Student questions: Jennifer Heldmann colloquium on "Terrestrial Analog Fieldwork: Overview of Science and Exploration Research to Enable Lunar & Planetary Exploration"
9/25/19

Question 1: What are some of the volcanics the FINESSE has helped identify on the moon using analoging?

For the FINESSE project, we've worked on identifying volcanic features on the Moon and then studying similar features here on Earth to better understand how these volcanic structures form and evolve. Much of our fieldwork takes place in Idaho, at Craters of the Moon National Monument and Preserve, where there are lots of volcanic features that look like lunar features and may have formed in a similar way! Some of the specific types of volcanic features we've studied include lava flows, lava tubes, self-secondary impact craters (e.g., blobs of lava that flyin the sky and then fall on top of the lava on the ground), volcanic vents, rilles, etc.

Question 2: Can you predict what data you currently have about the moon that will change as technology advances? (Like geologic history changing with Clearwater)

Great question! One of the great things about exploration is that sometimes it is hard to predict what will be learned in the future – and that is what keeps science and exploration exciting. ☺ As technology advances then we will be able to send different (and sometimes better) instruments to the Moon to collect different (and sometimes better) data to answer our questions about the Moon.
One area where technology advances are going to help us learn about the Moon is regarding the analysis of samples of the Moon returned to Earth by the Apollo astronauts. NASA was very smart and saved some of these samples (for 50 years!), knowing that technology will evolve and we'll be able to make measurements now that nobody could even dream of 50 years ago. NASA just awarded some scientists funding to study these rocks – and it will be very exciting to see what we learn.

Question 1: Based on what do you select analog sites?

We typically choose our analog sites based on the science and/or exploration objectives. We first outline the goals of our project and identify the questions we want to address. Then we do research to figure out what might be the best analog site (if there is a suitable analog site). We also consider practical issues such as permitting, accessibility of the field site, and anything else that could affect our ability to do our fieldwork. Safety is also a top priority – if the site isn't deemed safe for us to visit, we don't go.

Question 2: Based on the FINESSE project, how was the main objectives met?

For the FINESSE project, we meet our main objectives by conducting research and providing input and/or answers regarding our stated research questions for both science and exploration. These findings are then published in the literature, presented at meetings and conferences, and provided to NASA through various groups (e.g., teams planning human exploration missions, teams working on robotic mission planning, etc). We also are required to submit "progress reports" to NASA in order to document our work and how we're achieving our objectives.

Question 1: Why is there not a great out reach about these programs that you are offering?

Hopefully we are able to do more education and outreach for all of our NASA projects. The work that NASA does is very exciting and it is great to share this excitement with the public. For FINESSE we have done a great deal of outreach, including working with students and teachers and bringing them to the field, giving many seminars in different venues such as schools, museums, national parks, etc., hosting NASA events open to the public, etc.

Question 2: What did the water at the bottom crater looked like that we were able to identify it to be water?

Regarding the crater on the Moon where we found water, this crater is VERY cold and so the water was in the form of ice. We used a technique called "spectroscopy" to look at the light bouncing off the ice crystals which is a common technique to tell the composition, in this case to confirm the presence of water.

Question 1: Based on planetary research outside the moon and mars, are there any other terrestrial areas to analog that will simulate water content?

The choice of an analog site depends on the research questions you would like to address. For example, if you want to understand a rock glacier on Mars, you may decide to study a rock glacier on Earth. If you are interested in understanding subsurface ice on another planet, you may decide to study subsurface ice in Antarctica. A nice thing about using terrestrial analogs is that since these locations are on EARTH, we can actually GO there and make measurements and understand the system, which may help us understand how similar systems work on other planetary bodies.

Question 2: What is the difference in instrumentation used to determine the water content in the moon verses Earth when analoging?

For our research, we use the same techniques and instruments to determine water content on the Moon versus Earth. One of the things we want to test is how well do these instruments work for detecting water, and that is something we can measure and test here on Earth before sending that instrument to the Moon.

Question 1: How good actually are analog studies when it's almost impossible to know what the actual surface of an extraterrestrial field looks like?

Correct – we often do not know EXACTLY what the surface of an extraterrestrial field is like, but we DO have some idea. Typically we have already sent robotic missions to these other planetary bodies (orbiters, rovers, etc.) that have worked to characterize the surface, so we use that data to learn as much as we can about the surface.

Question 2: What factors are most important in deciding what the best place to do an analog study would be?

