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NUCLEAR REGULATORY COMMISSION

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33RD REGULATORY INFORMATION CONFERENCE (RIC)

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TECHNICAL SESSION - W15

MICROREACTORS: THE "NEXT BIG THING"

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WEDNESDAY,

MARCH 10, 2021

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The RIC session convened via Video Teleconference, at 10:45 a.m. EST, Annie Caputo, NRC Commissioner, presiding.

PRESENT:

ANNIE CAPUTO, NRC Commissioner

JESS GEHIN, Associate Laboratory Director for Nuclear Science & Technology, Idaho National Laboratory

GEORGE ROE, Director, U.S. Department of Energy, Office of Arctic Energy

JEFF WAKSMAN, Program Manager, Strategic Capabilities Office, U.S. Department of Defense, Office of the Secretary of Defense

ROBERT BOSTON, Manager, Idaho Operations Office,

Office of Nuclear Energy, U.S. Department of Energy

C-O-N-T-E-N-T-S

P R O C E E D I N G S

10:45 a.m.

COMMISSIONER CAPUTO: Good morning. I'm Commissioner Annie Caputo, and it's my pleasure to chair this session and welcome you to Microreactors: The Next Big Thing. My staff tells me this session had the highest number of registrations. There's clearly a significant interest in this topic which makes this session very timely.

The purpose of this session is to examine how the potential for unique and diverse applications of microreactors are stimulating interest across North America. This interest necessitates the NRC staff getting up to speed on the issues in technology of microreactors to prepare for potential licensing activities. There is significant momentum from government and industry for clean, reliable power to replace fossil fuels.

Microreactors offer electricity and heat in niche markets such as remote locations, defense facilities, and backup generation. Safely deploying microreactors raises unique issues for the NRC. Staff is engaging stakeholders on unique issues related to oversight, autonomous or remote operation, transportation of fuel for the reactors, just to name a few.

For additional information, I encourage you to read the information paper provided to the Commission last October, SECY-20-0093. And other issues are also discussed in the information paper. This was published in October of last year. The agency is also undertaking various initiatives to transform its regulatory framework to efficiently and effectively license and regulate microreactors.

Consistent with the Nuclear Energy Innovation and Modernization Act, the agency is increasing the use of risk insights in developing a new risk informed technology inclusive framework to safely regulate advanced reactors, including microreactors. Our panel will explore the drivers for microreactors, including government plans to support them in nontraditional roles such as providing power in remote locations and defense facilities or for resiliency and backup generation. This discussion will hopefully shed light on the impact for the NRC with regard to preparing for reviewing and licensing microreactor technologies.

I would now like to introduce our four

distinguished members of the panel. Jess Gehin, Associate Laboratory Director for Nuclear Science and Technology at Idaho National Lab, Dr. Gehin joined Idaho National Lab in 2018 as Chief Scientist and was recently promoted to Associate Lab Director for Nuclear Science and Technology.

He also recently served as the National Technical Director of DOE Office of Nuclear Energy's microreactor R&D program. Dr. Gehin worked at Oak Ridge National Lab from '92 to 2018 where he held several leadership roles. He holds a bachelor's degree in nuclear engineering from Kansas State University and a master's and PhD in nuclear engineering from MIT, and Dr. Gehin is a fellow from the American Nuclear Society.

We also have George Michael Roe, Director of DOE's Office of Arctic Energy. Mr. Roe joined the Department of Energy's Arctic Energy office on loan from the University of Alaska at Fairbanks where he has been a member of the research faculty since 2013. He holds joint appointments at DOE's Idaho National Lab and PNNL. Prior to joining the University of Alaska in 2013, Mr. Roe served in various engineering and management roles at Boeing for 35 years in research and development of aerospace-related energy subsystem technologies. Mr. Roe holds a Bachelor and Master's of Science degrees in mechanical engineering from the University of Washington.

We also have Jeff Waksman, Program Manager for Defense Strategic Capabilities Office. Dr. Waksman is Program Manager for the Strategic Capabilities Office within DOE. Prior to this position, Dr. Waksman's federal service was for Congress and NASA.

In Congress, he advised members on science and technology issues. He then served as a senior policy advisor for NASA's administrator on issues of strategy, planning, and interagency regulatory reform. Before his federal service, Dr. Waksman worked in the private sector for IBM where he was a staff scientist on advanced semiconductor programs such as quantum computing and heterogeneous integration. His PhD is in physics from the University of Wisconsin, go Badgers, with a master's degree in nuclear engineering.

Lastly, we have Mr. Robert Boston, Manager of the Idaho Operations Office for DOE's Office of Nuclear Energy. He is responsible for overseeing the nation's leading nuclear energy research, development, and demonstration laboratory at INL. Mr. Boston has a master's degree in nuclear engineering and is a licensed professional engineer, a certified health physicist, and a federal project director. He is adjunct faculty member at Idaho State University, a member of the Idaho State College of Science and Engineering Advisory Board, and the Reactor Safety Committee.

I'll now move to some administrative notes for the session. We will have two live polling questions, one question after the first presentation, and another after the third presentation. When they are announced, you can access them by clicking on the polls link to the right of the video window next to the Q&A link.

This is to keep you on your toes and also provide some real time feedback to our staff and our speakers and to improve our engagement with the audience. At the end of the presentations, we'll conduct a Q&A session as time permits. And I look forward to hopefully a robust discussion.

And with that, let's hear from our first presenter, Dr. Gehin, with his presentation, Microreactor Research, Development, and Demonstrations at Idaho National Laboratory. I ask the technician to display the first presentation, please.

DR. GEHIN: Okay. Thank you, Commissioner. And I'm very pleased to be talking as part of this panel. I'm going to -- as the title states, I'm going to talk about the work that we're doing at Idaho National Laboratory related to microreactors to bring them to fruition. So let's go ahead and get started. Next slide.

Okay. I'm going to start with sort of a timeline. I think most people are familiar with the history of Idaho National Lab and the site and the demonstrations and test reactors that we have. This provides a timeline starting with the first reactor we had on our site in 1951 and progresses through, noting some of the key reactor developments as the national reactor testing station.

