Geology: Field Investigations to Enable
Solar System Science and Exploration

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Coordinator: Recordings have started. All lines are open. Mute your lines when not speaking. Press Star 6 to mute and un-mute. Press Star 0 if you need assistance or to stop the recordings when the call is over. You may begin.

Anita Sohus: All right. Thank you very much. And also wanted to add please do not put us on hold because that interferes with hearing the speaker and also with getting a good transcript and recording.

So welcome everybody. This is Anita Sohus down at the NASA Jet Propulsion Laboratory in Pasadena, California. And really pleased this morning to have Dr. Jennifer Heldmann from Ames Research Center up at Moffett Field and Andrea Jones from Goddard Space Flight Center in Greenbelt, Maryland.

So we have three NASA centers here collaborating to bring you some great insights today. Andrea, do you want to introduce Jennifer?

Andrea Jones: That would be great. Thank you. So it is my pleasure to introduce Dr. Jennifer Heldmann who as Anita said is a Research Scientist at Ames in the Division of Space Science and Astrobiology. Her primary research focus is on the study in volatile deposits on the moon and Mars as well as understanding planetary geomorphology as an indicator of geologic processes working to shape the surfaces and interiors of planets.

She's also keenly interested in human and robotics solar system exploration and conducts research in field work in amazing places, which I will let her talk to you about and trying to optimize exploration strategies and architectures.

So she is going to be talking to you today about FINESSE, which is the Field Investigation to Enable Solar System exploration or Science and Exploration, which is part of NASA's Solar System Exploration Research Virtual Institute. So NASA SSERVI Team. So Jennifer is the PI of the FINESSE Team and she is going to talk to you about that today.

Dr. Jennifer Heldmann: Great. Thank you Andrea. Thanks to Anita for helping to organize this entire seminar series, which is a really great way to help get the word out about some of the fun and exciting work that we're doing here at NASA with some of these projects.

Slide 1: So as Andrea mentioned, I'm leading this team called FINESSE. And if you have you slide set up, on the first slide you have the FINESSE logo there. And we have a great team, which I'll show you some of the members of the team.

And hopefully through this talk I can give you an overview of what we're doing on the team and then also especially towards the end highlight some ways in which we're trying to promote more education and public outreach and participation from folks who might be interested in joining us and helping out on this project.

So if you go down to Slide 2, here's the logo for our new NASA Institute called SSERVI, the Solar System Exploration Research Virtual Institute. And we have an award under this umbrella.

And so this allows us to bring together collaborators from multiple different institutions, from multiple different countries and to come work together. It's not a brick and mortar type of institute. It's virtual. So we use online collaborative technologies in order to carry out our work.

And if you go down to Slide 3, here's just a smattering of the science teams that we have on FINESSE. I won't read everyone's name but as Anita even alluded to on the beginning of this call, there are multiple NASA centers involved in this project, multiple space agencies, universities, etc, etc.

And so we are a joint team that has both science. We have a suite of astronauts that join us out in the field as well to learn how to do field science. And if you go down to Slide 4, we also have an exploration team. So part of our work is trying to learn how to do science in the context of human exploration and robotic exploration on the moon, on asteroids at Phobos and Deimos, etc.

And so we team our exploration folks with the science folks so that we can go out and use analog locations on the earth, and I'll explain what I mean by that, in order to learn how to do this science beyond low earth orbit.

So if you go down to Slide 5, I just want to point out we also have international partners and we have a strong partnership with Canada just to the North of us, with Korea; some great instrumentation coming from there.

And then we also have our EPO Team, which Andrea is leading from here at Goddard and several other groups. So it's a broad perspective with a lot of different investigators. So you can see the breadth and depth of the work that's going on here.

If you go down to Slide 6, this just gives an overview of what this entire project is all about. It's a science and exploration field based research program. So we actually go out and dig in the dirt and pick up rocks out in the field.

And we do this so that we can learn how to prepare for both human and robotic exploration of the moon, nearest asteroids and Phobos and Deimos. And we go in with the overall philosophy that science enables exploration and then exploration enables science.

The two are intertwined because when we go out, when we go back to the moon, what are we going to do on the moon? We're going to fieldwork. We're going to do geology. We're going to learn about the moon. And we have to learn how to do that in the context with all the constraints of working in a space suit, driving rovers, communications delays, all those types of things.

So if you go to Slide 7, I outlined what are our prime research objectives for both science and exploration. And I might sound like a broken record; science and exploration, science and exploration. But they really go hand in hand and that's the crux of this whole project.

So for the science aspect we're trying to understand the effects of volcanism and impacts and dominant planetary processes. These are the processes that have most affected the moon, the earth, asteroids and Phobos and Deimos on the surface that we can see and study. And so we're going to focus on that. And we'll talk more about the science in a few minutes.

And then also the exploration part; we talk about the ConOps. That's our shorthand for concepts of operations. What do we need to do and how do we do it so that we can enhance scientific return when we send humans and robots out into space?

If you go to Slide 8, let's talk a little bit about the fieldwork. Let's lay the background for what we're actually doing. And actually we're going to focus on volcanics and impacts.

And it turns out that the records on earth are pretty important for understanding these processes throughout the solar system. So if we can't explain them on earth and we don't know how they're working here, then we are hard pressed to understand how volcanism is working on the moon.

And it's the same physical processes that work on the moon, on the earth, it's the same underlying geology. So we're going to take advantage of the fact that we actually live on the earth and we can get some firsthand information about these processes.

And if you go down to Slide 9, this is just talking about how we're going to actually do this, how we're going to actually merge the science and the exploration. And we're going to decipher the impact and volcanic questions and we're going to address new questions too. That's one of the great things about scientific research is the more we learn, the more we learn that we don't know.

We realize there is a lot that we don't actually know. And that's part of the scientific process where more questions come up as we address other ones.

