Danielle (00:14):

Today we have Niki WerkHeiser. Niki Werkheiser serves as the director for technology maturation in the space technology mission directory at NASA headquarters. In this role, she leads the advancement of key technologies for future space missions, including establishing policy, formulating budgets, and providing technological... Or, technical leadership. Mrs. Werkheiser has over 25 years of experience developing and flying new technologies in space. She began as an intern in the developing novel technologies with universities and industry for flight demonstrations on the space shuttle as part of NASA's space product development program. Mrs. Werkheiser holds a master of science degree from the University of Alabama at Huntsville with an emphasis in gravitational and space biology, as well as a bachelor of science in biology, and a bachelor of arts in Russian language, and studies. Today, Niki Werkheiser will be speaking about Lunar Surface Innovation Initiative and crosscutting technology for transformative missions.

Niki Werkheiser (01:38):

Excellent. Thanks so much. So, I hear that it's a beautiful day there. And so, I just want to thank everyone that was willing to give up a beautiful afternoon after I'm sure being on way more Zoom calls than you'd want to be to come listen to the talk. So I really appreciate it and I hope that we can have a good dialogue. My favorite part is questions at the end, so I'm going to probably speak a little quickly. I tend to do that anyway, because I get excited, and then hopefully we can have some good questions at the end. So, good afternoon again and thank you so much for having me today. I'm thrilled to be here to share some of the exciting activities and opportunities underway for lunar surface technology development.

Niki Werkheiser (02:16):

So, if we can go to the next slide. So, as Danielle mentioned, I work in the space technology mission directorate and our mantra is, "Technology drives exploration." Our programs are actually aligned along a technology readiness level, that whole spectrum, and it starts with low TRL in our early stage innovation programs, and those really focus more on R&D, and they primarily engage with universities across the nation to do that work. And then, we have the mid-TRL areas, which is our technology maturation program. Admittedly, I'm a little biased in this area, it's my favorite. I'm part of tech dev, and it's the area that I lead. I love it because it can be really viewed as the bridge between that early stage R&D and the mission or commercial infusion. So, we get to work across all the stakeholders and take the initial concepts to actual prototypes. And then finally, the end goal of course, is to evolve the high-TRL technologies that are led out of our technology demonstration missions, so that this area works more with industry and engineering implementation into actual NASA missions and commercial infusion.

Niki Werkheiser (03:25):

So, as you can see here on this chart, we have multiple technologies that we're developing across a whole mission life cycle from start to finish. And those are aligned along the themes of go, land, live, and explore. Later today John Dankanich will talk and he'll talk more about the go area in particular in propulsion. I'm going to talk today on the Lunar Surface Innovation Initiative and the technologies for that, which are captured there in that yellow box. And these focus more on the live and explore areas. So, the Lunar Surface Innovation Initiative was just started in 2019 as part of Artemis and it was established so that we could work across industry, academia, government, and nonprofits through in-house efforts in NASA, as well as public/private partnerships to develop those transformative capabilities for lunar surface exploration.

Niki Werkheiser (04:15):

And so, the way we do this is number one, we work to ensure that we have an ambitious, executable strategy. That means developing a lot of roadmaps and planning for the technology development across that whole spectrum I talked about. And then, planning for the development and deployment of those technologies. And then, formulating and integrating those activities across that TRL spectrum. And then, looking at how we can utilize our early uncrewed lunar surface mission that I'll talk about a little bit today to inform that key technology development before we start sending humans to live there. So we really have to test some of those things out on the surface. And then, very importantly, leveraging innovative collaborative approaches to expedite the technology developments. So it's really been a key tenant of LSII from the very first day to execute all of this through robust collaborations across industry, academia, government. And then, you'll hear me reiterate that a lot and give a lot of examples of that today, because that really is key. And it's also the most fun part of what we do.

Niki Werkheiser (05:14):

So if we go to the next slide, I'm going to talk a little bit about each of those LSII areas, you saw at the bottom of the previous chart and on the first chart in the yellow box. And I'll talk through each of these just a little bit to give a flavor of what all we're doing. The first one In-Situ Resource Utilization, or ISRU. This one is extremely important, because when we're so far from home, we just have to be able to use the local resources for our consumables. So in 2009, it was discovered that there is a lot of water at the moon's poles. Even the most conservative estimate suggests millions of metric tons. So this water is critical for mission consumables for the astronauts, obviously, as well as for our systems and even for making hydrogen-based propellant.