And you can see it proceeds up to current times with TREAT restart being the most recent reactor that was brought back online but with plans for the future. So the next slide talks about our plans for the future. It gives a high level extension of that timeline where you can see how the different reactors being developed fit into this schedule.

So microreactors, of course, on left-hand side, are the nearest term. We see those reactors being developed and demonstrated by 2025 with several reactors actively under development right now and closely followed by deployment. We're working on the virtual test reactor.

You all are probably familiar with the advanced reactor demonstration program supporting two reactor demonstrations this decade and then also the UAMPS NuScale's small modular reactor. So you can see we're continuing with the timeline of developing microreactors in general. But microreactors will be the nearest term. Next slide.

Okay. I'm going to go through some of the things that we're doing at Idaho National Lab. And one of the most important for demonstrations is the National Reactor Innovation Center led by Dr. Ashley Finan. The National Reactor Innovation Center referred to as NRIC was established by the Nuclear Energy Innovation Capabilities Act and has objectives as noted here to support the demonstration of two advanced reactors. And from that timeline I just showed, you can see those are likely to be microreactors.

There are a lot of activities that NRIC is doing I want to highlight too. These are on the next slide as far as test beds that will enable reactor demonstrations. One on the left is related to the EBR-II dome. And using that to support microreactor demonstrations, there's some pictures here of the dome, obviously reactor operated. And this fast and sodium cooled reactor operated in this dome for several decades. And it's now available to support future reactors.

On the right-hand side is a zero power physics reactor. So that also represents an existing location that we can use to develop and demonstrate reactors as well. So we're gearing up for those demonstrations and using the unique facilities that we have on our site. Next slide.

Another activity, and this is, as the Commissioner, a program that I previously led. It's the DOE microreactor program. It's now led by Dr. John Jackson, National Technical Director.

The program vision here also is to

perform research and development to support by 2025 microreactor demonstrations that will achieve the objectives that we have for distributed nuclear energy, this program is different than NRIC in that it's focusing on the R&D aspects as laid out in the boxes at the bottom. You can see the three technical areas on the right, system integration analysis, technology maturation, a demonstration to support capabilities that will lead to these microreactor demonstrations and applications. The objectives of the program is to perform cross cutting R&D that meet the needs to achieve the reactor development across these areas.

So we'll go to the next slide and we'll get into a little more detail. So we have a couple of experimental capabilities that we stood up that's specifically designed to help reactor development. Particularly the one shown here, a single primary heat extraction removal emulator sphere, is a capability that we can use to perform testing on single heat pipes.

There's a picture of this in the left -- lower left and in lower -- or the middle there, you can see a recent test that we did in heating up a heat pipe and its associated structure element. So we can do steady state transient thermal testing of heat pipes which, of course, are the key element of some of the microreactor concepts that are being developed. Some of the stats are provided on the right-hand side.

As you can see, this is for a single heat pipe. We're also considering core segments in larger elements, and this is covered on the next slide. So a larger scale facility that we're developing is called a Microreactor AGile Non-nuclear Experimental Testbed. A bit of a mouthful but easier to say MAGNET.

So this is a larger testbed you can see in the lower -- in the center there, and I'll show you a picture of it in a minute. But a drawing, this is a vacuum chamber that we can put test articles in that represents microreactor core segments for a heat pipe, gas cooled, or other reactor types. You can see the chamber size, 5 feet by 5 feet by 10 feet. I apologize for the non-metric units there.

But we can provide up to 250 kilowatts of power, remove that heat, and then also connect this to other applications within the laboratory that it's placed. This is up and running now and we've commissioned it in doing our first test. But I should mention that these facilities are available to support industry and happy to talk about that. Next slide.

This is a fish eye view of the laboratory that MAGNET is in. And if you look at sort of the center right, you can see a picture of MAGNET's environmental chamber. It's specifically placed in this laboratory to allow integration with some of the other technologies that we're doing research on.

So we have right to the left, a MAGNET thermal energy delivery system which involved thermal energy storage and transfer. We have high temperature electrolysis experimental capability in the middle upper part to support investigation of microreactor applications for hydrogen production. To the left, we have our vehicle and battery testing area.

So there's the ability to test microreactors integration with battery charging. And on the right side, we have our grid simulation microgrid simulator capability to test that out. The microreactors can integrate with the microgrids and grids. So we have the capability to do thermal testing. We have the capability to do integrated testing in this facility. Next slide.

Okay. And then the next project I want to talk about is actually a small reactor project we initiated called the Microreactor Applications Research Validation and Evaluation project, or we call it MARVEL. This is a project where we're actually developing a small 100-kilowatt reactor for integration testing and to try to do this in a very rapid time frame. You can see the time frame down in the third bullet, late 2022, early 2023.

This reactor is a small reactor so we can develop it relatively quickly. We plan to place it in the TREAT facility, an existing nuclear facility, and then have it produce electricity that we can then hook to -- or integrate with applications. The first will likely be a microgrid application for electricity, but there are also others, to get this early stage experience with the development and the integration of microreactor and application. Next slide.

This provides just some high level details. I mentioned it's a 100-kilowatt thermal power, 20 kilowatts electric. It can produce 450 C heat. It's a small natural circulation reactor using zirconium -- uranium zirconium hydride fuel, again, located at TREAT. There's a rendering of it on the left side right there. Next.

Okay. And then I just want to talk about an initiative we started thinking even beyond some of the things I just mentioned. We call it our fission battery initiative with the idea of thinking of these microreactors specifically as operating like a battery. And if you look, the vision, that's the vision of the project.

If you look down below on the bullet and you think about what a battery is, we've got some attributes here and we want to see how we can perform research and develop technology that would enable our microreactors to operate in a similar way. They'd have to be economic, of course. Thinking about your AA batteries, standardized, installed, easily installed, easily removed, operating in an unintended fashion to make them easy to deploy, and then also being very reliable.

