Notes from Extreme Access Monthly Meeting

July 2020

Notes From Discussion (shortform)

Longform discussion notes available on page 6

- Questions to answer:
  - What are the objectives for sites requiring extreme access?
  - Should be defined by as many players as possible (Science, industry, HEOMD, Artemis, etc.)
  - What technology needs further development to meet those objectives?
  - What kind of technology would humans need for access? What about robots?
  - What resources does technology need to gather?
  - What kind of design and integration, demonstration and testing tools are available?

- Areas of interest:
  - Permanently shadowed regions
  - Skylight floors
  - Swirls
  - Mountaintops
  - Long / permanent shadows
  - Steep slopes
  - Temperature extremes
  - Extreme rocky areas (i.e. Giordano Bruno crater)
  - Also moderate temperatures during long lunar nights after collecting heat
  - Rille floors
  - Crater walls
  - Far side
  - Lava tubes

- Needed technology:
  - Radiation shielding
  - Communication strategies
  - Penetrators
  - Hoppers

- Extreme Environments focus group is also defining such places - possibly schedule a tagup meeting
  - Will get list of extreme environments identified for the EA group to review

- Surface Power and ISRU groups are also discussing extraction goals and power needs
  - Want access to solar power, achieve by being next to PSR or climbing into Shackleton perhaps?

- Could potentially use features of the natural environment as access tools (i.e. swirls), but need to focus on the technology needed to foster access

- Facilitating collaboration and work on papers submitted to groups such as AGU is a goal for the focus group, encouraged using the listserv for coordination

- Need to parse out near-term technology needs from longer-term technology needs

- Should a ‘reconnaissance’ phase be considered, where information about extreme environments is collected and fed back to the group for analysis?

- Potential goal: Aim to have a categorized list of potential objectives to present at fall meeting in September.

- Consideration of planetary protection as being ‘in scope’

Notes From Chat (shortform)

Full chat transcript available on page 3

- Meeting slides and materials can be found at http://lsic.jhuapl.edu/Focus-Areas/Extreme-Access.php

- Funding Opportunities:
  - RFI open for the NASA "Watts on the Moon" challenge (https://www.herox.com/WattsOnTheMoon?utm_source=new-challenges-digest&utm;_medium=email&kme;=new-challenges-digest)
  - NIAC closes 22 July

- List of Extreme Places:
  - Permanently shadowed regions (referenced in NASA interim directive)
  - Skylight floors (extinct lava tubes that have caved)
  - Craters (both in and out of PSRs)
  - Rille floors

- Technology to Consider:
  - Radiation hardness for sensors and computers
  - Mobility and balancing systems, inc. unique challenges for larger vs. cube rovers

- LSIC's focus is the technology needed to access extreme areas - AGU and engineering conferences are potential venues

- Question from Power / ISRU perspective: "are there better/more viable routes that will help constrain the location of the lunar outposts?"

- Question to consider: What science goals or objectives can you point to to justify extreme access (rather than mobility that can be achieved with a traditional rover)

- Point to consider: this program should remain flexible enough to consider proposals for revolutionary technologies, even if they don't fit neatly into a "requirement"

- Backwards planetary protection and traditional planetary protection are both considerations

Complete Chat Record

marshall Eubanks: It's hard to read all this text at this scale :)

Deborah Domingue Lorin: Angela: Where can we get a copy of these slides? Will they be posted?

Andrea Harman: @Marshall, if you go to “view options” in your Zoom window, you can zoom in the view.

Jnaneshwar Das: @Deborah I see last call’s slides at http://lsic.jhuapl.edu/Focus-Areas/Extreme-Access.php

Deborah Domingue Lorin: thank you

marshall Eubanks: There is an RFI open for the NASA "Watts on the Moon" challenge - should this group respond to it? NASA's Watts on the Moon Challenge (https://www.herox.com/WattsOnTheMoon?utm_source=new-challenges-digest&utm;_medium=email&kme;=new-challenges-digest)

Deborah Domingue Lorin: Where can we apply for funding to work on these topics? Most calls are currently closed to non-profit leads.