So if you go to Slide 10. So I mentioned that we are going to do fieldwork on the earth. So the first order question we had to ask ourselves was where are we going to go to do this fieldwork.

So we went through a site selection process, and I'll just walk you through. I won't read all these words but you'll have them for you records. And look at some of the criteria that we use to choose of field sites.

Number 1 is science. It has to obviously be relevant to the scientific goals that we're looking for. So we need to find somewhere on earth that has the relevant volcanics or that has an impact structure.

If you go to Slide 11, exposure. So essentially you have to be able to see and study the geologic features you're looking for. If they're buried by dirt then that's not a very good place to go if you can't actually access them. If they're totally vegetated and covered in trees and shrubs and you can't get to the rocks that you're interested in then that's not a very good place to go. So we had to think about the exposure.

Go to Slide 12, the accessibility. This is actually a pretty important issue for us. Don’t go to a country that is designated as not a safe place to go because there are some great geologic outcrops there but the safety of our team comes first. So we need to go somewhere that we can actually work.

Sometimes we try to avoid places that are logistically difficult or too expensive to get to or hazardous. And also there's permitting issues. So we have to be good stewards of our planet. And so we can only go places where we can actually do the work that's required to answer the science questions. So if it's not an accessible place then it's not sensible or safe to consider it for our analog work.

So you go down to Slide 13. There's also the preservation and availability of the science targets. So the geology that we're looking for has to be relatively well preserved. It can't be too weathered. It can't be too eroded. Otherwise the data that we're trying to collect it just won't be there anymore.

And then Slide 14 is previous work done. So the analog missions that we're talking about are science driven. We're going there primarily to answer the science to the first order and we're going to do it in the context of exploration.

And so for the high fidelity of our mission operations we would like to go to places that are under explored or haven't been well investigated particularly recently with modern techniques and modern ways of doing the science.

And so this is going to allow us to learn new things. So we're trying to look for places where there hasn't been a whole lot of work done and it's ripe for the science picking so to speak.

So going through all of those five criterion we set up a nice big matrix and looked at a bunch of different sites and ranked them and had lots of discussions.

And if you go to Slide 15, you'll see that for our volcanic field site we chose Craters of the Moon, which is in Idaho and the surrounding East Snake River Plain. It's a relatively young basaltic volcanic system. It has a host of different types of volcanic processes that have gone on there. It's well exposed. And it's a great analog for the moon and other planetary bodies. And I'll show you some images there.

And so based on this, Craters of the Moon turned out to be a really great place for us to go. It's also accessible. We can get permits. The science is great. So this turned out to be a good choice. And so that was for our volcanics.

And if you go to Slide 16, you'll see where we're going for the impact studies. This is the West Clearwater Impact Structure. It's located up in Northern Canada up in Quebec. It's very interesting for several different reasons.

You can see in the picture on the right hand side there's the West Clearwater Impact Structure and the East Clearwater Impact Structure. And they're lakes now. They've now since been filled in with water. But you can see around the rim, around the circle, that they're exposed on rock layers.

And also at West Clearwater you can see there is a ring of island in the middle. And that's from the uplift from the crater itself. So there's some more exposed target rocks there, which is really interesting.

And it's about 300 million years or so give or take. That's one of the things we're doing is better age dating of when this impact actually occurred. And it has one of the best records of impact melt rocks and breccias known on planet earth.

So that was very interesting and why we wanted to go there. It's in a very remote place up in Quebec. So it was pretty hard to get to. You can get there. It requires floatplanes and helicopters and all sorts of fun things like that.

But because it is relatively difficult to get to, not impossible, but it's a little bit harder, it hasn't been studied a lot. It's been decades actually since people have gone there to really study the impact dynamics.

And so this was a place where we knew that we could go and learn a lot about impact studies. So we chose to go to West Clearwater. And you can see that - it's one of the outstanding questions. There's these two impacts.

And so this is one of the things that we're addressing where these two impacts form at the same time. Was it like a binary asteroid that came and hit or were they formed at two different times and this was just a very unlucky place to be? And so this is where some of the geochronology will come in to age date these two structures.

So if we move on to Slide 17. I want to step you through some of the reasons why we're going to Idaho and show you some of the analog features that are there that are relevant to the moon.

As I mentioned, we're focusing on the volcanics. We're investigating cinder cone, lava flows, lava tubes, etc, and comparing them to analogous features on the moon.

So if you go to Slide 18, here's just a picture of showing some of the variations at Craters of the Moon. And for the volcanic science we love this because there are so many different types of things to look at.

You can see up in the upper left the broker top flow. You've got these big blocks of wraps of lava that have broken apart. There's the Wapi Lava Field where you have these smooth flows that are coming down.

There’s a big craters flow, which you can see is very difficult to walk on. It's very blocky, lots of rocks. There's the King's Bowl Lava Field where we're focusing a lot of our work.

And so there's variations in the morphology. There's also variations in the composition as listed down here; differences in the scale - the roughness scales that you're looking at. And this all plays back into how these (volits) formed. So this is a volcanologist's dream.

And if we go to Slide 19, here's just some other features that you can see up at Craters of the Moon and the surroundings. This is a big chunk of rock, this image that was ripped out and carried kilometers from the vent when this eruption happened. This is eight meters high.

So you can see the magnitude and the amount of energy that was associated with these eruptions. And so you can see these blocks that are being thrown out.

So actually characterizing these blocks and trying to understand the dynamics of how these flows actually happened and how you get these rocky blocky drops of rocks that formed in all these different places and then compare that to the moon too. We can validate our models on the earth where we can do In Situ Measurements and then take that and apply it to the moon.

If you go to Slide 20, here's just a nice comparison of features. You can just look at them by eye. Look at the morphology. And they look similar. So you can see in the first panel - you can see that the earth pictures are on the top. The moon pictures are on the bottom.