And so many of those -- many concepts already have most of these or several of these attributes I should say. But we want to further that. We do have a series of workshops that have been underway. The remaining workshops in this series are on the right-hand side, transportation, siting, safeguards and security, and safety and licensing of fission batteries. That may be of interest to some of the members here. And then next slide. Okay. And I just included some resources here of things I refer to if people want to follow up. So Commissioner, that concludes my talk.

COMMISSIONER CAPUTO: Thank you, Dr. Gehin. Could I ask the technician to display our first polling question, please? What are the main drivers and markets for microreactors? You can select up to two among climate change, microgrids and remote industrial sites, resiliency, disaster relief, military logistical support and space exploration. So we look forward to seeing your opinions as they come in.

And thank you to those who have already responded. Our next presenter is Mr. George Roe with Alaska and Microreactor Applications. Could I ask the technician to display the next presentation, please?

MR. ROE: Thanks very much. It's a pleasure to join you and to talk about some of the applications for reactors potentially in the state of Alaska and perhaps beyond in other parts of the Arctic region. If you could go to the next slide.

I'd like to talk a little bit about Alaska itself, so click again. Alaska is a small place in terms of population, but it's a very big place in terms of geography. Nominally, it's on the order of almost two and a half times the size of the state of Texas yet with fewer than a million people. And it's a challenging place in which to live in and work. Next click.

It's remote. It's not tied in to any kind of a continental grid. And so everything has to be a standalone system. It needs to be able to operate in a self-sufficient kind of a way. And so a lot of experience has evolved in Alaska in terms of how to make that happen.

You see some examples on the right. In essence, these are all microgrids, some small, some large, some tied, some completely standalone, some remote, some in larger concentration areas. We'll talk a little bit about that, but there are estimates that indicate that more than ten percent of the microgrids that integrate renewables with fossil fuels are actually in the state of Alaska worldwide. And so next chart. Click, please.

The challenge in Alaska is it is largely a resource extraction driven economy. And so what you have is remote sites that are used to harvest various materials. And this doesn't just include minerals or fossil fuels. It includes seafood, timber, things like this. And so there are point source opportunities for using combined sources of heat and power such as reactors -- microreactors. But -- next chart.

The synergies don't just stop with the multiple applications in Alaska. They go well beyond. I mentioned the circumpolar north. There are so many communities that are very similar to those in Alaska, in northern Canada, Greenland, et cetera, where use cases can be compared and shared. And there are opportunities because of the small scale for applications in Alaska that we can gather lessons learned in the field and then extend them beyond. Next chart.

In Alaska, it's impossible to find any

kind of energy source or use that is not found somewhere else in the world. It's like a perfect testbed. This includes nuclear, by the way. The reactor that was in Alaska is no longer functioning, but it was decommissioned. But there's such a rich opportunity for looking at how microreactors can integrate with other kinds of reactors and the various kinds of loads. Next chart.

The challenge is that the loads are small when you think in a nuclear capacity, down to about 100 kilowatts for some small communities, maybe a little bit less in a couple, up to perhaps 385 megawatts in the case of some of the largest utilities in the central part of the state. If you look in the graphic on the right, toward the center of the slide, you see a line going up and down. That region is about the only thing we have that's connected to each other. Everything else is isolated.

And so it's in that large area that most of the -- or all of the major military bases are located. They're part of that grid. We call it the railbelt grid.

There's six utilities that are functioning there together. And so there's a very rich opportunity for exploring integration, different kinds of loads. And there are brand new opportunities that are evolving as well as retrofit opportunities. Next chart.

Back in 2009, the State of Alaska's legislature commissioned a study, which was performed by the Alaska Energy Authority and Alaska Center for Energy and Power, looking at what at that time were referred to as Small Modular Reactors -- microreactors weren't in the cards at that time -- and looking at possible applications. This study was completed. It did a very thorough review of the history of nuclear energy and nuclear work in the -- during the World War II time frame, and it's available online.

It's very, very instructive. For those who are interested in applications in Alaska, it's strongly recommended looking at the resources there and some of the history in particular that's captured. And I remember that was back in -- it was released in 2011. Within days of when it was finished, Fukushima happened. And so everything stopped in terms of interest in the reactors for a while. Next chart.

But that's changed with the evolution of microreactors. And so working with colleagues at the Idaho National Lab, at the University of Alaska, Anchorage, a study was done in terms of looking at what are the attitudes now toward nuclear energy in the state of Alaska. There's some hurt in some cases that has to be addressed responsibility but there's also potentially emerging opportunities. Next chart.

And so what happened is we did a combination of, like, a customer discovery process looking at a range of different stakeholders, asking questions, and doing a range of just kind of comparing different insights and reactions as the concept of what you feel about nuclear energy, how could you see it in the future, how could use this source of heat and power, et cetera, what opportunities would it be developed? And all those -- next, please. All of those results were brought together in several different use cases by different sectors.

And so the topic areas are, I think, very representative beyond the state as well as within the state. And this has all been very thoroughly documented, and I'll provide a link to this report at the end of presentation. Next chart. In addition, there have been a range of different stakeholder information sharing sessions.

We began back in April of 2019 with an in-person session in Anchorage. We had about 100 people that participated with us there. And then we've done some forums with smaller groups at the Alaska Forum on the Environment.

And then more recently fall and then this January, we did some information sessions where we -- it was a Zoom thing, of course, because of the virus restrictions on gathering. But explored these four different topics that are shown here, to gather input and to have experts from across the industry, well outside of Alaska, to share thoughts and insights with Alaska stakeholders. And then the study that I mentioned from 2011, that was updated.

The Alaska Center for Energy and Power coordinated that update. It looks at things that have changed since the 2011 time frame, both in terms of the technologies, licensing practices, the various policies, and then the economics. In Alaska, energy is very expensive. It's crazy when you think about it in terms of the Trans-Alaska Pipeline, et cetera.

But in some cases, the cost of energy can approach a dollar for a kilowatt-hour in some remote locations. And heating fuel can be on the order 8 dollars per gallon or higher. And so interesting economic aspects here. The challenge is logistics and workforce and communications, all of these things. And so in light of these challenges and these opportunities, some next steps and recommendations were developed which may warrant consideration. Next chart.

