding of resources under the AO, and making clear that there will likely be future AOs as well. As was mentioned at the workshop multiple times, a lot of the analysis that went into the EZs that were presented came from essentially pro-bono work, since no one was specifically funded to perform analysis of potential human landing sites. This is especially true of sites that were not previously proposed/funded as potential rover landing sites.
We can't select an EZ, or even begin downselecting potential EZs, until many more sites have been analyzed to the same depth that potential rover landing sites have been analyzed. And, unfortunately, the majority of the people who can perform those analyses are under very real constraints regarding the allocation of their time, which is directly related to their sources of funding. Accelerating the distribution of funding from the upcoming AO (while making sure that it is still being allocated according to some peer-reviewed process that will help to ensure quality) and distributing those funds quickly and efficiently will be very helpful in getting this process moving forward.
Also, it would be very helpful if it was made clear that there will be additional funding opportunities in the future for the analysis of potential EZs. I know, that is always difficult to promise/predict from a budgetary point-of-view, but more researchers are likely to join and actively participate in this community if they can foresee the possibility that it could be a long-term source of research funding, beyond just the single AO mentioned at the workshop.

11.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Melas Chasma	1007	☒	#1 polyhydrated sulfates at surface for ISRU, RSL, ancient and modern habitability, equatorial, low elevation, tremendous geologic diversity
Equatorial 5			
Jezero Crater	1034	☒	#3 polyhydrated sulfates for ISRU, great mineral diversity and ancient habitability.
High-Latitude 3			
Acheron Fossae	1011	☒	#2 Site with known shallow ice, at lowest latitude and N hemisphere for relatively constant temperatures (compared to same latitude in the south). If ISRU from hydrated minerals or RSL doesn't work, they will require shallow ice. Ancient and modern habitability.

Feedback

EZ Concept "existence proof"
67. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? That seemed to work, although somewhat arbitrary
68. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)? Drop anyplace above 45 N and S latitudes—seasonal CO2 frost and polar hoods would be a nightmare, and there is shallow ice from 39-45 N latitude.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
69. What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed? I think we need a lot more information about ISRU—what's realistic?
70. What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).
71. What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone? I don't see a need to accelerate it, except MRO lifetime, but the current process is okay for choosing MRO targets.

12.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Melas Chasma	[1007](#)	X	Valles Marineris and hydrated minerals for ISRU
Gale Crater	[1020](#)	X	Site well characterized; ISRU from dunes
High-Latitude 1			
Deuteronilus Mensae	[1033](#)	X	Geologic diversity; ISRU from buried water

Feedback

EZ Concept "existence proof"
72. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? I can't think of a better way to approach and bound the problem. The EZ concept leveled communication methods in a way that could cover the wide variety of sites.*
73. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?*

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
74. What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?
75. What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).
76. What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?
77. Anything else to discuss that is not covered by the previous items?

13.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Melas Chasma	1007	☒	Alfred McEwen picked fourteen science ROIs, and he said that there are many more regions of interest present. The canyon walls are 7 km high, and they preserve a detailed stratigraphic record, much like the Grand Canyon. There are at least three types of resources available: polyhydrated sulfates, water ice fogs, and RSL. In terms of public outreach, landing inside a huge canyon would obviously be very popular. The potential weaknesses of this site are that it would be difficult to land in and traverse, and RSL could jeopardize planetary protection concerns.
Equatorial 4			
Apollinaris Sulci	1046	☒	I am in favor of any of the three Gusev/Apollinaris EZs. We should consider at least one ground-truthed landing site for a human landing to ensure scientific success, operability, and safety. Of the three rover sites, Gusev probably has the greatest mineralogical diversity. There also is a diversity of resources, and many widespread geomorphologic landforms. The main weakness of this site is that it is interesting enough that not all ROIs fit in one EZ! Hopefully, there is a compromise that Jim, Laura, and I can agree on in the future, as this is a very interesting region with lots of science targets!
Equatorial 5			
Jezero Crater	1034	☒	The Isidis Basin EZ combines two of the top four Mars 2020 candidate landing sites. Jezero Crater has a scientifically interesting deltaic feature with a massive watershed covering diverse terrains, including another of the top 8 Mars 2020 sites. NE Syrtis Major has a diversity of aqueous phases and volcanic deposits reminiscent of the diversity found at the three rover sites. The main challenge for this EZ is a lack of resources, especially if hydrated minerals prove difficult to harvest.

Feedback

EZ Concept "existence proof"
78. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* I would be thrilled to see any human landing on Mars, no matter the form of the mission or the duration. However, I think that an EZ is an interesting way to approach manned Mars landings. By sending multiple crews and stockpiling supplies to one area, the mission risk and cost would decrease, while the scientific return would increase. By sending many missions to one area, we can study the environment in-depth, instead of just taking a cursory glance at it.
79. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* There are no necessary changes that are apparent.

Reference EZs
80. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., "stressing" situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: dd. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* ee. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?* ff. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?* I think six reference EZs is a good number to aim for. Here are some possible examples: 1. Valles Marineris/RSL: How can we land the crew and keep them safe on the surface? Do RSL features have significant astrobiologic potential? How will the Planetary Protection community deal with such a site? Which type of resource (hydrated minerals, RSL, fog, wind energy) will we use? 2. Hydrated mineral/delta site: Can hydrated minerals be easily harvested for water? Can we gather enough water to support a crew? Are these sites interesting enough to visit vs. a site with more abundant water?

3. Ground-truthed site: Can rover experience help plan a mission for a crew? Is a precursor mission necessary to scout a site, or can only orbital data be used to plan a mission? Are there many places left to explore, or does the rover date entirely explain the site?
4. Glacial/mid-latitude site: Can we launch an MAV from the mid-latitudes? How does hardware degrade there vs. at the equator? Will nuclear power be necessary, or can solar panels be a power source? How easy is it to harvest glacial ice for water? Does ice jeopardize planetary protection concerns? Can we find a site with both glaciers and ancient fluvial features/deposits?
5. Cave sites: Could astronauts live in caves or yardangs, as several presenters talked about? Is this a near-term goal, or a long-term goal? Is it safe to explore a deep cave and put a habitat inside? What kind of equipment would be needed, and what science and resources are nearby?
6. Deep biosphere sites – These sounded interesting at the workshop. What astrobiological potential do they have vs. other sites? What resources are present? Is a precursor mission necessary? Are there any sites with extant deep biosphere environments? How will a crew do science in such an EZ?

