UNITED STATES

NUCLEAR REGULATORY COMMISSION

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# OVERVIEW OF ADVANCED REACTOR FUEL ACTIVITIES

PUBLIC MEETING

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THURSDAY,

DECEMBER 8, 2022

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The Commission met in the Commissioners' Hearing Room, One White Flint North, Rockville, Maryland, at 9:00 a.m., Christopher T. Hanson, Chair, presiding.

COMMISSION MEMBERS:

CHRISTOPHER T. HANSON, Chair

JEFF BARAN, Commissioner

DAVID A. WRIGHT, Commissioner

ANNIE CAPUTO, Commissioner

BRADLEY R. CROWELL, Commissioner

ALSO PRESENT:

BROOKE P. CLARK, Secretary of the Commission

BERNICE AMMON, Acting General Counsel

NRC STAFF:

DANIEL H. DORMAN, Executive Director for Operations

JASON PIOTTER, Senior Mechanical Engineer, Division of Fuel Management, NMSS

DR. WENDY REED, Metallurgist, Division of Engineering, RES

MIRABELLE SHOEMAKER, International Safeguards Analyst, Division of Fuel Management, NMSS

ROBERT TAYLOR, Deputy Office Director for New Reactors, NRR

CHRISTOPHER VAN WERT, Senior Reactor Systems Engineer, Division of Advanced Reactors and Non-Power Production Utilization Facilities, NRR

EXTERNAL PANEL:

DR. CHRISTINA BACK, Vice President, General Atomics

ANDREW GRIFFITH, Deputy Assistant Secretary for Nuclear Fuel Cycle and Supply Chain, Office of Nuclear Energy, DOE

DR. EDWIN LYMAN, Director of Nuclear Power Safety, Union of Concerned Scientists

DR. RUSTY TOWELL, Director, NEXT Lab, Abilene Christian University

SANDER VAN TIL, Lead Scientist, Nuclear Fuel Research & Innovation, Nuclear Research and Consultancy Group

JAMES VOLLMER, Senior Manager Nuclear Design, TerraPower

JENNIFER WHEELER, Director of Regulatory Affairs, TRISO-X

PROCEEDINGS

9:00 a.m.

CHAIR HANSON: Good morning, everyone. I convene the Commission's public meeting on advanced reactor fuel activities. I thank you all for joining and supporting this meeting this morning. Welcome to all of our external participants, and those joining us online. I think it's very timely for us to be having this meeting and discuss it in a public forum. I think there's been a lot of innovation in the reactor fuels area over the last 20 years.

I think, for a long time, innovation in the nuclear sector, the fuels were kind of the constant, and there was a lot of innovation in other parts of the reactor system. And I think what we've seen is a lot of the research, and development supported by DOE, NRC, and other entities kind of come to fruition in the last four or five years, such that now we've got variables, if you will, on kind of both sides of the equation, where reactor developers are really exploring innovations and new ideas in both moderators and coolants, and other kinds of materials on the one side, and in the fuels themselves.

So, I think this is a great time to have this meeting, and I look forward to a really productive discussion. We'll hear from our first external panel, we'll have a short break, then we'll hear from the staff.

But before we begin, I'll ask my colleagues if they have any remarks they'd like to make. No? Okay. So, with that we'll begin with Andrew Griffith -- I'm not used to calling you Andrew, we're in official setting. Deputy Assistant Secretary for Nuclear Fuel Cycle and Supply Chain from the

Office of Nuclear Energy at the Department of Energy. Mr. Griffith, the floor is yours.

MR. GRIFFITH: Thank you, Chairman Hanson, and thank you all to the Commission. It's an honor to be here with you as always. Clearly the work you do is going to be essential as we go forward, and I think forums like this, where we can exchange information, are paving the way to all of our success going forward. So, really appreciate all that you do, and the independent regulatory oversight that you perform.

So, my slides, are they going to be projected? There they are. So, I have a lot of substance here, I'm just going to hit the high points. It will leave some room for some Q&A later on, but also our colleagues to my left will also add more detail for their specific lane, if you will. So, I'm going to start out with kind of a family portrait portfolio of our advanced reactor demonstration awards. Then I'll follow by some of the work we're doing in the advanced fuels area, and then I'll talk about the high assay LEU work that we're doing, which is really, I think essential to the future. Next slide please.

All right, these are the two advanced reactor demonstration reactors, 50/50 cost share. They are genuine Generation IV reactors, and they definitely will help set the stage over the next decade, as they plan to start up later this decade. Clearly they need the fuel, and we're working on that. Next slide please.

These are the five risk reduction awards, they're kind of the next wave if you will, and there's a good diversity of reactor concepts there as well. Four of them do need high assay LEU, the one light water reactor concept is the SMR-160 by Holtec. But there's a lot of work to be done here to set the stage for the future beyond this decade. Next slide please.

And these are the three advanced reactor concepts, ARC20 awards under the ARDP funding opportunity announcements. Less mature concepts, but this will help -- the funding that we're cost sharing with them, 80/20, will help prepare them for playing a role in the future beyond this decade as well. Next slide please.

Now, I'm getting into the three basic fuel concepts that we're working on in a research and development perspective. The most mature -- one of the most mature is the TRISO fuel. We spent two decades working on this starting in the 2002 time frame. We spent over 400 million dollars collectively on this over time and have made significant progress. It does build on concepts that were done elsewhere in Germany before, but we're coming to the point where we're at the end of the R&D phase, and ready for commercial fuel fabrication and deployment. There's still some work we can do to support the reactor developers and the fuel fabricators in scaling the technology up, making it more economic, and so that's still some work to be done.

But we've done, I think we've made tremendous progress in this area over the last decades, and it's definitely paving the way for the future. Next slide please.

So, the metal fuel area is one that is also mature. However, the reactors that are planning on using the metal fuel for sodium fast reactor applications are really based on the experimental breeder reactor two concept, sodium bonding. There are evolutions to be implemented there to develop the fuel without the sodium bonding, which as you all know is a reactive component, and it requires treatment before ultimate disposition. And so, that's the focus of this area and it's also building on the lessons that we gained in the TRISO development area, where the efficiencies that we've gained over the years of irradiation and post irradiation examination. And then when you add in the capabilities of today of high performance computing, the modern day post radiation examination concepts, where you get into multi-scale, multi-physics types of examination, data collection, and feed that into the high performance computing. And then the latest kind of innovation that's at play with the fuel qualification process is the instrumentation capabilities that we have. Where we have instrumented test leads connected to the experiments while they're being irradiated in piles. So, a lot of great innovation there. The idea is that as the advanced reactors are deployed, and the fuel concepts do evolve and improve, that we're able to do that, rather than introducing fuel in 20 year time frame, we can get that down to under a 10 or 5 year time frame with the tools that we have available. So, that's a key objective there. Next slide please.

So, molten salt, while there is some history in this, there's a lot we don't know about this approach. There's a number of challenges, clearly the corrosion, the criticality control, ensuring homogeneous chemistry, these things are all really important challenges that have to be addressed. There are more efforts today than there have been in the past to understand this, because the benefits are tremendous. Again, it has high temperature applications in both energy generation and industrial applications. And you have online refueling and fission product removal, possibilities that maximize the capacity factors. So, there's a lot of challenges here, but there's also a lot of benefits. Next slide please.

And then getting to the high assay low enriched uranium HALEU fuel supply, this is clearly a priority in my office. It's hard to imagine the weight of the future resting on your shoulders, but really with Russia being the only current supplier of high assay LEU, the alternative is us. And the good news is, while we have been chipping away at this over the recent years with the demonstration at Piketon, we were successful in awarding a contract last month to startup and operate that demonstration cascade. That's a good first step, however the big lift is incentivizing a commercial supply chain that doesn't exist today, the classic chicken and egg situation, needs to be broken. And we believe the government role is to establish that temporary demand signal to stand up that capacity. Fortunately, with the Inflation Reduction Act, we were given the resources to get started on that. Whether that's enough, or not still remains to be seen. I know there's still work within the administration to get additional funding on that, as well as in Congress. So, we're going to continue to work toward that end, because this is so incredibly important to be successful here. Next slide please.

So, this lays out what the Inflation Reduction Act, how the 700 million dollars that was appropriated under the Inflation Reduction Act, how it's allocated. The first three parts are criticality benchmarking, transportation package design adaptation. And support for certificates of compliance, amendments, or improvements to existing packages that obviously your agency will play a role. So, there's 100 million dollars allocated toward that. Whether, or not that's all needed for that scope of work is not clear, but we intend to test the waters in the coming months with a funding opportunity announcement for cost-shared awards to achieve that.

The next grouping is essentially to provide high assay LEU to the users, and that's where we're using the 500 million dollars allocated to that. The last bucket, if you will, is 100 million dollars for support, and there's a lot of flexibility there. The areas that come to mind on what that could be used for, and again it's most likely going to be through a funding opportunity announcement with cost shared awards, is things like the deconversion technology to take the high assay LEU from $UF_6$ to either oxide or metal. There's some opportunities for refinement and implementation that could be pursued there. The last piece is the -- that comes to mind, is new enrichment technology, such as laser technology could also be something that could mature under cost a cost shared award at that last bucket. Last slide please.

This is my summary. I think the area of fuel R&D is so important. One of the sacrifices the department made, and Chairman Hanson, I think you can recall this, the 2020 time frame when the ARDP program was stood up. It came at a price, it came at a price of some of our fundamental R&D programs, and fuel was one of the areas hit by that. And it has taken us a number of years to get traction on the LIFT program for accelerated fuel qualification. We hope that Congress in the coming weeks can resolve the continuing resolution, and support our request there, which supports that activity. And then beyond that, I can't overemphasize the importance of our activities supporting or incentivizing commercial high assay LEU supply. Thank you.

CHAIR HANSON: Thank you, Mr. Griffith. Next we'll go online to Mr. Sander Van Til. He's a lead scientist in nuclear fuel research and innovation at the Nuclear Research and Consultancy Group. Mr. Van Til?

MR. VAN TIL: Yes, good afternoon, well good morning for you. My name is Sander Van Til, I work at the NRG in Petten, Netherlands in the fuel irradiation department. I will tell you a bit about what kind of research and what kind of services we supply to the nuclear energy sector. So, if you'll go to the next slide?

So, first, where are we? In the top right, you see a picture of Europe, and the Netherlands is in the northwest. In the Netherlands, we are in the northwest, on the shores of the North Sea in Petten. And you see an aerial view of our site with two positions indicated, one being the high flux reactor on the left, and on the right we have several radiological facilities, that helps our laboratories in particular. Now, if you go to the next slide?

Some very basic specifications of our high flux reactor. It's a reactor that's over 60 years old now. It's a tank and cool pipe material test reactor, which basically we have a four-meter-high reactor vessel submerged in a pool, as you can see on the left hand side. And on the bottom of the reactor vessel is a core box where we place experiments. It's 45 megawatts thermal power, and a unique feature of the high flux reactor is that we are stable in a constant flux profile irradiation position.

We use our reactor mainly nowadays for isotope production, that's a large part of our turnover. But besides that, we supply services to the nuclear energy infrastructure for qualification of parts and components, but also a fair amount of R&D work that we do. Yeah, so we operate our reactor nine cycles in a year, approximately with 30 operational days per cycle. Summing up to approximately 300 full power days per year, so there's a high capacity factor. So, in our reactor 17 in core positions, which we use for irradiations of both isotopes and materials. We have pool side facility with 12 positions and some bin tubes, which mostly are out of use, but we still do some neutron diffractometry analyses. So, if you go to the next slide?