So I'd like to kind of go through some just quick flipping examples of inputs from the stakeholders across the state. You can see here the range of applications that are considered. And in general, there's an openness to exploring possible implementations of reactors, microreactors in the state. But it's cautious and it wants to be done responsibly. Next chart.

We're looking at a range of applications. Defense sites were mentioned. One of the things I'd like to point out is for early deployment of new technologies, it's important to be able to make sure that the application is ready to receive the technology. And so our large defense sites are combined heat and power installations.

And so there are opportunities to integrate sources of heat and power in existing distribution systems. The loads are very well characterized. There's not a lot of mystery, and there are very -- a range of security and environmental preparation, et cetera, for visions already in place. So defense sites seem like a very interesting application. Next chart.

We talked a little bit about the distributed mineral extraction. They're around different spots in the state. A challenge with integrating reactors into mining is the time frame for permits. Once permits are started, it is very, very expensive to undo the permit and change the source of energy. And so there is some challenge in terms of how can they -- reactors be integrated to existing mining operations versus new ones. Next chart.

In many parts of Alaska, we have legacy systems that have -- you see the center, some buildings on ACAT. They need to be destroyed to make the system safe. Reactors can provide incineration opportunities.

In terms of doing that safely, you see waste from a seafood processor on the right. You see landfills that need to have compact sources of dealing with waste that there's no way to haul it out of these remote locations. And on the lower left, that's an actual sewage lagoon. It's untreated sewage that is allowed to accumulate, and it percolates down after a while. But it's a challenge that sources of heat and power can be addressed. So waste management could be an interesting opportunity while we can get the technology where you need it. Next chart.

And in addition, we have many climate change situations in Alaska. If you would click again, this is not unique to the state of Alaska. There are on the order of 31 communities that have identified the nature of climate impact requiring them to relocate. The opportunity and the needs for characterizing this effectively and looking holistically at energy solutions is very keen there and is, I think, appropriate globally as a need. Next chart.

So I want to kind of talk through a couple of the application deployment. So if you just click and click. So there's a whole range of different applications. There are different technologies, but we need to migrate the technologies through lower risk settings to high risk settings. And so the progression here is what I am recommending in terms of looking at defense and defense to municipal utility ties, then perhaps to remote industry and then municipalities, larger communities and then maybe smaller communities. This is probably a 20-year evolution that we'd be looking at, as the technology evolves, always looking at the criteria there in the lower right. Next chart.

This chart shows you these defense and remote industry locations. You can see they're clustered in the center of the state. This, to me, seems like a logical place to concentrate initial efforts in terms of deployment of microreactors. Next chart.

And I think it's really useful for developers and people that are integrating, evaluating them, to look at some of the actual documented loads from some of our military sites because they provide some really great insight in terms of how the loads change. This is 15-minute data from Fort Wainwright which is in Fairbanks. You see the green line there on the top left. That's the electrical load.

And you can see, of course, it's bouncing up and down over the day as you might expect. But that's a whole year's worth of data. And what you see is it's not changing a lot during the year. So it's a very fairly steady state -- not steady state, but it's very predictable.

It's compared with that rainbow. That's the daily temperature, the ambient temperature. The curve on the lower left, that's the steam output from the combined heat and power plant, and you can see that January is on your left and December is on your right.

And what you can see is that the heat demand varies very significantly depending on the temperature. And you see there's huge differences seasonally with the heat and the heat to power ratio. So looking at the solutions that combine reactors with either load following and load heat to electricity shifting capabilities and integration with other kinds of technologies for storage and perhaps peaking kind of systems, very important, and some great on-ramps for some of the technologies that Dr. Gehin talked about being involved at INL for testing at Idaho National Lab.

So next chart shows the similar data for Eielson Air Force Base. This is on a monthly basis. It's four different snapshot months. But again, it shows you -- provides an opportunity comparing the electrical, the thermal changes. And you can see again the significant variations seasonally and even within a given month, the changes in terms of the magnitude of either power or -- of power in particular. Next chart.

This is for a community in Alaska called Kotzebue. It's north of the Arctic Circle just a little bit. Again, you see the data for the electricity fairly flat, but it does have some seasonal change.

In terms of one of the things that you see in some communities in Alaska is that the loads are seasonal. Schools operate during a certain time of the year, and industry operates at different times of the year. And so like a seafood processor can be a major, major element of a community's load, sometimes many, many times the magnitude of the community load. And so utilities have to be able to adjust their resource deployment to allow them to address the seasonal as well as daily.

The challenge that I want to focus on here is the fact that we don't have robust heating data -- heat requirement data for communities of any size. We have estimates. We have models. One of the models is shown here. They're reasonable for estimating purposes, but we need better data. And this is part of the efforts that are ongoing in the state of Alaska. Next chart.

There are a variety of technology needs that are documented that will be of use to developers. Next chart. These include technologies that are highly germane to microreactor integration. But there's needs for addressing other topics. This is something that we would be very keen to explore between the Department of Energy and other elements. Next chart. So next chart, quick.

We want to make sure we're not a solution looking for a problem. We want to make sure we're engaging stakeholders and then talking with them from a whole perspective. Many questions need to be addressed. Chair, click, please.

It's important that we think about the people. We're going to be using the businesses, the timing of their needs, where we should start, how we should deploy. Next chart. Addressing all of these factors, next chart.

I want to close with just why I think Alaska is a very excellent place to be considering applications here. A wide range of diversity and the needs, existing demonstration sites, small enough scales, magnitude of the investments is reasonable and yet existing infrastructure available for tie-in systems. And there's just the street credibility of doing things in Alaska. So we believe that there is much opportunity for deploying the technology beyond the state of Alaska based on the lessons learned. Could you click, please? Go to the next chart.

Lots to decide here. We need to -- there's ongoing interaction with the legislature, with other stakeholders across the state. We'd like to see these applications characterized and represented in some of the testing that's ongoing in Canada as well as in the United States at multiple locations, bringing use cases to bear there and then ultimately bringing the technologies north when the testing has validated them and shown that they are robust. Next chart.