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
81. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?* I think we made giant leaps in creating a united humans-to-Mars community. This is the start of our journey to Mars! So that more people (i.e. college students and foreign scientists) can attend, a larger conference room would be nice. The meeting was very well planned and organized (great job Rick and Ben)! I don't think the basic structure should be changed much for the next meeting.
82. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).* In future workshops, we could talk about what near-term precursor missions would be useful, and use these workshops as landing site workshops for these missions. A more detailed discussion on resources, perhaps as a separate webinar or workshop, could be useful to prioritize resource types.

83. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?*

    One speaker mentioned that the eventual human landing site might not have even been discussed yet. To identify other candidate sites, we could have a few grad students go through CTX and HRSC data to identify interesting areas, and then look at HiRISE and CRISM data to see if they could be potential EZs.

14.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Melas Chasma Alfred McEwen	1007	☒	Science rich area. Rich in polysilicates. Good data to back resource claims. Very well presented. Negatives: Southern hemisphere, no water ice.
Equatorial 2			
Equatorial Vallis Marineris	1023	☐	Good presentation. Compelling evidence for a good site. Evidence for water ice was not presented.
Equatorial 5			
Hypanis	1051	☐	
Jezero Crater J. F. Mustard	1034	☒	Very well presented. Lots of data backing observed terrain. Unlimited science opportunies and terrain variability. Similar resources to Nili Fossae region immediately to the north.
Nili Fossae	1010	☐	This was my site where water ice was presented. J. Mustard flagged that the 1500 CRISM signature is suspect, but would like to research further to collaborate the evidence. Very interesting site though for science.
High-Latitude 1			
Deuteronilus Mensae Jim Head	1033	☒	Best presentation. Very comprehensive. Best supporting evidence for water ice resource with additional science ROIs.

Feedback

EZ Concept "existence proof"
84. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* I thought this was an excellent idea. I liked the fact that different disciplines were able to come together to share ideas, knowledge, and help work through some of the challenges. In my case, I particularly liked that it was not limited to recognized scientists and/or teams, but was an open forum to outsiders as well. It allows someone to bring new ideas and thinking to the group.

85. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* I think in the future that some prework (perhaps a 1 day workshop at the beginning or a month or two in advance) with various teams would be helpful for those presenting so the data presented is consistent. Where one used one source of data, another used a different source or may have used data that was thought suspect or not complete.

Reference EZs

86. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include:
    - gg. A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?
    - hh. A hydrated mineral site—given the temperature requirements needed to extract water from these minerals, how would the ISRU community acquire and process the raw material?
    - ii. Given the mineral resources available and the power/capabilities to process those minerals (e.g. Mg/Fe/Al), is it realistic to consider this for the first missions where limited processing can be sent to Mars?
    - jj. Farming was not address. Perhaps not needed, but do the resources support the needs to grow crops? This seems to be a top priority to a long term presence.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

87. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?* It was easy for me to forget that this was the *first* meeting and while science was necessary and important, the objective of the workshop was to get ideas on where we should go and why. The criteria helped to govern the format. Keep that. The rubric was very difficult for me to fill out because of my lack in knowledge in each of the areas so should be filled out by a panel (1-3 for each area, present or online) so there is consistency and that they mean something. The presenter will be passionate about their own area so will skew the information to what they *want*, not necessarily what is actually been shown.

88. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).* Future workshops should take what ideas were given, and have a separate team consider what was presented and gage if there is enough science, interest, resources to take a deeper look – in spite of how good a job the presenter did in presenting it.
89. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?* I would have helped me to see more structured feedback from the different disciplines on their first thoughts for what was presented. For instance, have various representatives from geology, astrobiology, civil engineering, etc. to ask questions, not just leave it open where you may not get any questions.
90. *Anything else to discuss that is not covered by the previous items?* Farming and crops were not addressed. What are the criteria for growing crops? You need the right type of soil, a supplement of fertilizers and biodiversity to sustain plants. Seems this should be a main concern in picking a site that has the right type of soil to allow for this. Same as it is here on earth. You cannot just grow what you need anywhere you want.

15.

My top four exploration zones, all of which were not visited previously, are Apollinaris Sulci (Kerber et al), Hebrus Valles (Davila et al), Western Noachis (Hill and Christensen) and one of the sites within Valles Marineris (e.g. McEwen et al.)

Rather than going through the check-list, which is for a 100 km radius EZ rather cumbersome, since nearly all sites are extremely interesting and have something special to offer, I highlight what disguishes my selection from the other sites.

The emphasis is on resources, which in addition to water ice are in my view natural shelters that can and should be utilized (Apollinaris Sulci and Hebrus Valles). Although their suitability would need some effort, it would still be much easier than construct all habitats from scratch. In case, of Hebrus Valles the subsurface caves are expected to be so extensive that they might also contain liquid water and be a refugium of extant life.

Western Noachis has the advantage of extensive NaCl and other evaporite deposits. Based on analogy with the Atacama desert, that´s where the last habitats are to be expected in a desert environment, utilized by organisms that use deliquescence and can extract water directly from the atmosphere. For more information on this see Davila and Schulze-Makuch, The last possible outposts of life on Mars (in press at Astrobiology, first issue of 2016, happy to send a copy if you like).

The suggested sites within Valles Marineris are also of high interest, and particularly from an astrobiological context (though McEwen did not make this point in his presentation about Melas Chasm).   If there is no issue with communication (which is outside of my area of expertise), that would be a prefered EZ with many science and resource advantages.

From the sites that were already visited, the most suitable would be Gale Crater (e.g. Calef et al), as suggested by several groups. This, of course, will also depend on the future findings of the Curiosity Rover, but it would still - based on current knowledge - one of the sites ranked highly.

As a general comment I like to emphasize that the human mission would be a gigantic leap (on several fronts) from previous robotic missions, which also has to manifest in the goals of the mission. Just to look after rocks or liquid water will not cut it. The science objective has to include the possible presence of not only habitable environments and possibly extinct/fossilized life, but also the possibility to detect extant life. In my view, resources go first, astrobiology second, and rocks and geological interpretation and dating third (and I´m a geologist by training).

On another note, I´m currently at the Technical University in Berlin, Germany, and probably will be so for the next couple of years as grantee of a European Research Council Advanced Grant to investigate the Habitability of Martian Environments (and on leave from Washington State University). There is quite some interest for a human mission in Germany as well (e.g., at the universities, German AeroSpace Center, etc), and I´m sure you have your contacts on a high administrative level for implementing the planned international mission, but if I can be of some help or a bridge in some way, please let me know and I can try to help.

