UNITED STATES

NUCLEAR REGULATORY COMMISSION

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BRIEFING ON ADVANCED REACTORS ACTIVITIES WITH FEDERAL PARTNERS (PUBLIC MEETING)

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THURSDAY,

MAY 12, 2022

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The Commission met in the Commissioners' Conference Room, First Floor, One White Flint North, Rockville, Maryland, at 10:00 a.m., Christopher T. Hanson, Chairman, presiding.

COMMISSION MEMBERS:

CHRISTOPHER T. HANSON, Chairman

JEFF BARAN, Commissioner

DAVID A. WRIGHT, Commissioner

ALSO PRESENT:

BROOKE CLARK, Secretary of the Commission

MARIAN ZOBLER, General Counsel

PANEL MEMBERS:

DR. ANTHONY CALOMINO, Space Nuclear Technology Portfolio Manager, Space Technology Mission Directorate, National Aeronautics and Space Administration

ALISON HAHN, Director, Office of Nuclear Reactor Deployment, U.S. Department of Energy

JAMES SAMPLE, Principal Director of Infrastructure, Deputy Assistant Secretary of the Air Force for Environment, Safety, and Infrastructure, U.S. Air Force

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

PROCEEDINGS

10:00 a.m.

CHAIRMAN HANSON: Good morning everyone, I convene the commission's public meeting on advanced reactors activities with federal partners. It's a great pleasure to welcome colleagues from the Department of Defense, the U.S. Air Force, the Department of Energy, and the National Aeronautics and Space Administration. As we often say at the NRC, we're independent, but not isolated. And so it is important, I think, to do, and to have meetings like this today where we hear from our colleagues, and other branches of the federal government.

One of the NRC strategies for regulating new reactor technologies is effective coordination with DOE, and other U.S. government organizations, including DOD and NASA. NRC appreciates these interactions as opportunities to strengthen its capabilities for advanced reactor regulation, while being mindful of our role, again, as an independent regulatory authority.

So, I thank you all for supporting this meeting today, and I'm looking forward to a great conversation. Before we start, I'll ask my colleagues if they have any comments they'd like to make. Okay, with that, we're going to begin with our first speaker, Dr. Jeff Waksman, the program manager for the Strategic Capabilities Office of the U.S. Department of Defense. Dr. Waksman, the floor is yours.

DR. WAKSMAN: Thank you. So, I'm going to be talking today about Project Pele, if you could go to the next slide please. So, this is the bottom line up front slide about what Project Pele is. Project Pele derives from a 2016 Defense Science Board study on the need for mobile, reliable, sustainable, resilient power. So, it is a transportable nuclear reactor that will produce one to five megawatts of electrical power for a minimum of three years. It needs to be transportable by army equipment, so trucks, C17, et cetera. It's based on TRISO fuel, which I'll talk about on my next slide. We began a two-year reactor design competition in March 2020, we actually kicked that off in this building in the last week before COVID, so we had very good timing for that.

We started with three companies. We then down selected to two after one year, and we are now in the process of down selecting to one. That winning company, their design is not 100 percent completed, but it's close. So, we're going to wrap up the rest of the design, and then the plan is to begin ordering hardware later this year. The plan is to take about two years to fabricate, it will then be transported Idaho National Laboratory in mid-2024.

The reactor, and the fuel will be fabricated in different locations. They will be shipped separately to Idaho National Lab. It will then be fueled inside the treat facility, and then after operation readiness review, it will begin operation. And again, hopefully that will be in the tail part of 2024. Next slide please.

So, this is TRISO fuel. I'd imagine the Commission is probably familiar with this, but just for those watching who maybe are not, the image in the upper right, that cut away is what a TRISO pellet looks like. The red in the center is the uranium, and it's surrounded by these other layers that includes a porous carbon material to absorb the fission product gasses, and then silicon carbide.

The DOE spent a lot of effort and time developing this AGR TRISO variant since 2002, and this fuel has been tested to 1800 degrees

Celsius for 300 hours with almost no breakage, which is obviously much hotter than it'll ever experience inside a core.

Now, they did not primarily do this for safety, because as we all know, nuclear reactors are already very safe in this country. The primary goal was actually to reduce cost. The idea was that by having these additional layers of protection you would maybe not need to have such elaborate additional containment beyond, that would hopefully reduce capital costs, and also reduce O&M costs. This has a couple additional benefits for us in the DOD. In the DOD, we always have to consider the possibility of a kinetic strike breaking open the reactor.

And obviously that's going to be a bad day regardless, you're not going to have no radiation release, but the fact that the fission product gases are inside millions of these little pellets should significantly reduce the amount of fission gases that are able to escape. Also from a proliferation perspective, we think this will make these very resilient to proliferation. You'd have to get these tiny bits of uranium out from -- I don't think anyone's actually figured out a way to recycle this sort of fuel yet, to get through all the silicon carbide layers, everything else. So, and combine that with the fact that this not HEU fuel, this is HALEU fueled, it's a very unattractive proliferation target. So, next slide please.

So, this is a brief history lesson. For a lot of folks who don't know, Army nuclear power has existed before, back in the ‘50s, the Army, and the Air Force also had programs in addition to the Navy. The Army built eight reactors, the first reactor to be plugged into the U.S. electric grid was an Army reactor. That said, these were very unreliable. I'm sure it would give the safety officials here hives to try to regulate one of these reactors today, so we are certainly not bringing these designs back.

So, on the next slide please. So, why are we doing this now if we haven't done this in 45 years? So, the DSB identified that energy, and electricity are increasingly important to the DOD mission. Not only new weaponry, like directed energy weapons, and UAVs, and drones, but also we're looking to electrify the non-tactical fleet, and obviously climate change and reducing fossil fuels in general has become much more of a goal.

It's now considered a strategic threat to the DOD. And at the same time, getting energy around the world has never been more difficult. In previous wars, we've always been able to get fuel pretty close to the front before it's at risk, and that will not be the case in any future conflict. In fact even within the contiguous 48 states, there are now risks of cyber attacks that could take the grid down. And we need to be able to handle that as the DOD.

At the same time, nuclear power has advanced quite a lot. Generation three reactors have been producing power on the grid around the world since 1996, and generation four reactors are now here with the Chinese HTRPM, which turned on last year. So, their conclusion was, someone should see if nuclear power can work, someone should try to build one.

Next slide please. So, the Strategic Capabilities Office is a very small office, we have not done a nuclear project before. So, we certainly don't have a nuclear team in place. So, this has had to be a whole government effort. One of the first things we did was a trilateral agreement with the Department of Energy and Nuclear Regulatory Commission just to provide technical advice, design advice.

We also have asked NRC to help us with future licensing risk. We would like the possibility of either having the NRC potentially regulate the next generation of Pele, or at the very minimum, have a Pele commercial spin off that we'd want the NRC to regulate. So, we want to make sure that we're not going down a pathway that's going to be hard to license.

The DOE is providing the safety oversight, and authorization, that's also where the Price Anderson is flowing through. The NRC does have a role while you're not regulating the reactor itself, we are asking you to approve the -- or we're going to ask you to approve the reactor module as a transportation package, and I'll talk about that a little more in a future slide.

NEPA was done jointly with DOE and the Army Corps of Engineers. And the fuel we're getting is from NNSA, they're providing us with HEU, that we're getting ready to down blend to HALEU. And the TRISO is being done jointly at the commercial scale TRISO facility that we've set up at BWXT Lynchburg, we've done that jointly with DOE and NASA. Next slide please.

So, we believe that Pele will facilitate commercial advanced reactors in multiple ways. One is just obvious, once you build a reactor, you can build a commercial spin off, you'll have a lot of data, it should be a lot easier once you've already built one. But we hope that this will also be a path finder for other advanced commercial reactors. We know that there's a challenge in the country that no non-light water reactor has ever been regulated by the NRC. And it's a huge first mover problem, because any company that comes along doesn't know what's really going to be involved here, there's a huge uncertainty, and I know that the NRC is working very hard to develop that. I'm very familiar with the licensing modernization project, but there's still a lot of uncertainty.

So, I think the NRC being arm in arm with us, and watching what is involved in us demonstrating to DOE regulators that this reactor is safe will hopefully provide understanding of okay, how much time, and effort, and money is really involved in showing that a micro reactor is safe. TRISO was originally developed to be a commercial game changer, that's why the DOE spent 400 million dollars developing it.

But someone has to build one of these with AGR TRISO. Obviously there were TRISO reactors back in the day, back in the ‘60s, but that was obviously very different from the AGR TRISO variant. And we like to point out that this is how this was done in the ‘50s as well. The commercial sector did not come up with nuclear reactors from scratch. The first reactor, the shipping port reactor was an aircraft carrier reactor. And it was built by the Navy, and then it was handed off to industry. And to this day, the fact that most reactors around the world are light water pressurized water reactors is because that's what Admiral Rickover decided was best for a sub. And you get technological lock in, you get supply chain lock in, but at the same time the DOD can reduce risk. That allows commercial companies to say well rather than develop our own technology, why don't we just use this one that already has a lot of data? So, we do believe that this can be a real pathfinder in that way. Next slide please.