I want to thank you for your attention. Alaska's motto is north to the future. And with all of my heart, I believe this is a true application statement here for us. Those things that you can't read at the bottom right, those are actually hyperlinks to all of the documentation that I've shared. And I thank you so much for your time and attention.

COMMISSIONER CAPUTO: Thank you, Mr. Roe. That was very fascinating. We've had one question about wanting to view a slide. And I just want to let everyone know that slides should be available on the NRC's RIC web page if you want to peruse those again. Could I ask the technician to display the results of our first polling question? While we're waiting for those results to come up, our next presenter is Dr. Jeff Waksman with Project Pele Overview.

DR. WAKSMAN: Thank you, Commissioner.

COMMISSIONER CAPUTO: Oh, let's -- yeah, so let's just take a moment here to look at these drivers. So 43 percent, obviously very strong for microgrids in remote use and, of course, military logistical support and space exploration, 18 percent for climate change. So I guess is there anyone on the panel who would just like to comment or make an observation about these numbers and whether they are surprising or about what you would've expected? Feel free to take yourself off mute.

DR. GEHIN: This is Jess Gehin. I'll make a few comments. This matches our experience. I think this matches what you heard in just the previous presentation of particularly first movers having needs for this scale of energy.

And particularly when you look at the remote industrial sites and remote sites, the cost of energy is pretty high. And so from the competitiveness point of view, nuclear microreactors look pretty favorable there. And I would expect and hope as they're developed that these other applications and areas listed here would become more prevalent given the further development cost reductions.

COMMISSIONER CAPUTO: Thanks, Dr. Gehin.

MR. BOSTON: Yes, I would just say that --

COMMISSIONER CAPUTO: Sure.

MR. BOSTON: -- resiliency and climate change, I view those as interrelated as we saw in Texas. It's important to ensure that we have a resilient base load to provide the electricity to the population. And maybe Dr. Gehin can comment, but the Department of Energy is working across multiple labs on integrated energy systems. And we find that that integration, as Dr. Roe pointed out and I believe Dr. Gehin pointed out also, is entirely important for this deployment of microreactors.

COMMISSIONER CAPUTO: I agree. All right. Let's shift to Dr. Jeff Waksman with Project Pele. Would the technician please display the next presentation?

DR. WAKSMAN: Thank you, Commissioner. I want to second your important thought to go Badgers. And when we -- if you could advance one slide, you'll see what we call in the DoD the bottom line up front.

So the DoD has an energy problem. We have a huge need for energy. We have difficult logistical tails. There's been a need identified in a variety of places now, executive order, congressional lanes, et cetera.

We believe TRISO fuel is a game changing development that will allow us to make this feasible. We kicked off a two-year design competition back in March of 2020. So we are a year into that now, and we remain on pace to do outdoor mobility testing this reactor at a DOE installation in 2024. Next slide, please.

So this need was driven in part out of what was seen in Iraq and Afghanistan where 52 percent of all casualties happened on land transport missions. Moving fuel and water around is most of what the DoD moves. And if there's some way to make the fuel and energy and water locally, it would be a big game changer for the DoD.

So if you go to the next slide, this is a history lesson that a lot of people don't know that the Army did this before. The Army built eight reactors in the '50s and '60s. They had reactors in Alaska as George Roe pointed out.

The image on the bottom right is a photograph. That is a real mobile reactor that existed in 1958, so we've done this. These were not very safe reactors. These are very primitive reactors. And when they were cutting things during the Vietnam War trying to save money, you had the fact that these reactors were simply more expensive. And so they were cancelled. So we haven't seen them since in the Army.

If you go to the next slide, you get to the 2016, the Defense Science Board looked at this. And they said what I mentioned already which is that energy needs are growing rapidly and energy logistics have never got it harder. And they acknowledged that nuclear technology is a lot different from the way it was in the '50s and '60s.

You no longer have to have people manually moving control rods in and out a centimeter by centimeter. And if you do it wrong, you get S01. Those sorts of reactors are not what we can build now. We can build -- Generation III reactors are operating all around the world. We can build inherently safe reactors by design and largely autonomous.

So DSB recommended that someone go around and actually do something about this. Someone should prototype a reactor was their recommendation. See if we can make this work.

So if you go to the next slide, this is

not ready for this audience. But this is a slide I always drag around the Pentagon. And I'd like to remind them that whether the United States pursues this or not, our adversaries are.

On the upper left there, that's the Akademik Lomonosov which is the Russian floating nuclear reactor which is in service in Siberia right now providing 70 megawatts of power. The upper right is Vladimir Putin's nuclear powered cruise missile which is a terrible idea and I don't recommend. And on the bottom, I point out that China has a very similar problem to us in that China has built these artificial sand islands in the Pacific that are very important for their defense. And they're going to have difficulty getting power there too.

And so they have been very interested in reactors very similar to the sort of thing I'm talking about here. And they're a first full generation for nuclear power reactor, the HTR-PM. They claim it's going to start operation this year. So that's some photos of it on the bottom right. So go to the next slide.

We're really relying heavily on TRISO fuels. So if you look at that image on the right, it looks like it cut away the earth. The idea is that the red in the middle is the uranium. It is then surrounded by a spongy carbon material. And then around that is silicon carbide.

And this has been tested by DOE and INL to 1,800 degrees Celsius which is really, really hot, as you probably are aware. And this is a fuel that the Department of Energy has developed for us, and this is what the DoD is looking for. We don't want it to have to develop around fuel. We want to just use this one off the shelf.

It has other benefits for us in that the fact that it's hardened should make it resilient to proliferation. And also the fact that the fuel is separated amongst a million little pellets rather than through larger components means that even the case of a kinetic attack, we don't believe that we would have that bad of a radiological problem. It doesn't necessarily release all of your radiation components.

But that's simply saying that we need to test. It's saying that the Army wants to see. The Army is not going to take these reactors on if they're going to have kilometer-wide evacuation zones if things go wrong. So we know that this is a big part of the program and it's in our plan. So go to the next slide.