Rachel Klima: Yes, we’re encouraging all LSIC groups to respond to that if they’d like to—the link is also on the LSIC page now if anyone needs to find it again later

Rachel Klima: Per STMD the industry calls are open to non-profits as well

Melissa Roth, Off Planet Research: And what resources are missing (or not well known) to meet those objectives?

marshall Eubanks: Can we start with a list of extreme places?

marshall Eubanks: Permanently shadowed regions obviously

Jnaneshwar Das: In a NASA Interim Directive I saw today, it lists “future science in permanently shadowed regions”

Jnaneshwar Das: for sensors and compute, if we use next gen tech, we might have to think deeply about rad-hardness again

Cameron Grace: Hi there my name is Cameron Grace and I am a Ph.D. student with the Crashworthiness for Aerospace Structures and Hybrids (CRASH) Lab, and to Marshall's point, when I think of extreme places I generally think about extinct lava tubes which have caved. I believe JPL has explored such extreme access robotics in the past.

marshall Eubanks: To Cameron, that is what I meant by Skylight Floors.

Cameron Grace: Thanks Marshall

marshall Eubanks: Note that thermal modeling indicates the Skylight Floors will get considerably hotter than the typical Mare

Melissa Roth, Off Planet Research: Another extreme access location is venturing into craters- both in and out of PSRs.

marshall Eubanks: What about Rille Floors? Those will be hard to get to (due to landslides etc.).

marshall Eubanks: Note that inside the lava tubes temperatures should be more or less room temperature, and even at night the skylight floors may not get cold at all.

Rachel Klima: I think that is in scope, but remember this is extreme access and though the science informs some of the site analysis, our focus is on the technology needed to access these areas

Rachel Klima: So AGU would be OK, but also possibly engineering conferences

Rachel Klima: sorry ;)

Wesley Fuhrman: Bringing power and ISRU technologies into the PSRs will be a challenge —one question that would be helpful to answer for the LSIC surface power focus group is: are there better/more viable routes that will help constrain the location of the lunar outposts?

Jnaneshwar Das: For steep slopes JPL's AXeL comes to mind, tethered 2-wheeled robots, which could be released from a rover.

marshall Eubanks: Dave mentioned Guiodorno Bruno - a very fresh crater. Are there other extreme places (highest, lowest, etc.) that should go on the list?

Melissa Roth, Off Planet Research: For steep slopes or uneven ground: looking at mobility and balancing systems as well as the unique challenges between larger rovers vs. cube rovers.

Cameron Grace: Are the objectives dictated more via science or industry desires

marshall Eubanks: Or support of HEOMD?

Joseph Galante NASA GSFC: I'm the PI for a hopping/cartwheeling robot. To motivate this discussion, something I am frequently asked is what science goals or objectives can you point to to justify extreme access (rather than mobility that can be achieved with a traditional rover).

David L. Akin: I would like to take a "contrarian" view of this discussion - certainly systems engineering textbooks would support the concept that technological capabilities are developed in response to requirements (science requirements in this discussion), but frequently in the real world technologies resulting in new capabilities enable science opportunities that were never considered feasible before. This program should remain flexible enough to consider proposals for revolutionary technologies, even if they don't fit neatly into a "requirement"

Jnaneshwar Das: Regarding planetary protection, NASA's NID today, forward contamination was listed.

Deborah Domingue Lorin: I have to leave. Thank you everyone for an interesting discussion. Sorry if I monopolized the 'voice time'. Be well everyone.

Cameron Grace: If resources are brought back to Earth similar to the proposed Mars Sample Return there will also be backwards planetary protection.

Rachel Klima: I think that is exactly what they're encouraging here—looking beyond the expected

marshall Eubanks: NIAC closes July 22.

marshall Eubanks: Thanks!

Jnaneshwar Das: Thanks!

Cameron Grace: Thank you!

Sarah Brandt (Lockheed Martin): Thank you!

Longform Discussion Notes

Deborah – I don't really want to monopolize the conversation. Have we sat together as a group, or has a different group done this, to identify where we want the technology developments, for what purpose? So we have an objective, what are the technologies available to meet that objective, what's the technology that needs further development to meet that objective? Has that been outlined yet?

Angela - Not yet. So that's exactly what I think we need to do, and that's what I was hoping to get, some of those thoughts out today. Like what are some of the objectives.

Deborah – I too don't want to be the only one talking, but that would be the first thing to identify. In terms of Extreme Access, what are our objectives? Why do we need to go to extreme places, what do we hope to accomplish there? I would start just with that. If we could accomplish that, then the technology part will flow down from there. But I think we really need to focus on what we want to do and why do we want to do it? That also might flow into not only the technology but what science do we need to perform to back or define that technology. For example, extreme places, we want to go drill the ice. We want to scoop up some ice in extreme places. What kind of scoop will we need? We need to know the properties of that deposit, is that a fluffy deposit and I need a tiny shovel? Is this cemented in, am I going to have to be able to break off a piece? That will define the properties of the shovel, or if I even want a shovel. Once again what do we want to accomplish, what do we want to accomplish and what's the science that makes us understand how we want to define our tools.