16.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Melas Chasma	1007	☐	#1 polyhydrated sulfates at surface for ISRU, RSL, ancient and modern habitability, equatorial, low elevation, tremendous geologic diversity
Equatorial 5			
Jezero Crater	1034	☐	#3 polyhydrated sulfates for ISRU, great mineral diversity and ancient habitability.
High-Latitude 3			
Acheron Fossae	1011	☐	#2 Site with known shallow ice, at lowest latitude and N hemisphere for relatively constant temperatures (compared to same latitude in the south). If ISRU from hydrated minerals or RSL doesn't work, they will require shallow ice. Ancient and modern habitability.

Feedback

EZ Concept "existence proof"
91. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? That seemed to work, although somewhat arbitrary
92. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)? Drop anyplace above 45 N and S latitudes—seasonal CO2 frost and polar hoods would be a nightmare, and there is shallow ice from 39-45 N latitude.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
93. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?* I think we need a lot more information about ISRU—what's realistic?
94. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).*
95. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?* I don't see a need to accelerate it, except MRO lifetime, but the current process is okay for choosing MRO targets.
96. *Anything else to discuss that is not covered by the previous items?*

17.

Equatorial 1			
Melas Chasma	1007	4	Close 4th site: Easy access to materials for ISRU High preservation potential for biosignatures and potential for present habitability
Equatorial 2			
Gale Crater	1020	X	Precursor mission (MSL) has allowed for coverage and science start, can follow-up on science Adsorbed water for ISRU
Equatorial 6			
Mawrth Vallis	1009	X	Two different landing site options – already well-characterized areas from orbital imagery Regional investigations accessible, high potential for metabolic resource for microbes and high potential for biosignature preservation Clays with high water abundance – great for ISRU
High-Latitude 1			
Deuteronilus Mensae	1033	X	Team composed of several different backgrounds (including Civil Engineering) looking at this site; several expertise areas covered Ice accumulation and preservation – easy access to water At dichotomy boundary for science investigations, stratigraphic column

Feedback

EZ Concept "existence proof"
97. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* *The EZ concept is useful – it points out where science and ISRU zones are in relation to where habitats or landing sites would be placed. It is important to think about the geography early as some sites may be ruled out due to the location of resource areas related to the habitat.*

98. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?

The criteria are helpful – what would help assess the EZs would be teams made up of a variety of disciplines to comment on criteria based on their expertise. A scientist or an engineer filling out the entire bracket by themselves is a bit hand-wavy and doesn't line up the EZs on an equal footing for evaluation.

Reference EZs

99. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., "stressing" situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include:
    - kk. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?*
    - ll. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?*
    - mm. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

100. What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?

Additional workshops focused on civil engineering, geology, microbiology, etc. would help give some background and help each team think about various aspects of their landing sites from other perspectives. These can be done outside the landing site workshop.

Information for the teams to submit requests from MRO would also be helpful up-front (I have submitted instructions to Rich Zurek which will hopefully make their way out soon) so the teams can begin requesting targets. It takes a great deal of time to acquire targets and the sooner MRO can get started, the better for the overall landing site process!

101. What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).

See #4 – these can be addressed in webinars.

Also – it would be helpful to walk through the types of data products and requests that can be made for instruments on MRO and ODY and how to access the data.

102. What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?

Orbital data will take a while to gather – especially to cover a large area in an EZ. Understanding the ISRU potential of some sites may immediately cross some off the list and allow for focused *follow-up on a smaller amount of sites. Gathering information and lessoned learned from the Robotic Landing Site Workshops would also be of great use – i.e. pros/cons to sites, scientific merits. Also, there are some regions of the planet where data will take longer to gather from MRO (i.e. Gale Crater and Meridiani) due to relay support that occurs for landed assets. Due to observing restrictions and available science timeline, instruments on MRO cannot perform certain observing modes when hailing landed assets. This greatly increases the time to cover a landing site in these regions, for example.*

Creating inter-disciplinary teams such as Jim Head's team would also help cover the large range of aspects of a potential site and help for equal comparison of EZs at workshops. These landing sites are very different than those considered for robotic missions due to the human component. The science is highly important but ISRU must be valued just as high if we plan to send humans to "live off the land."

18.

<u>EZ Concept</u>

The concept of an EZ is useful and, because it's based on viable engineering estimates, most likely the right order of magnitude landing site that will be used in future missions. The minimum EZ criteria (dust cover, thermal inertia, latitude, etc.) were reasonable. While they cut out polar/high-latitude sites, those would be energy intensive to reach and therefore less likely to be used for the first few Mars missions.

<u>Data Collection</u>

Many high-quality sites were presented that lacked sufficient data to compare directly to other, more well-characterized sites. Because no human Mars mission date has been set by NASA, it is imperative that the focus of future MRO and ODY observations attempt to fill these data gaps for high-potential sites.

<u>Rubric Feedback</u>

While the individual line items in the rubric were a good first step, they were all weighted equally; I believe this was the biggest drawback of the rubric. Once the science community gets more educated about the operational limitations of ISRU (see next section) we can more accurately weight the various resources relative to each other in terms of: 1) abundance, 2) physical accessibility (which was sort of addressed already, but needs more detail), and 3) chemical accessibility (heat/energy required to extract water from hydrated minerals, Fe/Mg from rocks, etc.). A ranking system would be appropriate, where the "best" science or resource is weighted higher than others based on the abundance/accessibility criteria.

I also believe that it is imperative to get inputs from representatives of 1) the human spaceflight community and 2) the ISRU community on this rubric to make sure it encompasses their unique requirements/constraints.

<u>Additional Feedback</u>

Aside from the fact that there are many interesting sites on Mars, the main takeaway I had from the workshop was that the science community NEEDS to be more educated about: 1) human spaceflight (especially the engineering constraints imposed by humans) and 2) ISRU. Some representative questions that we should address include:

- How to we *currently* keep humans alive in space (life support systems, etc.)? The water recycling system, for example, is 85% efficient. When we go to Mars, we'll have a system that is likely 95+% efficient. What does this translate to in terms of water needed during martian surface operations (and return transit to Earth)? How would this system be impacted by the presence of perchlorates, for example?
- What resources do the ISRU community think will be most important in future missions? Perhaps titanium is more precious to them than iron (probably not true, but this is an example). Perhaps both of these metals are more greatly needed than water. Should water, metals, and building materials be weighted differently? How easy is it to extract water from hydrated minerals? Which hydrated minerals have the greatest resource potential?
- Are there some Apollo and/or Constellation folks around who have been through analogous selection processes that can help us? [The answer is Yes.] Instead of reinventing the wheel (to some extent) we should talk to them about their lessons learned and recommendations for how we should proceed.