You can see cinder cones on the earth and you see very similar features labeled A. And then just below it labeled C there's a very analogous cinder cone on the moon.

Same thing of Marius Hills. All these volcanic features on the earth where you see similar features that are on the moon. And so it's the similarities and morphology that we're focusing on to find where we look at Craters of the Moon and then apply that directly to specific features on the moon itself.

If you go down to Slide 21, here's just some more details. So here's the cones that we're seeing in Marius Hills. That's on the left. The scales of these are different because you can see there's a little black circle that's outlined in yellow that's showing the size of the cone in Idaho. So it's smaller in Idaho. But the morphologies are very similar. And you can compare that to the cone in Idaho is shown on the right.

So you've got this horseshoe morphology. You can see that there are flows surrounding it and flowing around it. And so we want to understand how these structures were built.

If you go to Slide 22, here's another analog of a chasm. So you can see here's the Marius Hills on the left. There's a rille that's coming out from a vent and you can see again the bigger size on the moon, the Inferno Chasm, which is in Idaho is shown in yellow.

You can see the size superimposed on the lunar image. And then on the right hand side you can see the Inferno Chasm at the Craters of the Moon site. Very similar morphologies. You have that circular rimless event area where things emanate from and then the channel meanders out of there. So we see similar features again. So want to understand, okay, how did these form the Idaho and what does that mean for the moon.

We go to Slide 23. We're looking at impact melt. So again, you see here the impact melt on the left that's on the moon. This is near Tycho Crater. And you can just see - I mean you can see the lighter tone material that just flowed in the middle of this image.

And we see very similar features happening at Craters of the Moon, which is over on the right hand side in Idaho. These ones have similar scales. You can see the textures on them. You can see the ripples that were forming when this was flowing. You can see the embayment on the edges of the flows.

And so we want to go to Idaho where we can actually walk on these and collect data and try and learn more that we see in the remote sensing data from the moon.

If you go to Slide 24, we actually did our first round of fieldwork last year in 2014. So this project was just getting started. So this was a good time for folks to learn about this and think about how you might like to be involved.

This is the King's Bowl lava mountain. So this is remnants of a lava lake where it was high standing, where you had lava flows that were coming in and not solidified into these rocks.

And what we can do is take topography profiles across these so we can get the topographic features and actually quantify what's going on with these. You can see there's profiles that are shown in the charts or the graphs that are down towards the bottom. As a function of distance you can get the elevation. And so it's a lot of painstaking work to pull these profiles out so we can further characterize these flows.

If you go to Slide 25, I just want to give you some examples of the work that folks were doing out in the field up here and the FINESSE Team measuring the boulder dimensions; this is at Craters of the Moon.

Again, this is near one of the phreatic craters. We're trying to understand what is the boulder distribution, how much energy was basically in ejecting these big rocks out from the central rim and seeing how far out they've gone and what is the size distribution as a function of distance out from where they started from and how much energy was involved.

So field geologists out in the field and it's the - it's a very simple - the measurements but they're very difficult to make and you have to make a lot of them here using a rope, measure how big this rock is, take the GPS coordinates, see where it is, measure how tall it is, et cetera, et cetera.

If you go down to Slide 26, this is just a picture that one of our colleagues took. There are snakes out there so you remember that we actually are on the earth so there are safety concerns. So you have to be aware of this and watch out for the snakes that can be out on the lava plain, which won't be an issue for the moon. They'll have other issues when we go there.

Go to Slide 27. We're also using different types of platforms to collect the data. So here are some UAVs, some unmanned aerial vehicles that are being operated by our colleagues from the Kennedy Space Center.

And so they brought these UAVs out. Had to get special flight clearances to be able to fly them in the locations that we need. And we're using these for science purposes. They've been equipped with cameras and I will be adding midars and hyperspectral imagers. And these are great because we can get data from places we can't access on foot.

There are some places you just can't get to. The terrain is too difficult. You can't get in. But it's very interesting scientifically. So what we do is before we go out there, the science team puts together basically traverse maps and areas of interest where we would like to collect the UAV data.

And then we go out in the field and we fly the UAVs and collect the data over the site. And it's been fantastic for science. And it's also very relevant for exploration objectives. Because for example, when we go, where to say explore an asteroid with a robotic asset, we would be doing similar types of measurements.

It'll be non-contact science where you're flying in relatively close proximity to your target. So you want to know what kind of data you would have, how you would process that data, how you would geo-reference that data, et cetera, et cetera, and how you would analyze it for science. So the UAVs have turned out to be really, really useful for both science and for exploration.

The next slide is Slide 28. Sometimes we don't go as high tech as that. One of our teammates, Derek Sears out at Ames built a kite because kites are actually a really good way you can mount a camera or other small instrumentation on there and you can get those aerial images that you can't otherwise get.

So we're testing new platforms for science data acquisition. And again, it's being driven by the science needs of the team in order for them to do the analysis and write up their scientific papers.

So that's just an overview of some of work we're doing out at Craters of the Moon. As I mentioned, last year was the first year and we're getting ready to go back into the field this summer to follow on and do the next round of measurements and fieldwork.

Slide 29: And as Part 2 of our science, we're also doing the impact study. So we're looking at impact cratering. And if you look at any images of the moon or even looking at asteroids, we know that impact cratering has been a very prominent geologic process that's been shaping the planetary surfaces for billions of years.

So if you go to Slide 30. What we're trying to understand is impact rock modification. Basically once that impact happens what does it do to those target rocks that it impacted into?

And you can see on the graphic on the left hand side - this is some work that our colleagues up in Canada have been doing. Gordon Osinski and his team at Western University looking at okay, what happens to the rocks; what happens to their stratigraphy.