You basically see a top view schematic of the reactor core, and basically the blue squares are the irradiation positions that we have, so the 17 I mentioned. And the red squares are the driving fuel of the reactor, and you see the control rods, we have set control rods in the reactor core surrounded by beryllium reflectors. So, on the left hand side you have what we call the pool side facility. It's a facility where we are able to move experiments, or isotope irradiation facilities from a distance towards the core box to increase the flux or the power in the experiment. So, inside the core, we have these facilities -- positions where we can put irradiation experiments. And from the left to the right the flux increases. So, the flow rate increases, and also the thermal flux ration increases.

As well on the left hand side, what you call the high flux region of the core, these are particularly suited for material irradiations, where the goal is to generate DPAs, and we can reach up to seven DPAs per year in that row. Fuel irradiations we typically do more on the right-hand side of the core. Where for nominal LWR fuel, the building makes about 300 to 400 per centimeter in these first rows. Yeah, so if you go to the next slide?

So, this is the selection of irradiations that we do. We address the various reactor types in fuels and materials. So, for fuels, one running program that we have is on irradiation induced creep for LWR fuels, both for $UO_2$ and MOX. We have carried out qualification of HDR fuel pebbles in the past, so these are experiments that we have carried out roughly in the last decade.

Most fuel irradiations that we did was for the liquid metal fast reactor concept, where we irradiated -- well, numerous rodlet irradiations, ranging from high plutonium content MOX to nitrite fuels, and some americium blanket candidates, also some matrix fuels and some other fuels.

Yeah, so several years ago we started molten salt irradiation program, where we started irradiations on fluoride salts. And in particular we look at the interaction of the fluoride salts, also with graphite and steels. And also we have a separate gamma irradiation to study the radiolysis of fluoride salts. So, on the materials side, we basically focus on nuclear graphite and steels, where one high profile program was on lifetime extension of AGR, so the advanced gas cooled reactors in the UK where we irradiate graphite samples from those AGRs to fast forward the irradiation damage to estimate the allowed lifetime extension. So, other irradiations that we do involve the qualification of nuclear graphite for MSR and HTR applications. Steel irradiations mainly involve aging, so reactor pressure vessel materials for long term operation, but also some new grade steels, nickel based steels in particular, also for MSR applications to study, for example, the helium embrittlement. So, we'll go to the next slide, and we'll go to an example of the HTR fuel qualification that we did.

So, this was for a commercial party who sent us five HTR pebbles, graphite pebbles with TRISO fuels. And basically from there on we assembled these fuels into the sample holder. In this particular case graphite, which is then double contained, which is a condition for us for our fuel irradiations, before we can put it in the HFR. So, these sample holders, they are equipped with -- well, basically with any experimentation that you want, which survives the radiation in the HFR. So, in this particular case, we assembled these five pebbles in the containment with 48 thermocouples dispersed throughout the sample holder to monitor the temperatures.

We have several gas handling facilities in the HFR, which allows us to control the temperatures in these experiments, but also to monitor the gas online. And in this particular case, we were looking at the online release to birth ratio of fission gases from these pebbles. So, additional instrumentation that we used was to look at the neutron fluence rates, so by self-powered neutron detectors.

And we have neutron activation monitor sets, which we retrieve after irradiation to have an accurate reconstruction of the local neutron fluence in the experiments. So, by our experiment design, we were able to have a very stable temperature throughout the experiment, and we have very narrow uncertainties. In this particular case, we were able to keep the central temperatures around 1050 degrees Centigrade, plus or minus 50. And we can even, with material irradiation, we can even go slightly lower, and as well as droplet irradiations because they're so much smaller. If you go to the next slide?

So, one of the more general irradiations that we do are droplets, which are small sections of fuel pins. We have these fuel pins that we can load into again, double contained sample holders. Generally these sample holders are sodium filled to have a proper heat dispersion from the fuel pins. And they can be up to 700 millimeters, but normally the effective height is about 500 millimeters, because beyond that the actual neutron flux -- the actual flux gradient gets too steep, so it's like 500 millimeters active experimental position.

So, depending on the fuel that you use, the application, if you have a fast reactor fuel that you want to have tested, that you want to tailor the fast to the thermal flux and without the faster thermal fission, we can replace -- shrouds for spectrum tailoring, and we have numerous options for instrumentation inside the sample holder to monitor temperatures, pressures, or displacements.

And again, self-powered neutron detectors for fluence rates locally, and the mounting sets I mentioned. So, the temperature control is through a gas cap between the containment of these experiments, where we can change the gas composition, and with that, the thermal conductivity of the gas and steer the temperature to a target within 20 degrees Centigrade. So, if we go to the next slide?

So, once you've achieved your irradiation target, we can transfer the experiments to the hot salt facility on the same side, where we can dismantle it and then proceed with any post irradiation examinations that are desired. So, we can dismantle and move it to hot cells for example non-destructive testing. So, performance scanning and any current measurements.

So, we have cell lined with flexible inner boxes, so basically you can load a box with any instrumentation or equipment that you want for your studies, and then carry out your post irradiation examinations. So, for example the fuel dissolution studies we did in the past. And we have alpha type hots aligned for further destructive analysis, for example microscopy or scanning electron microscopy with EDS, WDS, and EDSD options. And so, if we go to the next slide?

I won't name these all, but as I said, we have numerous options for post irradiation examinations, and on the right hand side, you see the options that we have basically for the fuels. Not all techniques are available for fuels. So, we basically have the standard techniques that you tend to do on irradiated fuels. And from next year on, it's envisioned to have a high burst test setup ready. So, if you go to the next slide?

Just as a summary, so what we can do basically is just from beginning to end, we can do whatever a customer wants. We can produce oxide fuels in a radiological lab, and do all kinds of characterization on these. Then for the design of an irradiation experiment, we have in-house, we have teams of dedicated engineers to perform the nuclear, thermal mechanical, and thermal hydraulic calculations, and we have on site, a mechanical workshop, high profile mechanical workshop, which basically produces high quality experiments. So, we are versatile in serving any customer, any nuclear application.

And we have extensive options for instrumentation in the high flux reactor, and we have extensive options for post irradiation examinations. We also have logistics units to organize international transport if that's desired, and also the waste handling, we can do. We have a disposal international repository, so that's also a possibility. And if you go to the next slide?

Just in closing, as I said, the HFR is a 60 year old reactor, and it's envisioned to run into the 2030s, but after that, the follow-up reactor has been defined, which is called the PALLAS reactor, and it's not known exactly when it will be ready, but it's in mid-2030s. The site is being prepared right now, so we are -- the design has been completed, and construction is planned to begin in the coming years. Yeah, so, that's basically my presentation, and thank you for your attention.

CHAIR HANSON: Thank you Mr. Van Til. I just would, as we kind of go along here, we've got a number of other presentations to get through this morning, so I just ask presenters to kind of be cognizant of the time. Next we'll hear from Ms. Jennifer Wheeler, she's director of regulatory affairs at TRISO-X.

MS. WHEELER: Good morning, thanks for letting us be here today with you. So, TRISO-X is an applicant. I think one of the few on this panel, but others are coming, for a 10 CFR 70 materials license, and you can see in the first slide's picture, that our facility is going to be sited in Oak Ridge, Tennessee on a 110-acre property. The processing facility in the background is over 500,000 square feet with an attached office building in the front.

The manufacturing process uses Category II special nuclear material in the form of uranium oxide. We may use different enrichments depending on what advanced reactor developers order, but our possession limit will be up to less than 20 percent, so we'll be able to cover the whole range. X-Energy's ARDP funding is actually being applied to both development of the Xe-100 reactor, and the fuel facility that you see in the picture here.

And Andy already covered some things about ARDP, so I don't have to cover that again. We appreciate the funding, thank you. So, tristructural isotropic based particle fuel products, or TRISO, can support a variety of advanced reactors. For example, and I brought a couple of things here, pebbles for Xe-100 reactor, these are all made of graphite.

Compacts for other types of reactors, they can be -- the particles can be shaped into other shapes, not these, planks, and cylinders, and other kinds of things depending on what the reactor developer wants. So, of course pebble is our favorite, because that's for us, but we'll be happy to make anything for anybody else as they may want it. The facility is being designed for a throughput of 16 metric tons uranium per year when operating at full capacity.

That equates to over 200 million pebbles produced per year if that's the product that we're making at the time. And our business plan is to be ready to start operations by the end of 2025. Next slide please.

I'll start with the bottom line up front on this slide. I'm really happy to report that the TRISO license application was accepted for review by the NRC staff on November 18. So, not that far back in time, just before Thanksgiving. Interactions for 2022 began with an exemption request submitted in February to allow submittal of our environmental report separately from and after the remainder of the license application. This request stemmed from an extensive site selection process with several sites being considered before selection of the final site in Oak Ridge.

As a result, the preparation of the environmental report tracked behind the remainder of the license application documents. We were anxious to get started, so the staff worked very efficiently through the review of that exemption request and approved that request in March. So, that timing supported submittal of the license application in April, followed by the environmental report submittal in September. So, as you can see on the slide, steady progress was made between February and November, working through the acceptance review steps. Next slide please.

So, previous licensing actions are some of the data points that are used by applicants and licensees to predict NRC review schedules. The acceptance review process did take longer than we anticipated when compared to the four new enrichment facility applications that were accepted between 2004 and 2009. But 13 years had passed by, things change, things get updated, one of those things was the licensing handbook that had been in place for quite some time was updated by the staff and replaced with the Division instruction. And we think that part of our surprise of this was taking a long time, was because acceptance review standards were updated, and we should all be looking for means of continuous improvement.

But my point of saying this is that communication can't happen too often in terms of what expectations the NRC staff has for what applicants or licensees are submitting, and what level of detail is needed to support reviews. We were -- typically some of the questions that we got in the request for supplemental information letter that came out in August were questions we would have seen in the past, during the technical review itself.

So, this will be -- this application is going to be an opportunity for everybody to fine tune what we're doing on the applicant side, on the NRC staff side, and looking for as many opportunities as we can find to communicate early and often to minimize the potential for surprises on either side, I think is going to be good for everybody. Next slide please.

So, TRISO is but one of several advanced reactor fuels being explored, as you can -- evidenced by in part the slate of speakers today. Next slide please.

And the market demand continues to grow, as more, and more potential applications for use of advanced reactors are identified. Next slide please.

So, in this rapidly changing environment, a predictable licensing process is a key enabler for meeting both NRC metrics, and applicant and licensee business plans. The existing NUREG-1520 toolbox includes a number of review techniques, and tools that have been proven to aid effective and efficient licensing reviews. Risk information from the integrated safety analysis should be used as input to plan and prioritize what needs to be inspected during construction and operational readiness reviews. Next slide please.

If market demand does increase as predicted, more applications will come after us. Whether from new applicants or existing licensees expanding their capabilities. Each fuel facility may be unique due to variations in the fuel types. So, use of lessons learned, improving techniques from past reviews will help focus resources, improve predictability, and reduce uncertainty for both NRC, and applicants or licensees.

Finally, at some point in the future, probably not now, depending on the volume of work that comes, and when it comes, it may be appropriate to revisit Division of Fuel Management staffing levels, and structure to ensure timely reviews of advanced fuel applications. So, I realize mine's a little bit different in that I didn't delve into the technology of TRISO, but since we are an applicant, and our review is active, I thought you might appreciate an update on our status, so thank you very much.

CHAIR HANSON: Thank you very much, Ms. Wheeler, for your presentation. We'll go back to the internet, we'll hear from Dr. Christina Back, who is Vice President at General Atomics. Dr. Back?

MS. BACK: Thank you, good morning. I really appreciate the opportunity to present to the NRC here, and I'm very sorry I can't be there in person, but GA is hosting a three-day meeting with the Department of Energy here. So, I'll jump right into the slides here.