Angela – I think that's a really good point. I agree with you 100%, I think it's important for us to understand why we're trying to go somewhere so that we have a requirement that we can use with the tech.

Deb – I see Marshall wrote a question a list of extreme places, yeah that's a great idea.

Ang – that is a good idea, we've been talking a bit about how to define these things.

Marshall – unfortunately I can't figure out how to raise my hand. Obviously permanently shadowed regions are one, but what about skylight floors, which are the opposite, quite hot. Skylight floors are probably over 200c. That seems like an extreme place to me. Are there other useful extreme places besides tops of mountains?

Deb – One of the places, if we're looking for implanted solar wind materials, if that's something we need as a resource, then swirls might be a place to go to. They are shielded from the solar wind but in some places they are …

Marshall – Are those hard to get to or extreme? I was interpreting that as hard to get to.

Deb – it's a higher radiation environment, so does that make it extreme?

Marshall – Let's say we don't know. We think some are shielded, so maybe they're lower. I heard maybe that's where you want to put a habitat.

Deb – if you look at the swirls the bright lanes are shielded but the dark lanes are not. If that's where the solar wind material is being implanted than that's what you need for your resource, we need to go in there.

Angela – Great points. I think it's an open question on how we define these extreme enviros, these unforeseen things like in a swirl. I do know that the extreme – there is a group for extreme environments and there's overlap, and they're working on definitions of places they consider extreme enviros. It might be useful for us to arrange a tagup with them, maybe a joint meeting to see if they have identified other things that they haven't done.

Josh – Deb you bring up an interesting point. You're advocating you're using the natural environment as the tool for access. The context for a swirl.

Deb – What I'm envisioning is, in my definition of extreme environments, it would be extreme to send a person into a higher radiation environment. it would be extreme to send a rover in a high radiation unless you have components that can survive. With that said, for the dark lanes and the swirls, that's where the solar wind is being redirected. If we need regions of higher hydrogen content, higher OH because it's interacting with the surface that's the place to go. So how do – one of the things we might want to consider is I need to go get the soil from this higher radiation environment, do I have the technology to do it, should I send a robot, send a person? Just a discussion to say there are places where – there are going to be research rich environments that will be more hostile than average. So we have the technology to go to those more hostile region to get those resources.

Josh – I think we're talking past each other. Using the natural environment to shield is a good idea. I think also in this context we're trying to think of the particular technology to actually get there. That the natural environment may not provide.

Angela – I'm going to jump in here, this is a good discussion. Deb made a. good point that there are paces that we want to consider normally, as swirls are not always at the poles, but they provide other challenges, higher radiation, so need to develop technology to deal with that and that's where we want to get to.

Deb – and I think it's … Marshall and Josh that the swirls also have places that are lower radiation. In that way you're using the environment as a tool to provide protection to your robotics, human beings. They're both angles to look at.

Marshall – Do we expect the swirls to have more than twice solar wind hitting them, like what you get at Venus? That seems like an unusual environment but not really that – it's not like it's high radiation in the sense of a nuclear reactor.

Deb – You're not – it's outside my area of expertise.

Marshall – What I'm getting from this discussion is we're morphing from extreme to unusual environments. These are special places.

Angela – I think that's one sense we should keep in mind, special places that require specific technology. That's something NASA wants to develop technology for, but we also want to keep in mind the purpose of LSII, to enable sustained presence at the south pole for instance. That has many more of these typical extreme places, places of long or permanent shadows lots of steep slots, wild temperature extremes. Those are also things we want to not lose sight of. We can do both.

Dave Paige – Wanted to add, to second what Deb was saying about need for on the ground or in the ground reconnaissance of permanently shadowed areas to understand what we're looking at before drilling or other activities. I wanted also to offer another potential candidate extreme environments, those are extreme rocky areas. We find from the LRO Diviner experiment there are recent impacts on the moon that have brought up to the surface large concentrations of boulders but only in a few recent craters. Giordano Bruno is one. There are a few other smaller craters in the maria that are extremely rocky. These are interesting because there are lot of rocks (science), but also from an engineering and survivability area the rocky areas are important because normally on the surface of the moon your temperatures go down to roughly 100K at night for 2 weeks, that's a significant challenge to survivability, but in these rocky areas the temps only get down to about 150K at night because they retain the heat throughout the lunar night. One could imagine if you could find a suitable configuration you could nestle in there and have a much better situation in terms of thermal design and survivability for robots and humans. The challenge is you can't land very easily in the rocky enviros because of landing hazards might want to consider these few extreme rocky environments as potentially interesting for extreme access.