In choosing an analog site we focus on identifying locations that can help us to address our research questions. Layered on that we consider other issues such as safety (if it’s not deemed safe for us to work there then we don’t go), site accessibility, permitting and logistics, cost, etc.

Question 1: How has the diverse backgrounds of your team benefit you work, i.e., what specifically been beneficial about having a team of interdisciplinary scientists, rather than just a focused in-depth study?

For our analog work, the questions we are trying to address are very complex and intrinsically interdisciplinary in nature. We address different types of science questions, different mission operations research, different types of technology used at the field sites, human factors research, etc. Having personnel with varied backgrounds is crucial, because all these different parts of the project have to work together in order for us to be successful. We also tend to come up with better ideas to complicated problems when a lot of different perspectives are represented, so interdisciplinary researchers help make our programs more robust.

Question 2: How can grad students get involved in your analog field work?

We already have grad students involved in analog field work – so email me! ☺

Question 1: What is the difference between enhanced Hydrogen and regular Hydrogen?

When we talk about "enhanced hydrogen" on the Moon, really we just mean places that have more hydrogen than most other parts of the Moon. Hydrogen is hydrogen all over the Moon (and throughout the entire Universe) – so in this context we are talking about the amount of hydrogen.

Question 2: If you are using a rover to do analog tests, do you then need to build an entirely new rover to send to the planetary body it will be used on?

Yes. The rovers we use in the field are typically simpler and are not flight-qualified pieces of hardware. The rovers that we send to the Moon will be different (although may be based on rovers tested in terrestrial analogs as we learn what works best) – but the rovers on the Moon have to be designed to withstand the harsh conditions of the Moon (e.g., radiation environment, changing thermal environment, be equipped with robust communications systems to talk to the Earth, be able to function in the vacuum of space, etc).

Question 1: Do you hope to use the moon or other planetary bodies as analogue sites in the future?

Yes! It would be great if we got to the point of doing relatively "routine" research on the Moon – and then using the lessons learned from lunar work to inform missions ever further out in the Solar System!

Question 2: What has been the most successful analogue site to date?

I think it is hard to choose one analog as "most successful", because there is so much work being done in a variety of analog environments on Earth, and each analog has different goals and objectives.

Question 1: If there is less than 5-6 wt. % water on the lunar surface, how are you going to extract enough water for both human use and rocket fuel? At that concentration, you'd need to process about 20kg of dust or rock to get a single liter of water. If the concentration of ice is that low, won't that require designing some sort of mining vehicle/aparatus that is capable of collecting and processing a lot of lunar soil/rock to extract the water from?

Correct – we will need mining vehicles and apparatus to extract the water ice on the Moon, transport the resource to a processing plant, and then process the water (e.g., remove contaminants and such) in order to produce a useable product.

Question 2: You said you are using the mojave as an analogue for the lunar surface for your water-seeking rover. How does the fact that water present in the soil of the mojave is present in the liquid/vapor state as opposed to ice as on the moon effect how your neutron spectrometer or other instrumentation measures the water?

Correct – the water in the Mojave Desert is at a similar concentration as water on the Moon (5-6 wt %), but in a different form (the Mojave water is primarily bound in clay minerals whereas the lunar water is in the form of ice). However, in terms of prospecting, for the most part water is water. The neutron spectrometer is sensitive to hydrogen – and vapor, liquid, and ice water are all made of H2) (contains hydrogen, which is what the neutron spectrometer will detect). The near-infrared spectrometer is also sensitive to water bands (and slight changes can tell you if it's ice, vapor, etc). So we are aware of these slight differences and take these into account in any analysis.

Question 1: How do you decide which analog site will be the best fit for a given mission and what criteria must it meet?

In choosing an analog site we focus on identifying locations that can help us to address our research questions. Layered on that we consider other issues such as safety (if it's not deemed safe for us to work there then we don't go), site accessibility, permitting and logistics, cost, etc.

Question 2: Could using water already on the moon have an unforeseen environmental impact on the moon?

This is an important point and critical to consider. We have a relatively good understanding of the lunar environment (which is drastically different from here on Earth) – and folks are actively working to ensure that any lunar resource use is done in a sustainable and responsible manner in order to preserve the integrity of our Moon for generations to come.

Question 1: What does a mission do if there are no reasonable analogues on earth for the mission destination?