Niki Werkheiser (06:01):

So, one of the most crucial goals is demonstrating that we can find water, extract it, collect it, and use it. And furthermore, much of the development we're doing on the moon and the demonstrations for these ISRU lunar capabilities feed forward to the capabilities we're going to need on Mars. So the moon itself is a test bed for us to get ready for Mars. So, in space tech and ISRU, we're working to develop the needed technologies for collection, processing, storing, and using the materials found and manufactured on the moon. We've planned for several early lunar demonstrations on those uncrewed missions that I talked about. And those will ultimately lead to what we call our ISRU Pilot Plant, which is an integrated scalable system for collecting consumables on the lunar surface.

Niki Werkheiser (06:45):

The interesting thing there is, NASA doesn't want to be the one to build and develop these. We just want to be able to buy the consumables from production, from industry. So, this could be really big business on the moon, and we're very excited about that. And, we're also working on methods for size sorting the granular lunar regolith and measuring mineral properties and oxygen content before and after processing. So if we go to the next slide, in these two areas I'll give an example of some of the projects that we're working to give you a flavor of that. One example of an early ISRU demo that's going in the relatively near future is the Polar Resources Ice Mining Experiment or PRIME-1. PRIME-1 will actually be the first instrument to land at a lunar pole, and then assess the volatiles, and determine the water content. It'll be integrated onto a commercial lunar mission, which is the Intuitive Machines flight was selected. It's going around December of 2022, and it's via NASA's Commercial Lunar Payload Services or CLPS to a lunar pole.

Niki Werkheiser (07:49):

So, the PRIME-1 consists of two high TRL instruments, it includes a mass spectrometer for observing lunar operations, it's called MSolo. And then, the drill that's called The Regolith and Ice Drill for Exploring Mew Terrain or TRIDENT. You see why we have acronyms, because we'd be talking forever without them. These technologies will be used to test the common volatile detection and the drill capabilities that will then be utilized in a later mission that's called VIPER, Volatiles Investigating Polar Exploration Rover mission. That one's going to go a little over a year after PRIME-1. And what it does is it adds mobility. It has a rover, so it can go to different locations to drill for water. So it's really important that we have missions like PRIME-1.

Niki Werkheiser (08:32):

Obviously, autonomously drilling on the moon surface in an area that we haven't been to before and looking for water is a big task, right? And you'd want to test that out before you do the VIPER permission, so we're doing that. This is another example of where we're working with industry participants. For example, Honeybee Robotics is developed in the TRIDENT drill and a company called INFICON is developing the mass spectrometer.

Niki Werkheiser (08:57):

And of course, to do almost anything on the moon, we will require reliable, sustainable power sources to enable lunar habitats, and base stations, and rovers, and even construction systems for the uncrewed and crewed missions. So, we're developing technologies which can provide the capability for continuous power throughout the day and night. And these technologies can really be grouped into three basic categories, power generation, power management, and distribution, and energy storage. So, some examples of some of the areas that we're developing are vision surface power, deployable solar arrays, power needs for the foundational habitat that the astronauts would live in, regenerative fuel cells for storage, and then also all the ancillary and supplemental type technologies you need to make this work like power transmission cabling, converters, regulators, and switch gear.

Niki Werkheiser (09:47):

So if we go to the next slide, I'll give an example there of one of our power projects that we're going to be flying. Recently, we just selected five companies to develop the Lunar Vertical Solar Technologies. This is really important because existing solar race structures, like we use on space station, for example, and deployment systems for space are designed for either zero gravity or horizontal surface deployment. So the vertical position and the height of these new designs would actually help prevent loss of power at the lunar poles where the sun doesn't rise very far above the horizon. So you want to get the taller vertical array. So when this low-angled light hits rock formations like hills and slopes that are in the areas, it casts a shadow over the surface, and that can block horizontally structured solar arrays from obtaining light. So a tall vertical solar array power structure would greatly increase the likelihood of obtaining uninterrupted light and thus power.

Niki Werkheiser (10:42):

So, these companies will design solar array technologies that can autonomously deploy up to 32 feet high, and then retract for relocation if necessary. So we're really excited about that. So, if we're going to operate on the moon and use those resources, then we need technologies that are going to enable humans or robotic systems to efficiently access, navigate, and explore previously inaccessible lunar or planetary surface areas. A lot of the areas like permanently shadowed regions, where we think there's a good bit of water, would be unsafe for astronauts, for example. So, you really want to do that autonomously or with robots. And so, this area requires integration of a large cross section of technologies in order to enable robust, sustained surface activities, extended operations in permanently shadowed regions, like I talked about, ingress, exploration, and egress. And then, hazard detection in all lunar environments and conditions is really important. Navigation. And then importantly, you'll see a theme throughout many of these do require autonomous operations, without the human in the loop. So that's another crosscutting technology that applies to many of these areas.