You get a crater rim. You get this faulting that happens. You get the central uplift. You get ejecta that's flown out ballistically. And so we want to characterize this so we can understand, okay, the energies that are associated in it. With that, how that affected the rocks and what that means for the lunar cases as well.

So if you go to Slide 31. Here are just some examples of different types of impact craters and some of the different features that we see on the moon that we would like to be able to understand.

So for example, in Image A there's a central peak in the middle of that crater. So what are the details and parameter you need to form the central peak? In Image B you have a central peak basin where you actually got a whole basin in the middle. You have rebound that's happening in there. How do you form that?

In Image C there's a peak ring basin. And you can see that ring going around in the center. It looks like blocky pieces of material that are in there. And then in D you have a multi-ring basin. So you have all these different morphologies at different scales for the impact cratering. And so we want to understand what is the influence of the target materials and in the process of the crater formation?

If you go to Slide 32, we're also looking at the chronologic record. This is something I alluded to earlier. Basically age dating when did these events actually happen? And we want to understand this for the science perspective because we want to know were these - especially at the Clearwater site where there's these two impact basins right next to each other.

Did they happen together? Did they happen separately? When did they happen? How old are they, et cetera? And so that's for our science. And we're also trying to do some exploration with this as well. And this goes into the sampling techniques.

It's very important to collect the right samples out in the field especially for doing detailed geochronology studies such as this. So it's a natural way to try and test out some of the exploration techniques and protocols that we put in place for sampling when we go to the moon or we go to asteroids.

And when we go to Clearwater, we are limited in the amount of rock we can bring back. You can only fit so much weight into the Twin Otter plane that's flying out of Clearwater. You can't just bring back every single rock you've ever wanted. That said, we can still bring back a fair amount but it's not unlimited.

You can imagine when you go to the moon your constraints become much greater. So there has to be even greater care taken in selecting the right samples if you're going to return them to the earth for further study in the laboratory.

So we are evaluating different sample techniques ranging in specification from just grabbing samples just to get something and then doing some rudimentary basically high grading. Do some measurements in the field to see which samples would be the best for bringing back. So we're doing some of that work.

And then once we bring them back in the lab, we have colleagues at Marshall Space Flight Center, at Arizona State University, also at Western in Canada. They're doing some of this geochronology and using different age dating and isotopic techniques to date those rocks. So that's pretty exciting science.

If you go to Slide 33, just wanted to talk about the asteroids as well. We're studying the moon but also some of the work is relevant to asteroids and asteroid connections.

And here's just some of the surprising things that we're seeing at Vesta during the Dawn Mission. So you can see in the upper left there's pits in the bottom of a crater, which was very surprising because if you look at pits on Mars they're usually formed from the interactions of water and rock. And we didn't necessarily expect so much water activity on an asteroid.

There's also dark materials on Vesta as you can see in the right hand side. And these are usually associated with water bearing material that's in fallen from asteroids. So more of evidence of maybe some water activity on these asteroids.

That also is a corollary to -- you see the hydrogen abundances down on the lower right -- varying amounts of hydrogen and hydrogen bearing compounds. We're trying to understand well where did these come from and what are these doing on the asteroid.

And also OH abundance in the lower left. You can see that there's increased OH across the surface of the asteroid seen from spectroscopy. And so it's a very interesting and new area of study for trying to understand okay, well what if any is the role of water and its byproducts on these asteroids.

And if you go down to Slide 34, this is more about those pits. Pits on Vesta and pits on Mars, very curious because we didn't actually expect to see these on the asteroids. They've been studied on Mars and some members of our group have been leading these studies trying to understand the interaction of water on the subsurface.

And then even stranger are gullies on a pit in Vesta, which is really, really strange for me. I used to many years ago -- I still do -- study gullies on Mars. And most people believe that those were formed by flowing water. So to see even similar morphologies on an asteroid is something very interesting to try and wrap your mind around.

And along those lines on Slide 35 there has been the presence of water. It's been pretty well established on certain chondritic meteorites. You can see samples have been put in the lab. And there are non-trivial amounts of water that are sequestered in these asteroids.

So there's some water out there and we're trying to unravel that story. How does that play into the whole, you know, dynamics and processes happening within the solar system?

So our approach for actually trying to answer these geologic questions -- go to Slide 36 -- is we send people out into the field to do the fieldwork.

And so here I just want to show you some images of what it's like doing fieldwork up at West Clearwater. This is just last year. And this is inside the tent at the beginning of the day. Morning briefings. Everyone's looking at the map of Clearwater and deciding where each person's going to go based on their science objectives and needs for that day.

And then the next slide, Slide 37, this is just a fun slide of our team wearing their special bug shirts that we had to acquire for them because there's lots of bugs and mosquitoes and flies and all sorts of not fun things. Fieldwork's not always glamorous.

They needed this to do their science so they're all wearing their bug vests and their bug, you know, hats and screens and everything else that they needed out in the field.

And if you go to Slide 38, here is part of the reason why we went there. So here are some shatter cones that were seen by our team up at West Clearwater.

And shatter cones are pretty definitive evidence of an impact event. And so I should say that there have been earlier papers several decades ago arguing that the West and East Clearwater structures were volcanic in origin.

And so we were going to this place to really determine even at a most fundamental level how it even formed. And the presence of shatter cones as well as the britches and the impact melts and all the other types of features that were seen by our team out there is pretty strong evidence that these are impact conduced structures.

Okay. So if you go to Slide 39. I want us to just touch a little bit on some of the exploration research by giving you some background on the impacts and volcanic science that we would like to do.

And I mentioned we're doing this in the context of exploration because after all this is NASA and we're planning to send humans and/or robots out in the solar system to do science.

We would like to optimize the ways to do that. And so we can practice on the earth and learn the best techniques, learn the capabilities that are needed, the hardware that's needed, and the operations that work the best. And so that's what we're trying to do here while doing real science.