Not all missions require analog research, so if there is no acceptable terrestrial analog, that is ok. Another option when testing is required or research questions need to be addressed is to use laboratory chambers that simulate the conditions on other planetary body. We have chambers for a variety of different planetary objects, and sometimes this is the best way to address any science or exploration questions.

Question 2: For finding analogue locations on earth what are the most important aspects to look for?

In choosing an analog site we focus on identifying locations that can help us to address our research questions. Layered on that we consider other issues such as safety (if it's not deemed safe for us to work there then we don't go), site accessibility, permitting and logistics, cost, etc.

Question 1: Are there any planned VR/AR projects in the works for planned surface missions to the moon or Mars, for example to plan out an astronauts travel for the day using 3d modeled DEMs in VR.

Yes. VR/AR is an active area of research and many folks are working on figuring out how to infuse VR/AR into mission operations for both human and robotic missions. Here is a link with a lot of additional information of a particular mixed reality package called OnSight which allows people to virtually walk on Mars, for example:
https://mars.nasa.gov/news/8374/mars-virtual-reality-software-wins-nasa-award/

Question 2: What is the greatest challenge you face in integrating science with the human element of exploration?

I think the greatest challenge integrating science with human exploration is bridging cultural gaps between the two communities. Even things such as the vocabulary used by the two different communities can be a challenge. This is one reason it is so important going forward to have people trained in an interdisciplinary setting, such that they are able to work in both worlds, so to speak.

Question 1: Is NASA currently working on instruments that will allow for faster communication between the moon/mars?

Yes. In particular, NASA is working on optical communication systems which will allow for increased bandwidth & data rates for the Moon and Mars. More information can be found here: https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_opticalcomm_benefits.html

Question 2: Is there an estimated timeline for building a habitable moon base?

The timeline that NASA has released is sending the first woman and next man to the lunar south pole region by 2024. Sustainable exploration would follow after that with longer duration missions and eventually sending more people to the Moon.

Question 1: Which mission would you say started the partnership with human exploration?

Even from the very first human missions to space, there has always been a strong interdisciplinary partnership. Sending humans to space is highly complex and involves skill sets from a vast array of different disciplines, and so having people with different backgrounds working together is an inherent component of human exploration of space.

Question 2: During the missions how long are the delays when speaking with the astronauts for "direct" communication?

The time delay for communications between a planetary surface (the Moon, Mars, etc.) and people back on Earth is fundamentally limited by distance and the speed of light. We refer to the OWLT (one way light time) which is the amount of time it takes for light to travel from Earth to the planetary surface. On top of the OWLT, there are also other practical considerations, such as limits on the availability of receivers on Earth to receive the data (especially when there are many different missions happening at the same time, and NASA must prioritie which data is returned and when). NASA uses the Deep Space Network (DSN) for space communications. More information on the DSN can be found here:
https://deepspace.jpl.nasa.gov/

Question 1: Why are the rover camera feeds in black and white?

For our field test, the rover camera feeds were in black and white because our science objectives didn't require color imagery, and also the black and white images use less bandwidth to transmit which was advantageous for our communications system.

Question 2: How do you harvest water from a 6% water content piece of ice on the moon?

There are many ways to extract water from a 6% water ice content piece of the Moon. NASA is currently working on new technologies to extract water ice in the most efficient way possible. More detailed information on ISRU (in situ resource utilization) can be found here: https://www.nasa.gov/isru

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Question 1: Are we as humans limited to size when it comes to exploration?

Regarding exploration, I think we are mostly limited by our imaginations. We need to be visionary and think about where we want to go as humans with space exploration, and then do the technical work to figure out how to make those dreams a reality.

Question 2: Do we still intend to make lunar missions or are we focused as humans for mars or other bodies within our solar system?

NASA's plans right now are to first send humans to the Moon so we can learn to live and work effectively on another planetary body, and then use that knowledge for future human missions to Mars (and beyond).

Question 1: How can VR and AR be used to help investigate analyze subsurface data, such as with hydrosphere systems or tectonic systems?

VR/AR has a variety of exciting possible applications. In this case, I can imagine VR/AR being useful to let a person explore the subsurface as if you were really there, being able to see and examine subsurface structures (hydrosphere systems, tectonic systems, etc). in ways we aren't able to visualize now.

Question 2: Can these technologies eventually be developed to even assist in the geologic classroom environment by providing a 3D environment of the subject matter?

Yes! The use of VR/AR in the classroom would be a great application of this capability. VR/AR would allow us to "bring" different field sites or planetary surfaces to students in their classrooms, and allow the students to explore and study these areas in new and exciting ways.