So, speaking of Admiral Rickover, this is my scared straight slide. So, Admiral Rickover has this famous essay that most people who are involved in nuclear are familiar with. I put a piece on the left there, where he talks about the difference between what he called an academic reactor, and a practical reactor, which in 2022 parlance is a power point reactor versus a real reactor. The nuclear industry is awash in power point reactors. And his point here is things you think are hard might be easy, but things you think are easy will be hard. And there's just a big step from power point reactors to real reactors, and as I'm sure you're aware, all of the reactors that produce power in the United States broke ground no later than the 1970s, and per the IAEA, as of about two weeks ago, the number of non-naval power reactors under construction in the U.S. is two; those are the Vogtle reactors. And two ties us with such economic powerhouses as Bangladesh and Slovakia.

And we have to be realistic of where we are as a country, in terms of where our supply chain is and where our industry is. So, we just have to be realistic about that. So, next slide please.

So, how do we hope to actually do this? So, there's a few pieces to it. One is obviously trying to wrap up the design, that's what we're trying to do now. We have -- we're certainly aware that if we have to do significant redesigns after we start manufacturing, that will be crippling to budget and schedule, so we're going to try to avoid that at all costs. We know that quality assurance is going to be a major issue. We're certainly aware of the challenges that the Vogtle reactor had. It's not only that finding NQA1 certified suppliers is hard, but even if they're NQA1 certified, it does not mean that they can necessarily deliver.

The Navy has gone through a lot of effort to develop its supply chain, and it's not as easy as going on Amazon and buying components. So, we cannot assume that subcontractors can deliver what they say they can deliver, and that's a big part of what we're focused on. The DOE authorization process is obviously something we have to do. We have to get through PSAR, the FSAR, all the acceptance reviews, all the things you would imagine you have to do, and obviously the operational readiness review will be the last step there. Training operators, we have already -- I think we've actually completed the hiring of a few people now who will be our first tranche of operators. They will be learning off a demo, so that they'll be ready to operate the reactor when it's there. And then they will also serve to train the second generation of operators who will come from the Army Corps of Engineers and the National Guard, who will be brought out to Idaho to learn how to move the reactor, assemble, disassemble, and how to operate the reactor. So, part of what we're doing now, is figuring out what the training needs to be for folks like that who have experience doing prime power, but don't have a nuclear background. Next slide please.

So, this gets me to our NRC engagement, and so we have been engaging the NRC at a working level from the start. And I think we've certainly had a very good relationship with the NRC. We're trying not to just show up one day, and say hey, can you guys regulate this without having coordinated to work this out with you all. So, as I mentioned before, a lot of what NRC is doing is just providing informal advice. When we have design reviews, folks at the NRC sit in, they're free to express thoughts or concerns to us about our testing plan, anything else in an unofficial way. In a formal way, what we are trying to do that's novel is to define the reactor as an over the road transfer package per 10 CFR Part 71.

So, the idea is that our system is multiple 20-foot CONEX boxes, so shipping containers. One of those boxes will have the reactor in it, and any kind of control rod, or drum mechanisms I'm going to have to say vaguely, and then the shielding. And then that box, in the field, should never be opened. The idea is we try to move as many moving parts as possible outside the radiative area so that we can do maintenance in a non-radiated environment. And then that box should not be opened, which is good from a proliferation perspective, you know now one is going to actually be able to get to the uranium. But that box is what we want to ship, and obviously we need to meet the whatever it is, ten millirems per hour, two meters. And obviously a variety of other things we have to show we meet. So, this is obviously something that hasn't been done before, and so we've been engaging the NRC on this for awhile. In the end, it will be the winning vendor who will be submitting, they will be submitting for this approval, it will not be us submitting, it will be the company. And we've also -- DOT has been engaged as part of this as well, we've engaged with DOT for a couple years as well. Next slide please.

So, I'm not going to read this whole slide, because I don't like people who just read slides, but there's a lot here of the different steps we're undertaking here, starting with the probabilistic risk assessment, and going down. And we're certainly happy to talk about this, and I've only got 73 seconds here, so I'm not going to try to read through more of this. But certainly, this is stuff we've been going back, and forth many times with your experts on a working level here, and I think we've had a very productive -- we know there's work left to do, there's a lot of work left to do. But certainly the folks we work with don't think there's any show stoppers here. So, I'm just going to go to the last slide to close here.

And I have closed with this slide for a couple years in my slide decks, and my point here is that I think there's two things about nuclear power that literally everybody in America can agree with. And one is that if we can make nuclear power work, if we can do it safely and cheaply, then it's a total game changer for the DOD and the commercial sector, I think we can all agree on that.

But I think also everyone can agree that it's hard. There's a reason why no one has built one, it's not because smart people haven't tried, and I think the challenges are not so much engineering, it's all the other things. It's the regulatory regime, not that the regulatory regime is unreasonable, but just figuring it out. Figuring out what exactly the regulatory regime is. The environmental procedures, supply chain is a huge, huge problem, if anything I would underline that one as the biggest one, supply chain. But figuring out con ops, what exactly the technical requirements are, what the training's going to be, there's just a lot that has to be done. And so to get back to the point from the beginning, The only way we're going to know if we can do this is if we build one. And that is the point of Project Pele. And so that's the end of my slide deck, and thanks for the opportunity to speak to you, and I look forward to any questions.

CHAIRMAN HANSON: Thank you Dr. Waksman, I appreciate that presentation. We're going to hand it over now to Mr. Jim Sample, he's the acting deputy assistant secretary of the Air Force for environment safety, and infrastructure. Mr. Sample, the floor is yours.

MR. SAMPLE: Thank you sir. My presentation is going to echo a lot of Jeff's I guess, themes, but we're kind of going in a little bit of a different way. If you go to the next slide, thank you sir. I was the acting director until about a week ago, we do have a new director, Ms. Nancy Balkus would love to be here, she sends her thanks. She's actually in Colorado right now, as we spin her up, and give her all the stuff that's going on. But our division, when I was the acting, and what she's in charge of now, we are in charge of for the Air Force, let me throw one caveat quick, I need to do it, we're the department of the Air Force, because we now do have two services, we have the Space Force and the Air Force. I find myself slip several times, and say Air Force. A lot of combined requirements in those two services, and some really unique requirements that really lend themselves to your area of expertise. So, we'll be working with you, we're working with you extremely closely on all this stuff, and we'll also be doing with some Space Force things in the very near future.

As I said, my division does installation energy, all military construction, environment, and safety. So, a lot of the stuff you're dealing with, I'm relatively new to this, but it is an amazing technology, and we are so excited about the project that we're going through. As I said, I'm the director of built infrastructure now, so I'm in charge of all military construction the Air Force does across the board.

We're going to use a contractor for this, but we are going to do some lessons learned, and we're watching it from our construction side. I do have to throw one shout out. Ms. Judith Willis, who is sitting in the back, is my expert on all this. If I have to phone a friend, that's who I'm going to. If we go to the agenda slide next. You'll see quickly, I'm just going to run through these things. Not need to go over that -- good.

This is simply the what, why, and how we're going to do this project. We could probably spend a lot of time on this, I'll go into more detail as we go through. First off, as Jeff mentioned, this technology, micro nuclear reactors, to the Air Force, just checks so many boxes for us. From the ability both to produce power, and heat. Heat gets lost on a lot of things. People don't realize heat, and when we get into Alaska, heat is ridiculously important. Also supply chain, all the different supply chain issues we're having at the moment, this technology is just amazing. You'll see, I'll go through this, there's huge benefits for greenhouse gases, and things of that sort with this technology, that's not why we're doing this, these are truly operational reasons.

So, we're excited by this technology, what are we going to do now? We are going to do a pilot project, and it's not a technology demonstrator, this is a pilot project solely to determine the best way to integrate these into our installations. So, we know this is a tactile issue we want to go to, let's do a pilot project to run all the traps working with the NRC, how we do that, working with states. I'll get to that in a little bit.

Working with the state, and local, public, environmental, all those things are stuff that my shop does. What we don't do is operate nuclear reactors. So, that is not a core competency in the Air Force, so we are going to go, as part of this, we are going to work to buy the power from a commercial product. So, while we don't do nuclear reactors, we do spend money well.

So, our goal is to do a 20-year power purchase agreement, that we will guarantee we will buy the power for 20 years from a contractor that comes in, and puts a small nuclear reactor on our location. So, we were looking at places, where can we best do this? We're going to do a pilot project in Alison Air Force Base in Alaska. Alaska, ridiculously remote, at the tip of the spear at the moment, dealing with Russia, and things of that sort.

What we are operating at Alison is vitally important to our operations, and the national interest. Currently, Alison is run, powered both heat and power by a coal plant. That coal plant runs just on average, we're burning 800 tons of coal a day at that location. Beyond the logistics of just keeping that running getting the coal to it, you can see the vulnerabilities associated with that.

That if we can get a small micro nuclear reactor to take some of that load off. At the moment, we're just talking about five megawatts, they have anywhere from 15 to 20 need daily, for a pilot project. But once again, a pilot project is to determine how we can best do this and move forward going there. That was most of the first slide. If you go to the next slide, where are we at now, the current status.

We are in the process, we're almost done, we're actually in the coordination of the RFP for this to go out. We're working with DLA Energy, we mentioned their GC branch has it, they're having some problems with staffing in GC, so that's the current hold up, but things are moving forward extremely quickly. I have to say once again, thanks from the Department of the Air Force to NRC. You guys, we have been teaming amazingly well with you pushing this forward. You can see -- read all the slides on that.