EM$^2$ is an initial reactor that we proposed for a commercial one-megawatt size, go to the next slide. But actually we are pursuing the fast modular reactor, so there was a slight title change there relative to your agenda. I'll be talking about the fast modular reactor, which actually is a forerunner, and a rethink of nuclear reactor with helium gas coolant for the distributed energy market. So, just as an overall philosophy, we believe this technology is ready for the conceptual stage. We're in the first phase of the pipeline of the advanced reactors, because we need a fast spectrum to use the fuel more efficiently. We also use new materials for higher temperatures, which allows us to look at the efficiencies and get higher efficiencies, as well as take advantage of other aspects of the reactor design, which I'll get to in a minute.

We use silicon carbide cladding for a higher temperature, and it really comes back to the fact that you need your advanced reactors to be safe. You need to be cost competitive, and you want to make sure you're in the non-proliferation status with your fuel, and you want to generate as little waste as possible. So, in that image you see in the upper left-hand side, we use dry cooling, we have auxiliary processes. But you can see that the footprint of the entire reactor, which is underground, as you see on the bottom right-hand side, but the whole footprint of the reactor is much smaller because we're using a direct Brayton Cycle. So, you can see the thermal power there is 100 megawatts. The electrical output is 44 megawatts. The coolant there I mentioned, helium, system pressure 7 megapascals. And the system temperature, this is the helium temperature, 500 to 800 degrees Centigrade, so that we can use that Brayton Cycle. So, it builds off work from the modular high temperature gas-cooled reactors, and so we basically updated it, and the amount of fuel that we use in total number of kilograms is about 20 percent of what a usual pressurized water reactor is. So, if you could go to the next slide?

We have a pre-licensing activity going on with the NRC, and this just gives you a general timeline of where we are. As I said, we're doing the initial pre-licensing, so it's the principal design criteria. So, we sent in some documentation in March, and then in June/July timeframe, we submitted the principal design criteria. So, we're in a very good place now, we got very good feedback from the NRC. Basically, we're using a regulatory basis that follows the Regulatory Guide 1.232. It also takes into account the usual design criteria, plus the non-light water reactor criteria that has been developed more recently, and also from the NEI documentation that helps develop the technology-inclusive risk-informed performance-based process.

So, with both things, you can see that later in the year we'll be submitting some documentation for review on the source term calculation, the licensing basis events, and following what should look generally familiar for an NRC process, I'll just call out a few things in particular for our reactor design. Maybe you could go back to the previous slide for a moment?

The slight changes, which were not interpreted by the NRC to be major changes, so we got actually very little requests for upgrading or changing our submission, because of the differences. So, just going into a little bit to give a sense of why an advanced reactor, and is not as deterministic as a typical light water reactor, our reactor takes advantage of radiative cooling because we're at such high temperature. So, for that kind of reason, words like core coverage, where the coolant needs to make sure that it's covering the fuel elements, that kind of language is not necessary because our passive heat removal is really radiation from the silicon carbide uranium oxide fuels -- sorry, uranium oxide fuels inside a silicon carbide cladding, which goes as the power of $T^4$, so it's very effective at high temperature.

And the reactant coolant pressure boundary, which is typically the language in the general design criteria becomes something more broad, which is the reactor helium pressure boundary, because that's more inclusive of the other structures that are needed in a helium-cooled system. Then we go through the typical licensing activity, the basis. The accidents basically for the loss of -- in our case, a turbine blade, a pre-cooler tube rupture, pressurization loss, force cooling, subcriticality analyses, control rod withdrawal accidents. So, those are all just very typical of a reactor, but in our case we're looking at a fast reactor, small changes. Maybe I'll go to the next slide now, which says accelerated fuel qualification.

The big difference here is that we are using new materials to be able to take advantage of the higher temperatures, and the new technologies that exist. So, I just want to put up this slide, and one more slide after this to talk about how we're approaching that.

So, in general, accelerated fuel qualification is a methodology to take advantage of the modeling and simulation that has really come to the forefront in the last five to ten years, where multi scale modeling can address on a more physics basis, the actual fuel performance and behavior in accidents. So, we're bringing together, modeling, and simulation with targeted experiments, which doesn't mean fewer just because we want to do fewer, but really more specifically chosen experiments that are relevant in the temperature and pressure regimes that are important.

So, the emphasis is on physics-based modeling, but it doesn't change the fact that you need experiments to benchmark those, and integral experiments to pull together all the separate effects and accelerated experiments that may be used. So, if you look at the top arrow, typically it's all empirical, so you have out of pile and in pile data, and you license your fuel. And in the bottom arrow, you can see the arrow is shorter, that's to represent that as we use more, and more physics basis for some of these calculations to aid in the understanding of the fuel behavior, your uncertainty actually goes down, your safety goes up, and ultimately you reduce the time that you're needing for licensing of fuel.

You can see a couple papers there. One is an initial paper on accelerator fuel qualification, talking about ways to use modeling in simulation more intelligently with experiments, and then the NUREG that was released recently. That is also along the same lines of figuring out how to incorporate, especially for new materials, these processes. So, the last slide I'll go through very quickly.

What I've tried to do here is to show you, in our thinking through for the fuel test plan, we use both the accelerated testing and a separate effects testing. In this case, a sub-integral test, and all of those recognize the fact that we're having a long lifetime fuel, so it can go from 9 to 15 years. We have different boundaries that we calculate there, but the point is the high burn-up needs you're needing to do an accelerated testing.

We're making use of the fast test approach that Idaho National Lab is developing, and you can see we do calculations on the right-hand side for the fuel and the cladding, I can explain that more in detail. But basically, you do have to look at what the test is actually going to see in temperature and burn up, as well as the cladding. And you can't necessarily meet both. But you make an intelligent choice, in our case we chose it to meet the cladding. So, the orange dots are what the test will do, the blue dots are the range that the experiment -- that the fuel is expected to go through in terms of temperature and burn up. So, we'll meet that, we'll be able to justify then and qualify the data in a faster way than if we were taking 30 years of empirical data.

Separate effects tests is somewhat straightforward here, when you think about the reactivity initiated accidents. So, we're trying to mimic that in the treat facility, and then pulling those together with a sub integral fuel test. Which again, we're in the pre-licensing phase, so this is really to inform the fast modular reactor design.

So, I want to try to stay to my time, so I'm happy to answer questions, and I appreciate the time to be able to present to you. Thank you.

CHAIR HANSON: Thank you Dr. Back. Next we'll hear from Mr. James Vollmer, he's a Senior Manager for Nuclear Design at TerraPower. Mr. Vollmer?

MR. VOLLMER: Thank you. Next slide please. So, since the very beginning of TerraPower's history, we really realized fuel is the key to advancing the technology that we need, specifically for our breed,and burn designs that require very long lifetimes, and very high burn ups, and very high DPAs on the fuel. Quickly after the traveling wave reactor efforts, we also actually looked at the molten chloride fast reactor, and kind of pursuing -- better?

Okay. Been pursuing both reactor's designs in parallel, so we've been very active in the fuel area, and actively engaging the NRC, as well as part of it, and it's been very helpful for us. One key example is for the SFR design or the metallic fuel design, we actually, through our regulatory assistance grant from the DOE, we actually submitted white papers, and got early review and engagement from the NRC. And that really helped shape our plans as far as fuel qualification for the metallic fuel that we are leveraging for the Natrium reactor as well. Next slide please.

So, this is just a quick overview showing what the metallic fuel designs look like, and kind of the key thing I wanted to highlight on the left panel, you see kind of pinned cross sections of the historic metallic fuel designs used in EBR-II, as well as FFTF. There was a subset of metallic fuel assemblies in FFTF as well. And you see just the cross section of how closely our type one fuel mimics the historic designs as well, and that is intentional because we are leveraging those historic databases to support it. The bottom is actually our advanced fuel design, so that's where we want to go as soon as possible, but we realized starting up a new reactor with an advanced fuel is challenging enough using the historic designs.

We're going to go piece-wise, and go through an LTA program to get to our advanced fuel design. On the right panel, you see kind of the cross-section comparison to the fuel assemblies. The key things I wanted to note is you see the FFTF design, look at the red fuel region compared to the red fuel region in our Natrium type one fuel design. That although our Natrium one fuel assembly is longer, the fuel region is actually very similar in height, and that's one of the reasons we do consider these MFF, metallic fuel assembles, for FFTF to be kind of our key database that we are using for our operating experience. Next slide please.

So, this kind of shows our parallel fuel qualification pathways. So, our type one fuel is to startup within our Natrium reactor, but then we are trying to get to our type 1B advanced fuel as quickly as possible. For the type one fuel, I mentioned the reliance on historic fuel data. So, we are actually able to leverage some of the opportunities from Argonne National Lab of qualifying that data from EBR-II, the metallic fuel data. So, we actually are working in hand with them as part of our ARDP proposal.

And then in addition, I mentioned the metallic fuel pins from FFTF really are very applicable to our type one fuel. There is very little PIE done on those fuel pins, so we are pursuing additional PIE. Those pins have been archived, and we are trying to fill in gaps with that.

Another key aspect is actually the transient testing of that, that that was something that was the prism program, and the IFR programs were shut down before those transient tests were performed, so we recognize that gap, and we're pursuing that as well.

For the bottom side of it, for the advanced fuel, we really are kind of filling in the gaps, relying on the advanced test reactor at Idaho National Lab to get kind of fuel phenomena information, kind of separate effects, and understanding gas release, other aspects of the fuel, is it behaving as we expect? So, it is actually very comparable to the historic fuel from performance with some key features and differences from that. We also will be looking at kind of transient testing to fill gaps. And then I had mentioned kind of a lead test assembly program and lead test pins. And the Natrium reactor will be kind of the final qualification step before we consider that fuel qualified. Next slide.

So, this is a high-level road map of our Natrium reactor program development, just to show that we do kind of integral steps of leveraging historic experience, as well as going to our initial plant, the Natrium plant that is being built in Wyoming. And then through that, we'll go through our lead test assembly programs to go to our advanced fuel design, to actually get to more commercial plant designs that can deploy more broadly. Next slide please.

Touching briefly on the molten chloride fast reactor technology development road map, so they also received an ARDP award for the risk reduction portion of it. The key aspects there is that molten chloride reactor experiment shown. That really is kind of a critical effects test, if you would, to address some of these key uncertainties about how these molten fuels behave in particular the delayed neutron fraction, how that behaves when it's going in, and out of the core, and how that impacts the overall reactor performance.

And then also the integrated effects test, that's actually been underway -- construction of that has been underway, and actually is starting up soon in our Everett facility as well to look at more of the transient performance of these molten fuels, of how they would behave during transience. But again, the long-term road map for that as well to gradually step up to commercial scale reactors. I believe that's it for me. Thank you.

CHAIR HANSON: Thank you, Mr. Vollmer, very much. Next we'll hear from Dr. Rusty Towell, he's the director of the NEXT Lab at Abilene Christian University. Dr. Towell?

DR. TOWELL: Thank you. I appreciate the opportunity to come and share with you about what we're doing at Abilene Christian University, about our molten salt research reactor, and the fuels that we need to support that. Next slide please.

So, the Abilene Christian University is a private university in the middle of the state of Texas. Our mission at ACU is to educate students for Christian service and leadership throughout the world. The main campus is in Abilene, Texas, and for the last five years, we've continued to grow in size despite the pandemic and other challenges, we've increased in number. But we're more excited about the quality, U.S. News, and World Report, and many others have given us awards, and particularly relevant to this effort is the focus on undergraduate teaching and research. Next slide please.

NEXT stands for Nuclear Energy Experimental Testing, and the mission of NEXT Lab is to provide global solutions to the world's need for energy, water, and medical isotopes by advancing the technology of molten salt reactors while educating the future leaders in nuclear science, and engineering. Shown in the image is the work force on this project at ACU; 60 students, and 30 faculty, and staff working together to advance the technical readiness level of molten salt and to design and build this molten salt reactor. We're not doing it alone though. Next slide please.