Selection Priorities

I believe that science will not be the deciding factor in choosing a landing site – it will be 1) crew safety, and 2) engineering limitations. Therefore, landing site selection should more heavily weight these fields (to the degree possible with the current data) relative to science. I believe this was done at a high level for the Humans to Mars Workshop through the incorporation of dust, thermal inertia, latitude, etc., requirements. However, to more accurately assess the viability of a site, a more detailed understanding of the engineering requirements is needed. Coupled with these engineering requirements is the need for scientific data that will allow us to determine whether a site meets the engineering constraints (or not). To bound the extent of these engineering needs, I made the following list of data needs in order of mission criticality: 1) Surface hardware and engineering operations, 2) ISRU, and 3) Science. For science, I focused on big-picture questions and how to prioritize different science topics (i.e. pure geology vs. astrobiology). However, not all science questions are of equal importance, and will likely need to be prioritized for final site selection.

1. Surface hardware and engineering operations (including both systems and operations)
    - a. Habitat structure (science information needed in list below)
        - i. Surface stability for landing (sand vs. cobbles vs. bedrock)
        - ii. Wind forces
        - iii. Solar insolation levels
        - iv. Thermal variations (diurnal and annual)
        - v. Radiation – types and levels
        - vi. Allowable leak rate into martian atmosphere and allowable contaminants
        - vii. Allowable contamination into vehicle (quantity and composition of martian atmosphere and dust)
    - b. Radiation protection
        - i. Types of radiation
        - ii. Levels/intensities of radiation
        - iii. Contingency situations: solar flares, etc. and their impacts
    - c. Life support systems
        - i. Water recovery
            1. Quantities of water
            2. Types of contaminants
        - ii. Atmospheric revitalization
            1. Available atmospheric gases to replenish habitat atmosphere (especially nitrogen)
            2. Dust composition and grain size distribution to constrain allowable dust in habitat and filters needed
            3. Minerals available for contaminant collection and/or humidity control (zeolites, hygroscopic minerals, etc.)
            4. Quantities and types of trace contaminants
            5. Allowable loss rates of gases leaked into martian atmosphere
    - d. Thermal control systems
        - i. Diurnal temperature variations
        - ii. Annual thermal variations
        - iii. Weather characterization
            1. Winds

        2. Dust fall (dust would cover radiators)
        3. Cloud cover
    e. Extra-vehicular Activity: Impacts and Constraints
        i. Dust cover
        ii. Dust composition
        iii. Dust grain size distribution
        iv. Topographic variations on human traverse scale (1-5km and less)
        v. Allowable gases to leak to martian atmosphere from EVA suits (due to suit leakage)
        vi. Planetary protection/contamination constraints
        vii. Contaminants that would be introduced into habitat when returning from EVA (dust, gases, sand/geologic materials)
        viii. Solar insolation for power
        ix. Temperature variations
    f. Rover/traverse technologies
        i. Plausible traverse routes based on slope and topography
        ii. Detailed characterization of rock types along traverse routes
        iii. Distribution of grain sizes and grain morphologies (jagged vs. smooth) along traverse route
        iv. Dust cover along traverse route
        v. Dust composition
        vi. Dust grain size distribution
    g. Power systems
        i. Solar insolation
        ii. Dust cover
        iii. Dust composition/grain size distribution
        iv. Thermal variations
        v. Radiation impacts on power systems and electrical insulation

2. ISRU
    a. Water resources
        i. Total water needed (with margin) for duration of mission
        ii. Water uses (need to define quantities and purities needed for each)
            1. Crew consumption
                a. Efficiency of water recycling system
                b. Allowed contaminants into water recycling system
                c. Data needed to show that martian water is actually potable
            2. Propulsion
                a. Quantity needed over course of mission
                b. Energy requirements for oxygen extraction
            3. Coolant
                a. Purity of coolant
                b. Alternative substances that could serve as coolant
            4. Radiation protection
                a. Types and intensities of radiation
                b. Quantity of water needed to block incoming radiation
            5. Crop growth
                a. Contaminants allowed into soil from martian water

            b. Water needed to grow crops of various sizes and plant species
    iii. Sources of water
        1. Hydrated minerals
            a. Energy required to extract water (chemical accessibility)
            b. Composition of slag (is it hazardous?)
            c. Mass of mineral needed to support humans
        2. Subsurface Ice
            a. Contaminants in ice and their concentrations
            b. Quantity available
            c. Depth of ice/accessibility
        3. Atmospheric Water Vapor
            a. Quantity available for human use and seasonal/diurnal variation
            b. Energy required for extraction from atmosphere
        4. Recurring Slope Lineae
            a. Planetary protection constraints
            b. Quantity of water available
            c. Source of water for RSL (can it be used?)
            d. Accessibility (can telerobotics be used for steep slopes?)

b. Sources of metals
    i. Types of metals that are most important for human use and prioritization
        1. Iron
        2. Titanium
        3. Silicon
        4. Magnesium (?)
        5. Others
    ii. Minerals that contain these metals
    iii. Abundance (areal abundance and depth of deposits, if possible)
    iv. Accessibility
        1. Physical accessibility
        2. Chemical accessibility

c. Food production
    i. Quantities of martian soil available
    ii. Quantities needed for crop growth
    iii. Composition of martian soil
        1. Which contaminants will kill plants?
        2. How can those contaminants be removed?
    iv. Energy needed for lighting
    v. Additives needed to make martian soil viable
        1. Fertilizer/other nitrogen source
        2. Microbes?

d. Construction Materials
    i. Definition of possible uses for construction material on Mars (this was very open-ended at the workshop)
    ii. Processes required to convert raw materials to construction materials
    iii. Quantity needed for various uses

iv. Mechanical properties of martian sand and impacts on viability for construction

3. Science
    a. Geologic processes
        i. Breadth
            1. How many global-scale questions does the site address?
            2. How many fundamental geologic processes are represented?
            3. How many datable geologic units are present?
        ii. Depth
            1. Would the site only address regional-scale processes in detail?
            2. Does the site only have astrobiological potential or aqueous processes?
            3. Is only one geologic unit represented?
        iii. Fundamental geologic processes/areas of scientific focus:
            1. Volcanism
            2. Tectonic evolution
            3. Gradational processes (aeolian, etc.)
            4. Impact processes
            5. Aqueous processes
            6. Mars interior and evolution
    b. Astrobiology
        i. Planetary protection requirements
        ii. Definition of priority relative to geologic processes
        iii. Current life-detection techniques
        iv. Extraction and processing constraints for fossilized/ancient life
        v. Crew protection constraints from extant life

19.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Chryse Planitia	1019	☒	Study of environmental wear on Viking; flat & safe
Apollinaris Sulci	1043	☒	Use of yardangs for shelter
Equatorial 5			
Nili Fossae	1010	☒	Potential for easy access to H2O

Feedback

EZ Concept "existence proof"
103. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? Good concept, but I think it should focus more on resources/ISRU than on science. While the goal of a Mars mission might be primarily driven by science, no research can be done if the astronauts can't survive.
104. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)? Minimum requirement for the number of resource ROIs to make sure the site will be viable from an ISRU standpoint. This should get more collaboration between scientists and engineers, too.