This is a whole government approach. The Strategic Capabilities Office is about 100 people and most of them are doing other things. So we can't do this all ourselves, and so we depend very much on the help of our friends. So the Department of Energy and Nuclear Regulatory Commission are both providing a variety of help from technical support, safety advice.

The NRC, while they're not regulating this reactor, they are providing us a lot of input on making this what I call certifiable -- NRC certifiable, meaning that we want whatever we make here to be NRC certifiable, either for commercial spinoffs but also to allow the DoD to have the option of letting the NRC certify the designs so that the Army doesn't have to ramp up their own naval reactors. Department of Energy in addition is providing the safety oversight. So we're doing this under -- the way a DOE reactor would be done. That also provides legal notification.

On the NEPA, which is very important,

it's my long schedule pull right now. We are working closely with the Army Corps of Engineers as well as the Department of Energy. In terms of our uranium for this, we're using HALEU, 19.75 percent.

We're actually getting HEU from the NNSA stockpile, and we are going to downblend it to 19.75 percent. And then in terms of the TRISO facility where we're going to make it, we're doing that at BWXT Lynchburg. This is a joint interagency effort.

This is another good example of the government working together across agencies. NASA and Department of Energy are working on this together. We are joint funding this. And then once the line is fully up and producing, each agency will buy whatever they want by the pound. But we want to make sure that it's an interagency effort to make this deal happen. Next slide, please.

So where are we since we kicked it off last year? In fact, when we were going to have this panel a year ago before COVID cancelled it, I was going to announce that we just started designing the reactor. So since then, we've gone all the way to a preliminary engineering design, what the DOE calls a 50 percent design.

We had those reviews in late January. Excuse me. We're in the process of downselecting. The three companies we were using were BWXT, Westinghouse, and X-energy. After the PDR, we've downselected from three to two, and you should expect to see an announcement about that probably Monday, maybe Tuesday that will announce which two of those three are moving on.

We are on pace for final engineering design due no later than March, probably February of next year, to allow construction to begin in mid-2022, assuming we choose to do that. The Army has stood up the Army Mobile Reactor Advisory Council to advise us on the technical specifications and requirements. That's very key for us.

We want to make sure that we don't just go to a nuclear reactor that goes in a museum. We want to make sure that this is what the Army can actually use. This first of a kind reactor meets some low hanging fruit needs that the Army has.

We're proceeding -- I'm not going to read all these things here other than to point out that we are on pace here with the regulatory front and on the nuclear fuel and on NEPA and everything else. So basically, the government will make a decision on what they want to do in 2022. Do we want to fund the construction of this reactor? And so we will have two final engineering designs. And at that point, we will decide whether we're going to build or not. So we go to the next slide.

My first two big black bullets here are things that -- well, actually, I guess all three really are things that I think everyone can agree here which is, A, nuclear power is a potential paradigm shift. Moving colossal amounts of fuel around every day which is what the DoD is right now is not just expensive and not just bad for the climate. But it's a huge vulnerability that the DoD has.

We are very dependent upon the electrical grid. And the odds are that your worst day for the electrical grid is going to be the day that the DoD really needs it. So that's a huge problem.

At the same time, we know that this is really hard. It's not just building a nuclear reactor. It's, what is the regulatory regime? How do you make sure that all the environmental rules are satisfied? How do you make sure the supply chain is there? Because right now, I don't think the supply chain is there.

How do you make it cost effective? How do you employ these things? How do you train people in the Army to operate these? There's just a lot of things we've got to figure out, and that's the really hard part in this program.

But we hope that -- there's been a promise for a long time about actually building microreactors, truly advanced non-light water reactors. And we believe that Pele can be the pathfinder. The Strategic Capabilities Office, we are a rapid prototyping organization.

We make prototypes happen. And so we intend, assuming that the funding is there, to build this reactor. And we hope that this springs out a commercial sector that has a lower regulatory risk and lower financial risk and actually feel confident that they can make this happen.

So we are optimistic in the way the designs are going, and we hope that in 2024 we'll have a reactor somewhere that's powering light bulbs. And that's all I had to say today. Thank you very much.

COMMISSIONER CAPUTO: Thank you, Dr. Waksman. It's a very, very exciting time, certainly with the DoD engagement on advanced designs in microreactors. Can I ask the technician to display our second polling question, please? What are the biggest impediments to deploying microreactors?

Viewers can select up to two, financing cost and return on investment, technology development, availability of nuclear fuel/supply chain, lack of performance history, regulatory risk, licensing and authorization, and defined market needs. And while folks are thinking about these and pondering their selections, we will hear from Mr. Robert Boston with his presentation, DOE Safety Authorization Process for New Test reactors. And would the technician please display Mr. Boston's presentation.

MR. BOSTON: Well, thank you very much for the opportunity, Commissioner Caputo, to participate in this panel. Very exciting. We can put the presentation up, please. Thank you.

So as Dr. Waksman just discussed, DOE is the authorization authority for the Pele reactor. And so we'll discuss that process here. I just want to mention on the cover slide the ATR core is shown on the left. I'll dare say that it's the world's most flexible test reactor.

And on the very right is a rendition of the transient reactor test reactor or TREAT which I'll discuss further on that too coming up. As I go through this presentation when I discuss documented safety analysis, that is equivalent to the NRC final safety analysis reports. That terminology changes in 1991 for DOE. And if I bounce back and forth, there are some legacy facilities that use both terms. Similarly, technical specifications in DOE parlance are called technical safety requirements. And please, next slide.

So I want to provide a historical context. The DOE grew out of the Atomic Energy Commission and Manhattan Project, key historic themes from that outgrowth was we had a cultural production focused on military or wartime mission. We had a closed and secret system versus transparent. Autonomy was -- or authority and autonomy was varied depending on the mission. And we were production focused over safety and environment.

When Admiral Watkins came in, we had a

paradigm shift. And today's contemporary themes are to ensure we have technically qualified staff. We focus on career organizational culture. We have a system called integrated safety management which we test the flow down from the rules, Code of Federal Regulations all the way down to the contractor's procedures.

We're focused on environmental stewardship. We do adopt commercial nuclear standards and NRC standards. And we focus also on community engagement which includes a citizens' advisory board, courts, outreach to local communities, and certainly outreach to the Native American tribes. Next slide, please.