NEXT was started in 2016, started building salt loops and working with analysis of salt, but in 2020 we formed the first-of-a-kind research alliance between Abilene Christian University and three other R1 universities: University of Texas, Texas A&M, and Georgia Institute of Technology all joined our research alliance. The industry sponsor for all four universities is Natura Resources. And so we have sponsored research agreements with those that are forming this research and with the efforts across the research alliance, we submitted our construction permit in August of this year, and it was docketed last month, and we're expecting an 18 month review period. And we're very, very excited, and appreciative of that tight time frame, because we do have a goal to go critical in 2025. Next slide please.

The molten salt research reactor is heavily leveraging the lessons learned from the molten salt reactor experiment at Oak Ridge in the 1960s. And so, a very quick description of our reactor, what's similar, and what's different compared to the MSRE. In similar form, we're using uranium tetrafluoride, the lithium fluoride, beryllium fluoride fuel bearing salt. A loop design graphite moderated, have a drain tank that allows for safe and secure shut down by draining the fuel, and the salt from the core region to a sub critical shielded tank. It's all in a subterranean trench and designed for a reactor lifetime that's less than what we typically think of for a reactor.

Where we differ, we try to make things differ where it simplifies licensing and construction. So, we're using low enriched uranium instead of high enriched uranium, we'll drop in power by almost an order of magnitude to one megawatt thermal. Using stainless steel 316, instead of some of the more exotic materials. No freeze valve, that's really one of the more interesting design changes. Instead of a freeze valve, we just use pneumatic pressure to keep the fuel bearing salt in the primary loop. Also, it makes it easier to drain and shut down, and then of course other advances over the last 50 years. But heavily leveraging the advances from MSRE in our design. Next slide please.

The reactor is going to be put inside of the Science and Engineering Research Center. And so the upper left is an architectural image of this facility that's under construction. The real main feature in it is it has a research bay with very high, 50-foot high walls, 40 ton crane on the top, and a shielded trench in the bottom of it. 80 feet long, 25 feet deep, 15 feet wide trench, and the bottom left image here is the construction of this facility, that started earlier this year. And this image is from a couple months ago, so you can still see the trench. Since that time, the tilt up walls have been raised around it, and so you couldn't see that major feature in the way it is today. This facility is scheduled to be finished in July of next year, and we're going to take use of 10 CFR 50.10 that allows us to apply for a construction permit in a pre-existing building, and this building will be pre-existing by the time our construction permit is granted. Next slide please.

So, what are the fuel needs? Before we started this project, we started dialogue with the Department of Energy, and said that this is a university research reactor, and we would like to be part of the Research Reactor Infrastructure Program. We need 500 kilograms of high assay low enriched uranium in uranium tetrafluoride form, mixed in with FliBe salt to be our fuel. And so, we got this programmatic letter of support from the Department of Energy that said this research reactor would be part of the University Research Reactor Infrastructure Program. Current dialogue is continuing with what's the source material for this. It's a relatively small amount, and we're able to accept some impurities, so some stocks that are available to us are not useful to other vendors. But fuel qualification plan, transport, final disposal are all things we're in continued discussion with Department of Energy about partnering together, and how we're going to do that. Next slide please.

We think that this university molten salt research reactor is going to be very, very useful to the nation, and even the world. It's the only advanced university research reactor submitted under review with the NRC. And so, we think it's going to be important to demonstrate licensure of this new technology. It'll be important to DOE to have the data that comes from that and vendors as we want to design future and larger commercial reactors, and so we think that the data, and this experience will be useful to Department of Energy, NRC, and vendors alike. Next slide please.

I'll just end with a slide that says thank you, and acknowledges Natura Resources, the Department of Energy, and other funders.

CHAIR HANSON: Thank you very much, Dr. Towell. And last, but certainly not least, we'll hear from Dr. Ed Lyman from the Union of Concerned Scientists. He's the Director of Nuclear Power Safety. Dr. Lyman?

MR. LYMAN: Yes, good morning, Chairman Hanson and Commissioners. As always, UCS appreciates the opportunity to present on this important topic. May I have the next slide please?

So, introducing new fuels and new fuel cycles are going to introduce new challenges in every aspect of the fuel cycle and reactor operation. And this is a self-evident statement. But what I do want to impress on the Commission, is I don't think that these challenges should be underestimated. And we've heard about some of the gaps already in the existing databases for the range of advanced reactors that have been discussed, and those gaps really need to be taken seriously, and the NRC needs to ensure that there'll be adequate safety margin when these facilities are licensed and operated. Next slide please.

So, fuel qualifications needed not only for normal operation, but also to establish the source terms and behavior for design basis and severe accidents. Also other important data that might be necessary for regulatory applications would be the impact of sabotage on fuels in reactors in the fuel cycle. And also given some of the military applications that are being pursued, the potential impact of a military attack on reactors and these advanced fuels. And certainly compared to the current light water reactor fuel database, these advanced reactor fuels do not have anywhere near the same level of operating experience, the thousands of reactor years that have been accumulated for light water reactor fuel development operation transience, and even accidents. And that experience base provides a very solid foundation for light water reactor fuel safety.

And that is what we don't have for many of these advanced reactor designs. Fuel qualification is generally a lengthy, and a costly, and a painstaking process that involves trial and error, and I am skeptical about efforts to accelerate fuel qualifications, especially using modeling and simulation when those modeling and simulation tools have not had sufficient validation. So, when you're trying to use them to extrapolate beyond the fuel performance envelopes that exist, you have to do that with caution, because those tools need the data to be validated if they're going to be used for extrapolation. Next slide please.

So, my -- we have a general concern about what's been going on in recent years. That the NRC will be under undue pressure to accelerate approvals by weakening its standards for demonstration of fuel performance and for development of accident source terms. The applicants are facing externally mandated, very aggressive, and arbitrary time-lines for one thing, and also many of these fuel designs, at least the existing experimental -- or the fuel's performance within existing experimental experience do not support the kind of claims for efficiency and performance that the vendors are promising.

And so, I'm afraid that that pressure to accelerate, or to use new fuels to push the burn ups well beyond the existing experience base to justify the claims that the vendors are making is another source of potentially undue pressure to speed the process up. And if you look at the schedules for deploying fuel facilities versus reactors, there just is not sufficient time for qualification. Especially the production scale as fabricated fuel. And this is particularly important for TRISO fuel, where the fuel qualification must involve the actual factory fabricated fuel, because of the sensitivity of the performance of the product to the production conditions. And the AGR program, while impressive, expensive, and very well constructed, only provided data of very limited applicability.

And, in fact, the program did not even meet a number of its own goals. So, even the data that's available is not what was originally expected as far as could be used for fuel qualification. That is, qualification of a particular compact or fuel form, rather than just the TRISO particles. Also with regard to metallic fuel, we heard about some of the gaps there. I understand there's still -- there may be the possibility of different fabrication processes from historical -- for instance using extruded fuel versus casks, and that would raise questions about the validity of the existing database for applying that information before qualifying the fuels for this reactor. And as a result, because of these accelerated time-lines, the demonstration reactors themselves will likely serve as de facto test reactors. And that raises additional issues. Next slide please. Next slide.

This is just all of the claims that are being made by vendors that rely on the performance (audio interference) The safety concerns associated with accelerated fuel qualification without due diligence for taking all the steps necessary is a particular concern because of the various regulatory applications that the Commission has either approved, or is (audio interference) credit for radionuclide retention as part of the desired functional containment concept. Then that qualification becomes even more important, and so when you're talking about (audio interference) is also essential for routine operation, because of course, those fuels will as a matter of (audio interference) in this context of the approved partition permits (audio interference) cases would eventually require (audio interference) next slide please.

CHAIR HANSON: Dr. Lyman, you may turn your video off, the audio is breaking up a little bit.

MR. LYMAN: Next slide, please. Sorry. (Audio interference) proprietary and there are often good reasons for that, but also that has to be understood that that does create gaps in the public's understanding of decisions that are based on some of this (audio interference) a lot of this basic data, for example what the public will see when they look at some of the publicly available documents. And I'm going to end here, because I think I'm taking too long, and this technical problem is an issue. I'll look forward to your questions, I apologize for any technical problems, thank you.

CHAIR HANSON: No worries, it happens. It's a symptom of the age these days. Thanks everyone for your presentations. We'll begin questions this morning with Commissioner Wright.

COMMISSIONER WRIGHT: Thank you, Chair. And thank you for your presentations today, this is a very interesting topic, a lot of things going on, and I'm very excited about the test reactor at Abilene Christian, that's going to be -- looking forward to coming down, and seeing it at some point too.

So, Mr. Griffith, I'll start with you. So, you highlighted the, I guess significant government funding that's available to establish the whole HALEU market. I understand it's early, but can you share maybe with us any near-term successes, or maybe major obstacles, or obstacles that you're facing right now?

MR. GRIFFITH: Sure, I'll start with the successes. As I mentioned, we did award a contract for the startup and operation of the high assay LEU demonstration at Piketon, Ohio. It will be able to produce 900kg of freshly enriched high assay LEU, demonstrate U.S. technology on U.S. soil, so we consider that a big win. The challenge is it's not a commercial scale, and so it's expensive.

However, we will benefit from performance data from the machines that are in operation there. In the other side of the country, Urenco, they do have an application to go up to ten percent, which is a good step in the right direction, I think. And so, that will set the stage for their role in producing high assay LEU as well. So, I think this is good momentum.

We still have the chicken, and the egg. Until we can incentivize a commercial scale production, and recognizing that there is a role for government to get started, ultimately, it will need commercial contracts. And so, we have a projection of what kind of HALEU demand would be required in order for us to successfully meet our climate objectives of net zero carbon on the electricity grid by 2035, and net zero total energy by 2050.

The ramp up of HALEU demand is significant from that scenario that we analyzed, but it's not reality. It's just a scenario that is put out there for consideration. The real test will be in both the X-Energy, and Natrium activities that are underway. PacifiCorp is evaluating five more sites for Natrium deployment. How that unfolds will be a key data point. X-Energy has an agreement with Dow Chemical to establish another four pack to support their operations. How that becomes a certainty, not just an agreement will be another clear data point. And so, those kind of commercial demand signals will be really important to take it just from getting started to being fully operational, and establish the marketplace that's going to be necessary.

And let me just add that diversity is going to be a real key to that. Funding limitations to us, to get started might compromise establishing diversity to start with. But ultimately to be successful, the diversity of supply is going to be absolutely essential. Thanks.

COMMISSIONER WRIGHT: You're already involved with the NRC, and we're engaged in a lot of things right now. Are there other areas that maybe we're not engaged in right now, that we're going to be looking to to be engaged with?

MR. GRIFFITH: I sure can't think of any. The NRC staff has been great, we've tried to reach out as much as possible to stay engaged. I think the discussion is healthy and respectful of each of our roles in the process.

COMMISSIONER WRIGHT: Thank you so much. Hello Ms. Wheeler, how are you? So, I want to go back to your comments about -- and I guess the letter that you sent back in October. I guess -- because you mentioned it here, there were surprises that maybe the acceptance review standards had changed. Were you aware that those standards had changed, or was that one of the surprises?

MS. WHEELER: I think loosely aware, and I think it just highlights sometimes the -- it can be either the applicant's view, or the staff's view of, I'm in this, and I don't think this is much different than what we've done before. But the other party may see it quite differently. So, I think that was part of it, it was not for lack of trying to communicate between the staff, and our team. Just the practicality of how the acceptance review played out, and the level of detail in the questions were different than we were expecting. We worked through it, I'm glad, but --

COMMISSIONER WRIGHT: Yeah, well I know in this whole process in this area, or in the development of Part 53 or anything else that's going on, the communication part of it has been key. And to quote you,

you said you can't -- what did you say? You said can't happen too often, right?