Reference EZs
105. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: nn. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* oo. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?* pp. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?* Equatorial regions are the best bet to reduce cost and increase ease of landing. However, this creates a more “stressing” situation with water being mainly available in rocks and hydrated soils instead of ice. Mission cost for a high-latitude landing site with water-ice available in the subsurface should be compared with the cost of heating rock and soil to access water-ice at equatorial landing sites.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
106. What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?

107. What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop). - Mining for Scientists - ISRU for Scientists - Geology for Engineers Basic introduction to what is most beneficial to each of these fields on a Mars mission
108. What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone? Make sure there is a wide range of interested parties present at the next workshop. This one was heavily planetary science. There should be equal parts science, engineering, and operations.

20.

Equatorial 4			
Apollinaris Sulci	1043	3	Good scientific potential, equatorial setting, plenty of volcanic interest (missing from most), resource potential?
Equatorial 5			
Jezero Crater	1034	1	Best scientific variety and importance, low elevation, equatorial setting, abundant resources. By far the most valuable EZ. I won't repeat the specific characteristics, since the Jezero team have done this admirably. If there was shallow water ice available this place would be perfect. The opportunity to sample materials from a variety of sources and modes of genesis is fabulous.
Session	Abstract No.	Pick 3	
Equatorial 1			
Melas Chasma	1007	2	Good science potential, low altitude, low latitude, resource potential?

Feedback

EZ Concept Existence Proof
1. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* *It's a very valuable and appropriate approach. I like the EZ concept because it addresses several concerns at once and tends to help select a location that is not a one-dimensional value*
2. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* *I believe that engineering constraints will trump many of the science desires represented in the EZs as proposed. In particular, the prospect of getting useable quantities of water from hydrated mineral deposits seems like wishful thinking to me. Additionally, it does not seem likely to me that early missions will have the heavy equipment that it would take to dig deep for buried ice. Shallow and abundant ice deposits seem therefore critical.*

Reference EZs
3. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations /scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: a. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* b. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?* c. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?* Are you asking for intentionally difficult scenarios? I’m not sure that I understand the question. I think we ought to keep things simple: ideally low latitude, low altitude, good science return and eminently useable for settlement/further exploration in the long-term (this would pre-suppose an accessible water supply - admittedly maybe not so easy at low latitudes). We need to maximize the benefits that come from being in the warmest and best-lighted part of the planet. As for how the ISRU community could acquire and process raw hydrated minerals or shallow ice or RSL (questions posed above)- this is where I say the engineers take over. I’m not engineer enough to make an informed statement about how these things could/should be done. If there is one weakness in our site selection process so far it has to be a lack of real, practical input regarding engineering constraints. Liaison with the engineering community as a next step would be advisable.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
4. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?* *Perhaps a follow-on workshop might begin the process of eliminating some of the proposed sites so as to be able to dig deeper into the better ones.*
5. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).* *As stated above, engineering constraints ought to begin to play a role in future workshops - perhaps as a distinct topic of consideration for each site.*
6. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?* *Keep the meetings fairly frequent. Be ruthless in eliminating the weaker sites early.*
7. *Anything else to discuss that is not covered by the previous items?* *A web-based, ongoing discussion by team members, critically regarding and reflecting upon your conclusions as well as making additional argument about the better sites could be useful in advancing the process of digging deeper into those sites and eliminating the ones that are less valuable - prior to the next meeting.*

21.

Equatorial 2			Rationale
Gale Crater	[1020](#)	☐	One of three sites where EZ criteria can currently be evaluated (group in other Gale proposals)
Equatorial 3			
Meridiani Planum	[1030](#)	☐	One of three sites where EZ criteria can currently be evaluated (group in Endeavour Crater proposal)
Gusev Crater	[1008](#)	☐	One of three sites where EZ criteria can currently be evaluated

Feedback

EZ Concept "existence proof"

2. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?

EZ Sizing:
There appears to be a disconnect between the Evolvable Mars Campaign and the ISRU/CivilEngineering groups on the expected range of the pressured rover. EMC is assuming a pressurized rover range of 100km-150km, which ISRU/CE is assuming a 400km range for the same rover. The pressurized rover range will be the driving factor in sizing EZs. The rover range estimates need to be made consistent for the AO, and preferably before that.

I recommend that EMC, ISRU/CE, and rover mobility experts outside of those two groups meet independently to establish the expected maximum range of the rover as a function of both distance and sols for life support. The EZ radius should then be sized assuming appropriate margin for non-direct traverses and EVA time during the traverse. This may reduce the EZ radius from 100km to a shorter distance.

ISRU Consistency:
From talking with other participants during there is a disconnect on what ISRU is expected to be used. The EMC participants were talking atmospheric ISRU only while the ISRC/CE group from KSC was focused on extracting resources from the surface. Which ISRU is to be used will drive EZ selection. This needs to be decided, or at least conservatively bounded prior any AO.

ISRU Dependence:

At the workshop I was not convinced that ISRU is necessary for the first field station and EZ. By making the EZ architecture dependent on ISRU, the timeline for the initial EZ crew missions may be delayed. Precursor missions would be required prior to committing a crew to use an ISRU dependent mission.

ISRU dependence is not required for the first field station. Work performed by Hoppy Price, John Baker, and Firouz Naderi at JPL have analyzed and had independently costed a Mars architecture that would support the build up of a field station. This work has been published in New Space ("A Minimal Architecture for Human Journeys to Mars". Price Hoppy, Baker John, and Naderi Firouz. New Space. June 2015, 3(2): 73-81. doi:10.1089/space.2015.0018.)

This architecture makes use of a hypergolic bi-propellant Mars Descent/Ascent Vehicle to land the crew. Use of this vehicle does not preclude the inclusion of ISRU in the final architecture, but does significantly reduce the dependence on ISRU for crew safety (Mars ascent).