As you're aware, numerous technologies are coming into play, molten salt reactors, gas cooled reactors, unique fuel designs. As Dr. Waksman said, the TRISOs will be a game changer. There's a broad size, range in size and functionality as Dr. Gehin discussed. The MARVEL reactor, 100 kilowatts up to a commercial test reactor in DOE is 300 megawatts, certainly a rapid pace of progression in the technology life cycle. A lot of additional data is needed. So DOE has to have a regulatory framework that is rigorous, flexible, and adaptable. Next slide, please.

You're probably familiar with this. We call this graphic valley of death. Basic science is developed in the universities and the national labs. It flows into the basic applied science and then to applied engineering.

That's where national labs such as the Idaho National Lab, Oak Ridge National Lab, Argonne National Lab among others can assist in the development of these technologies. And then certainly DOE can assist with the demonstration and deployment for technology readiness levels such as TRL-789 where it's not quite ready for commercialization. And at this point, we engage with our NRC partners such as we're doing with Pele to help assist in authorization and commercialization of that technology. Next slide.

National lab capabilities, I won't spend a lot of time here because Dr. Gehin talked about it. But the National Reactor Innovation Center enables deployment, the gateway for advancements in nuclear GAIN and provides nuclear energy industry with access to technical, regulatory, and financial support necessary to make innovative nuclear technology gains. We engage in public-private partnerships, allow access to nuclear -- the DOE nuclear labs in collaboration.

DOE also has field fabrication and development capabilities. And we are working with some vendors on providing those capabilities. And DOE assisted the NRC the licensing modernization project and the technology inclusive content of application. We are becoming a lead in cybersecurity. Certainly labs like Oak Ridge have a tremendous super communicating ability. Next slide.

So the DOE authorization process supports advancements of this technology. We call -- instead of licensing, we call it the authorization basis, provides a reasonable assurance of public environmental protection. We have the same safety goals as the NRC.

Here at the Idaho National Lab, I am the authorization official for the new reactors that will deploy here. And I challenge the contractor to go beyond the safety goals. And I would like to see no design basis events that challenge our local guidelines beyond the facility fence line. Now that's a lofty goal that I think with fuels such as TRISO, it's certainly achievable.

We have a regulatory environment that's designed to support a broad array of capabilities and needs, fuel fabrication and reactors. We are very involved in national security missions other than Pele. And we have complex and multi-mission nuclear R&D facilities across the complex.

So as I talked about before, we have to be technically rigorous, flexible, and adaptable. We have to use up front tailoring approach to best fit the application. And this is where I'll go back to the TREAT reactor transient reactor test.

We know it was decided that TREAT had to be restarted after more than 20 years of being shut down to meet the goals of the advanced accident tolerant fuel program. It had a very short turnaround. And we were able to, from start to finish, rewrite and approve the TREAT documented safety analysis in 18 months. And we did that by sitting down with the contractor whenever he had difficult situations.

We did not send over a request for information. If we had questions, we arranged a meeting. We sat down and we worked through those questions verbally, and then we followed it up with a formatted formal comment response. Where we had issues, and we did have some issues, we sat down in focus session and resolved those issues between the contractor and my staff. And we were able to, again, be successful in that project and a documented safety analysis approval in 18 months. Next slide.

So the relationships of the regulatory requirements, for those not familiar with DOE, the outer or the purple oval is the contract. This provides us somewhat more flexibility than the NRC because we can provide incentives for positive performance and safety and security in programmer project performance. And we can also analyze in the incentive -- or a safety or security performance in that area.

This is also where we flow down the -- the requirements below, the Code of Federal Regulations, we'll get to this in the next few slides. We call them DOE orders, and they flow down into the contract. And we can tailor those from the specific contract.

The next oval, the authorization basis,

this includes the safety basis which is the inner oval. But it also includes environmental protection. It includes emergency management in the security plan. And this is where the DOE Office of Enforcement which is DOE-wide can take enforcement actions against safety and security issues and leverage civil penalties against the contractor if needed.

And then finally, the internal oval -- the inner oval is the safety basis. This includes the documented safety analysis, so in NRC parlance, similar to a license. It's technical safety requirements. The SA commitments which are equivalent to -- sort of equivalent to the license commitments. The DOE safety evaluation report and the unreviewed safety questioning process and the USQ process was modeled -- plagiarized, I'll say, from the NRC's 50.59 process. Next slide.

Our regulatory structure flows down from the DOE policy which is signed by the Secretary down to the Code of Federal Regulations or the rules. The DOE orders, you also hear them described as directives, implement the rules. And the manuals, the standards implement the orders, but those are generally laid out in the contract -- specific contract with the labs. And then finally, we have guides which are assistance on how to implement the orders themselves. But the guides are generally not part of the contract. Next slide.

This is very similar to what the NRC does as far as hazards and safety analysis. So I won't go into details. All I'm going to say about this slide is we leverage many NRC documents for our approval process. For instance, for the reactors that we're authorizing at this time, NUREG-1537 as well as industry standard ANS 15.21, we have just developed a new DOE standard, Standard 1237, which is called Documented Safety Analysis for DOE Reactor Facilities, and Reg Guide 1.232 which is design requirements for non-light water reactors. Next slide.

This is just to highlight some of the -- for those not familiar, some of the DOE requirements that flow down to nuclear facilities and their documented safety analysis. In this example, 10 CFR 830, nuclear safety management rolls down to DOE Order 420.1(c) which is facility safety which then implements numerous standards and other industry standards. For example, in the middle, DOE Standard 1066, really implements many national fire protection codes. And as I previously stated for the reactors, we've got a new DOE standard. And we've also are leveraging Reg Guide 1.232. Next.

So in summary, DOE is uniquely qualified to assist the industry and the NRC to demonstrate new reactor technology. We have a very similar process to the NRC for authorizing DOE reactors. And we have the same adequate protection standards for the public, but we are striving to ensure that we have a very low design base accident doses at the public boundary. And so with that, thank you very much.