So if you go to Slide 40. Just so there's some terminologies and we're all on the same page, we'll talk a little bit about ConOps, Concepts of Operation. These are operational design elements to guide the organization and flow pertaining to a variety of different things; hardware, personnel, communications, data products, all the things you need to build the mission and make it happen.

We also use the term capabilities. So these are specific functional mission aspects. They can be hardware or software. Things like bandwidth, how much data can you send back and forth between the target where your astronauts are and back in the science backroom?

It can be how well you camera works, what's the zoom on your camera? What's the resolution on your camera? These are capabilities. How well does your space suit work? You know, how fast can the astronaut walk? What terrain can the rover traverse over? What is it capable of?

So these are the ConOps and Capabilities that we're going to be talking about. And we want to learn how to manage these the best we can and decide what's really critical, what do we really need, what do we not need and where do we need to make the investments so that we can maximize the science return when we do send robots and astronauts out to see the other solar system destination.

Go to Slide 41. When we're sending humans out into hostile environments there are some basic needs that need to be met. Number 1 is stay alive. Obviously that comes first. Number 2; protect the environment whichever planet or planetary body you're on. We believe you need to be cognizant of where you are and have good environmental stewardship of wherever we're exploring.

Three, productive conduct your science. So try to collect the data, the measurements, the observations that you need to answer your scientific objective and answer those science questions. And then four, explore to make discoveries because if that's one thing that we've learned from going out into the field over many, many years is that nature is pretty smart and interesting.

And we go out with our nice science traceability matrix and we go out there with our science question that we'd like to address and we're going to answer. Then you get out there and you collect that data but then you find a whole host of other interesting science questions you'd like to investigate further.

And that's one of the exciting things about doing this type of fieldwork and whether it's here on earth of on other places it continually happens. So we need to be able to explore and let serendipity guide us a little bit. So the questions we want to ask in this program are which ConOps and capabilities enable and enhance the science return.

So if we go to Slide 42 to talk about the exploration program. Just as a reminder we're using science to enable the exploration and exploration to enable the science. And so we'll do all our exploration work in the context of the science program to understand the volcanism and the impacts.

If you go to Slide 43, here we've just outlined the four areas that we're focusing on for the exploration research. One is the robotic concept of operations. So whether that's rovers or other assets, aerial assets, et cetera.

Two, the science concept of operations and mission capabilities. So maybe that's how your astronauts interact in the field, how you interact with the science backroom, et cetera, et cetera.

Three, communications. Not only the bandwidth of how much data you can send back but how frequently do you communicate, what assets do you need to communicate, what information should be communicated between who? What's too much information? What's not? A very layered question.

And four, the hardware capabilities. What hardware do you actually need? What does that suit need to do? What does that rover need to do? What does that science instrument need to do? What data does it need to collect? So we want to test out all these things in the field.

If you go to Slide 44, just touching on the robotic ConOps. So we're looking at the human robotic partnerships. And how do humans and robots work together out in the field?

There are three real phases of robotic rolls that the robot could play. Reconnaissance. So that's sending robotic assets before you send the humans to do some recon. Basically check out the lay of the land, allow you to decide where the high priority targets are for the humans, collect some preliminary science data, et cetera.

Two is support. So you're going to have robots in the field with the humans and there are many different ways that can be done. The robots can be side by side with humans. The robots can be scouting ahead from the humans. The robots can be doing follow up activities after the humans have been at the site. There's a lot of different ways to set that up.

And then three is follow up. So after the humans have left, there may be more data that you'd like to collect if places have been identified. And you can send your robotic assets out to collect that data after the humans have gone.

And so here are just the two examples of two of the robotic assets that we're using. KRex is a planetary rover that's been developed at NASA Ames you can take out into the field. We have taken into the field. We can mount various instruments on it. We can operate it remotely. It's a really great platform to use. And then here are the UAVs as well that we talked on before that we're using up at Craters of the Moon.

So if you go to Slide 45. This is talking about the science ConOps and the mission capabilities. We want to learn best practices and what capabilities enhance and enable scientific data return, discovery and innovation.

And so there have been exploration concepts of operation developed and tested at analog. And we're trying to evaluate those within these specific scientific exploration scenarios.

And so we have a whole systematic evaluation procedure that's in place in order to see what works best and what could use improvement so to speak.

If you go to Slide 46, here's an example for the Craters of the Moon; here's a communications and network plan. So essentially on the left hand side you've got your two explorer astronauts who are out in the field doing your scientific research.

They may or may not have a robotic asset next to them. That's the KRex mobile instrument platform or the MIP. So then you've got these assets out in the field. Then you have COM relays to relay that information back to a command center, which is basically funneling all that communication through it.

You can have a delay emulator. So if you were - if you have astronauts out at Phobos and Deimos, you can't communicate with them in real time. You're limited by speed of light. So we can invoke a delay and see how that affects the communication between the assets that are out in the field. And then you can see there's a science backroom on the right hand side and relaying that information back.

And so we've done some field deployments with this type of setup and it's very interesting to see what information is really the most important to come back, what data is the most important to come back, how much interaction there should be with the science backroom team and the explorers that are out in the field and how that should actually occur and in what format that should occur and what the operational hierarchy should be, console positions, et cetera.

So there's a lot of testing that's going on in here. One of the best ways to figure out what's the best is to actually just try it because we can set up all the greatest plans in the world from our desks and on telecons but until the rubber hits the road and you actually test it out, that's where you really start learning some interesting things.

Now if you go down to Slide 47. Here are some other things that we're going to be looking at. Habitat inter-vehicular workstations. So for those astronauts that are out at the field site or out on the moon or on an asteroid, what tools do they need actually in hab?

So one example is what science instruments do they need to do some preliminary analysis to high grade their samples to decide which samples to send back to earth. What are the capabilities that they need in that workstation? And so we'll bring some instrumentation out and have that act as our IV workstation and see what works best and what else might be needed.