One other thing I want to mention before, dealing with the states. As we've been working this with 2016, working the project, we realized when we chose Alaska, the Alaska state regulations involved in this, they don't have anything for micro reactors. They all deal with big reactors, just the time line, and reviews associated with the siting, and everything in Alaska would have doomed this project. There's no way we would have it anywhere in the near future to actually get results so we can move forward. With that said, the Alaska legislature, both their state and their federal senators have taken great interest in this. We've had a great relationship with them, they have written an act relating to micro reactors, Senate bill 177, that just passed the Senate May 3rd. We think it's going to go through, I think it had -- I have the votes, it was like only two votes against. Great teaming, part of that has been working with you all, but also the transparency of this.

We've gone to the communities, we've gone to the tribes, I'll go into communications a little bit later. Frankly, we thought we were going to have a lot more opposition, and we've been extremely happy with the way things have been moving along. Next slide. So, the acquisition process. It's kind of an eye chart on this. You see where we are at the moment. We have completed almost everything associated with the RFP. We're doing the final coordination, we hope to have plotted that out this summer. I can go through the excruciating details on that, but you can see the details, a 30 year lease for the land, 20 year power purchase agreement, that's just those targets, it can be more, and we'll look at it as we go forward. Next slide.

Kind of interesting talking to the NRC about the application process, considering you guys are the experts on this, not me. But you can see this slide is just where we're going to get to the point where we get the vendor to do an application. Kind of like Jeff said, we're hoping the vendor will be the proponent for the application. They'll be the proponent for a lot of the environmental work, but we are going to help them with this. We know we are the catalyst for this, we are the reason it's happening, so we have to be involved. But like I said, we're not the experts on this aspect of it, we are great at the community outreach, 106 consultations, environmental, and things of that sort, but we'll work with NRC on those things.

And that bottom line, the continuous stakeholder engagement is by far the most important thing with this, as you've seen with any nuclear project. So, once we get to the licensing application, if you go to the next slide. You notice that left bar is still the same, so this is actually we get the application to you, then we get to the licensing process.

You'll notice on this there's a little yellow dot that says DAF involvement. That's kind of misleading, because we are obviously involved in every aspect. Every box you see on this, the yellow dots are where we're going to take a major -- not a lead, because you still have the rules of who is in charge of it, but for public scoping meetings, obviously it's going to be on an Air Force base, so we need to be up front. Environmental review, it's going to be on an Air Force base, we need to be up front. But we will be working with the NRC, and other partners going forward on this, including the public comments. They should be talking to us. We're the ones driving this, we need to be answering the public comments, we need your help from a regulatory standpoint/expertise standpoint. But we know we're partners on this, and this is not going to work without the partnership.

Part of this aspect will be the environmental, how we go through the NEPA law on that. We see where we're still working with the lawyers, and that's part of the stuff that's holding up, how exactly we do that, where we're a cooperating agency, who is the lead agency. We don't see any hiccups in doing that. We see we're all going to be a team working on this anyway, but who is the actual stuckee for the lead, that's still coming forward. Next slide.

This has been the greatest success so far. As I mentioned, we thought we were going to have a lot more opposition, both from tribes, and local. We've had very little. We've been out in the bushes telling people what our plans are. Asking for their input, asking what they're worried about. We had several interviews on local radio, just trying to get everyone's concerns, and amazingly there hasn't been as much. I think that goes a lot to your credit, and Jeff, and everyone else has been doing, getting this technology out there, and they see what a benefit this is for us. Also the national defense aspects of it. It's the end of the coal plant up there, we thought we'd had more issues from coal lobbyists, we haven't had much at all. The important thing is we're going to continue this process, continue complete transparency all the way through, and want to be your partners on that. Next slide.

So here's from, I mentioned that I'm in charge of military construction for the Air Force. This is the chart, this schedule amazes me, and excites me. You can see where we are in 2022, this is where we'll release the RFP. One thing I skipped over, if you saw on some of the slides, the previous slide on the stakeholder engagement. We're going to release the RFP hopefully this summer, and then we're going to have a conference, we're calling it a pre-proposal conference up in Alaska, where we can get vendors in to look at the base.

If they want to make a proposal, they need to see where can they put sites, where can it be on the base, ask questions of us, try to get as much information out there to get successful proposals in as we possibly can up front. We're going to probably do it somewhat hybrid, but every question that's asked from any of the vendors will document, and put out, so everyone has the same information that we're starting forward.

We would love NRC to be a part of this, either remotely, or up in Alaska, it will be very interesting. So, that's going to happen this summer, after we release the RFP. And then you can see the rest of that time line, the interesting thing is that last foot, we expect this to be operational in 2027. So, between proposal, vendor, NRC license, you'll notice that 2026 bullet is the build.

I know, I've taken to heart Jeff's last slide of yes, don't be optimistic on planning, but with this technology, and with some of the work Jeff's done with other folks, we think that's actually doable. That the actual construction and development of this thing will only be about a year, and we'll actually start using electricity and heat from this at Alison in 2027 with all your help. And that's actually the last slide I had. I look forward to questions.

CHAIRMAN HANSON: Thank you, Mr. Sample. Next we're going to hear from Ms. Alison Hahn, she's the director of Advanced Reactor Deployment in the U.S. Department of Energy. Ms. Hahn?

MS. HAHN: Good morning, thank you for having me here today. So, at the department we are working to address challenges in the nuclear energy sector, and to leverage nuclear energy's role in combating the climate crisis by enabling the continued operation of the existing fleet, enabling the deployment of the advanced nuclear reactors, and developing the advanced nuclear fuel cycle.

I'm pleased to be here today to share the work that DOE is doing to ensure that innovative advanced reactors are available to meet our energy needs, and our ambitious carbon production goals, while supporting the economic vitality of our communities. Next slide please.

So, President Biden continues to make addressing climate change a priority, and the Administration has set those ambitious goals of achieving a 100 percent clean electricity generation mix by 2035, and a net zero economy by 2050. And we know that we cannot meet these ambitious goals without the clean, reliable power provided by nuclear energy. That's why we are focused on both preserving that existing fleet, and driving deployment of innovative advanced reactors. Next slide please.

So, while the current landscape for nuclear energy in the United States is our large existing plants that provide that reliable firm power for distributed grids, the future energy landscape is expected to look quite different. A combination of existing fleet, advanced nuclear power plants, coupled with fossil energy with CCUS, and renewable sources will not only produce the electricity that we're used to seeing, but we'll be able to flexibly provide heat and electricity to decarbonize other sectors of the economy, and support the needs of the grid. And to meet these needs, dozens of U.S. companies are working on advanced nuclear projects for a wide array of capabilities.

These newer technologies are being offered in a variety of sizes. The designs include light water cooled SMRs, as well as advanced sodium, gas, and molten salt cooled reactors. And we see significant levels of private sector investment, including with international partners to build out the supply chain. Diversification beyond electricity will enable the decarbonization of industrial processes that rely on thermal energy like hydrogen production, as well as the electrification of new sectors, like transportation. Next slide please.

Our advanced reactor technologies, or the ART Program, works with industry, national labs, other federal agencies like the NRC, universities, and international entities to support the development, and future commercialization of innovative advanced reactors. Within the ART Program there are four research campaigns.

So, first we have the fast reactor campaign, which focuses on de-risking, and demonstrating fast reactor components and technologies providing validated codes, and experimental databases to support licensing, and code qualifying advanced structural materials to reduce costs, and increase safety margins.

Then we have the gas reactor campaign. Within the ART Program, this campaign is focused on metal alloy qualification and scaled experiments. And as my colleagues have mentioned, we also have a separate program that's working to qualify that TRISO fuel, and nuclear grades of graphite for use in high temperature reactors.

Third, we have the molten salt, MSR research campaign. This is focused on investigating fundamental salt properties, materials, models, and fuels to support these reactors. And then lastly we have the micro reactor research program. This program funds activities to mature innovative components and semi autonomous operating regimes for micro reactors. The program also supports non-nuclear testing to support micro reactor development. And we're also working to establish the micro reactor applications research validation, and evaluation, or MARVEL test bed, which will offer nuclear integrated systems testing, and I have a slide on that momentarily.

In addition to the four research campaigns, the ART Program also supports cost shared partnerships with industry to reduce the technical, and regulatory risks associated with a diverse set of advanced reactor designs. The ARC20 Program, or Advanced Reactor Concepts 2020 is funding the development of three designs that could have a significant impact on the energy market in the mid 2030s, so 2035 or later. Those three concepts are Advanced Reactor Concepts, LLC, conveniently named, General Atomics, and MIT. Next slide please.

In addition to supporting reactor development, the department supports two programs focused on security and safeguards. The advanced reactor safeguards program is working to address near term challenges that advanced reactor vendors face in meeting U.S. domestic material control and accounting, and then physical protection system requirements as well.

So, specific focus areas for the ARS program, it doesn't look great on the slides up there, but we have physical security. We're evaluating new technologies, and approaches to physical security seeking to reduce up front, and operational costs, and improve economics. The pebble bed reactor MC&A approach is based around three item control areas. We've got the fresh pebble storage, and then the reactor and pebble handling system, and then the spent pebble storage area.

For the combined micro reactor PPS, and MC&A area, we're working to develop a domestic licensing framework for micro reactors as a function of design options. The liquid-fueled reactor MC&A approach for liquid-fueled MSRs is being developed, and discussed with the NRC staff to help inform work on measurement possibilities to support future licensing applications.

Internationally, the ARS Program supports the generation four, or Gen4 proliferation resistance, and physical protection working group, and we're coordinating with the National Nuclear Security Administration to support U.S. vendors with a deeper understanding of the differences between the domestic, and international requirements. And then lastly, we're working again with NSA on exploring potential vendor engagements.