Niki Werkheiser (11:50):

And if we go to the next slide, I want to talk a little bit about one example of a technology that we have under extreme access that we're really excited about. This is called... We're developing this with NASA's Jet Propulsion Laboratory, and it's called the Cooperative Autonomous Distributed Robotic Explorers, or CADRE for short. CADRE is a network of shoebox-sized mobile robots, or small scouts if you will, that can autonomously explore the lunar environment in a cooperative manner and enable multiple types of operations or science. So, this one to me is really exciting because we can envision how this could ultimately become an open source platform. Like CubeSats, I'm sure many of you're familiar with CubeSats and how many universities that have really started out at universities can come up with different ideas and ways to use them, same here. If we had an open source platform for the CADRE scout, then folks, including students from all over the world can develop small payloads that you can operate on the scouts.

Niki Werkheiser (12:48):

So in addition, just the testing out the technology itself on this first CLPS mission, we're also testing new ways to collaborate with novel crowdsourcing challenges. So for cadre, we released a global challenge through HeroX, which is a partner of NASA's Tournament Lab to develop miniaturized payloads, they're about the size of a bar of soap, that could go on CADRE and could perform different operations or science. So we have selected five of those payloads to be developed in phase two of this challenge and we're really excited about that. So, I'm hoping we can have a lot more student designed challenges and maybe some of y'all [inaudible 00:13:22] on a CADRE in the future.

Niki Werkheiser (13:24):

So, similarly to extreme access, the technologies that we need for extreme environments in order to survive that full range of lunar surface conditions really have to be diverse and cross-cutting in order to enable rovers, manipulators, and other systems to operate on the lunar surface within the conditions there. This includes a lunar noon, so when you think about these temperatures you're talking about at lunar noon, you have to go up to 150 degrees Celsius, lunar night down to minus 180 degrees Celsius, and then multiple day/night cycles. And then, you have those permanently shadowed regions, which we really want to get into, because we think they have a lot of good resources, that go down to minus 240 C. So, not only do we need develop the technologies, we must also have the subject matter experts, the facilities, and the processes in place to test the components and the systems in the most analogous environments on earth that we can to verify that the hardware that's designed will work in the actual lunar environment.

Niki Werkheiser (14:23):

So, we're also developing what we're calling an external environment users guide that folks can use internal and external to NASA for designing demonstrations or experiments on the moon. So that you know how to design and test for that. Because, it's a pretty harsh environment. An example of one of our extreme environment demonstrations that we're doing as an early demonstration is the Cold Operable Lunar Deployable Arm or COLDArm. So this one consists of a 4 degree of freedom robotic arm that has an end effector that can interact with the lunar surface and can provide manipulation capabilities again throughout that lunar night. So, potential type of applications that you could use COLDArm for would include, measuring geotechnical properties, or resource collection, deploying instruments or payloads, and sampling, and/or even surface or habitat construction type activities. The other interesting thing about COLDArm is it's capable of operating at temperatures as low as that minus 180 C, via cold motor controllers and actuators with another technology that we're testing called Bolt Metallic Glass Gears or BMGG.

Niki Werkheiser (15:31):

So, COLDArm is actually multiple demonstrations in one, because we'll be testing out the new BMGG that will help other types of experiments and demonstrations work as well in these cold environments. I'm going to talk a little bit about dust mitigation. So there's a good reason that we call this dust mitigation, rather than dust solutions. Dust issues are very real and they have impacts and effects on pretty much everything that we do on the lunar surface. For example, during Apollo 17, the crew members, Jack Schmitt and Eugene Cernon had trouble moving their arms during moonwalk, because the dust had really gummed up the joints. And it was so abrasive that it actually wore through three layers of their Kevlar like material on Jack's boot, which could be quite dangerous, obviously. So, we've initiated active, passive, and operational measures to address dust mitigation.

Niki Werkheiser (16:22):

We've also recently selected seven different universities for our dust mitigation. It's called a BIG Idea Challenge for the universities, Breakthrough, Innovative, Game-changing is what BIG stands for, Ideas Challenge. The year before that we did ISSRU, permanently shadowed regions. And, we did dust this year. And they're helping to work on some of these development areas to find novel solutions. And last but not least, we have excavation and construction. Excavation is really a bridge between is ISRU and construction. It's required for drilling and digging into the regolith to extract resources, as well as to gather up that same regolith to be used for construction. So, construction using the moons resources is definitely going to be needed to provide protection for crew members, hardware, and electronics on the surface. So that could be habitats, or burns, or storage shelters.