Refinement of Allowable Exploration Zone Latitude/Altitude Limits:
Prior to the AO being released, refinement of the latitude/altitude is likely necessary. While landing site engineering constraint assumptions were included in the Workshop documentation, they may result is landing sites that are not reachable. Similarly the habitation zone engineering requirements may result in Exploration Zones that cannot support year

			Rationale
Equatorial 5			
Hypanis	1051	☒	Access to highland-lowland transition with diversity of stratigraphically relevant depositional environments.
Equatorial 7			
Huygens Crater	1032	☒	Potential access to variety deep crustal rocks and good stratigraphic section of highland rocks.
High-Latitude 1			
Hellas Rim	1037	☒	Presence of lobate debris aprons with better access to diverse, geologically important materials than the Deuteronilus Mensae sites.

Feedback

EZ Concept “existence proof”
109. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars?* **RESPONSE: The EZ concept is much preferred to multiple locations visited once because it enables a much for “evolvable” investigative campaign. Multiple sites visited once would tend to result in static traverses, more similar to Apollo. A single site visited multiple times would tend to result in much more flexible exploration. I think it makes much more sense to establish a single, long-term, independent base at a location that provides maximum, reliable resources as well as access in the near- and far-field to locations that are highly relevant to deciphering the broad range of scientific questions regarding Mars’ evolution, especially as compared to Earth. Scientific relevance is critical and something that the community (at least as expressed in the most recent workshop) does not have a good handle on yet.**
110. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* **RESPONSE: The basic criteria are fine, but we need to have better information on what resources are needed and what is possible via current and perceived future extraction methods. Identifying resource ROIs was a complete shot in the dark because the criteria were ill-established (which is expected at this stage in the process). Identifying “points” to visit seems pre-mature (results in “my point is better than your point”) … rather, I would like to see the community focus on the “kinds” of environments that should be explored. This would enable the use of “masks” to down-select scientifically relevant areas, in a similar way that engineering masks can identify “go” and “no-go” regions. Points don’t really work all that well at this stage of the process.**

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
111. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?* **RESPONSE: (1) I appreciated the group presentations and then discussions and suggest keeping this in some format. (2) I think we were missing presentations from EDL engineers as well as ISRU/civil engineers … these folks were in the room, but the presentations were from scientists, who largely don't know (or perhaps care) about these constraints. Thus, the perception was that observational science is a primary driver (which is not really my perspective). We need to get humans there safely … that is the driver. There are rocks everywhere and many, many places can yield exceptional new science observation. (3) There is a difference between applied science as a driver and observational science as a driver. See previous comment. (4) Organizers need to encourage cross-discipline participation at every workshop … it is not sufficient to have one group present to another group, as this does not encourage serious discussion. (5) Any presentation template should be delivered well in advance of the meeting. (6) A location that compiles discipline and cross-discipline meetings would be helpful**
112. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).* **RESPONSE: More presentations from all facets of the community … science, ISRU, landed ops, orbital ops, civil engineering, biology. I don't really have an opinion about the order in which things are presented other than to organize in a way so all groups are present … don't order so that science can present and then bail (for example). Face-to-face workshops are time consuming but are by far and away better for serious discussion and community interaction.**
113. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?* **RESPONSE: Need annual workshops. Need NASA AO to support the work and travel. Need cross-discipline emphasis. Need flexible science and engineering masks to down-select AREAS of interest rather than POINTS of interest. Need feasibility studies for ISRU identity, extraction, and use. Need to match scale-based unknowns to potential range of pre-cursor orbital and landed observations as well as in-mission use of robotic assets. (For example, do we need intermediate resolution imaging data or is current data resolution sufficient? Need to leverage existing landed operations lessons-learned. Need to ensure that technical capabilities are in place - and continue to be maintained and improved upon – in order to efficiently process acquired data into accurate, reliable high-level data products (registered image mosaics, DTMs, co-registered data). Need to ensure that traverse planning tools are developed and tested, including science decision-making protocols.**

23.

			Rationale
Equatorial 3			
Meridiani Planum	1030	1	We have some data on this site, enough to know it is very intriguing. Offers every criteria (resource and diverse science) within a 100 km radius, most within a 50 km radius.
Equatorial 4			
Hebrus Valles	1012	2	Potential for accessible underground resource and habitat
Equatorial 5			
Aram Chaos	1048	3	The terrain provides vertical outcrop exposure and possible habitat shelter.

Feedback

EZ Concept "existence proof"
114. *What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? Most, if not every place on Mars, is going to have valuable science. I think it was good to include the exploration zone- it allows a practical/ feasibility assessment of the science as well.*
115. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?* *1. Include a critera: 1: If there is water in the area, what form is it in and what evidence is there? Form: ice, bound in mineral, frost, etc. and Include mission and instrument for evidence.* *2. How frequent are dust storms/ are there sand dunes in this area.* *3. If the site is selected , what three instruments would you want on a rover/ lander to that area.*

Reference EZs
116. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: qq. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* rr. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?* ss. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
117. What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed? *Many of the sites are both resource rich and of course scientifically interesting. However if the site is used as a resource it is no longer scientifically pristine for research. Possibly include a metric that states “This site would benefit Humans on Mars best as a science or a resource site” Or have the resource sites investigated first before being allowed to become an official ‘resource area”* *A metric on the “ Can this site be lost for science ” How often do we see this type of feature on Mars? Basically, Why is this site scientifically unique? (i.e It is the only canyon of this size, there are only 10 craters with these features and this is the only one in the equatorial region, etc).*

118. What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).

The issue of water: What form is it in, how is it extracted, and at what cost? Is this being done on Earth and if so, what can be reduced for Mars.

The presence or lack thereof of water in the equatorial region. Webinar would be fine. See comment 6

119. What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?

There was some debate on the water near the equator. Several papers have published the presence of "Ice ramparts" based on instrument data (CRISM?), but the PI of the instrument argued (via discussion) that the data showed the absence of water.

To me the PI would know the instrument data best, however there are multiple publications which means at least three people for each paper agreed with the water interpretation. The room seemed to be divided on the subject, so I think it would be good to have a workshop to discuss / come to a general conclusion on the presence of and general amount of water in the equatorial region.

120. Anything else to discuss that is not covered by the previous items?

It was a great workshop, thanks for hosting it. I think other factors such as human medical health in particular dust grain size and perchlorate in the dust should also be considered when evaluating the sites.

24.