MS. WHEELER: No, it cannot.

COMMISSIONER WRIGHT: And I believe you cannot over communicate as well, but I just wanted to be -- I wanted to kind of understand a little bit more what your situation, or your concerns were. I mean do you think that -- you seem to think, and what you're saying, that NRC staff's been open, and they've taken your feedback, and they've tried to be responsive.

MS. WHEELER: They have been open. I think they want to communicate as much as we do. We all want to be on the same page, that's how we're going to get through this review, and any that follow us. I think that the gap of time between the last round of new applications and now, licensee and applicant people have changed. NRC staff has changed. The regulations haven't changed, but as you get any new people into any equation with a new project, things are going to be looked at differently, and so again, back to we can't communicate often and early enough to be sure that we're all headed down the same road. Make sure that we're giving the information to the staff that they need to do their job.

COMMISSIONER WRIGHT: Absolutely, thank you. And let's go to staffing for a second. You mentioned later, as you closed really, that at some point you thought revisiting the whole staffing levels in the Division of Fuel Management would be needed. Can you maybe give me a little bit of your opinion of what that new structure and staffing level might look like?

MS. WHEELER: I think it is working now because we only have one application in. And they've budgeted clearly for one big thing, some medium-sized things, and then some routine stuff. So, I think it's really going to depend on how many more applications come, and what time frame, how quickly, and do they stack up on each other, as to whether the staffing levels remain good. Or need to be looked at for improving that to be able to handle more business from our side. So, you can't tell that today. Nobody wants to overstaff too early, we get that. But I think all we're asking really as an industry, is just let's keep an eye on it, and the better we can do from the industry side to communicate early as to what our plans are, when we're coming with applications only helps you and your staff plan for those efforts to come.

COMMISSIONER WRIGHT: Yes, I totally agree with that part, for sure. I'm going to come to you, Doctor. So, the whole next generation of workers, and stuff in this sector is big, especially here at the NRC, too, as regulators. Can you talk to me a little bit more about the structure of the NEXT Lab, and how the students are supported, and how do you deal with the knowledge management when the students graduate?

DR. TOWELL: Great question. With 60 students working with us, that's a lot of turn over, and so we emphasize from day one that what they do only lives beyond their exit if it's written down. So, if you don't write it down, it doesn't exist. So, we have that sort of policy on day one, and that's part of their coming in, and as they leave, we collect notebooks and make sure that reports and data are archived correctly. Hopefully it's been done along the way, but we double check it before they leave. So, there is an entry and exit method. We've also -- we have a staff of 30, so when you look at the ratio, it's sort of two to one, so it's pretty easy on the average for a mentor to work with two students, and make sure that they both have a good, positive experience, but also that their work is archived.

And so, one of the advantages of Abilene Christian University is we have a very long history of working with undergraduate students, and so that's something that we feel very comfortable with, and proud of our work with them. Give them the opportunity, but also they're energetic and they do a lot of productive, good work for us, so we enjoy that.

COMMISSIONER WRIGHT: Thank you. And Mr. Vollmer, I'm going to end with you. So, given the level of engagement that you've had with the NRC, and the staff in this area already, how would you gauge the NRC staff's readiness to support the advanced fuel licensing, and is the agency, in your opinion, well prepared, or do we have some additional work we're going to need to do?

MR. VOLLMER: Thus far everything has been extremely positive, and very good engagements, and we've been getting useful information back and forth. So, currently I don't foresee a change. I think we need to do a better job, we have our regulatory engagement plan, and are keeping up to date, but just doing a better job on our end probably, planning to make sure that you guys can align with that.

COMMISSIONER WRIGHT: Thank you. Thank you, Mr.

Chair.

CHAIR HANSON: Thank you, Commissioner Wright. Commissioner Caputo?

COMMISSIONER CAPUTO: Good morning. Good afternoon, Mr. Van Til, thank you all for coming today. Obviously this is a fascinating topic, and we're quite a bit behind. I've got several questions, but if I could just ask your patience, could you just please give me as concise an answer as possible so we can squeeze these in without falling further behind? I'd like to start with Dr. Back. It’s great to see you again.

MS. BACK: Hello.

COMMISSIONER CAPUTO: You've been a popular speaker, both here and in the Senate, and I thank you for contributing your expertise over the years. I'm interested about the silicon carbide cladding. How robust is the testing experience behind that cladding? And just in particular, the ability to contain the fission products without migration.

MS. BACK: Yeah, totally agree with the importance of measuring that and doing those actual tests. So, we have a series of out of pile tests, meaning outside of the reactor, without neutrons in the irradiation. Those have all shown good behavior, and what we expect from both our manufacturer and fabrication techniques with respect to the modeling, and simulation. But modeling, and simulation absolutely needs to be validated in a neutron irradiation environment. So, we have a series of three raw mat sets going into the ATR reactor at Idaho National Lab. We've already had testing at Oak Ridge for small material properties and samples. So, hardness, strength, those things have been tested. But with the ATR being delayed a little bit, we don't have that data yet, but it is coming.

COMMISSIONER CAPUTO: Okay, thank you very much. Mrs. Wheeler mentioned the potential for unique fuel facility applications resulting from various designs and fuel types, and TRISO is a fuel type for which there's been a great deal of testing over the years, as Mr. Griffith mentioned. And we recently approved a topical report on generic TRISO.

The question I have for Mr. Griffith is, are vendors developing specialized variations on TRISO that might fall outside the scope of that report, and do you anticipate possibly needing additional irradiation testing to support qualification of these more customized types of TRISO?

MR. GRIFFITH: I'm not aware of the developers or vendors developing TRISO fuel outside those parameters. But I can take the question back and get back to you and give you a more fulsome answer.

COMMISSIONER CAPUTO: That would be great. I think it would be really good to know whether or not we've really fully enveloped everything that vendors are intending within the scope of that topical report. Mrs. Wheeler and Mr. Vollmer, a question for you. So, as you are engaging either in pre-application space or now in application space with the staff, how important do you think it is to have in-person meetings when you're dealing with some of the more complicated issues arising with these technologies?

MS. WHEELER: I'll go first if that's okay. I think it's extremely important. Back in the 2000s, when a lot of licensing actions were going on, virtual meetings weren't a thing. So, you met in person, sometimes you had phone calls, or you didn't meet. So, I'm a big proponent of meeting in-person. We actually just did a process overview briefing with Region II inspection staff.

We went in person, now we have an advantage, we're only three hours away, but we're going to do the same thing for the headquarters review team in January, and we're coming in person because I think that the face-to-face offerings to be able to ask questions, give answers just is -- it works better in-person where you can. I realize that there are some cases where maybe it's not practical, or maybe you need to do it too often, and coming every day isn't the thing to do. But where possible, we're definitely very supportive of in person meetings.

COMMISSIONER CAPUTO: Mr. Vollmer?

MR. VOLLMER: I definitely agree that in person is very helpful. It has been nice actually having the option of remote as well, because at some topics, you do get early engagement on those that may not be worth a full trip out to discuss. So, it has been nice having the option of both. But I do agree, especially the bigger topics, in-person is useful.

COMMISSIONER CAPUTO: Okay. Mr. Van Til?

MR. VAN TIL: Yes.

COMMISSIONER CAPUTO: You have a very impressive facility with the high flux reactor and all the post irradiation capabilities. With the closure of Halden, I would imagine your facility has gotten pretty popular. Is there still availability for additional experiments and to be able to schedule time in your reactor, or are you fully subscribed for some period of time?

What's the ability for people to still be able to sign up and utilize your facility over the next few years?

MR. VAN TIL: Well, you are correct that with the closure of Halden, interest in the HFR has intensified. But yeah, we expect to run approximately for at least ten more years, and the availability of the core of course we have, the planning has become tighter, but it also depends a lot on the type of experiment that you want to do.

So, for example the role with the high fast flux, which is typically used for material irradiations, it would be hard to get a position in the coming period, I would say in a few years there is room. For the lower flux positions, where you typically do the fuel irradiation qualifications there is more space, because we have more experimental facilities available.

We also -- within the available core positions, we have irradiation facilities which can hold three, or four sample holders. So, we can make space in that sense.

COMMISSIONER CAPUTO: Thank you very much. It sounds like a fascinating facility. I certainly, at this point, hope to visit at some point in the future, because I'd love to learn a lot more about what you folks can do.

Mr. Griffith, one more question for you. You talked about the Inflation Reduction Act and the HALEU funding, and the activities that you're going to be funding with that. Where do you see within those activities, where do you see the greatest potential for schedule risk that would perhaps threaten the availability of HALEU by '26?

MR. GRIFFITH: Thank you for the question, Commissioner. I think that the current situation with Russia's unprovoked aggression in Ukraine has put a lot of uncertainty in the enrichment market, up to five percent. Clearly that has potential for impacts on our existing fleet. Recognizing that all high assay LEU will depend on feed material up to five percent, at least. And so, that's a dynamic that's going to be challenging to navigate given on one hand we need to fuel the future. On the other hand, we also need to fuel our current fleet. And so, that's going to be a challenging dynamic.

Recognizing that while we don't have funding to do that, we've certainly had some thoughts on replacing Russian supply, because our existing fleet relies on about 20 percent of supply from Russia annually. And that's governed by the Russian suspension agreement, managed by the Department of Commerce. We'd like to wean ourselves of that, and we'd like to add capacity on U.S. soil to fuel both our existing fleet, as well as prepare for a sustainable commercial supply of high assay LEU. So, I think that's probably the biggest challenge there, and it does --

COMMISSIONER CAPUTO: What challenges do you see in making that happen and finding those alternatives, or getting those alternatives licensed and capable of actually producing?

MR. GRIFFITH: I don't see many challenges in the regulatory space. I think that the path that has been charted by the demonstration in Piketon has certainly primed the pump if you will, for that technology there. And I think the efforts that Urenco is taking to enrich up to ten percent at their facility is helping to pave the way as well. I think the biggest challenge is funding. Can we get the capacity for both HALEU, and LEU replacement in a time frame that will meet our needs, and wean ourselves off of unreliable partners?

COMMISSIONER CAPUTO: Thank you. Thank you, Mr. Chair.

CHAIR HANSON: Thank you, Commissioner Caputo. Commissioner Crowell?

COMMISSIONER CROWELL: Thank you, and thank you all for being here today. I'm going to pick up kind of right where Commissioner Caputo left off with Mr. Griffith and HALEU. You referenced, and I read in the news recently, the announcement of the DOE-led consortium on HALEU availability. What role do you envision for the NRC playing in that consortium?

MR. GRIFFITH: Thank you for the question. So, the legislation, the Energy Act of 2020, Section 2001 assigned the Secretary the responsibility of establishing a consortium. And it's essentially organizations that play a role in potentially HALEU supply or its use. From a regulatory perspective, I don't see a direct role for NRC; perhaps as an observer. But the specific things that are articulated in the legislation are to inform the department, provide input to the department on standing up that capacity, including cost recovery schedule. And so I don't see a big regulatory space, but certainly from an awareness standpoint, as an observer to the inputs that we receive, and your consideration of those inputs from your perspective. I think that would be a constructive role.

We have been approached by other offices in the department, and I imagine other agencies expressing what role could they play, for example State Department. We want to keep the door open and be as inclusive as possible. However, we don't want to dilute, if you will, that input from what I understand to be industry input to the department on solutions going forward.

COMMISSIONER CROWELL: Just I ask because I know the legislation references government organizations participating in it, and I'm curious which types of government organizations, be it regulatory, NRC policy, State, whichever. So, I just want to make sure we're leveraging the opportunity if it's there, and not missing the opportunity.