Niki Werkheiser (17:15):

So, this is another area where we have a great deal of industry and university involvement. For both of these areas, we leverage and we learn a lot from companies that are on the earth that are doing these things terrestrially. So, we're working a great deal with universities, for example, to understand the regolith properties and even make regolith simulant, so that we can use those to test the hardware here on earth. So pretty much, making formulas for fake moon dirt, right? So we can test everything out before we get to the moon. But there are really major differences and challenges as well that we're working through and developing these technologies. For example, the excavation technologies will really need to be lightweight, yet capable of digging in reduced gravity. And then, large-scale construction systems must be autonomous and equipped to work without the astronaut's help.

Niki Werkheiser (18:02):

So, for all of these systems, one of the big challenges we always face is, having them to be able to work reliably in those extreme environments, without humans in the loop. So, we work a lot with the companies terrestrially, like Caterpillar, for example, that they deal with. They have autonomous systems that work in remote or dangerous areas, and they deal with a lot of reliability issues. So, that's been very, very helpful. Another early demonstration that we're planning is a small excavator. It's known as the Regolith Advanced Surface Systems Operations Robot or RASSOR. It can reliably... And you see the video there. It's actually moving. It's really, really cool. It can reliably excavate and deliver a total of 10 metric tons of lunar regolith in just over 11 days. So, that's about 200 times more than the state of the art right now. This is being developed out of Kennedy Space Center and with the company Honeybee Robotics.

Niki Werkheiser (18:59):

This is another example too, of how we use crowdsourcing. We actually put out a GrabCAD challenge for folks to submit different design ideas for optimizing the razor bucket scoop. And we received some really novel approaches that our designers had not considered previously. So, that was very exciting. We have the Moon-to Mars Planetary Autonomous Construction, or IMPACT project. This is an example of one of our construction early demonstrations. IMPACT is a very exciting project that's led out of Marshall Space Flight Center, because it has such a diverse team of core members, including the company ICON that's located in Austin, Texas, and the Air Force. ICON, and you should Google them, they're doing some really cool stuff, I think the CEO, Jason Ballard, I think he was on the Kelly Clarkson Show the other day. And he does a lot of really cool things.

Niki Werkheiser (19:48):

But, ICON was one of the finalists in NASA's 3D printed habitat challenge a few years ago. And they've actually 3D printed communities of homes and structures on earth. It's testing this out, demonstrating that the construction method and technology really can be useful right here on our planet and adaptable for applications beyond. So, we're really excited about this one too.

Niki Werkheiser (20:09):

So, you've heard me state that the key tenant of the Lunar Surface Innovation Initiative is to work hand-in-hand across universities, industry, government, and non-profits. And, you've heard several examples throughout the talk of how we're doing that, but I really cannot emphasize enough how important these collaborations are if we're going to be able to develop these technologies in a meaningful timeframe for us to use them. So, shortly after LSII was initiated, we worked with an existing university affiliated research center, or UARC, and with the Johns Hopkins Applied Physics Lab to establish the Lunar Surface Innovation Consortium, or LSIC, with this focus in mind. So, the LSIC is a nationwide alliance of universities, nonprofit research institutions, commercial companies, NASA, and other government agencies that all have a invested interest in establishing a sustained presence on the moon.

Niki Werkheiser (21:01):

So the part that's unique about the LSIC from other types of organizations or forums is that it does focus specifically on developing the needed surface technologies for living and operating on the moon. So, in addition to the bi-annual LSIC-wide meetings, we also have monthly virtual focus groups for each of those six capability areas that I've talked through. And the focus groups, to me, are really the most fun, because this is where we have continuous informal dialogue with all the different stakeholders. And it really helps to build a community, and develop talent, and compile all that member input that we're receiving, so we can report those outcomes and recommendations back. So, we have a lot of student involvement right now at LSIC, but it's really important to us to continue growing that.

Niki Werkheiser (21:47):

So, if you're interested, I wanted to let you know that membership is free. You can find out more about it and sign up on the website that's there below. They do have monthly newsletters. You can sign up for just one focus group, or for all of them, or just for the main big group. And, there's a lot of really interesting people, both from new space, traditional space, big universities, small universities, nonprofits. So, there's a lot of networking virtually, and then eventually in-person again too. And our next bi-annual meeting is actually coming up on May 11th and 12th. So if you're interested, make sure to go check out the website. And there's also some good publications there, some of the workshops and things that APL has held as part of LSIC that you might find interesting.