So, while these engagements will produce generic deliverables to share with all reactor vendors, they provide the opportunity for more targeted work with specific reactor designs as well. And then we have the cross-cutting technology development cyber security program, which develops technologies, and methods to address cyber threats to the U.S. nuclear power infrastructure. We work very closely with the Department of Energy Cyber Security, Energy Security and Emergency Response, or CESER Office, and support secure implementation of advanced technology, such as wireless control, and remove, or autonomous operations. Next slide.

Through our advanced reactor regulatory development program, the Office of Nuclear Energy coordinates closely again, with the NRC and industry to address and resolve key regulatory framework issues that directly impact advanced reactor demonstration, and deployment.

A key part of this program has been supporting an industry led project developed to develop proposed guidance for an NRC license application through the technology inclusive content of applications project, TICAP. This cost shared project builds on the outcomes of the NRC endorsed licensing modernization projects, risk informed, and performance based approach, and proposes a structure to right-size license application content through guidance that is flexible, clear, and appropriate for industry applicants planning to use that approach. The advanced reactor regulatory development program also supports targeted R&D to reduce the technical, and regulatory risks by providing bases for the establishment of licensing technical requirements. Work in this area generally addresses topics that are beyond private sector capabilities, or that can be significantly accelerated using national lab resources. Next slide.

So, I talked about the R&D. Through the Gateway for Accelerated Innovation in Nuclear (GAIN), we facilitate the private access to the technical, regulatory, and financial support. which is necessary to move new reactor technology towards commercial deployment.

GAIN supports funding opportunities to accelerate deployment through its voucher program, providing companies direct access to national laboratory expertise, and capabilities to advance the commercial readiness of their technologies. Next slide.

And if you think about GAIN being kind of a lower TRL focus, and NRIC's more of the higher TRL focus. So, NRIC, the National Reactor Innovation Center, led by the Idaho National Lab, is providing a range of capabilities to support nuclear technology demonstrations, including the establishment of demonstration test beds. These test beds will provide the infrastructure where developers can demonstrate and test their technology, such as fueled test reactors, and obtain the data they need to support their designs in licensing applications. The demonstration and operation of micro reactor experiments, DOME, got a lot of acronyms today, will support demonstration of micro reactor technologies, and is expected to be ready for the first planned test in 2024; that's the date we're working towards. We're also working to establish a second NRIC test bed, which can support experimental reactors that use safeguards category one materials for operation.

Although not required for commercial concepts, some reactor demonstrations, and experiments require that higher enrichment fuel to keep the size of the reactor small, while still ensuring that neutronics and thermal hydraulics are representative of their commercial designs. This requires a safeguards category one facility for operation, which is difficult to find outside of the DOE complex.

And then earlier this year, NRIC also initiated the advanced construction technologies initiative. This initiative aims to reduce cost overruns, and schedule slippages that we have seen recently in the construction of nuclear plant projects. NRIC, in collaboration with industry partners will develop advanced nuclear plant construction technologies that can drive down costs and speed up the pace of advanced nuclear deployment. Next slide.

I'm going to not read the title again, and just go with MARVEL was inspired by the SNAP 10A space nuclear reactor with a primary objective to produce an operational micro reactor on the most accelerated time line as possible. We're planning to generate approximately 20 kilowatt electric, using four commercially available off the shelf sterling engines.

The core will be made up of 36 fuel pins, and each pin will have five uranium zirconium hydroxide fuel pellets using HALEU. MARVEL will be installed in the treat storage pit at INL. This will allow us to leverage the existing treat control room for the MARVEL reactor. Once operational, MARVEL will serve as a nuclear test platform to validate operating regimes and end use applications for micro reactors that haven't been demonstrated before. So, think data centers, and things of the sort. One significant accomplishment for the project, is that MARVEL is the first new reactor to complete an environmental assessment array for NEPA compliance, which sets the precedence for reactors being DOE authorized, and eventually NRC licensed. Again, MARVEL is planned for operation in 2024. Next slide.

I mentioned this briefly earlier, but future energy systems will need to be highly flexible and responsive, integrated energy systems will provide a more secure, resilient, and sustainable energy infrastructure, resource efficiency, national economic stability, and international competitiveness. DETAIL combines systems that represent energy generation sources, distribution systems, energy storage, and energy users to demonstrate how novel integrated energy systems might be operated within a microgrid under both nominal and off-nominal conditions. This allows researchers to show how a nuclear reactor, which will be represented by a 250 kilowatt electrical heater, would physically connect with renewable energy, energy storage, industrial plants, and within a microgrid.

It will also demonstrate control systems for this new type of multi input, multi output energy system that can support multiple energy use sectors. DETAIL integrates real world energy storage, electrical vehicles, solar power, and more using physical hardware, grade emulators, and modeling and simulation tools to form a working model of tomorrow's electric grid. Next slide.

So, we are deeply invested in private, public partnerships with a range of nuclear developers to address the highest technical, and regulatory risks for commercialization. We're supporting three demonstration projects to deploy first-of-a-kind reactors on the grid by the end of this decade. It's hard to see the letters, but on the upper left we have the first one, the Carbon Free Power Project will result in the first commercial demonstration of the NuScale light water cooled SMR out of the national lab in 2029. The natrium reactor is a sodium cooled fast reactor that's being demonstrated by TerraPower in partnership with GE Hitachi. A novel molten salt thermal energy storage system allows the plant to ramp up its electricity from 100 megawatt electric to 500 megawatt electric over five hours, making this plant a price follower on the grid. The natrium plant will be sited at a retiring coal site in the state of Wyoming, which is in the top coal producing region in the United States. The Natrium reactor will be an energy powerhouse for Wyoming, providing hundreds of high paying jobs and attracting industrial manufacturing to the region.

And our third demonstration project is the X Energy high temperature gas cooled reactor. This four module plant configuration of the XE-100 module will provide 320 megawatt electric, and is ideally suited to provide flexible electricity output again, as well as process heat for a wide range of high temperature industrial heat applications, you'll see a trend there. The reactor design will be fueled by TRISO pebbles providing a robust safety profile. X Energy recently submitted a license application for its TRISO X fuel fabrication facility to the NRC, I believe. And it is worth repeating that all three of these demonstration plans are ideally sized to take advantage of the infrastructure and work force of retiring coal plants, bringing energy security to regions seeking to transition away from fossil fuels.

In addition to the three demonstration projects, we're also funding five risk reduction projects aimed at reducing risk, and technical uncertainty for a broad range of advanced reactor designs. Again, they're located in the top right of the slide. The first project is Kairos Power; it will support the design, construction, and operation of the Hermes test reactor to be located in East Tennessee Technology Park in Oak Ridge, Tennessee.

We then have two micro reactor projects led by Westinghouse and BWXT respectively. Westinghouse's design is a heat pipe cooled design, while the BWXT banner reactor will be a high temperature gas cooled reactor. Holtech is our only light water cooled SMR in the Advanced Reactor Demonstration Program.

And then finally we have a project led by Southern Company to design, construct, and build a molten chloride reactor experiment, or MCRE. MCRE will be sited at the Idaho National Lab, and will not be NRC-licensed, but will be authorized by DOE. Then I should note here the XE 100, the Kairos Power/Hermes test reactor, and the Westinghouse, and BWXT micro reactor designs again, as my colleagues have already pointed out, are proposing to use that robust TRISO fuel form, which is being qualified by DOE. And again, as was mentioned earlier, DOE has spent over 400 million dollars to qualify this fuel, and graphite to be used in these programs. Next slide please.

In conclusion, advanced reactors are crucial for achieving national, and global carbon reduction goals. DOE's continuing to perform foundational R&D on advanced reactor, and fuel cycle technologies to improve nuclear energy safety, and performance. We are connecting developers with the expertise, and capabilities of our national labs, and private public partnerships are bringing first of kind demonstrations to the grid within this decade. Thank you.

CHAIRMAN HANSON: Thank you, Ms. Hahn. Next we'll hear from Dr. Anthony Calomino, he's the Space Nuclear Technology Portfolio Manager for the Space Technology Mission Directorate within the National Aeronautics and Space Administration. Dr. Calomino?

DR. CALOMINO: Thank you. Thank you for inviting me to talk today, and I apologize for not being able to be there in person. Are you guys hearing an echo?

CHAIRMAN HANSON: We're not hearing an echo here.

DR. CALOMINO: Okay, that's all that matters then. So, I had some personal conflicts that prevented me from being there today, so I apologize for that. If the slides are up, and you're looking at the slides, I can start talking on where we're at. So, on the first slide, I just want to kind of talk a little bit why NASA is interested in space nuclear technologies.

We've been interested in nuclear technology since the early 1960s. We've had activities related to propulsion on using actually fission technology. As we begin to expand our interests in human exploration, both near-term, or near cislunar and lunar operations, as well as looking for some deep space missions, the two investments that we're looking to actually gain from this is on power and propulsion.

As we expand the capabilities, NASA needs, one of the things we're looking for is that it will help maintain our space leadership role, as a global leader in space leadership. We are working towards, and interested in working technology, but also contribute to enhancing the national security, our global competition position, looking for infusion of products back into the domestic economy, to grow that. And then contributing where we can to green energy, and the reduction of our carbon footprint. Next slide please.