MR. GRIFFITH: And the door is always open. We don't need consortium for our dialogue.

COMMISSIONER CROWELL: If we wrote to ask to join, I'm sure the response would be positive.

MR. GRIFFITH: Yeah.

COMMISSIONER CROWELL: You referenced earlier, the concern about HALEU availability through 2035 in reference to our climate goals. What is the projected HALEU supply needed through 2025?

MR. GRIFFITH: Great question. So, our -- based on the clear demand by the two-way RDB demos that are 50/50 cost shared, the estimate is about 40 metric tons through 2030. Given all the fuel developmental work and qualification experiments, you could add easily another metric ton or two. But that's fairly minor. Depending on how quickly the commercial activities could materialize before that time frame, it could easily double by 2032-, 2033-, or 4-time frame. The legislation has the program sun setting in 2034, or before. So, our preference would be to exit before, if possible, recognizing that would depend on those market dynamics being established.

COMMISSIONER CROWELL: I think the market dynamics and diversification, which you mentioned previously, are critical. Because I'm not great at math, but you could run multiple cascades full-time all year, and you're still going to come up short on 40 plus metric tons. And so, I'm a little bit concerned about how this all matches up in terms of commercialization of new reactors, availability of fuel, and bending the carbon curve, which is critically important that we get to that. That's why we're all here, trying to advance these technologies.

With that kind of in mind, Ms. Wheeler I was going to ask you, you referenced that now that your application has been accepted, it's going to be about a 30-month review period, and I won't comment on whether that's too long, or too short, or what have you. But how does it match up with prospective off takes for your fuel for advanced reactors who hope to use your fuel? Are they going to be ready before, are you going to be -- how does the timeline match up?

MS. WHEELER: That timing actually fits right in with our business plan at this time. Even if we just talk about the Xe-100s, and them trying to be ready to receive fuel, so that they can start up in the 2027-

timeframe. Finishing the NRC's licensing review by middle of '25, and then we'll follow that by physical inspections of things that we have ready, so that hopefully we gain agreement that we can turn the factory on by the end of '25. That timing fits right in. I will say there's not a lot of margin on our side for getting our part of the project done. I think that the 30-month review period, assuming we deliver good deliverable products to the staff for review, I think that's reasonable, and is actually in line with most of the new applications that were reviewed back in the 2004 to '9 time frame. So, even though this is a different project, different technology, it's not enrichment, the timeline lines up from both a business perspective, and the efforts that will be needed for the licensing review.

COMMISSIONER CROWELL: I agree, there's little, if no room for slippage of these timelines.

MS. WHEELER: Yes, on anybody's part.

COMMISSIONER CROWELL: Yeah, on anybody's part, which is why the work force issues are critically important. NRC being prepared to, knowing how many applications are going to come in, and when, and being prepared to respond to those, and with the overhang of climate change looking at us, we really can't afford any slippage if nuclear is going to be a part of that solution. That being said, we've got to do it safely.

And Dr. Lyman, if you're still online, that leads me to you. I know your presentation was broken up a little bit, but I share your concerns about safety and protection of public health, environment, preserving, and building public trust in the process of current and new nuclear technologies.

Given your presentation got a little broken up, I just want to give you an opportunity to articulate your concerns about those public health safety and environmental, and public trust issues, and how we can do a better job to make sure we're meeting that standard.

MR. LYMAN: Thanks. I'm not sure what you heard, and what you didn't unfortunately, but my main point is that qualification of these fuels is an essential component of safety, and that the regulatory processes that are being pursued for advanced reactors may make those even more important. For instance, functional containment concepts that would put more reliance on the fuel itself, like TRISO.

So, the concern is that trying to short-circuit the fuel qualification processes may compromise safety if there's an undue push to meet these timelines, which I think are artificially imposed, for instance, the Advanced Reactor Demonstration Program timelines. Especially given that the unavailability of HALEU is probably going to delay these demonstrations anyway.

So, again, I would urge the Commission to make sure that they did not accept accelerated fuel qualification programs if that would potentially reduce safety margin, not give enough information to actually validate the processes that require, for instance, mechanistic source term characterization.

COMMISSIONER CROWELL: Okay. Just quickly with the time I have remaining, do you feel like your organization and other stakeholders have had an adequate opportunity to participate in the regulatory process via the NRC?

MR. LYMAN: Well, yes, certainly in some instances, for instance in rulemaking development of Part 53. But the other point I was trying to make is when it comes to details of the fuel qualification, because so much of that data is proprietary, that makes it a little harder for the public to meaningfully have input.

And there's certainly some case to be made for excluding some data as proprietary, but maybe that line needs to be adjusted, especially when again, the fuel performance takes on increased emphasis in safety, and especially since so much of that fuel qualification work was done with public money and government facilities, the issue of what's a trade secret and what should be proprietary may be a little less clear.

COMMISSIONER CROWELL: Thank you for that. I agree that finding that right balance to strike to maintain and build public trust is important. Thank you, Mr. Chairman.

CHAIR HANSON: Thank you, Commissioner Crowell. As usual, I'll pick up on a topic that you introduced. I wanted to kind of put this question to Mr. Griffith, Dr. Back, and you Dr. Lyman, really about kind of accelerated fuel qualification. And I think the use of physics-based modeling and simulation tools are really important. The Department of Energy, and others have made a lot of progress on this in the last 15 or 20 years.

And yet it's important that those models be underpinned and validated with empirical data. And so this question is kind of deliberately, it touches on a gray area, right? But I would like to get each of your kind of perspectives on this issue of how much empirical data is enough? What's the right amount for not just accelerated fuel qualification, but maybe fuel qualification writ large. And I understand that it's incumbent on kind of the NRC to strike that balance or figure out where that line is. But I am interested in hearing from each of you about how much is enough in this area to kind of ensure the safety and performance in a variety of conditions for these types of advanced fuels.

Mr. Griffith, you're sitting in front of me, so maybe you can go first, and we can hear from Dr. Back and Dr. Lyman.

MR. GRIFFITH: Thanks, great question. And to be frank, the objective of accelerated fuel qualification is not to shortcut anything. It's to be more predictive, better predictive, so that when you're modeling, and your multi-physics, multi-scale simulations point to a solution, you have to validate it. So, it still requires that empirical data to validate the results of the modeling in the conditions that were analyzed.

And then once you do that, it's not like one data point is sufficient. You need to do some sensitivity analysis and sensitivity testing to test the boundaries, and the limitations as well. So, I don't think there's any textbook answer per se. I think the LIFT program that we're proposing helps answer that question more comprehensively and ultimately, it's just that you still need to validate what the computers are telling you.

CHAIR HANSON: Okay, thank you. Dr. Back?

MS. BACK: Yeah, so, okay, I'm on here. I'd like to follow-up with what was said already. We are not trying to accelerate to avoid safety, right? And I think maybe it might help to think of it in two aspects. There is developing models, and simulations that means taking advantage in the last ten years, where there is super computers, there are new algorithms, new test methods on the experimental side to bring together.

That is to develop the computational capability, that's something that NEAMS is doing very well, as an example for uranium oxide, which is the most well developed, because there is a lot of data to compare against. You can do test cases, and you can look at the regime, and how well it's described over a certain temperature range, for instance. Even when you have that model for your particular fuel, you will still need to go, and validate it with an integral test.

And the idea of the accelerated fuel qualification is that you learn and identify those parts which are important to the sensitivity. If you change the temperature and it doesn't really materially affect the performance, and you can validate that over a temperature range by taking data at the low boundary and the high boundary, and you understand that there is no change in the physics basis.

Then maybe you can take just one more data point in between to validate that you have a consistent performance that is understood by the physics-basis in the code. So, it's very hard to give a quantitative number to say you need ten points. But it's a methodology where the model has to be written, described, checked out for all its various computational algorithms, and so on.

You might describe a physics phenomena, and have it calculated wrong. So, you get rid of that part first, that's validating a model, but then you apply it. So, for every fuel, like for our fuel, we're using uranium oxide and silicon carbide in the fast modular reactor. We have a series of tests, which are right now in the pre-licensing state to identify those boundaries. So, that when we do the integral test for actually licensing data, we need to get the data that the NRC deems important for the safety case, and that will be an iteration with the Commission and the people at the NRC involved with our licensing application. And we go forward from there. So, I think it's -- in the case of uranium oxide, it's well-developed. In the case of ceramic fuels like uranium carbide that can build on uranium oxide, you have to show that, and then actually test it on the fuel. So, it's very difficult to give a specific number. I think it's really methodology that we're talking about.

CHAIR HANSON: That's okay, I didn't need a specific number necessarily, I'm just kind of interested in the perspectives on that question. Dr. Lyman?

MR. LYMAN: Yeah, I would just add I think it's very technology-specific, where that line is drawn. But just to have a healthy respect for uncertainty and the black art of fuel qualification, and all the things are not known even with regard to TRISO, so it's clearly of all the advanced reactor fuels, it probably has the most experience in development and operation. Yet there still seems to be a lot of fundamental things that aren't known, still surprises occur, and if you look at what happened in the AGR program, you just see how glitches come up, and how difficult those experiments are, how hard they are to interpret. And so it's just not easy, and so it makes me nervous to think of possibly not respecting that uncertainty, or trying to push ahead without understanding where you need to set the margin to be comfortable and maintain safety.

CHAIR HANSON: Thank you. Mr. Griffith?

MR. GRIFFITH: Yeah, if I could just follow up with a shameless plug for the Versatile Test Reactor. We've been unsuccessful in getting sufficient funding to get that up and running. However, that would be a test capability that would be invaluable in the 2030s to evolve the fuel, and to provide the answer you're looking for on accelerated fuel and material testing with fast neutrons.

CHAIR HANSON: Thank you. Mr. Vollmer, it occurred to me while the others were talking, that you might have some perspective on this, or thoughts you might like to share.

MR. VOLLMER: Just a few quick thoughts. I guess in general we've struggled also, because it is -- internally it has a comfort level of how much data is good enough, but we really have kind of, with our lead fuel performance model, at least found a way to propagate uncertainties through our full analysis. So, we can basically predict what's the probability of a fuel pin exceeding this limit, or whatnot.

So, really our role is quantify the uncertainty for all the experimental we have, and make sure that uncertainty carries through our simulations as well. So, that's been kind of the balancing act we've found there. But definitely all of our models are built on data, and we have a good database to back those up.

CHAIR HANSON: Thank you. Thank you all very much, I recognize the importance of experimental facilities like Mr. Van Til's in the Netherlands, and TREAT, and other key things, and actually kind of moving us forward, and being able to ensure the safety of these new technologies, so thanks for that very much. I'll hand it over to Commissioner Baran.

COMMISSIONER BARAN: Thanks. Well, I'll thank you all for being here and for sharing your thoughts. There's a lot of exciting work going on in this area.

Andy, I had a couple questions to ask you to start with. One of your slides that was talking about the Inflation Reduction Act, and kind of where the HALEU funding was going to be used talked about, or noted the need for additional criticality benchmark data for HALEU. Can you tell us more about the work DOE and others are doing there, and how that's coming along?

MR. GRIFFITH: Sure. I think the benchmark data that we have today is sufficient. I think that the big potential that that can provide to us is it can remove some of the uncertainty, some of the conservatism for some of the data that we have. And from a starting point, nothing materialized to us before we had this funding that was right for addressing.

However, now with that funding, it provides us some resources, that if there is some net benefit from transportation storage standards that we can achieve with a little sharper look in some specific areas, we're hoping to explore those. And so, I think it's going to be very interesting to see what kind of responses we get when we solicit those.

COMMISSIONER BARAN: Okay, and you actually touched on another question I was going to ask you on that same slide. One of the other issues is new transportation packages for HALEU. How are the design and development efforts there coming along?