Question 1: What troubleshooting problems do you face in real time when you collect river data in a steep topographic area?

I have collected river data before by standing in the middle of a river or stream to measure flow rates, and it can be challenging to stand in flowing water. This is made even more challenging when you have to stand on steep topographic terrain.

Question 2: Most of the terrain tested is land locked, is there any merit to conducting tests in coastal, underwater terrain that would be analogous to deep space tests?

Yes. In fact, NASA has recently conducted analog tests in an underwater environment as an analog for underwater oceans in the outer Solar System. Check out the SUBSEA project: https://spacescience.arc.nasa.gov/subsea/

Question 1: What is the most important type of sample astronauts would need to collect during EVA missions and are there any that astronauts should avoid collecting?

The samples collected by astronauts out on EVA depend on the science questions being addressed during that EVA – so the answer regarding which samples are most important will be different every time.
In general, astronauts should avoid collecting any samples that in any way would pose a safety hazard.

Question 2: How can we assure that certain terrestrial analogs are "true" analogs to another planet?

There is no “perfect” analog, e.g., there is no site on Earth that is EXACTLY like another place on another Solar System body. Therefore, when choosing an analog site it is important to identify those site characteristics that are most important to the science or exploration questions you are trying to address with the analog research.

Question 1: I am part of a student organization here at Arizona State University called Helios Rocketry. Helios is competing in the Base 11 Space Challenge. This is a competition for a student-run university team to design, create, and launch a liquid propelled rocket to 100 km (the Karman Line). We have been working on this project for over a year and plan to launch in December of 2020. The current altitude record for a student-lead team of this kind is 40,000 feet. Keep in mind we are planning on making it to 330,000 feet. We currently have 30 active members and 160 more have shown interest during this past Passport ASU. We have already received funding from KEEN and sponsorship from DEWESOFT, IMS Metals, and other companies in the Phoenix area. We are currently looking for a payload we could take on the ride to the Karman line. If you have questions or other ideas about how Helios Rocketry and SESE could collaborate please let me know. Can Helios do anything to help NASA's Analog Research?

Wow – this is a great question! It sounds like it would be useful for you to network within the community and seek investigations that could be flown as a payload on your rocket launch. I think giving talks at conferences, events, etc. and spreading the word about Helios and the launch opportunity is a great idea. I am in the planetary science world, and if you wanted to interface with planetary scientists, I would suggest looking at the annual Lunar and Planetary Science Conference (LPSC) in Houston, TX and the NASA Exploration Science Forum (hosted by NASA's SSERVI – Solar System Exploration Research Virtual Institute). ASU also has a host of world-class planetary scientists and they can likely help as well.

Question 2: Are there any specific positions for a structural engineering student in any of your field operations?

We do work with engineers on many of our projects since the field deployments often require signficant amounts of equipment to be operated in the field.

Question 1: What are some examples of machine learning domain adaptation utilizing data collected from analogs?

One example where we used machine learning in the field was with an instrument called TextureCam which we mounted on a rover and drove across desert pavements. TextureCam was "trained" to autonomously identify different rock abundances and types of pavements within different images.

Question 2: How are good analog sites found and how are the limitations of the analog site handled?

In choosing an analog site we focus on identifying locations that can help us to address our research questions. Layered on that we consider other issues such as safety (if it's not deemed safe for us to work there then we don't go), site accessibility, permitting and logistics, cost, etc. We are always aware of the limitations of an analog field site, and these limitations must be taken into consideration when drawing conclusions from any of our analog field testing.

Question 1: Is the virtual reality you are using projecting a mosaic of the photos using a pointcloud mesh or is it a stitching of the photos? We generated a VR scene with the pointcloud mesh and it pixelated/blurred our images to the point where it was not useful for outcrop scale observations. I'm interested in your process.

For the VR we've been working on lately, we collect LiDAR data in the field and that data is then rendered in VR. The resolution of the LiDAR data is quite good (sub-cm in cases), and so the rendering of the field site is very realistic and allows for detailed field measurements in VR.

Question 2: Beyond ice and water, are there other in situ resources you will be investigating with the RESOURCES program on the Moon?

Good point that there are other possible resources on the Moon (minerals as one example). We will assess mineral ISRU in RESOURCE, but the bulk of this project will be focused on water ice as a resource.