If you go to Slide 48, also looking at what I mentioned is the MIP, the Mobile Instrument Platform. So you can see there's an astronaut out in the field in this particular picture. They have a little blue box. There's a little robotic asset right there.

So how will we use a Mobile Instrument Platform? And we'll test it in several different configurations. Could be used to collect data, as I mentioned before we head out into the field and do some recons. We can set a traverse plan.

It can go alongside the astronaut and carry some tools the astronaut might need. It can be used - the astronaut can put samples on it. So it can carry samples back. It could be used for follow up. To follow the astronaut and then collect - or collect data after the fact. So what is the best way to use this? What instruments do you want to have on there? Is it useful at all? So we can test all that out in the field.

Slide 49. These are in a shirtsleeve backpack. So we'll be developing these to wear out in the field. What are the assets that you need on the backpacks in order to make them work? What are the communications that they need? What's the data that they need?

What's the best way to have that data coming in so that it can be easily digestible by the astronaut and useful to help guide their science? So we'll be testing out some of these and some of the different capabilities that are on here.

And then if you go to Slide 50, Science Backroom Teams and distributed operation. This is from a field test we just did last fall where we had a rover out in the Mojave Dessert for a lunar polar rover analog mission.

And you can see up at the top this was the Science Operations Center we had at NASA Ames. So there's a lot of learning in how we set up the Science Operations Center. What are the different console positions that you have there?

There are people for different instruments, for science communications, for operations manager, science lead, test directors, timeliners, traverse planners, all of these different moving parts that all have to come together in order to conduct the operations and get the data from the robot.

There's also a Rover Operations Center out in the Mojave Dessert and you can see you're doing some of the tactical work for actually making the rover move based on the plans that the science team have put together.

And how do you do this when you have operations teams that are in different places that aren't necessarily co-located? Very interesting question and it's really a great place to test it is out in the field.

And then if you go to Slide 51, another thing that we'll be testing for science ops capabilities is our ground data systems. We use something called xGDS, exploration ground data system.

And this is a really nifty software package that's been put together by the Intelligent Robotics Group out at NASA Ames. And we use it in all phases for mission.

So in the example of our lunar robotic analog mission, we used it before the mission actually happened for planning. So what you see here is a traverse plan. So there are different waypoints numbered with the different numbers. And the red line shows where the science team wanted the rover to drive. Based on our science objectives, this was the plan for that day.

And so you put that plan into xGDS and it gets uploaded to the rover. The rover executes that plan. And in real time xGDS also displays to you what the rover is doing.

So it displays where the rover is. It displays the data that's coming back. You can take notes. And then after the whole traverse plan has been completed, xGDS is great for post-mission data analysis. It stores all the data and allows you to actually look at that data afterwards and analyze it and do your science.

So we're testing out the capabilities of xGDS. What do we need it to do? What does it do now that's great? What do we need it to do in the future? What are the interfaces? How is it best used by the science team, by the operations teams, et cetera. And so we need to get these types of software tools up and running to the best of their ability in order to enable future safe missions.

Now if you go down to Slide 52. This is just getting into some of the complexities, we won't walk through this whole chart -- but of the key indication structure. And it can get very complicated very quickly when you have multiple assets in the field whether it's human and/or robot.

Who talks to who? What data comes out? And you've got a science team that's also looking at that data providing input in real time or near real time. And who's allowed to communicate with who and which information flows from which person?

How much information do you need? Are you getting the right information at your console position, et cetera? So we're looking at the communication structure and also the influences of communication delays in this whole process.

Go to Slide 53. Just some of the nuances of what we're testing. For example, communications latency as we've mentioned. You can't have actual real time communications when you have someone on the moon or out at an asteroid or Phobos and Deimos. There's a delay. And that we are finding has a pretty significant influence on how you conduct your operations as we're testing this out in the field.

And here's Slide 54. It's just an example of what communications delays are between earth and some of the human destinations. So you can look, if you're going earth to moon, a second or so, lunar surface a little over a second. It actually turns out to be maybe a little bit more once you put in like DSN delays and what not.

But you're going to have some pretty significant changes when you get out to the Mars orbit for example. And that really changes how you'll actually conduct your mission.

Slide 55 is also bandwidth. So we're bandwidth limited when we go to the moon and when we go to the asteroids. And so we can't send back all the data all the time all at once.

And so there's a lot of work that goes into clever ways to compress data so you can send back more information and staggering when data is sent back and highlighting which data is most critical to get back quick. What do you want sent back first? What can wait until a little bit later?

And so there's a strategy involved in the communications architecture for how you deal with your limitations in bandwidth while optimizing your science return.

And Slide 56, this is the evaluation program that I mentioned earlier. So you can see on the bottom there's basically a color chart. And we have different questions that are looking at these ConOps and capabilities. What's working in green and what's not working you would give it a red.

And so we can - we're integrating multiple assets, multiple field teams, different instruments, different exploration platforms and we're trying to see how do we maximize our science data and sample return priorities.

So we want to test all these ConOps, all these capabilities and see where improvements are needed to make recommendations for what needs to be worked on in the future.

So that's a general overview of the whole science and exploration part of what FINESSE is doing. So we're trying to have a high fidelity analog field campaign going on. And a big part of what we're doing is also the education and public outreach.

So if you go to Slide 57, I'll talk a little bit about our flagship EPO project, which is called Spaceward Bound. One of the great things about doing fieldwork is that it's on earth. And so people can go there.

And we can bring people out into the field and give people real hands on experience with hardware, with operations, with science and it's been working out really well for us.

And so we are continuing what is termed Spaceward Bound. And this is a program to bring students and teachers out into the field to conduct science and exploration research right alongside all of the FINESSE personnel.