MR. GRIFFITH: So, as I understand it, there is at least one current package that's in the process for each $UF_6$, and for oxide transportation that are looking to amend their existing certificates of compliance, and that's great. That didn't take any funding from us, so that's always a good thing that industry is taking action to address the needs of the future. Because we've got more -- we do have more demands than we do funding.

However, it does, again, it allows more of the existing players to look at their packages and explore revised designs that can meet the needs of the future, and that would provide diversity of transport packages. So, again, diversity of supply is, I think going to be really important to move forward.

COMMISSIONER BARAN: Okay, great, thanks. This is kind of a broad question and anyone can weigh in. It builds a little bit off of Commissioner Caputo's earlier question, which is just kind of a big picture as you're thinking about challenges for developing and licensing advanced reactor fuels. Are there any challenges you're looking at, and thinking right now NRC really needs to be doing more on any of those challenges? I know that's kind of a big question, but are there things that are kind of keeping you up at night, and you're thinking there's a role for NRC on that challenge? And it's okay if the answer is no. That would be a little surprising, but nice to hear.

MS. WHEELER: Well, I think maybe two, three years ago the thought was security and material control and accountability were going to be big challenges for Category II materials. While work does need to be done there, and some has been accomplished; there's been an updated NUREG issued for Category II material MC&A, security is being handled more on a site-specific basis, which I think is appropriate. Especially since every facility is not the same, every site is not the same. I think those are actually working.

So, at this point sitting in the applicant's chair, knowing that I have documents in for eight or ten different required elements, including the two that were thought to be challenging looking forward from a few years ago, I think we're going to do okay. I think that working through the integrated safety analysis, while the methods are no different than anyone else is using, just understanding the hazards of my process versus his process, versus somebody else's process, that's going to be something we have to work through each and every time you get an application. So, the better we get at that, I think, and irrespective of which staff persons are filling the roles, I think we're going to see a lot of gains from that. But I think really, we're doing okay.

COMMISSIONER BARAN: Good. And Dr. Back, did you have something you wanted to add?

MS. BACK: Yes, I did. I would like to just bring up the opportunity to talk about moving into a modernized nuclear industry, which has a diversity of reactors with different coolants. I see a challenge of, you know, you are the NRC. We have had light water reactors, and I see as my job, informing the NRC about our new technologies, and engaging you in discussion, and figuring out what will be the necessary safety basis for this case. But it is a situation where the technology, and the information about that technology is not very easy to -- there's no real mechanism for the NRC to bring in new technologies, and learnings.

So, for instance the research office, when you get an application for a new reactor, that's when they engage. But there is no ability of the NRC to proactively kind of learn about some of these technologies. And some mechanism for that is also where understanding how to bring in modeling and simulation, which is used in pretty much every other industry does not mean it's less safe. We all, as a community, need to figure out how to find the balance. I don't think it's just the NRC, it's all of us, to find the balance to ensure its safety. But that is over and above what the NRC has customarily done for light water reactors. Because it's not a water coolant, and that's pretty much true for any advanced reactor. Other reactors have more data, historically from the 60s. I would argue that data that you took today can be more sophisticated, higher resolution, higher fidelity, and so on. So, data from the 60s is not necessarily the same as the data for today.

But if we have to take 30 years of data to qualify any new fuel, or any new material, that's obviously a challenge for the whole industry in the United States. So, there needs to be some mechanism to continually keep the NRC involved in the technology developments and go forward as efficiently as possible. Thanks.

COMMISSIONER BARAN: Great, well thank you for that.

And I think on the next panel, we'll hear a little bit more about our Office of Research and what they're doing in this area.

Ed, let me ask you, your slides mention that you served on the National Academies Panel that looked at different fuel cycles and technology options. And your slides flagged a few of those findings. Are there any other findings of that study that you think NRC should focus on in particular?

MR. LYMAN: Yes, I mean while there weren't too many findings that addressed directly NRC activities, but I think overall, and I don't have the whole list in front of me, so I don't want to speak out of pocket, but focus on the particular need -- well, waste. One of the aspects of the study that we were asked to consider was advanced reactor wastes. And that's certainly an issue where there are going to be gaps that you're going to need to fill in, both for management of different types of wastes, both with regard to enrichment levels, chemical, and physical properties, and fission products. So, that's certainly something where there's going to be more attention.

One of the things the committee noted, and again I'm paraphrasing here was that the vendors largely are not putting so much attention into waste issues as other aspects of reactor design. And that's simply because there isn't much of a forcing function from anyone to address those issues. Of course, dealing of waste has always been the can that's been kicked down the road, and the committee believes that that's not appropriate, that those waste issues need to be considered in a more integrated fashion at the very beginning of each product.

COMMISSIONER BARAN: Okay, thanks Ed, and we'll give Andy the last word, and that'll wrap up the panel.

MR. GRIFFITH: Thank you. Yeah, I would just like to add that kicking the can down the road, we don't quite think that's an option, that we do have to consider that as we make decisions today as part of the evaluation process for the applications we received under the Advanced Reactor Demonstration Program funding opportunity announcement. The spent fuel management concepts, they had to be -- their approach had to be submitted and evaluated as part of the process, so it wasn't something that was not considered.

But I also want to point out that we just recently released a study through Argonne national laboratory that my office supported, that concluded that essentially you can't -- it's difficult to broad brush a broad range of technologies. That you really do have to look at the specifics, and the context. And that if any conclusion we have today, it's just simply that the advanced reactors that we're considering for the future have roughly the same challenges that our existing light water reactor fleet has. And having spent some time in the spent fuel and waste disposition area, it's not a technical challenge. It's more of a societal challenge that we -- I think there are solutions that can be pursued, it's just a matter of patience and persistence, and openness to allow communities to consider and be part of the solution. Thank you.

COMMISSIONER BARAN: Thanks everyone, appreciate it.

CHAIR HANSON: Thank you, Commissioner Baran. Thanks to all our presenters in this first panel. I think we had a really good discussion, and we touched on a number of really important topics. Thank you all again, we're going to take a short break. We're going to try and convene here at like 11:02, or something with the staff panel, and thanks all again.

(Whereupon, the above-entitled matter went off the record at 10:58 a.m. and resumed at 11:04 a.m.)

CHAIR HANSON: All right. Thanks, everyone. We're going to reconvene here for our staff panel. With that, I'll hand it over to our Executive Director of Operations Dan Dorman.

MR. DORMAN: Thank you, Chair. Good morning, Chair Hanson and Commissioners. It's a pleasure for staff to be here to provide an update on the staff's efforts to prepare for the review of applications to use advanced reactor fuel technologies and an overview of the work that is being done across the agency.

To support the efficient and predictable review and regulation of advanced reactors, staff across the agency are working collaboratively to ensure that we are prepared to review in-reactor fuel performance, address fuel cycle, transportation, and storage issues, performing independent confirmatory calculations, develop guidance, and lead research to enhance our knowledge of advanced reactor fuels.

You will hear today that we continue to successfully implement the vision and strategy for advanced reactor by developing the necessary knowledge, skills, and capacity, computer codes and tools, and review guidance needed to perform reviews of advanced reactor fuels. We are ready to review advanced reactor fuels to support near-term license applications and are exploring ways to optimize our infrastructure to maintain safety while enhancing efficiency, clarity, and reliability. Openness through early and frequent engagement with stakeholders continues to be a large contributor to our early successes in reviewing and approving advanced reactor fuels. And we are proactively engaging with applicants across business lines and technologies. You will also hear today that inter- and intra-agency partnerships, as well as international partnerships have been important to our success. Next slide, please.

So, on this panel you will hear from Rob Taylor, the Deputy Office Director for New Reactors in the Office of Nuclear Reactor Regulation, or NRR. Rob will provide you with a strategic overview of advanced reactor fuels activities.

Christopher Van Wert, our Senior Advisor on Reactor Fuel Systems for the Division of Safety Systems in NRR, will discuss our readiness to review in-reactor fuel performance, our engagement and collaboration efforts in this area, and our recent licensing activities.

Jason Piotter, Acting Branch Chief for the Nuclear Analysis and Risk Assessment Branch in the Division of Fuel Management in the Office of Nuclear Material Safety and Safeguards, or NMSS, will discuss our preparedness and recent licensing activities in the areas of enrichment, fabrication, transportation and storage of advanced reactor fuels.

Mirabelle Shoemaker, an International Safeguards Analyst in NMSS's Division of Fuel Management, will discuss international safeguards considerations as they relate to advanced nuclear fuels.

And, finally, Wendy Reed, a metallurgist in the Division of Engineering in the Office of Nuclear Regulatory Research, will provide an overview of research activities supporting the advanced reactor fuel cycle. Next slide, please. And I'll turn the presentation over to Rob.

MR. TAYLOR: Thank you, Dan. Good morning, Chair and Commissioners. The NRC and its predecessor, the Atomic Energy Commission, have over 70 years of combined experience regulating the safe use of nuclear fuels throughout the entire fuel cycle. And we built -- we will build on this experience to regulate advanced fuels.

As the state of knowledge progresses, advanced reactor designs with potentially enhanced safety and operational performance are being developed. The NRC is leading initiatives to keep pace with this evolution in the technology, and working with external stakeholders to leverage and harmonize efforts to update or develop new tools and guidance. Our activities are guided by the principles of good regulation as we execute our regulatory activities to accomplish our safety mission. Next slide, please.

Advanced reactor fuels present unique opportunities and challenges as the NRC transforms its traditional regulatory framework to be agile and reliable in the licensing and oversight of these technologies. The NRC provides regulatory oversight for the entire fuel cycle to ensure regulated activities, provide reasonable assurance of adequate protection of public health and safety. As such, we recognize that preparing for the next generation of fuel technologies requires a collaborative effort across the agency. To that end, we are working to realize the vision of making the safe use of these technologies possible throughout the entire nuclear fuel cycle, including enrichment, fuel fabrication, transportation, in-reactor requirements, and spent fuel storage.

Traditional light-water reactor, or LWR, fuel consists of uranium oxide fuel pellets enriched to 5 weight percent uranium 235, U-235, within an array of zirconium-based cladding. The nuclear industry is designing reactor fuels with operational conditions that differ significantly from traditional LWR fuels in that they may take different forms and include new materials. For example, advanced reactor designers are considering several fuel types, including fuels based on tri-structural isotropic or TRISO particles, metallic uranium alloys, and liquid salt fuels, which hold potential for advanced safety. To achieve the staff's vision, our work in this area of advanced reactor fuels encompasses enhancing technical readiness, optimizing regulatory readiness, and leveraging communication to engage with stakeholders and coordinate priorities. Next slide, please.

In the area of technical readiness, we are focused on enhancing our analytical tools, preparing our talented staff, and bolstering our scientific understanding. To ensure our tools are ready, we continue to partner with the Office of Nuclear Regulatory Research to develop and update fuel analysis codes for new technologies, to ensure readiness for the review of applications involving advanced reactor fuels.

The NRC is also working collaboratively with the Department of Energy, or DOE, to prepare our analytical capabilities to model the performance of these new fuels during normal and accident conditions, to understand the safety margins, and the performance capabilities. Staff is actively engaged in research activities to enhance our knowledge of technical considerations related to advanced fuel cycle, including fresh fuel transportation and spent fuel management.

In addition to preparing our tools, we are also investing in preparing our people. To prepare our talented staff we have ongoing efforts to retain, develop, and recruit highly qualified staff with the specialized skill sets needed to review advanced reactor fuels. We are taking advantage of various recruitment opportunities to expand our applicant pool, and we are proactively enhancing our agency knowledge of advanced reactor fuel topics through development of Nuclepedia resources and technical seminars.