Angela – That's a great point. As my follow up question would be you mentioned a couple things but what sorts of special technology would we want to aim towards? Hazard avoidance, ability to have rovers go over big rocks.

Dave – I've never seen a proposal to go to this place as a mission, but if we're making a catalog of lunar extreme environments I think these qualify and are potentially interesting from a number of perspectives.

DAP was Dave's hand raised.

Marshall also put rille floors.

Marshall – Is it in scope for this group to talk about AGU abstracts?

Angela – Depends upon what sense. Part of our goal is to enable collaborations, so if you're seeking collaborators.

Marshall – just thinking, in other contexts we would talk about other types of groups, talking about putting in a an AGU abstract to talk about where we are and what kind of extreme environments there are.

Angela – that's something this group could be used for. Could be easier to do over the listserv to have more voices easily added.

Marshall – Also external communication – are we going to be talking to other larger sets of scientists here? I don't know what's in scope here.

Angela – Absolutely. I think we could have things presented at places like AGU from the group or other conferences. It depends – the specific focus of our group is not necessarily on the science but on the tech needs, maybe the science drives but how to develop tech needs and how to do some development of those things. I see Rachel put things in the chat I was going to say. As a group I think arranging those sorts of types of papers or abstracts is something we want to facilitate within this group.

Angela – So we have a few more minutes we can chat about things. People have brought up some really good points and identified where we need to go, which is an important first step. I think we identified a few things, I saw Melissa also put in crater walls as difficult for access things.

Marshall – There's also the entire far side. Which right now has to be regarded as extreme because we don't know how to talk to it.

Angela – So do we have to come up with other communication strategies there, that's definitely true. So we've identified a handful of places and I've made a note to reach out to Ben Greenhagen to see the list they're coming up with and send it out to everybody. We have a decent list to start with here, a lot seem to deal with steep slopes or temperatures. PSRs. Want to open it up then, if we think we're looking at a place with a steep slope and is very cold what sorts of technologies are we looking at needing for that? Do we think we already know what those technologies are and whether they're well on their way to being developed? Haven't been developed?

Marshall – Technology to get to the place?

Angela – Either landing, or once we've landed how do we get down into a crater, how do we get down into a lava tube, navigate in the dark, any of those things.

Marshall – We're working on penetrators, things you could throw in places difficult to get into otherwise. I think some people are working on hoppers which are more or less in the same parameter space. There's a question to me of cost – I've heard very elaborate plans for going into Shackleton crater, including beaming power and winches and a large surface structure. I'm thinking in terms of decadal survey, not for this one but the next one.

Angela – Keep in mind – we're just brainstorming so it's a bit of everything. The idea of this is for a near term but also longer term infrastructure. in the near term, technology needs are going to be very different, can we land and drive in the dark. But in the long term maybe it's the other things.

Deb – This comes back to the objectives and why. It's not like we have all the answers right now – we don't. We need to see what our goal /objective is, what technology we have, what science we have, how well we understand these areas to divine the technology. If we don't have the science, what do we do short term to understand these areas to send technology after resources. We may have a reconnaissance stage we need before we can do any resource gathering or research utilization. We've never been in these places. All our knowledge is based on remote sensing from orbit.

Angela – I agree. I guess my question to try to turn that around is what does that reconnaissance stage entail? Do we need to send 10 small rovers into a crater?

Deb – What are your objectives. That's – outside of defining what we mean by an extreme access location, the next step is defining objectives, what do you hope to accomplish. That needs to be done before you can do any tech or give guidance to technology. It might come out that we need to do science reconnaissance. What drives that is what is your objective, your goal for going into these extreme access locations. Going back to get water to drink, to create fuel, different sets of requirements.

Angela – Absolutely. Part of our job is to define what objectives could be.

Deb – Yes. If we got that done by September, that would be a major accomplishment. Defining where they are and why we want to go there, what are our objectives / goals for going into those areas. Then you can start the conversation about technology reconnaissance. What do we know, what don't we know, what do we need to know to define our technology.