And so the teachers and students are just fully integrated into the team. They collect science data. They help with the analysis. They participate in the discussions. There's really not much distinction made between who's a NASA scientists and who's a teacher that's coming in.

Everyone gets to work. Everyone gets to carry heavy equipment through the desert. Everyone gets to collect data and participate in all the team meetings. So it's been really great for us. And it's also been great for the teachers I think.

Slide 58. Here's just an example out in the field. This is Brent Garry in the bright vest. He's a Planetary Scientist at NASA Goddard. And he is explaining to Jeff Karlin who is one of the teacher participants from Spaceward Bound how to use the Lidar system at the highway flow at Craters of the Moon. And so they're collecting data to measure this flow here.

So the teachers are fully integrated and are given responsibilities and are fully part of the field team. Because they're part of the field team, if you go to Slide 59, they actually are included in the post-field deployment analysis and science. Can even get scientific publications out.

So from this past year we had our Spaceward Bound teacher Heather Guy - she was a co-author on AGU, American Geophysical Union abstract and presentation at that annual meeting in San Francisco based on looking at - it was reconstruction of phreatic explosion from block dispersion modeling at King's Bowl, Idaho for her participation in that fieldwork and science.

If you go to Slide 60, I'll just point out that we have partnered with the Idaho Space Grant for the Spaceward Bound program. Because we're working at Craters of the Moon it's a natural connection there. We've done some Spaceward Bound work with them before too.

And it works out well because the Idaho Space Grant solicits for teachers and applications come in and then selections are made for who will be supported by the Idaho Space Grant to come participate in Spaceward Bound.

So it's been a really nice collaboration that we've had with them and will be continuing this coming year and probably for several years out for the duration of FINESSE.

If you go to Slide 61, just some other components of the education and public outreach. We have a Haven House Shelter Series. This was started by our Deputy PI, Darlene Lim, out at NASA Ames in California.

And so what's we've done is had a series of speakers from the team and from Ames going to the shelter and giving talks to students and families to talk to them about the research that we're doing; also just to show them some of their career opportunities in STEM fields and try and over some connections to them if they're interested in pursuing some of those opportunities.

If you go to Slide 62, there's also International Observe the Moon Night. Andrea can talk more about this since she's a big organizer of this. But we have been supporting International Observe the Moon Night.

Last year we did a virtual event keeping in the spirit of SSERVI and the Virtual Institute Team. So I've listed the Web site there if you'd like to go watch that event online. There's a series of really great talks by lunar scientists talking about various aspects of the moon. And so there's been this up on the SSERVI Web site; also on YouTube so that anyone can go and see that.

And Slide 63 is just my final thank you talk. I think hopefully I've left a few minutes for Andrea to say a few more words about the Education and Public Outreach Program because that's really an important part of what we do.

Andrea Jones: Sure. Well thank you very much Jen. That was a great overview of all things FINESSE. So I hope that you have some time for questions for those of you online.

But yes, if you're interested in getting involved in FINESSE Education and Public Outreach, if you would like to go out into the fields, if you would benefit from doing that and you could share it with students and others that you work with, please feel free to get in touch with us. Our emails - Anita could get them to you.

And if you are not aware of International Observe the Moon Night, you haven't been coming to all the Museum Alliance talks because we have featured it here several times. But just in case you have missed them, it is an annual worldwide observing campaign and celebration of lunar science and beyond and exploration as well.

So that's every year. This year it's coming up on September 19, 2015. And anyone anywhere can participate in that. And we will definitely be having some more talks just about that program. And you can stay tuned for that. But if you have any specific questions, please let me know. But for the moment I'll just turn things over back if anybody has any questions.

Anita Sohus: Everybody don't forget to un-mute your phones, Star 6.

Dr. Jennifer Heldmann: Sorry. Could you repeat the question? Kind of cut out a little.

Anita Sohus: How did you get into fieldwork from where you started in your studies?

Dr. Jennifer Heldmann: Yes. I think the fieldwork component started for me in graduate school. I had the opportunity to work with some NASA scientists who were going into the field and kindly took me along. And it turned out I really liked that because it was a way to do planetary science but I didn't have to sit behind a computer all day long. I could actually get out, get outside, dig in the dirt, and get your hands on instrumentation and what not.

And so from those early exposures to doing fieldwork I was able to parlay that into some of my graduate studies into my PhD dissertation and was able to continue to do different types of projects and just grow from there. So it started out I guess in grad school and then throughout my post-doc and then throughout the rest of my career.

Anita Sohus: Is Spaceward Bound going on long enough to have any longer-term impact whether students then pursue these fields or teachers how they use it in their classrooms?

Dr. Jennifer Heldmann: Yes. I think it has. Spaceward Bound was actually started many years ago by Chris McKay out at NASA Ames. Chris has long for decades been doing tremendous fieldwork in really interesting places around the world. And he just started organically bringing students and teachers out in the field and then got it formalized into a more formal program supported by NASA.

And it's been really successful. It had been Liza Coe, has since retired but she had been leading the EPO portion of that and has been following pretty closely with the teachers and students after the fact.

And had been reporting for many years on the metrics of the influence that the teachers had been having in bringing this back into their classroom, following the students to see where they had gone in their careers, how many of them followed through with STEM.

There have been cases where the students continued on and have gone into these fields and what not. So there has been work that's been done on that. And it's something we should continue with FINESSE as well to continue to show the effects of Spaceward Bound and bringing people into the field and letting them have these hands on experiences.

Makes it a more tangible thing to understand what NASA's doing and how that actually can benefit them and their students and just humanity in general. So I think it's been a pretty - been a pretty great program. And those statistics do exist somewhere.

Anita Sohus: Yes. That's the name of the game these days is prove it.

Dr. Jennifer Heldmann: Exactly. Exactly. Have your metrics and prove that it works.