Session	Abstract No.	Pick 3	Rationale
Equatorial 1			
Melas Chasma	1007	x☐	
High-Latitude 1			
Deuteronilus Mensae	1033	☐x	
Acheron Fossae	1011	x☐	

Feedback

EZ Concept "existence proof"
121. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? *I like the concept, but I actually think it is too soon to be picking things down to 100 km areas. We should rather be thinking in terms of regions. I think of the Valles Marineris as a region, the ice rich deposits in the Northern hemisphere such as Amazonis Planitia as a region. We need to work it by addressing what are the resource extraction technologies that are most relevant. We can get water out of Martian soil anywhere, but is that what is wanted, or do we want to access ground ice.*
122. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)? *See above*

Reference EZs

123. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., “stressing” situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include:

tt. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?*

Ice cemented ground is just that, cement. So excavation of ground ice will require high forces that could imply blasting it loose. A significant issue for ice rich sites is to first determine whether there is modern life, because if there is that may rule out these sites from a planetary protection perspective. But also if there is an active biosphere anywhere, the whole planet may be off limits. We really need to address this issue as a near term precursor. It is nieve to think that we can just stay away from and not disturb modern life without knowing more about it.

uu. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?*

It depends on the material strength properties of the hydrated minerals. Probably the easiest to deal with is sulfate rich soils or sulfate mineral deposits because they will be soft compared to ground ice.

vv. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

The RSLs have no more strict planetary protection constraints than the high latitude ground ice, in that both may be habitable but not necessarily inhabited. The RSL’s may be forming from deliquescense alone. If so, whether or not they are habitable depends on the salt upon which water is deliquescing. If it is perchlorate, then it is not habitable. If it is calcium chloride, then they may be. A precursor mission could determine both of these things but it will require actually getting a rover down a steep slope into the RSL zone to sample. Sample return to Earth is not needed. The sampling should include life detection instrumentation and chemical analysis to determine what salt is involved. The Icebreaker instruments (Signs of Life Detector and Wet Chemistry Laboratory) would be appropriate for the measurements.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
124. What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed? *Process was good. But the community is too focused on the "best geology site" too early in the process.*
125. What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop). *Address the topic of what precursor information is needed before we can move forward with human exploration anywhere on Mars needs to be addressed. We can find plenty of interesting geology on Mars. But precursors relevant to human exploration need to be addressed. I claim that a life detection mission is a necessary precursor. There may be others related to ISRU extraction approach.*
126. What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone? *See above*

25.

Session	Abstract No.	Pick 3	Rationale
			The planetary protection discipline is entirely agnostic about which EZ should be chosen from a science perspective, although landing sites in an area with potential special regions should be avoided. EZ sites need to be appropriately selected so that planetary protection constraints for those sites and for the end-to-end mission(s) can be implementable within the available hardware capabilities and understanding of the EZ site, so that harmful contamination does not occur. Right now, that is zero allowable sites (based on current policy and understood hardware capability), but with an expectation that additional information e.g., about the lethality of the Mars environment to terrestrial organisms to be obtained by precursor missions, would allow human missions once an end-to-end concept that could be completed without harmful contamination has been demonstrated. As an observation, low altitude equatorial sites may represent the most affordable in terms of sustaining a program of missions to a single EZ site, including the precursor missions necessary to generate the data to ***allow*** a crewed mission from a planetary protection perspective.

Feedback

EZ Concept "existence proof"
127. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? - Valuable as a focus (pick 1 and plan for it). - Provides for a valid trade between sites (though trade "science vs science" is easier than "enhanced science vs. more difficult access", which was not done at this workshop). Preferred would be if the best science was accessible at the most benign site, obviously.

128. *What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)?*

The 100km circle is a useful constraining device, but once we are comparing a smaller subset of potential EZs, an accessibility/risk parameter ought to be employed: How much science can be accessed, and at what risk to the crew and h/ware to access it (would favor EZs with SROI and RROIs within easiest access). Some notion of "traversability" based on the capability of the mobility systems should be included before too much effort is spent imaging science opportunities at "unreachable" locations.

Reference EZs

129. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., "stressing" situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include:

- ww. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?*
- xx. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?*
- yy. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the ISRU community access and process the water given the same planetary protection guidelines/constraints?*

  It's difficult to see there being different constraints for RSL sites vs other selected sites with astrobiological interest. I expect all missions to have a need for sterilizable robotic elements to allow for sampling special regions, and for "keep out" zones for astronauts. Although a mission to a particular target location might have unique elements (sterilizable cliff-bot, sterilizable deep drill), planning a mission only to sites not of astrobiological interest is difficult to support, scientifically and politically.

  It's difficult to envisage there being a different process for any of the Mars water used for IRSU in human accessible locations. I expect it will all need to be accessed as if it contained Mars life/was from a location habitable for Earth organisms, and processed as if it was hazardous (with the possible exception of robotic fuel production).

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)
130. *What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?* To Add: best available image data so that sites can be compared on an equal footing (may need to limit to just a subset of candidates)
131. *What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).* It would potentially be useful to understand the engineering/cost trades in the context of e.g., the high vs low latitude
132. *What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?* Much of the science would be common at multiple locations. Might be handy to get two communities (science and engineering) to rank each site separately on a 1-5 scale based on science yield and engineering risk, then plot on a 5x5 matrix. May help pick out easy winners/losers
133. *Anything else to discuss that is not covered by the previous items?* May be useful to know the practicalities of a precursor program. Is an option to probe multiple EZs and see if they are as good as we think (bearing in mind the most persuasively presented EZs were those where we already have ground truth from previous robotic missions), or do we need to decide now before precursors are sent to a single selected EZ site?

26.

I did not fill in which sites, mostly because they had vastly different levels of detail and background research. I did fill in the feedback questions below.

Feedback

EZ Concept "existence proof"
134. What is your opinion regarding the viability/value of the EZ concept in describing and assessing human exploration on Mars? I think the concept is good, it forces looking at constraints as well as opportunities within a proposed EZ and their relative position with respect to each other. It also makes a level playing field for every proposed site.
135. What changes should be made to the EZ criteria distributed prior to the workshop (including rationale for the change)? It would be nice to look at a smaller scale (look at slopes, traversibility etc.) because the devil is in the details. I think that is relevant in being able to reach all sites of interest within the EZ. Then again, this information will not be available for all proposed sites at this point in time.

Reference EZs
136. Considering the EZ proposals made at the Workshop, describe those situations or scenarios [alternative: ask for a specific number or a maximum number of situations/scenarios] that you consider to exhibit a high potential benefit for science, ISRU/CE, or both but are also challenging from a technological or operational point of view (i.e., "stressing" situations or scenarios). Include your rationale for the potential benefit and the challenging aspect(s). Several representative examples include: zz. *A high latitude site with shallow ice potential—how would the ISRU community access and process the ice?* aaa. *A hydrated mineral site—how would the ISRU community acquire and process the raw material?* bbb. *Recurring Slope Lineae (RSL) site—how would the science community explore such a feature given planetary protection guidelines/constraints? How would the*

ISRU community access and process the water given the same planetary protection guidelines/constraints?