Angela – Let's open to the rest of the group, anyone else have thoughts on that?

Wes Fuhrman – We're dealing with a lot of these same sorts of things. What goals are we trying to accomplish. One of the things nice about LSIC is that we can sit on these things together. I've been working with Karl Hibbits who's the ISRU facilitator to figure out what are the actual goals for extraction are and what demands there are in terms of power and transmission of that power. One of the things that could be helpful for us is we're thinking about power, solar, places where we want to max illumination. Want to be next to PSR so we can go down in, are there particular routes into Shackleton that would be better for us? Might be spots along rim, that have more than months of continuous illumination. Could some of the extreme access intuition inform decision on where those might go.

Sarah Brandt – I was going to comment on Deb's comments, not answering Wes' question. I really agree with what Deb is saying about defining objectives. I think the technology is driven by the science. If we can come up with, by Sept a list of objectives then you can go into the next step of maybe grouping these into categories, these are the different objectives and break it down further into what technology you need, then survey what's out there, what needs to be developed, when could we potentially use this and define that maturation plan for the technology once you have those objectives defined. That science, and using the community here to define the science for the technology, is the right approach.

Deb – Just in context to what has been said about chat about objectives being decided by science of industry or HEOMD. It's all of the above. There is a reason for going into an extreme environment. It might be to understand resources, to retrieve resources, are those resources for people to support life, are they to support our next step to Mars, are they to support commercialization of the moon. There will be different drivers for the objectives, not just science or industry. We are trying to put people on the moon. We have to have a reason why we're putting them there. The reason they are there, they will need resource to do what they're supposed to be doing. That's our goal to say, can those extreme environments, we have to access them to support Artemis, how are we supporting Artemis? Am I making sense?

Angela – it's a good point. It's one that when we've been talking to our NASA folks at LSII. What they've said as well Is that part of going back to the moon is scientific, for exploration, for a commercial endeavor. We want to have tech and infra that helps everybody.

Deb – It's really important for this group to define those objectives from all those different perspectives.

Angela – I agree. We have a nice mix of folks from industry, academia, government, etc., so hopefully we'll get to hear all those voices. We have another hand.

Jnaneshwar Das – I'm coming more from robotics side, software development, one thing we can think about is what kind of design and integration tools do we have, can we do end to end simulation and modeling. As we get more data we have a playground to test what we can do on a particular terrain to the extent we can model it.

Angela – That's a great point. Something we want to consider too because was we're developing these technologies we'll need a way to demonstrate and test them, at what scale is that appropriate? I want to circle back to Wes' question. I know we've gone away – I think one of the benefits of the way LSIC is structured, we do have these groups, we don't want them to be stove piped. So the idea of maximizing power via solar for PSR, but how much, should that be a constraint, should they be closer, choose your PSR wisely? We can always do it via email as well.

Marshall – is planetary protection in scope here?

Ang – maybe. It's not necessarily something that we need for accessing these groups. In terms of lunar surface infrastructure could be but I'm not sure it falls in our purview. planetary protection level is maybe in flux. I don't know that it's really what this focus group is tasked to do.

Deb – we probably will have to take into account planetary protection. I was on one of the lunar dialogues before this, that was one of the topics. The NASA admin announced they're releasing an interim directive about planetary protection and the Moon is in there, and they classified it on where you're going, the level of protection you'd need. If you're going into the permanently shadowed area that's a higher protection area. Those directives will have to fold into any …

Marshall – The lava tubes weren't listed but I believe that should be included.

Deb – Released as an interim directive because they will be revisited, revised, and they're changing.

Angela – There's also a point in the chat, not going to read the whole thing, we want to remain flexible, technology development is going to be ongoing and will need to account for things that might change. Including planetary protection levels.

David Akin – I just wanted to make sure, it's been frustrating as a technology developer that NASA has been tightly focused on, we want a left-handed differential grammastat so don't propose anything else. I think for something of this scope I'd like to think that NASA, especially through LSIC, would remain open to concepts that are off the page. That people hadn't considered before. If someone comes in with an interesting technology concept that could enable things we couldn't do any other way, even if what they enable isn't o a list of requirement, it ought to be given serious consideration for support.

Angela – Great point. In all our discussions with the folks at LSCII, part of the point of this initiative is to get those sorts of technologies in the mix. We've had discussions, there are big agencies and NASA has a lot of very smart people but they all work for NASA and maybe there are other voices that haven' been heard yet, and this group can be avenue for that and provide that feedback.