Question 1: How do you deal with presence of plate tectonic movements on earth when searching environments that are similar to earth's on planets/ moons with no active plates?

For our analog research, it is OK that Earth has plate tectonics and other planetary bodies (such as the Moon and Mars) do not. Often we are studying features or addressing research questions which are not dependent upon the presence (or absence) of plate tectonics, so this is OK for our research purposes.

Question 2: Does presence of life on earth make getting analog environments on other planets harder?

For our research, it is perfectly fine that Earth has life! Life on Earth is fantastic, and I am glad we have it. ☺ That said, much of our research focuses on geology, so it is ok that life is also present. The fact that we have life on Earth is also useful for terrestrial field studies of life in extreme environments and astrobiology (e.g., studying the limits of life and how/when/why life might exist in other similar environments on other planets).

Question 1: What kind of the on-the-fly / in-situ changes do researchers make on space analog missions?

For our space analog missions, we make all sorts of on the fly / in situ changes as needed (and that are acceptable within the bounds of the analog simulation). The types of changes we have made in the past include fixing hardware, software tweaks, changes to operations, etc.

Question 2: What is the best way for students to get involved in FINESSE and similar organizations – submit proposals and apply?

For getting involved in analog missions, the process is likely different for each case. One could start with contacting the analog leadership team and asking about opportunities. Sometimes there are team members at universities who include students in the research. Sometimes there are posted opportunities where students can apply to participate. Sometimes there are opportunities through State Space Grant offices or other entitities. Engaging with the folks conducting the field campaigns and learning about their work and opportunities to participate can be a good way to get started.

Question 1: What's the main issue that is hard to conduct the analog exploration on Earth?

Analog fieldwork can be challenging, and there are a lot of different issues to be addressed in order to accomplish a successful analog field campaign. A good leadership team can help navigate these issues, though, and will take into consideration all aspects of analog research including, but not limited to, analog site selection based on the project goals and objectives, field site permitting, logistics, safety, etc.

Question 2: How long does it to train a astronaut to realize how to conduct those works they need to do for space mission?

The amount of required training for an astronaut varies depending on their experience, the goals of their mission, etc. Astronauts train for YEARS, though, before they fly in space.

Question 1: How can we get involved in one of your trips?

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Question 2: What do you do to make sure your data is correct for the environment you are looking into and not polluted with data from things in the analog environment that isn't the same?

For each analog field investigation, we must be very aware of the analog environment and cognizant of the aspects of that environment that both do and do not simulate the conditions on another planetary body. Armed with that knowledge, we analyze and interpret the field data appropriately in order to draw conclusions that are most relevant for the science and/or exploration questions we are trying to address.

Question 1: Is there a circumstance when field testing isn't possible for a specific mission or piece of equipment?

Yes. Field testing is not required for all missions or equipment, so is only done when it makes sense to do so.

Question 2: Has there been a time when the use of hand measuring devices were more useful than the use of LIDAR when surveying?

Yes. Depending on the information required, we use different instrumentation. For example, if rock composition is needed in order to determine whether or not to collect a sample, a hand-held spectrometer might be more useful to use than a LiDAR.

Question 1: How can we improve our robotics to get better observations of gas giants?

Improving robotics for better observations of gas giants (or any other application) can start with a set of requirements that are needed (e.g., what specifically needs to be made "better"). Then engineering solutions can be designed to meet these requirements.

Question 2: What can studying the moon's composition tell us about Earth and our solar system?

Studying the Moon (including it's composition, but also impact history, evolution, etc.) is very informative because the Moon actually formed when a giant impact hit the early Earth and essentially knocked material off the Earth to form the Moon – so we have a very intricate shared history with the Moon! The Moon also lacks processes that can destroy rocks like on Earth (e.g., wind, rain, plate tectonics, etc.) so the Moon has VERY old rocks that are well-preserved and act like a time record of the early action happening when the Earth and Moon were still very young.

Question 1: Does the fact that the vacuum tests and the analog field experiments are done separately impact the outcome of the tests?

Typically field tests and vacuum tests are conducted to address different questions, so it is OK that these are done separately, and both types of testing can inform the mission in different ways.

Question 2: Will drones be used on other planets in the forseeable future, or is the plan to stick with rovers?

On the Mars 2020 rover that will be launching next summer, there is a small helicopter that will be tested and flown on Mars. More information can be found here: https://www.nasa.gov/feature/jpl/nasas-mars-helicopter-attached-to-mars-2020-rover

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Question 1: What determines the astronaut crew size for exploration missions?