The two technologies that I indicated that we're investing in, fission surface power as well as nuclear propulsion. On fission surface power, we're looking for something very close in power category, or class to what the MARVEL system is that was spoken to. We're actually looking to demonstrate something that would be on the lunar surface at first, and then we want to have something that would be evolvable, or extensible to a Mars human exploration mission, it would be somewhere in the late 2030s, or early 2040s timeframe. The space nuclear propulsion is enabling capability for its mass density, for its efficiency in propellant, and actually being able to conduct some cislunar operations, lunar tugs, moving to and from the surface of the moon. But also for some of our deep space missions, where solar electric-type applications will become prohibitive because of the fact that we've lost a lot of the solar intensity that we would have, plus temperatures would decrease the efficiency of some of the solar power cells as well.

Our current focus right now is actually on the fission surface power system that has a broad range of applications for our mission needs. And so this is actually the priority that NASA has in terms of developing capabilities. But we do have investments in both power, and propulsion that are effective right now. The next slide on nuclear power for the moon and Mars, I just want to talk a little bit on why it is that this is important for NASA.

Beyond the fact that we have these high energy density systems, which are solar or chemical that we eventually use, fission power systems are looked at as providing abundant, continuous power for all the operations that we would need on the moon and Mars. You look at the moon, and the day/night cycle, the night on a lunar night is about 14, and a half days. It is a time period when you essentially have very cold operations on the moon itself, the environment itself is one where you need to have these atomic sources of power to maintain habitats, to keep them warm, to keep rovers running, to continue to do operations during the night for 14 ½ days. The other interest we have large regions on the moon, NASA knows that we're going to look for resources that we would use. One of the important ones is ice water, and to actually be able to extract the ice from the ground, use that to produce oxygen and hydrogen that can be used in the operations by the overall architecture. But the ice deposits are actually sitting in the colder region, so if we want to be able to operate in those regions to extract that ice, mine it, and process it.

As you begin to look at operation on Mars, the big challenge there that we have is the fact that we have the probability of dust storms on the surface of Mars. Actually these dust storms could be rather significant. If you look at the image there, between 2016 and 2018, you can see that during one of the dust storms in 2018, a lot of the planet is actually obscured by the dust storm that was going on the surface of Mars.

The dust storm has a few adverse effects for some of the conventional systems like solar cells. One, it would cut down on the amount of light we're going to get, and the other is that the dust itself deposits onto the cells decreasing their efficiency even when the dust storm ends. For a nuclear system, a nuclear system is not only mass competitive for the power ranges needed on the surface of Mars. But it also is insensitive to the dust storms, and to a lot of the other aspects that solar systems or conventional power systems would need to be designed to survive. Next slide please.

So, just talking a little bit about what our requirements are, and I would point out that as far as NASA is going down these lines, we're not in terms of actual hardware designs, and activities related to hardware designs for these end applications. We're not as far along as DOD Pele activity, but we are on a course that hopefully will get us there relatively soon. For the things such as power requirements, we are looking for about 40 kilowatt capability to demonstrate that on the moon. As I said, that's close to the same power category as the MARVEL system. We do want to have a system that is capable of being transported, taken off of a landing platform, put onto a rover.

Having the ability to move that power plant to where it is going to be needed, depending on where the operations are moved as well. One of the things that's important for a space based system that is not as important for a land based system, and I think probably it is a bit of an issue for Pele, because the mobility, but for NASA, it's really about mass. We have to take this hardware, we have to get it out of the earth gravity well, and then we have to transport it to another terrestrial body and deposit it, or land it safely on that surface. So, whether we're landing it safely on the surface of Mars, or landing it safely on the surface of the moon, all of that in terms of looking at the mass, is a big driver in terms of architecture, and some of the things that we can do.

We're looking to have a 40 kilowatt system that can weigh about six metric tons, or less to fit into our architecture. And then we're also looking for a lifetime on these power units of ten years, operate for ten years. And one of the other aspects that we need, is we need to have fault tolerance. So, if the system actually has a single fault, we want to still be able to produce power at the kilowatt level, and that means we need to build some redundancy into that power system itself.

Early on NASA was interested in looking at highly enriched uranium solutions, and the big interest for highly enriched uranium solutions is that will always give us the lightest, and the smallest reactor for a space application. So, when you look at that mass driver, it is sort of a natural thing that you want to look for higher enrichments to get that mass and volume down.

But we've also looked at the opportunities, and the benefits of engaging commercial industry and having partners in developing these systems. And actually pulling from them on their innovation and some of their technology that they have been working on getting this basis. So, we have been looking at high assay LEU thermal reactor applications for NASA on the propulsion side and on the power side.

And we're very surprised, that depending on what kinds of technologies that can mature and get into these reactors, we can actually end up with systems that have very comparable mass and slightly higher volumes than where we were with HEU systems. And so we have been pivoting for targeting more of our investments into the highly enriched LEU solutions. Next slide.

For nuclear propulsion, just talking about two of the capabilities that NASA is looking at, and when we look at these systems, one of the aspects that we were interested in doing is targeting a human Mars mission. And in that regard, we have payload requirements, we have both opposition-class missions as well as conjunction-class missions that we're looking at, sometimes those two words, opposition, and conjunction don't carry a lot of meaning for others. But basically the way it works is that there's an alignment between Earth and Mars, the synodic period, where we can have very low amounts of energy to make the jump from Earth to Mars, and it's typically about every two years, and it's something that we've been doing with our probes and our rovers to date. Mars 2020 was actually launched on the synodic period.

But once you do that, you actually arrive at Mars, and you're basically going to be there until the alignment for the next period arrives, which is about two years. So, if the astronauts do a conjunction class mission, they have a relatively short transportation time to Mars, but then their stay there is going to be a little longer before they can come back.

And then we have this other opposition class mission, which is basically doing a fast transit out, you have about a 30-day mission that you can conduct on the surface of Mars, and then you can do a fast transit back to Earth. And that actually though requires a lot more energy. That's really where some of these nuclear systems pay big dividends for NASA, in terms of the energy capability that they provide.

While the nuclear thermal propulsion, as well as nuclear electric propulsion can close that mission, and we're looking at both, the nuclear electric propulsion has some benefits associated with fewer launches, a little lower mass, and also the technologies that we would use for a nuclear electric system are considered to be of a higher maturity. The challenges in terms of getting them in use are not as big on those. And we can actually even leverage some of the technology that we would be developing, hopefully from the fission surface power system to advance the nuclear electric system. On a nuclear electric system, we're using the reactor to generate the electricity. That electricity is then distributed out to electric thrusters, hull thrusters. And then the hull thrusters are actually what push the vehicle forward. Very high propellant efficiency on those.

The other system, which is a much simpler system, but it has quite a few other higher challenges associated with it, particularly on the reactor side, is that we're using the nuclear reactor as a large heat exchanger generating a significant amounts of heat in the reactor, typically right now we're looking at these reactors that operate somewhere in 2700 Celsius region, the heat propellant that we need. And then we exhaust that heated propellant out the back. The big challenge for the nuclear thermal propulsion system is materials that we can use. There's very few, and actually getting them to survive that high temperature environment with flowing hydrogen, and the neutronics has been a big challenge for us, but we have been working that, and we do have some material solutions that have been evolving as we've been moving forward. Next slide.

So, as I said, we kind of pivoted towards a low enriched uranium solution, as this has opened up our ability to actually reach out, and engage some of the commercial industry reactor designers in this. Back in August, we released three design awards with industry partners: USNC, BWXT, and General Atomics; began to develop a reactor that is capable of handling the temperatures, and the performance goals that we need for the nuclear thermal propulsion system.

We're a little more than halfway through the execution of those contracts right now. What they're going to deliver, is they'll end up delivering a preliminary design for reactors with frequent design innovations from industry on this. Those performance periods will end in August of 2021. And our intent is to use the information gained from these design efforts to look at additional engagements with industry downstream; to actually tighten some of our design requirements; to get better alignment with industry; and to have a better sense of their innovations and their approaches to be able to (audio interference) on within NASA. Next slide.

We are also recognizing that as we move towards these low enriched uranium solutions for NASA's application, the technologies that we need to get the mass and volume down have lower technology maturity. so we need to do investments there to bring them up to speed. A lot of this is associated with fuel development. We are partnering with DOD on some fuel manufacturing capabilities; I'll talk a little bit about that in some later slides. Although Jeff, and his team are looking at really the TRISO, which is really --- the TRISO fuel for their application, and want to take advantage of the 400 million dollar investment that DOE has in qualifying that fuel.

That fuel system for NASA's application is not going to get us to the performance metrics that we need, particularly for the NTP reactor. But one of the things that it does do, it gives us the advantage of the carbide manufacturing capability, probably look at changing the fuel chemistry, looking at a uranium nitrate chemistry, and a zirconium carbide pressure coating on the system to get to the higher temperatures, and the other performance metrics that NASA needs.

But in terms of the manufacturing capability itself, we can basically do that in some very similar facilities, or actually the same exact facility as the DOD scope. So, we're looking at these fuel chemistries, we're looking at some of the processing requirements for those chemistries. We're also making investments in moderator materials to be able to use liquid hydride materials, and reactors at the base. To take advantage of the neutron benefits they provide to the reactor itself. And then for us, it's back to the manufacturing these reactors in space, they're not going to look like terrestrial systems. They're not going to perform exactly as terrestrial systems do. We need higher temperatures speaking on the power side, than what we would see in a power system. So, the manufacturing methods bring in some of the more advanced materials into these reactor designs, and working those technologies as well. A lot of this effort is being worked both between and in partnership with DOE. We have been actually integrating with our development teams, and we work together to advance these technologies and get them ready.