Niki Werkheiser (22:30):

So, simply put, universities are really a key part of developing new technologies. I'm a big believer in that. You might have heard in my bio that's where I started out with working on university with commercial space product development that we flew on space shuttles lights. So, I'm very passionate about that. Working with universities, I really believe that we get novel ideas with students and professors working on real problems across multiple disciplines with ambitious budgets and schedules. So, for all of us, I think it's really a win-win when we work together. Any large agency like NASA at any point can have group think, it's just inevitable. So, it's really important to me to get out and talk to you, talk to students, and work with industry to get fresh ideas. So, this slide is not comprehensive, but just shows some examples of a few of the LSII university activities that space tech has worked with, OSTEM, as well as the Science and the Human Exploration Operations Mission Directorates. And we're continuing to grow and expand these opportunities.

Niki Werkheiser (23:29):

One of them there you can see is that BIG Dust mitigation challenge that I mentioned. And then, we have the LSII eXploration Systems and Habitation challenges, or X-HAB that are with the National Space Grant Foundation. And then of course, the NASA Space Grant Artemis Challenges. I just wanted to mention, one example of how we're growing that university involvement, it's called the Lunar Surface Technology Research, or LuSTR Opportunities. We just started this last year. We actually announced it at the very first LSIC Consortium meeting that was February 28th a year ago, this past February. And, we recently awarded a six universities for the first round. This first round, we didn't open up to all six capability areas, but we do plan to do that. This first round was focused on subtopics across ISRU and surface power. So LuSTR, we set it up so that it focuses on unique, disruptive, or transformational lunar surface technology development across those six focus areas. We look at the low to mid technology readiness levels. So, between two and five.

Niki Werkheiser (24:32):

And then, very importantly, our goal here is to have post-award infusion opportunities, meaning that, whatever you produce or that comes out of this actually has an on-ramp into a program, or even potentially a lunar demonstration flight. The award duration is two years with 1 to 2 million for each award. And then, also the selectees debrief at the bi-annual LSIC meetings, which is a great networking opportunity as well.

Niki Werkheiser (24:57):

So, we are planning the next call for later this year. This says summer, I'm hoping that we do get out in the summer, but we are working on that too. So, wanted to mention that here. And then, if we go to the next slide. Lastly, I'm very proud to say that we've only been established, I guess, a little over a year, maybe on a year and a half. And, in just that timeframe, we've engaged over a 1000 participants across 300 organizations in 44 states in Puerto Rico. So, for us, every one of these collaborators are helping to shape the technologies that are needed for a sustainable lunar presence and stimulate a linear economy. So I do hope that we'll get to work together with each of you in the near future. And with that, I'll pause and take any questions.

Danielle (25:44):

Thank you so much, Niki Werkheiser. If anyone has any questions, you should be able to unmute yourself now.

Speaker 3 (25:50):

I do have a question though, just going into a little bit more about the BIG Idea Challenges. So, those are open to all college groups, right? College-aged students, and some of them, are they high school too, or is it any just college age?

Niki Werkheiser (26:08):

Yeah, BIG Idea is specifically for university groups, and we do one a year and it's through our Game Changing Development Program. And, we have different themes each year, but yeah, we usually have university teams that submit to those. And then, it's a year long activity where they develop those, and then we give a briefing at the end. And we just finished up, just a few months ago, our ISRU one, and we had administrator Bridenstine. I think it was one of the last talks that he did before he left. He came and met with the students, and had a fireside chat, and they presented, and he listened to their outbriefs. And, it's really great because we work together with NASA subject matter experts and leadership with the students. Yeah.

Speaker 3 (26:50):

Great.

Niki Werkheiser (26:50):

So, we're formulating our next one now. Yeah.

Speaker 3 (26:54):

From Dr. Shelton, "Are there currently any passive power generation technologies being considered that takes into account the large temperature differences on the lunar surface?"

Niki Werkheiser (27:06):

So, I would have to look... See, our whole power approach, the whole roadmap is really based on the fact that we know we're going to need multiple different approaches to power generation and storage. So, we're really looking at a broad set, in addition of course to division surface power, as well as I mentioned the vertical solar arrays, but some novel technologies too. We do have one that's called CHIPS, that's a Chemical Heat Integrated Power Source. And so, we are looking at some different mid-

TRL technologies that are in development that I think hold a lot of promise. And of course, this is another area where we can work with terrestrial industries, and get a lot of good university ideas too, for novel approaches. In addition to the more traditional type of power systems.