There are MANY factors that determine the crew size for exploration missions. Considerations such as vehicle size, mission objectives, expertise required, human factors, cost, risk, etc. are all important when considering the number of people to send on a mission.

Question 2: What target regions are next for analog projects?

The target regions for any analog project depends on the goals and objectives for that particular area of research. Different projects happen every year which go to different areas around the globe, depending on the needs of each program.

Question 1: What was the most effective outreach program you were involved in?

Good question! There have been a variety of outreach programs that have been excellent and I've been glad to work on them. I enjoy projects which bring students and teachers to the field and within NASA projects with us, so I have enjoyed partnering with universities and also conducting the Spaceward Bound program.

Question 2: What project were you the most proud to work on?

I am proud to have worked on the LCROSS (Lunar Crater Observation and Sensing Satellite) mission. Within the span of about 3 years, we came up with the mission idea and flew the mission to the Moon, which is pretty quick for a planetary mission. We revolutionized our understanding of water on the Moon with this mission, so that was exciting as well.

Question 1: What is the approximate cost benefit from inferring planetary structures using terrestrial analoging as opposed to getting accurate results with planetary probes?

The cost and risk of conducting an analog field deployment is much less than sending a space mission to another planet, and so sometimes it makes sense to do intial testing and research in an analog setting first before going to flight.

Question 2: Is there any other technology in your field that you see VR playing a beneficial role in terms of data collection?

In the future I see VR playing an even larger role in our field science. We can collect high-resolution data in VR and then make measurements later, back home in the comforts of our offices or labs, instead of having to spend so much time out in the field. Having the field site in VR also gives us more time to make field measurements, because time in the field is often so limited and precious.

Question 1: Is there a reason that we don't send scientists in person to test the rover's accuracy in the field after trial runs?

Whenever we have a rover in the field we have rover engineers on site and so they are best poised with the knowledge and experience to handle and operate the rover during the field test. Sometimes we do send scientists to the field after the field test to ground truth and test the rover's accuracy and see how well the scientists did using data collected by the rover. This is usually a very useful and informative exercise.

Question 2: With advancements in technology, would it be possible or useful to create a virtual reality simulation of the martian surface or of the lunar surface by using rover and satellite data?

Yes! In fact, we have already been doing this, and the surface of Mars has been rendered in VR. See this site for more info: https://mars.nasa.gov/news/8374/mars-virtual-reality-software-wins-nasa-award/

Question 1: Will the moon ever be used as an analogue site in the future?

Yes – I hope so! NASA plans to send humans to the Moon and then on to Mars, so in a sense, one could consider the Moon as an analog for future human exploration further into the Solar System.

Question 2: What kinds of scientific questions/topics could be answered/helped if you could use the moon as an analogue site?

There are many aspects of research where the Moon could be used as an analog site. NASA plans to send humans to the Moon to learn to live and work on another planetary surface, which will provide feed-forward information for planning missions further out into our Solar System. Topics that will be studied include, but are not limited to, human landing systems and habitat design, human factors, tools and equipment required for astronaut use, optimal field instrumentation for enabling science, communication and navigation technologies, life support systems, etc.

Question 1: Are there situations that arise in which several different terrestrial analogues can be combined in data to approximate operational environment of the equipment?

Yes. Since no one site on Earth is EXACTLY the same as a place on another planetary body, sometimes different analog sites are useful to consider different aspects of the planetary environment. We have this situation now in trying to find an analog for lunar polar ice. We can go to Antarctica where the form and stratigraphy of the ice is similar to the Moon (but the ice concentration is higher in Antarctica than on the Moon), or we can go to the Mojave Desert where the concentration of the ice is more similar to the Moon (but the form of the water is different).

Question 2: Given the difficulty in envisioning all environmental conditions that a piece of equipment will face, is there ever any consideration given to testing equipment in an analogue that is far outside a given mission profile to test for contingencies?

When choosing an analog site for a project, we consider and try to approximate the various aspects of the planetary environment that are most relevant for our research and/or testing objectives. However, our knowledge of environments on othet planetary bodies is not perfect, and so we recognize that there may be some differerences in reality vs our understanding of that other world, and so it is OK to have a range of environmental conditions deemed appropriate for an analog study. Also, equipment flown in space is routinely first tested on the ground in harsher conditions than are expected to be experienced during flight in order to make sure that the equipment will continue to function during the space mission.