One of the things I want to point out in terms of our operating conditions and what we're doing. Any of the testing that we would do on the ground for flight hardware for NASA is really going to be at zero power critical. We're going to minimize the generation of any of the fission products, because it would be a logical concerns with operating in and around, and actually getting a hardware system into the launcher payload to prepare it for either the moon or for Mars. Next slide.

So, on the interagency collaborations, we have been reaching out, and this is actually also motivated by some of the policy changes, NSPM 20 and SPD 6, looking to have better synergy and commonality with other government agencies to advance this technology. I think this is a win/win for us all. We all have our use cases that we have for these technologies. We've reached out to, and work with the Defense Innovation Unit on some of their small NEP high efficiency systems, and contributing to some of the ideations of their proposals. We are collaborating with DARPA on their DRACO space craft flight demonstrator that right now is planned for FY26. As I said already, we've been working for a few years now with DOD and the Pele Program to invest in a common field manufacturing capability.

And then we do work with DOE in terms of the materials element, and some of the tests that we need to get those done. And that is an ability for us to actually leverage commonality between the two where we have alignment, and use capabilities that have benefit for us all. Next slide.

On the federal policy and processes and how it's impacted NASA, NSPM 20 has really had a big benefit to us in terms of coming back and giving us quantifiable tiers that we can design in mission to minimize the radiological risks or exposure to the public for any of the nuclear payloads. And it actually lays out a path that NASA can follow in terms of its procedures and requirements to develop a process that would get us to align a flight approval of the launch as we're actually developing, and designing the hardware itself.

The nice thing about NSPM 20, it does to a level/allow us to keep the launch authorization process within the agency itself, as opposed to going up to the Executive Office. SPD 6 has actually worked out well for us in terms of laying out some of the common road maps between some of the different agencies. It also lays out some guidelines on when and how both LEU and HEU can be used. And so it's good to have all of that codified into a policy for our development on our efforts as well.

And then the other two things that we've been working on is we are about to issue a report that outlines what NASA's 20-year mission outlook looks like for nuclear missions, and the capabilities that we're going to need to complete those missions. That report should be out in the next couple of months. And then we continue to work with OSTP and NSC on evolving these policies and procedures, and making sure that as they're implemented as we're moving further down the development pathway, that we're getting good alignment with other federal agencies, and with our needs that -- within our own agency. Next slide.

I'm not going to go over into this too much. I just want to leave this out there, we do have a road map, this is going to be an evolving process. We're identifying our synergies and our link ups with agencies like DARPA. Obviously, DARPA is a big player with us right now in terms of nuclear propulsion, and we're working very closely with them on that capability. As we begin to make more significant investments into the electric propulsion, we'll reach out to more of the electric propulsion technology areas, particularly our fission surface power effort, as well as looking towards investments, and innovations that are coming out of the Pele program, and some of the terrestrial programs for power units on Earth. Next slide.

This is my get off the stage slide. I kind of want to go here though -- we are pretty far along in terms of where we're going, and what we're doing. In terms of getting some of these technologies in place, I think the reach out to industry, getting them engaged on the propulsion side. We expect to have very similar industry engagements on the power side next month, we have awards for a power reactor in the next month. And we realize it's just the beginning. And as we look to establish these capabilities and look actually at eventually finishing out detailed designs, and building and testing hardware, there are other areas that we begin to need to explore as we move forward.

We need to resolve what it means to have a space irradiated reactor and space design standards. Although a lot of the terrestrial design standards are going to be great guides, and we certainly are going to use them to guide our work, not all of them are going to be able to be applied to a space reactor.

So, we need to understand where some of our design standards are going to have to be modified or tailored to adapt to these systems. NASA's going to need probability methods for nuclear launch safety analyses and to change that landscape a little bit, we've got to modify some of our methods and analysis methods for nuclear launch safety.

We're going to have to address human operations and safety concerns for operating reactors off Earth, and make certain that we have the same level of safety and operational reliability for a reactor that would be either on the moon or on Mars, as you would want on Earth for human operations around them. One of the other aspects, and it’s been talked a little bit about here, is that NASA, we don't want to own this capability. It's not a government capability, which is one of the big benefits of bringing commercial interests in, and that is to be able to infuse this into industry, make it an industry capability. And we would look to industry as sort of the leaders in terms of looking at what is going to be required to commercialize and license that capability for space.

Eventually we've got to look at reactor controls, maintenance, disposal, we're not considering things right now in terms of refueling these systems, but it could be a possibility. We do want them to operate for ten years without maintenance for the initial couple of operations that we're out. But eventually that would be something that we could look at downstream, is having a maintenance cycle on them.

And then end of life disposal is another area that we are going to have to look at as we get further into this. And then as NASA begins to enter its build, test, and development for flight units, obviously we'll begin to engage some of the same activities that DARPA and DOD are doing right now in terms of looking at NEPA, ground testing requirements, transportation, launch operations for (audio interference) as on Earth.

And in terms of the Price Anderson, and coverage for activities related to that, a lot of the work that we do is through DOE, and we do that to gain that coverage now from some of our industry participants, and activities. And that's the end of my time.

CHAIRMAN HANSON: Thank you Dr. Calomino. Thank you all for your presentations. We'll start with questions with Commissioner Baran.

COMMISSIONER BARAN: Thanks. Well, thank you all for joining us today, and for presentations on these initiatives, which are really very exciting. Mr. Sample, since the application for Alison Air Force Base micro reactor will be reviewed by NRC, let's start with that one. What's the latest thinking on when the Air Force will select a vendor - is that something you're planning on for later this year?

MR. SAMPLE: So, the RFP should come out later this year, so it's probably in the next year, or so.

COMMISSIONER BARAN: Okay, and then what's your expectation about how long it would take for the vendor to put together an application for submission to NRC?

MR. SAMPLE: I think we have that on that last one, so let me -- just so I don't tell you the wrong thing. We're hoping to get the application by the end of ‘23.

COMMISSIONER BARAN: Okay, so about a year then, basically.

MR. SAMPLE: About a year for that, yeah.

COMMISSIONER BARAN: And does the Air Force have a view about which NRC regulatory framework would be used for the application? Are you contemplating a Part 50 approach with a construction permit, followed by an operating license? Are you thinking that's going to be up to the vendor - how are you looking at that?

MR. SAMPLE: We would like to leave it up to the vendor for the moment. I expect that will be the case, but we are going to look at the applications or proposals, and see what they propose. So, we're not putting that as a constraint that “you shall follow this,” or “you shall follow that.” We are saying that they will be responsible for going through the NRC process - how they choose to do that is up to them, and that'll be reviewed as part of the proposals.

COMMISSIONER BARAN: And what level of pre-application engagement between the vendor and the NRC staff are you anticipating? We've seen that where we have really good pre-application engagement like we recently had with Kairos and their Hermes application. That can put NRC in a position to have a shorter review period, and more certainty. Is that something you all are thinking about?

MR. SAMPLE: Absolutely. Between the conference, after we release the RFP to -- I mean that will start the game there. But once we do select a vendor, we see a lot of pre-application work between them and us also, all of us as a whole-of-government team. Because we want the application to be good and hit it all right at once.

COMMISSIONER BARAN: All right, good. Dr. Waksman, I appreciate your Admiral Rickover slide about how nuclear power is hard, and in some ways, Project Pele is especially hard, right? Because you're contemplating something that's both mobile and could be operated in a battlefield setting. Could you talk a little bit -- probably at a high level, about how DOD is approaching this kind of question of reactor survivability and the hostile conditions of a battlefield? You referred a little bit to the TRISO, is that the primary focus? Are there other ways in which you're looking at making it more robust than something that you would see deployed domestically?

DR. WAKSMAN: Yeah, so one clarification is that in Army parlance, this is actually not a mobile reactor, it's a transportable reactor. They define mobile, and different agencies define those words differently. Because in Army world, a mobile reactor, you could just plug your cell phone right into the side of the truck and from the highway you can power it, and that's obviously not what we're doing here.

In terms of battlefield, so in some sense the whole world is a battlefield. But we do not anticipate these being in a tactical zone. We don't think that's really the best use of these. So, if you envision a front per se, we anticipate being minimum, hundreds of miles, if not thousands of miles behind where that is. Now, obviously anywhere in the world things can be struck. We know our adversaries have missiles that can hit anywhere in the world, that's why we still have to take into account kinetic, in addition there's always the risk of sabotage, terror attack, all of these things are things that we've had to take into account. So, we view this as part of the risk calculus. The Army has a lot of experience having to protect valuable things. They have modular protection systems that are used to protect things, and there's also always going to be the option of taking this reactor, and say trying to bury it underground, something like that. So, the way we view it is we need to provide the data of what a certain threat would do to it, and then the Army can consider where they feel most comfortable deploying it, that they feel confident they won't create a radiological incident.

COMMISSIONER BARAN: Okay, that's helpful. And you mentioned the commercial scale TRISO facility at BWXT, can you talk again at a high level probably about capabilities volumetrically, and other things there?

DR. WAKSMAN: Sure, so I'm sure you guys are very familiar with that facility, it's the same facility where they make the naval reactor cores. It's also the same facility where DOE did the AGR TRISO work. A lot of that equipment was still sitting there, it was mothballed. And so with the money, jointly NASA money and DOD money, along with some incoming work from DOE, we got that equipment back up. We've also bought additional equipment to expand the throughput. Right now we're talking about a through put of maybe a few hundred kilograms a year. It's not a huge throughput, but they have the ability to expand further if there were to be additional demand. There's additional space in the facility that they could buy more equipment and expand the throughput.