COMMISSIONER CAPUTO: Thank you, Mr. Boston, and thank you to all of our presenters. Could I ask the technician to please display the results of our second polling question? Biggest impediments, cost, number one, and regulatory risk, a close second. Would any of our speakers like to comment? Don't forget to unmute.

MR. BOSTON: I would say that the regulatory risk of licensing is a -- adds to the financial risk. We are -- DOE is assessing the licensing basis for UAMPS NuScale at the Idaho

National Lab. And that is a driver. And again with the Project Pele and some of the other demonstration technologies, we can -- DOE can certainly assist in reducing that risk.

MR. ROE: This is George. I'd add in on that. As we've interacted with community utilities, the unknowns in terms of the costs and the relatively high cost compared to what is already installed is a very significant issue in terms of embracing the technology and one that I think create a, like, power purchase agreement and (audio interference) helping with the earlier adoption.

DR. WAKSMAN: Yeah, I would also add that I'm not sure I would necessarily rank them. I'd almost invert the question if they all matter because if any of those things fail, you're not going to get there. And I think in TRL parlance -- to use, sorry, a technical term. But we like to say that if your design has ten subcomponents and they're all TRL-9 except for one key subcomponent that's TRL-5, your whole design is TRL-5 because if that one thing doesn't work, you're not going to build it. So we have to make sure all of these things advance because if any one of those areas is not solved, then you're not going to have real tangible nuclear reactors powering things.

COMMISSIONER CAPUTO: Good point. I think I'd like to go back to George with our first question. So the question is, why do you think a microreactor will be economical even in Alaska where you have high energy costs? The cost for a microreactor can still be expensive considering the upfront costs.

MR. ROE: Yeah, I think that, like I said earlier, that is a very big unknown. The challenge with implementing a reactor in a high cost of energy setting is you have to realize it's not just the source of power that is the cost driver. Also, all of the utility management, et cetera, that's there regardless of whether the system source is a nuclear one or a diesel source or something in between.

And so it's important as developers are evaluating different opportunities for the technology to be mindful of what the cost elements are. And I think that's why it's so important to be in communication as several of the speakers have talked about with the end users to understand what are their cost drivers, et cetera. I think that the challenge of economics is why you want to go to places where they woke counsel (phonetic) faster in some cases. But the technology has got to be ready and robust enough to not introduce a risk that could unfortunately take back the whole industry if there was an adverse situation.

COMMISSIONER CAPUTO: Okay. Thank you for that. I think I'd like to direct our next question to Dr. Waksman. We heard a fair amount from Mr. Boston about DOE's licensing process. Can you talk to us about the licensing requirements at DoD and what the process entails?

DR. WAKSMAN: So we're kind of in a bit of a gray area here because the DoD, it has authority to really regulate itself. So the Navy, for those who are not aware, regulates itself. But they do audits with groups like the NRC to make sure that they have some other people looking into what they're doing.

But in terms of what the Army would do, we actually have the opportunity here to really recreate it from scratch. And so right now, we're working with the Army on multiple different ways that they might regulate this. And like I said, my preference is really to push a lot of that work off onto groups like the NRC because I don't think it's going to be good if the Army has to hire dozens of technology experts the way that the naval reactor has.

It creates a huge up front cost for something for which we don't know. There's a lot of huge up front demand. But there is an Army reactor office. The Army is starting to be -- actually, I'll also point out that as of a few weeks ago, the Army Corps of Engineers now has a nuclear power branch. So we are starting to put the pieces in place, but they're still just pieces. And it's a long way to go before the Army really finalizes how they would regulate this.

COMMISSIONER CAPUTO: Okay, great. Dr. Gehin, you mentioned fission batteries. Is there a possible application of that technology in space?

DR. GEHIN: In space? Commissioner, did you say in space?

(Simultaneous speaking.)

COMMISSIONER CAPUTO: In space, right. Are there possible space applications for what you're looking at, or is it slightly different?

DR. GEHIN: Well, we're not specifically looking at that with the fission battery initiative. But the technology is very related to strictly the fission surface power and electrical power in space. And certainly NASA has activities and interests that they're working on with Department of Energy using energy in space. So while our application is really looking for applications on Earth, the technology is fully applicable and can be extended for space nuclear power as well.

COMMISSIONER CAPUTO: All right. I'll pose this question to Dr. Gehin and Mr. Boston. What are the main challenges that you see with the verification and validation of computer codes for microreactors?

DR. GEHIN: Bob, you're on mute.

MR. BOSTON: Would you like to go first?

DR. GEHIN: Yeah, go ahead.

MR. BOSTON: For my particular focus right now is on fuel qualification. And so the V&V of computer codes that can lead to adequate fuel verification so that we can, in fact, authorize these reactors is my lead concern. There's a lot of other issues with V&V, but those are longer term challenges. And for example, for the MARVEL reactor, to meet the goals or the timing, they're going to be using TRIGA fuel which is well characterized. So that is less of a concern for me.

DR. GEHIN: Yeah, maybe I'll add to that. I mean, a lot of our data for V&V or validation in particular comes from these legacy reactors, some of which I talked about. So we rely heavily on that.

But one of the purposes of the experimental capabilities I talked about is to generate data specifically to help validate some of our new codes, measure things in more detail. And then I think these demonstrations themselves offer really the first time in my career to be able to collect data in real time to support validation and then can be used as the reactors are commercialized. So it's really a unique opportunity, not only leveraging what's been done before, building up the experimental infrastructure, but actually having these operating demonstrations that can support further data.

COMMISSIONER CAPUTO: Well, we have come to that point in our conversation where we have to acknowledge that we are what stands between people and lunch. And so I would like to thank our presenters for taking the time to appear today and share their thoughts. I think it was a fabulous discussion.

I'm sure we could continue with Q&A for quite a long time. But they are going to give us the hook momentarily. So thank you, everyone, for participating today.

And with that, I will turn control back to the technician and wish everyone a happy and healthy lunch. And hopefully, you will return to the RIC in the afternoon. Thanks, everyone.

(Whereupon, the above-entitled matter went off the record at 12:00 p.m.)