Anita Sohus: Yes.

Dr. Jennifer Heldmann: And fair enough.

Anita Sohus: Fair enough. Fair enough. Great. So do we have any other questions for Jennifer or Andrea from the group?

Man: How much knowledge of geology do you have to have to go do this?

Dr. Jennifer Heldmann: For the teachers?

Man: Yes.

Dr. Jennifer Heldmann: Minimal.

Andrea Jones: Yes, I mean so what we are going to be doing this year with our program that we didn't do last year because I was out on maternity leave. But we are going to be providing some pre-field training in terms of virtual presentations, a little bit just and overview of FINESSE, what it is and actually you've just gotten much of that here.

And then what do you need to do, what do you need to know, what do you need to wear, that kind of information and just to give you a background. But you don't actually need to know a whole lot ahead of time. The more you know the more you can get out of that experience. But you are still able to help when you're out there and you're still able to participate.

So I mean as with anything, the more you know before you visit a national park the more you can really appreciate what you're seeing and how you got to be there. But anyone can go and just appreciate it on a basic level.

But we are going to be providing more context and then afterward we're going to be putting together some packages of information for teachers such as activities that are related to the impact and volcanic studies that FINESSE does and programs that you can implement just to try to help ease the transition from the field into the classroom to make it more apparent to you as an instructor how you can bring that and share your experience with your students.

Dr. Jennifer Heldmann: Yes. And I feel like from a science perspective there are so many different projects going on. Like you won't only go out in the field. Like for people doing ground penetrating radar studies and people doing the geochronology studies and people looking at the chemistry and people looking at the morphology of the flows that I'm not an expert in any of those.

And so from the science thing no one's an expert in everything. And so I think that we're all going in and learning as we go. So there's something new for everyone. And so not everyone has all of the background and expertise, so. I think everyone - the scientists included that are going are learning as well.

Anita Sohus: How do people learn about the opportunity? I mean like is there an application period, announcement or something?

Andrea Jones: Yes. So that will be up on the FINESSE Web site. And it will be posted through the Idaho Space Grant. So they are the ones that are actually leading this portion of the FINESSE Education and Public Outreach Program. So it'll be up there but we'll certainly have a link to it through the main FINESSE page.

Anita Sohus: We'd be happy to pass the information along when you open an application period if you want to shoot us an email to share with the listeners, that'd be great.

Dr. Jennifer Heldmann: Sure. Yes. Great.

Anita Sohus: Might get you more applicants than you can handle, but.

Andrea Jones: Yes. Probably more than we can handle because I think right now we're trying to keep it around two teachers per experience because we really want to make sure that you have a good experience as a teacher but also doesn't impact the science team in terms of their objectives for the field.

So we want to make sure that everybody has the best experience possible. And having a whole lot of teachers out together will really not give you the flavor of what it's really like to be on and part of a science team. So it's a very exciting select experience to be a part of.

Anita Sohus: And one I'm sure that is memorable for a lifetime.

Andrea Jones: Yes.

Anita Sohus: Maybe opens lots of doors.

Andrea Jones: Yes.

Anita Sohus: Great.

Andrea Jones: And we do have our science team maintaining contact with the teachers after the experience, which is really great. So we've had Brent Garry who you saw in the image earlier has been talking to the teachers and other members of the team to have been participating in presentations for the students or just available for questions from the teachers. So it's something that we try to maintain a connection.

Anita Sohus: That's wonderful. Any other questions from folks or should we call it a day?

Kevin Koske: I've got one more. This is Kevin Koske from Arizona. When is the application period open for this year or this summer or however you guys do it?

Andrea Jones: Good question. You know, it should be coming up soon. I don't even know if it's up now. Let's find out right now.

Dr. Jennifer Heldmann: There is a - I kept the link. There's the link listed in the PowerPoint - in the presentation slides for the Idaho Space Grant Web site. And so their first story if you go to that Web site is Spaceward Bound FINESSE.

Kevin Koske: Okay.

Andrea Jones: So if it's not up now, it will be there. And if you're interested, jump onboard. We would love the creme de la creme to come join us in the field.

Kevin Koske: All right. Thanks.

Anita Sohus: These folks definitely are the creme de la creme.

Dr. Jennifer Heldmann: Oh I know.

Andrea Jones: That's why we're talking to them.

Dr. Jennifer Heldmann: Yes. That's why we're recruiting them.

Andrea Jones: That's right.

Anita Sohus: Terrific. Okay. Anybody else? If not, then I want to thank Jennifer so much for this great peek into fieldwork. And also Andrea for sharing the EPO information with us and we'll be talking to you again I hope.

Andrea Jones: Yes. And actually just before we go, I want to mention that this is the start of information that we're hoping to provide on behalf of the FINESSE Team but also of other SSERVI teams from that same virtual institute from NASA.

So if you are interested, we are trying to provide more and more information and maybe we'll try to do that under - it's we call it internally the SSERVI Seminar Speaker Series. But I don't know. Anita, we can talk about whether you'd like to send that along with all of these talks just to give everyone an idea of which pieces connect together or if we'll just announce them all separately. But this is the first of what we hope will be many to come.

Anita Sohus: Terrific. And I wanted to remind everybody we do have a demonstration on Monday with the - oh, gosh. I can't remember the acronym. LMMP, the Lunar Mapping Module. Which is I think also a part of this SSERVI Institute. Apologies for the acronyms. But that's Friday afternoon I believe - Monday afternoon, 2:00 Pacific Time. And it's a really incredible compilation of datasets that are now all co-registered and very explorable. So we'll have a demonstration of that for everybody, so. Great. Thanks a bunch everybody and we'll talk to you next time.

Andrea Jones: Thank you.

Woman: Thanks Anita.

Anita Sohus: Thank you. Bye.

Man: Thanks.

END