COMMISSIONER BARAN: Okay, great. And Dr. Calomino, the discussion of the fission surface power effort for the moon and Mars is fascinating. As NASA looks to develop a 40 kilowatt reactor, who is going to handle the safety and environmental reviews and oversight? Is NASA going to do that itself, or is DOE going to take on that role?

DR. CALOMINO: Currently we would expect that DOE would handle that role, that NASA would not -- we work in partnership with DOE, but because we are using DOE for coverage on Price Anderson, we would rely on them to be the custodians of what that would be.

COMMISSIONER BARAN: Okay. And you mentioned end of life disposal, as you kind of gaze into the future, if one or more of these micro reactors are used on the moon or Mars, what would happen to them after their ten year power production period? Are you envisioning they would be left in place or retrieved? Is that something you all are thinking about at this stage, or is it too early to be focused on that?

DR. CALOMINO: It's still early to focus on this. I mean certainly we've talked about it, I can tell you what we're not going to do. And that is that we're not going to bring these assets back to Earth. Once a reactor is off Earth and it's away, we're not bringing them back into Earth and running a risk that we would have any kind of public exposure from that.

So, a lunar system would stay on the lunar surface, and the question about whether or not it would stay in place, I don't know that that's what we would do. We may very well -- it would still be in an operational area; we may very well move that to another location, another safe location where it would be stored.

COMMISSIONER BARAN: Okay, great, thank you very much. Thanks, Chairman.

CHAIRMAN HANSON: Thank you Commissioner Baran. Commissioner Wright?

COMMISSIONER WRIGHT: Thank you, Chairman. That’s very interesting conversations and presentations, thank you so much. And this is an area that's becoming more and more interesting, and we're getting more and more involved in it every day with our trips and things that we're involved in. Jeff, I want to start with you I guess. So, in licensing the Pele reactor module as a transportation package under Part 71, it's novel, right? And it requires a different way of looking at things, looking at commercial nuclear power, particularly the use of PRA, right? So, do you have any initial sense of what might be the most challenging to address or resolve in these?

DR. WAKSMAN: Yeah, so I think there's two parts that are going to be challenging. So, one is water inundation is a challenge, because high temperature gas reactors are under moderated, and so you have to be able to show that in any sort of water inundation scenario, that it's not going to go critical. But in addition, a challenge for us is going to be that we do not anticipate being able to meet all the requirements that a traditional spent fuel cask can do. We're not going to take this reactor and drop it from 30 feet. And so when we've been working with the NRC staff at a working level on is okay, how do we modify those and then try to make up for it with some sort of mitigation? And we've talked about the different sort of mitigations that we can do. And I'm not going to get to all them here, and I'd probably miss one if I tried to say it, but that's the perspective that we've been trying to take. And I think the NRC staff has been very helpful in helping to guide us in what would be the right level of mitigation.

COMMISSIONER WRIGHT: Very good, yeah, that's very interesting, the mitigation part of it. So, there's been considerable attention on how our advanced reactor regulatory framework, called Part 53, and I'm sure you're familiar with it, and whether or not it's hitting the right mark, in particular with consideration of certain things like again, PRA and ALARA. So, I'd be interested in hearing your perspectives, and the rest of you too if you have any, on what role you see PRA having in smaller micro reactor concepts - a leading role, a supporting role, or anything like that?

DR. WAKSMAN: Yeah, I mean I think just the nature of how different these designs are from what's come before. In the past, while the traditional fleet that were all pressurized water reactors, they're all different, but they're all kind of the same. And when you're trying to envision how would you regulate, I don't know, a molten salt reactor, it's going to be so different that it seems like you've got to use some sort of probabilistic risk assessment. Try to get all the smart safety folks, and try to come up with everything that could go wrong. What happens if there's an earthquake, what happens if some tree falls on it, what happens if it falls off a bridge into the river? And just figure out what the likelihoods of that are, and what the consequences of it are. I mean I'm hardly an expert in this, I have people a lot smarter than me supporting me on this, but at least to my unfrozen cave man brain, it seems like the way you've got to go.

COMMISSIONER WRIGHT: Anybody else? That makes perfect sense to me.

MS. HAHN: I would just like to say that for the knowledge that we've gained in the PRA space, incorporating early on in this advanced reactor design is going to be key. The existing fleet uses PRAs, but being able to start early, and incorporating that stuff early on in the design is going to be very helpful.

COMMISSIONER WRIGHT: Thank you. So, I'm going to stay with you for a minute. In one of your slides, I think it was 12, if I remember right, but you had like three things that were listed. You noticed some significant regulatory challenges, that's what you were talking about, that would have to be addressed in the area of uncertainty. Can you elaborate a little bit on which one, do you see one of these being more critical to address in the near term? And I guess how, if at all, could the NRC help?

DR. WAKSMAN: Well, I would say in terms of regulatory challenges, the challenge is not so much on the first-of-a-kind, because we're using DOE process, that is, I think, fairly well understood. It's how we would regulate the Nth of a kind. Because if these are actually being deployed operationally, they're not going to be DOE licensed. So, figuring out how that would be, whether the Army is going to have to -- or whatever service would have to hire up, get their own regulators, or would the NRC license approve the design, and then that way the services could leverage that. I certainly think it would be a lot easier if the services did not have to hire up. I don't think anyone is going to try to create a second Naval reactors.

So, being able to leverage the NRC's expertise, and being able to demonstrate that the designs are safe, and to have confidence that the factory that's making these reactors is doing everything up to snuff, then the service can feel confident in it. Now, these are certainly decisions being made later, that a service would have to make if they choose to transition this. But I would think to myself, that the NRC would have to play a large role in that, because the non-Navy services simply don't already have the infrastructure to do that.

COMMISSIONER WRIGHT: Yeah. Earlier in your comments, I was watching your reactions on some things, and kind of going at what do you see is the biggest obstacle is what I'm looking for from you here maybe, to get something like Project Pele up to scale, is it the licensing process, is it going to be available resources, or funding, or is there something else?

DR. WAKSMAN: I think all those things are major challenges. Obviously funding is a big one. We certainly appreciate the healthy funding that this administration has given us, as well as bipartisan support in Congress. I'm very concerned about supply chain and I am constantly hammering that one. We have heard some unbelievable horror stories from other programs.

And one of the big things that happens from power point reactor to real reactor is to figure out well who can actually make that? Can someone actually make that? Just because your CAD system can make that, doesn't mean that it can actually be made. And what happens if it's in a radiative environment - is it going to become brittle, is it going to start to fall apart?

And this is a way, I think Pele can actually help other reactors. Because I know one of the challenges that other reactors have had is well how do you demonstrate that reactor will be safe in a regime that hasn't been done before? You can model all you want, but if you don't have data of a real reactor, it's a challenge. So, hopefully the data that we collect from this reactor will help facilitate other reactors.

COMMISSIONER WRIGHT: Okay, thank you. Alison, good to see you. As I mentioned to you earlier, I was at RPE yesterday, and had a couple hour meeting, great meeting with the team over there and they shared with me all the different projects that they were kind of standing up, and that some of those things might flow through, that NE would be pushing out the door even more.

Which kind of brings me to a question that there is a tool out there, and it's from NEICA, the Nuclear Energy Innovation Capabilities Act that was passed, where the possibility would exist if -- so DOE's the promoter, they're the salesman. We're the safety regulator, we've got to be prepared to review anything that comes before us. But the Department of Energy doesn't necessarily have to do that, right?

You can pick a winner and if Congress wants to help you, they can help fund, where you could fund, maybe pass money along with that project to the NRC in an MOU to review that particular technology, whatever it is. Is that something that y'all are -- is that something that you're looking to maybe get involved in with the NRC on a partnership kind of thing? Where we would dedicate our people to do that through the process, but there would be funding that would come to help the -- I guess it would assist the applicant in a way, right? Because some of them don't have deep pockets.

MS. HAHN: I'm sorry, I misunderstood the question. Would it be helpful for NRC to be involved in the process of selecting?

COMMISSIONER WRIGHT: No, y'all would -- it's your technology, and then you would say to the NRC, hey we'd like to enter into an MOU, where we're going to send this technology applicant to you to review. But we're going to send some money along with it, but with that money we'd like for you to dedicate your tiger team, core team, whatever, to take this through the process start to finish. In order to try to, I guess gain some -- build some time, shorten the timeframe through. Is that something that DOE is looking at doing some of, or more of?

MS. HAHN: So, for DOE developed technology, we try to include NRC staff from the very beginning so that we've gotten the feedback early on, we can incorporate any comments, and feedback that NRC is able to give us throughout the process. In terms of providing money for DOE technology to go through a more official NRC review process, which is what I think you're saying, it could be very helpful. We've got a number of codes and technologies that would be very helpful to be NRC qualified or licensed moving forward.

COMMISSIONER WRIGHT: Right, because I think that might be the purpose of what NEICA was there for. So, just would like to see how that plays out, right?

MS. HAHN: Yeah.

COMMISSIONER WRIGHT: Thank you Mr. Chairman, that's all I've got.