I would certainly like to see more details on any of the ISRU and civil engineering aspects. Stating that 'hydrated mineral A exists and thus there is a viable source of water' is too simple. I think the presented scenarios were all very light on details. This is for a large part due to a lack of data but also due to the ISRU community and scientific community not being very familiar with eachother.

For the reference EZ's I would include (besides the one you mentioned) also include some vertical relief and traversibility issues (e.g. Valles Marineris) which have high scientific interest but pose problems from a technical standpoint of how to get data. The sites should have a range (extremes) of engineering, ISRU and science challenges.

EZ Workshop Feedback (i.e. this workshop, including the steps preceding it and proposed steps after, such as follow-on workshops)

137. What should be kept more or less intact, what should be changed, what should be added, what should be removed, what was missed?

Perhaps a team requirement that science (geology, astrobiology, etc.) AND CE/ISRU are represented in the team members. I liked the format but they started blending by the end. I thought that there was good science to be done at each EZ but the potential for ISRU was vastly different.

138. What topics should be covered in future workshops? Please indicate if there is any precedence in these topics (e.g., Topic A is more useful if it follows Topic B). Please indicate if any of these topics could be reasonably handled as a webinar (instead of a face-to-face workshop).

What is a space resource and what does it take to mine/process it (e.g. concrete is a hydrated mineral). Definitions of common terms (e.g. 'dust', elements vs. minerals, soil mechanical properties and particle size matters for CE/ISRU) to make sure we are all talking about the same thing. What terrain is traversable? Planetary Protection (what IS allowed, what is NOT allowed). Establish a procedure for 'clearing' ice/water sites from initial planetary protection such that it can now be used as a resource. Depth of detected layers of minerals. Estimates of mineable resource is important and needs ground verification (can include in this stage geologic inference).

139. What other recommendations do you have to improve/accelerate our ability to pick a human landing site/Exploration Zone?

An expert exchange.. a phonebook / yellow pages of experts and their specialties so teams can be formed from different communities and can find contact information for them.

A funding mechanism to do quick projects to quantify and answer some of the basic questions related to ISRU and what it takes to liberate water from hydrated minerals. Science community is far ahead in organization compared to ISRU community and we have some catching up to do.

140. Anything else to discuss that is not covered by the previous items?

Environmental monitoring on the surface will be needed on any site to establish a baseline as well as to monitor changes once humans arrive.

Places that you want to go for Civil Engineering and ISRU are places often on do not go list from safety (engineering such as rover wheels getting stuck in loose sand/silt) or planetary protection (ice is easier to harvest than hydrated minerals) we cannot just copy the same rules as for previous mars rovers and the way planetary protection is described it was not clear to me that we would be allowed to even go to the surface of Mars with humans without clarifying the applicable rules.

Some wild claims were made based on data interpretation by most teams based that did not properly evaluate the data since it was not known how to process the data properly to extract the desired information (e.g. CRISM data needed quantitative unmixing and be converted to single scattering to discover certain minerals as well as the interpretations of the different wavelengths to map the correct minerals)

27.

The first three places are defined by the aggregate of the strongest arguments

1 place - The Eastern Outlet of Valles Marineris (1054)

- The place is characterized with widescale impulses of inner heat and water streams taking place there. This “bottleneck” can give us a key to the dramatic history of melting of the mantle and of planetary floods.
- Water streams activation had compulsive nature. That is why conceivable organic remnants from habitats hadn’t been exposed for prolong time. They were quickly buried and frozen into alluvial layers.
- Lake facies and injection bodies of permafrost nature (aka pingo) allows to research habitability of environment with medium and long-term of water activity.
- Terracing of river sediments make easy access to the layers at their ledges
- Steep western ledge of the valley exposes in significant death (3-3,5) early pre-aquatic sediments. It gives an edge in competition with other sites in terms of stratigraphic value and age of exposed lithosphere
- There are three very interesting mud-streams under the steep wall, which can provide us with integral material for preliminary analysis.
- Post-aquatic landscapes are widespread on the planet. They are relatively little cratered and leveled off, what makes them favorable targets for mission deployment, movement and development. Facies of river streams should have typical structure, same as on the Earth. Therefore local study would be applicable to other places and very informatory.
- Diversity of the available in the area resources is defined by the access to the layers of different historic epochs. Minimally we can count on water in form of crystalline hydrates, iron (material for basalts) and silicon
- This area also has advantage of equator and thicker atmosphere
- This site has advantage over inner parts of Valles Marineris in terms of landing and freedom of movement.

2st place - Hypanis (1051)

- Powerful set of science.
- The availability of water, metals and silicon.
- Favorable conditions for life in the past, good geological conditions of preservation and access to a possible organic materials.
- Low latitudes.
- A thick atmosphere.
- Noachian rocks.
- Presence of hydrolakkolits, hydrovolcanoes.

Gale Crater (1020) - **pretends to the 3(a)rd place** if Curiosity did not examine the sequence of layers in the canyon and did not clarify the nature of Mount Sharp.

- The crater is located in the transition zone of the sublime southern continent in the northern plains, it has a sloping bottom and sliding deformed array of mountain Sharpe. Abnormal height of the mountain is probably due to the intrusion of subpermafrost water, which is confirmed by the pingo of 600 m diameter at the base of mountain to the east for landing of Curiosity. Riddle of large flows of water and deep canyons. An array of relatively fresh light precipitation in the north-western slope was probably formed from subpermafrost waters.
- Actually there is water in hydrated minerals.
- There are black and light sand - a possible source of iron, aluminum and silicon.
- Large chronicle of layers convenient for testing and searching for traces of life.
- There are real sources of methane.
- Confident passability with no dust.
- High reliability of the data, the quantitative characteristics.

3(b)rd place - Cerberus (1017)

- Big set of goals of science in a typical landscape of the northern plains.
- A deep cut in the northern plains of Mars.
- Evidence of flooding 2-10 mln years ago, the most recent alluvial sediments.
- Pingos conserve subpermafrost water that was liquid for a certain time and could be a ground for microorganisms.
- Guaranteed water supplies.
- The possible presence of ice,
- Low latitudes.
- A thick atmosphere.
- The plains for landing.
- Question other resources needs work.

More sites

3(c)rd place - Mawrth Vallis (1009)

- Several types of astrobiological substrates.
- The environment is favorable for microbes.
- The border of two cratons is opened.
- Extremely watery mineral resources - 7-9%.
- There are sources of aluminum, silicon, iron.

3(d)rd place - Nactis Landing (1050)

- Deep geological section with possible biosignatures.
- The water in unlimited quantities, pingos, hydrates.
- Volcanic sediments