CHAIRMAN HANSON: Thank you, Commissioner Wright. Thanks all again for your presentations. Part of the mission of the NRC is to promote the common defense and security, so our collaboration with DOD, and DOE, and NASA, and others is really critical. I guess I'll start with kind of a high-level question kind of for the three of you, maybe particularly Mr. Sample and Ms. Hahn, the two of you.

This actually came from a comment that Dr. Calomino said, which is he said NASA doesn't want to own this. And that made me think back to kind of a payment for milestones approach that I think NASA has taken to commercial launch vehicles. And there's been some thought promulgated by Matt Bowen, and others about applying this to the nuclear realm as well. And it has the potential to apply to NRC, because you can incentivize potentially licensability, or NRC reviews. You get through your environmental review, you get a payment, you get through your safety review with the NRC, you get a payment. Is that something that, as you explore these concepts for deployment, that DOD or DOE has considered for some of these technologies?

MS. HAHN: So, the other transaction authority is something that is very intriguing and very interesting. The milestone-based payments, as you said, could be something that's very helpful moving through these awards. It's something that yeah, we're interested in looking at. We haven't done it yet at DOE, NE specifically, but we are currently working through a possibility in the near term.

MR. SAMPLE: I can't say that we've looked at it specifically for this, but we use other transaction authority across the Air Force for other things. So, it seems like it would make perfect sense to open up to something like this.

CHAIRMAN HANSON: Okay. Go ahead Dr. Waksman.

DR. WAKSMAN: Sure. So, I was going to mention Pele is an OTA, and as just an interesting historical coincidence, the two people at NASA who were behind the COTS program went to DOD, and started Pele. So, we have, we're cousins with it. And I can tell you that as part of our evaluation and our recent down select, one of the things that the companies were graded on was going to be their ability to meet the NRC requirements for transportation. So, we were evaluating what their transportation plan was, how they were going to apply, and deliver, and that was one of the things that was a significant grading metric.

CHAIRMAN HANSON: Great, thank you. Ms. Hahn, you've had, I think in one of your slides talking about helping fill regulatory, and technical risk, particularly with some of the facilities out at Idaho. And I think from an NRC perspective, that kind of thing is absolutely valuable, absolutely critical. Filling those gaps with experimental and real world data as much as possible. I was just wondering if you could kind of talk about, get a little more specific, and give us some examples of that work.

MS. HAHN: Absolutely. So, the DOME test bed and the LOTUS test bed that NRIC is hosting will provide that real world data to some of the concepts that are coming in. For example, we've got the MCRE reactor led by Southern that will go into the LOTUS test bed to operate and provide that data for you for the commercial design later on, so that's one example.

Another example is the MARVEL test platform that I mentioned. We're developing that test -- the nuclear driven test platform, but we're going to also connect it to these end use applications. And there's a lot of discussion about what can nuclear do besides electricity production, but we haven't done it quite yet. DOE has a couple hydrogen demonstrations, I think at four operating facilities, we've awarded so far. But what else can we do? What else are the options? And so having that platform for other industries not usually tied to nuclear come in, connect it to a nuclear driven platform, and demonstrate that the capability is there, and achievable. Those are just two examples.

CHAIRMAN HANSON: Yeah, that's great, thank you. One of the things I noticed was, I think the micro reactor test bed for the 40 that you have, as well as MARVEL, those were going to be ready in kind of the 2024 timeframe. That 2024 is a critical year for Mr. Sample's project as well, and just kind of, because a lot of the engagement that you're going to have at Idaho, the technologies that are going to come off that then are going to be potentially available for Mr. Sample. So, maybe the two of you can just kind of talk about how that's -- and it implies us as well, maybe you can talk about how you think -- see that syncing up.

MS. HAHN: We're trying to work very closely with all of our partners, industry, and other government entities to identify their needs, and make sure that our capabilities are there and ready and supporting them. I don't know if you have anything else to add.

MR. SAMPLE: Nothing to say, other than we are completely dependent on both these people. We feel like we're taking all their hard work, and we'll take credit for it later. But with that said, no, MARVEL, we're already talking about a trip up to see it in two months, or so, yes. We love all the stuff they're doing, and we're working as a whole government -- the things we learn as we go through, feed them back to our teammates to help the development of that.

CHAIRMAN HANSON: Okay. Is transportability -- not mobility - is transportability a criteria in the RFP for the Alison project?

MR. SAMPLE: Currently the Department of the Air Force is not really looking at transportability. Part of that is the way we operate. The Department of the Air Force and completely, the Space Force, our installations are our power platforms. Until we come up with a nuclear airplane, our forward deploy stuff are kind of dependent on jet fuel. So, we do our operations from the U.S. or from our installations, wherever they are. Not that we're going to benefit from the mobile, even if it's something we just take and park, but that's not a component in our application at the moment.

CHAIRMAN HANSON: Thank you. Dr. Waksman, the international engagements that the NRC has are really important, not only to the U.S. government kind of writ large, but also here, our work with both very mature regulators around the world, but also kind of embarking countries, and capacity building is really critical. So, I'm thinking about the deployment of Pele down the road.

And how important is acceptability outside the continental United States for one of these reactors? And kind of, is there a role there for NRC to engage international partners on maybe standing up a regulatory framework or an oversight framework? I don't know what -- I'm not sure what we want to call it yet, but have you all thought a little bit about that into the future?

DR. WAKSMAN: Yes, so as a historical thing, one of the reactors that the Army had in the ‘50s' and ‘60s was Project Iceworm in Greenland. And my understanding is that they initially installed up there without informing the Danish government, and the Danish government was not happy when they found out. And that is not the way the DOD operates in the 21st century, whatever century we're in.

Yeah, so we've been thinking a lot about that. And so we were tasked by Congress in the ‘21 NDAA to do a report about a number of things, which included international issues, and we've been working closely with the NRC staff, and OSD policy, and State Department to develop that out. And I think part of the conclusion is that we are in a grey area. Is this a submarine? Is this an export? I don't think it's an export, but these are things that I think have yet to be 100 percent decided. So, the nature of our report is not going to be to tell everybody what all the answers are, but to simply establish the questions and the options. And I think this will need to be continued to be discussed. I think the Aukus is a really important pathfinder for us. And in our engagement with the State Department, they are continually tying Pele to Aukus. It's obviously a bit different, but there are a lot of similarities to it. So, I think a lot of that is going to be TBD.

CHAIRMAN HANSON: Yeah, well the NRC is happy to contribute, particularly on Aukus, where we're talking to our regulatory counterparts, sometimes we've got overlapping and sometimes separate regulatory responsibilities, but there's a lot of creative thinking yet to be done, so I hope we can participate in that.

I also hope that we can participate or inform some of the personnel issues. You were talking about the operations core potentially being lodged in the Army Corps of Engineers. Finding qualified people across the industry for NRC with our agreement states, and even I've had these discussions internationally, is really critical. Certified health physicists, radiation protection people, so it's not just operators, et cetera.

Is there a kind of strategic work force plan that's in the works at DOD, that maybe DOE is informing? We spend a lot of time on work force planning here just for our own needs, let alone needs kind of more broadly out there in the world.

DR. WAKSMAN: Yes, I can tell you in our case, so for putting together our training plan, we've actually hired a long time NRC employee to help put that together.

CHAIRMAN HANSON: Excellent.

DR. WAKSMAN: And we continue to engage with the NRC on that, and certainly we appreciate the help on that. In terms of work force, I'd say in general the nuclear industry has a shortage of people right now. I know the NRC is struggling with a shortage of people, I know Naval reactors is struggling, every company is just hiring from each other, it's a zero sum game. And so if there are any undergraduates listening right now, now's a very good time to go into nuclear engineering grad school. But it's definitely a challenge that we are taking seriously, and we are focusing on it.

CHAIRMAN HANSON: Great, thank you. All right, well I think that -- go ahead Alison.

MS. HAHN: I was just going to mention Department of Energy has that nuclear energy university program, which provides fellowships, and scholarships not just to four-year institutions, but also trade schools, and community colleges as well to help with the PhDs, master's program, but also some of the trades that we need in the industry as well.

CHAIRMAN HANSON: Great. Well, and we've got the university nuclear leadership program here to do both faculty development, as well as support students. And we're looking at hopefully to expand that to minority serving institutions. Kind of no brain left behind when it comes to nuclear these days, so really appreciate that. All right, well I think we've come to the end of our time. Again, really appreciate your presentations.

I would like to take the opportunity to recognize we have a number of foreign assignees here from Poland, I'd like to recognize them. We're going to be hosting them for lunch here in just a little while. They are here in the United States for some on the job training from both the Polish Atomic Authority, as well as their industrial regulator.

They're here at headquarters. They're going down to our technical training center is Chattanooga, Tennessee, as well as to visit the Vogtle construction site, and get some, like I said, on-the-job training. Our relationship with Poland now goes back probably a decade, and helping them on their path, and building a robust regulatory entity is a high priority both for the NRC and the U.S. government writ large.

So, I'd like to welcome them, and recognize them this morning, I'm glad they could join us for a Commission meeting. With that, I want to thank you all again. I am really gratified, I think, by the level of coordination, and the partnership we have with you all, with NASA, and glad we could do this, thanks again for coming to Rockville. Mr. Calomino, I'm sure we'll see you in person here at some point, thanks for --

DR. CALOMINO: Yes, I hope to be there in person the next visit.

CHAIRMAN HANSON: No worries at all. Thanks to my colleagues. As usual, we've covered a lot of real estate this morning, and with that we're adjourned.

(Whereupon, the above-entitled matter went off the record at 11:41 a.m.)