We are also providing relevant training on non-LWR fuel concepts and their anticipated effects on the licensing of fuel cycle facilities, transportation packages, and spent fuel storage systems. It is also a priority for us to establish and document the technical knowledge needed to safely regulate these advanced reactor concepts. We are continually engaged in efforts to identify and enhance our understanding of these advanced reactor fuels through the use of phenomenon identification and ranking tables, or PIRTs, literature reviews, and independent assessments of advanced fuel cycle technical considerations.

Staff has relied on early and frequent engagements with

DOE and other external stakeholders to leverage experimental data, for validating confirmatory models, and computational tools to assess uncertainties and risk. Next slide, please.

Regarding safely regulating these advanced reactor fuel concepts, the current regulatory framework is adequate to review and regulate near-term use of these fuel designs, including review of applications. And we're working to optimize our regulatory readiness while using data and risk insights to further improve our licensing reviews, while maintaining focus on safety.

Moreover, the staff has established guidance for the staff review of non-LWR fuels qualification. And there is ongoing rulemaking effort for Part 53 that would establish a technology-inclusive regulatory framework for licensing reactors that use advanced fuel designs using methods of evaluation that are flexible and practical for application to a variety of reactor technologies. Next slide, please.

Consistent with our principle of openness, we are performing significant outreach to our stakeholders to enhance communication and continue to sharpen our focus on the latest developments in the area of advanced reactor fuels. By engaging with domestic and international stakeholders we are ensuring a broad spectrum of input and experience, and actively working to share insights. This engagement helps strengthen our technical foundation for the review of advanced reactor fuel technologies. We engage in early and frequent communication with stakeholders to stay informed of the industry's priorities in order to prepare the agency with the needed near-term and long-term regulatory tools.

We are extensively leveraging robust pre-application engagements to ensure we understand the technologies that we'll be asked to review, and that the information necessary to support our review is understood and included in the applications that are submitted for NRC review. We are also actively participating in domestic and international conferences, NRC-sponsored meetings, industry group information exchanges, and periodic meetings with the Department of Energy and international groups, such as IAEA and NEA.

We frequently update and enhance our public website to share information with the stakeholders and provide them with access to our recent advanced reactor activities, including updates to our fuel guidance. We also leverage various forums, including our periodic advanced reactor stakeholder meetings, to encourage active participation from the industry, the public, other federal and state agencies, and the inter-agency and international partners to enhance regulatory information exchange.

In the rest of the staff's presentation today, you will hear greater detail about how we are building on the NRC's prior experience, adapting to the current state of knowledge, and continuing to communicate and engage with industry and stakeholders to ensure we are postured to regulate advanced reactor fuels. Next slide, please.

Thank you. And I will now turn the presentation over to Chris.

MR. VAN WERT: Thank you, Rob. Good morning, Chair and Commissioners. I am pleased to be here today to provide an update on the readiness for our application review, engagement efforts, and recent licensing activities related to advanced reactor fuels. Next slide, please.

The staff has been actively preparing for advanced reactor fuel reviews by developing guidance for fuel qualification, developing tools for evaluating fuel designs, and leveraging past experience with non-LWR designs, such as Peach Bottom Unit 1, Fort St. Vrain, PRISM, and the Next Generation Nuclear Plant.

In order to reduce regulatory reviews, scheduling uncertainty, and to provide regulatory clarity in terms of fuel qualification, the staff developed technology-neutral advanced reactor fuel qualification guidance in NUREG-2246, and contracted with Oak Ridge National Laboratory to develop similar molten salt reactor specific fuel qualification guidance. These documents helped designers by providing a framework that would support regulatory findings associated with nuclear fuel qualification.

In addition to providing fuel qualification guidance, NRR partnered with research to develop evaluation tools to assist in advanced reactor fuel licensing reviews by updating the NRC-funded fuel performance code, FAST, which stands for Fuel Analysis under Steady-state and Transients. The updated FAST program models fuel behavior for several advanced fuel designs. Wendy Reed from Research will discuss this more in depth during her presentation.

These updates will increase regulatory review efficiency by focusing the staff's review on topics that are of greater safety significance.

The staff has set the stage by developing guidance for non-LWR fuel qualification and approving a generic TRISO particle fuel qualification topical report. However, an advanced reactor developer has an important role in that it must demonstrate that its fuel design is qualified for the necessary operational parameters.

For example, applicants need to demonstrate that the behavior of their fuel is well understood and can be predicted for the foreseen operational and transient conditions, with consideration for the role that the fuel plays in the safety analysis for a particular reactor design, fuel testing and the critical path in the development of advanced reactor designs. Therefore, the staff strongly encourages early engagement on fuel testing plans to reduce the risk of missing data that is necessary to support fuel qualification. By using pre-application engagements and available guidance, developers can seek early approval of fuel designs; for example, the submission of a topical report for NRC staff review. This can lead to more predictable licensing reviews for advanced reactor designs. Next slide, please.

In order to develop guidance documents and to prepare staff for advanced reactor fuel qualification reviews, the staff formed and expanded engagements with domestic and international partners. The NRC has developed working relationships with the advanced reactor community that maintain NRC independence without isolation. These working relationships enhance our understanding of the needs of potential applicants, leverage available experience in national laboratories, and facilitates participation in codes and standards committees that are related to advanced reactors.

For example, the NRC staff has collaborated with various national laboratories to provide input to fuel qualification guidance and to exercise this guidance. Additionally, NRC staff members participated as observers in advanced reactor fuel working groups. As an example of this, NRC staff members attended the industry-led and DOE-funded Accelerated Fuel Qualification Working Group as observers to better understand the concerns of the advanced reactor fuel community, and to learn about potential directions that future fuel qualification licensing requests might take.

In addition to our domestic activities, the NRC staff actively engages with various international organizations to exchange information on the safety of advanced reactor fuel designs. For example, NRC staff representatives led the development of the report titled "Regulatory Perspectives on Nuclear Fuel Qualification for Advanced Reactors" through the Nuclear Energy Agency, or NEA, which later served as the foundation for the NRC's own Non-LWR Fuel Qualification Guidance, published in NUREG-2246. Because the staff actively collaborated on the development of the NEA report and closely aligned our NRC specific guidance with it, NUREG-2246 enhances regulatory predictability for our fuel vendors seeking approval in multiple countries. The NRC is also collaborating with the Canadian Nuclear Safety Commission under the Memorandum of Cooperation to develop a joint position paper on the TRISO fuel qualification. Next slide, please.

As mentioned previously, the NRC staff actively prepared for advanced reactor fuel qualification reviews by developing guidance and addressing knowledge management via international and domestic engagement efforts. Recent licensing activities demonstrate the effectiveness of our efforts. The NRC has completed, or is in the process of completing, review of four advanced reactor fuel qualification and fuel performance topical reports and provided feedback on three similar White Papers. Perhaps more important than the number of reviews completed is the method by which the staff and applicants have approached fuel qualification regulatory reviews. This approach has led to a process that enhances regulatory clarity and reliability.

This approach includes, first, engaging with the industry early to identify opportunities to develop common products, such as this topical report, that can support multiple advanced reactor designs with use of similar fuel forms. And, second, engaging with potential applications in pre-application activities to increase understanding of the NRC's regulatory requirements so that applicants will be -- applications will be of high quality and increase the likelihood of an applicant successfully demonstrating compliance with all applicable rules and regulations.

One example of this process is the approach which was used to support TRISO-based fuel qualification regulatory reviews. Before any TRISO-based advanced reactor designers were ready to engage with the staff, the staff reviewed and approved a TRISO particle fuel qualification topical report submitted by the Electric Power Research Institute, or EPRI, in coordination with Idaho National Laboratory. The TRISO particle design covered by this topical report is common amongst multiple TRISO-based advanced reactor designs and therefore, the staff's approval is applicable to similar designs which meet the conditions of the topical report. This increases efficiency for licensing request applications by allowing TRISO-based advanced reactor designers to rely on the previously approved TRISO particle, and to focus the regulatory applications on the final fuel forms; for example, TRISO pebbles or prismatic core designs.

The staff further supported fuel qualification by encouraging pre-application engagements with interested advanced reactor designers. These engagements can include activities such as position papers or meetings to discuss future licensing requests, and for the NRC staff to provide early feedback and clarity regarding requirements for fuel qualification.

The approval of the EPRI TRISO fuel qualification topical report and the use of pre-application engagements has supported fuel qualification topical reports for applicants, including Kairos and X-energy. The use of this process resulted in higher quality topical report submittals and more streamlined regulatory reviews. Next slide, please. I will now turn the presentation over to Jason.

MR. PIOTTER: Thank you, Chris. Good morning, Chair and Commissioners. I am pleased to be here today to provide an update on the readiness for reviewing applications relating to the front-end and back-end of the advanced reactor fuel cycle. Next slide, please.

The staff has been actively preparing for the advanced reactor fuel reviews by leveraging past licensing experience, performing preliminary technical evaluations, and evaluating the regulatory framework applicability to non-LWR fuel designs.

For clarity, the front-end of the fuel cycle includes conversion, enrichment, and fuel fabrication facilities, as well as fresh fuel transportation. And the back-end of the fuel cycle includes spent fuel storage, spent fuel transportation and, ultimately spent fuel disposal, or possibly recycling or reprocessing. We have made significant strides in our readiness to review applications for licenses and certifications for the fabrication and transportation of near-term advanced reactor fuels, and our preparatory activities built upon previous experience we have licensing enrichment and fuel fabrication facilities with high enrichments, and certifying transportation packages with high enrichments in novel fuel designs.

We are actively gathering technical information for longer-term advanced reactor fuel concepts to support front-end fuel cycle licensing reviews. We remain ready to review technical information and licensing actions for the back-end of the fuel cycle, for both near-term and long-term fuel concepts. Specifically, we are actively seeking technical information, including fuel performance data, which will inform ongoing evaluations of the regulatory framework and guidance for the back-end of the fuel cycle.

In 2021, the staff released seven technical reports prepared for the NRC by the Center for Nuclear Waste Regulatory Analysis focusing on near-term advanced reactor fuel concepts such as TRISO and metal fuels. These analyses evaluated unirradiated or fresh fuel transport, storage of spent fuel, irradiated or spent fuel transport, and disposal. With respect to longer-term advanced reactor fuel concepts, the NRC recently published a report on front-end considerations for molten salt fuels, which Wendy will discuss further in her presentation.

As a complementary activity to ongoing technical evaluations, the NRC and Oak Ridge National Laboratory conducted a week-long fuel seminar late last year. This seminar focused on non-LWR high-assay low-enriched uranium, or HALEU, fuel concepts enriched between 10 and 20 weight percent U-235, and how these new technologies will affect fuel cycle facility transportation package and spent fuel storage system licensing. The seminar covered advanced reactor fuel technologies, including fuel types using TRISO fuel, metallic uranium fuel, molten salt reactor fuel, and transportable micro-reactor fuels.

The staff has concluded that current regulatory framework for the front-end and the back-end of the fuel cycle is flexible enough to accommodate near-term and advanced reactor fuels. The regulations are performance-based, technology-inclusive, and are expected to be sufficiently comprehensive for risk-informed licensing of advanced reactor fuel processing and fabrication operations, transportation, and storage. While staff has not yet identified the need to make any changes to the regulations for near-term fuel concepts, such as TRISO or metal fuels, or longer-term advanced reactor fuel concepts such as molten salts, we continue to assess our regulatory framework to identify any challenges and/or data needs to ensure our readiness. Next slide, please.

Consistent with our current practice, applications for advanced reactor fuel facilities licensing, design certification of fresh fuel transportation packages, design certification of spent fuel storage casks, and design certification of spent fuel transportation packages must all demonstrate compliance with NRC regulations such that advanced reactor fuels can be safely managed in all phases of the fuel cycle. The NRC is actively reviewing applications for licensing and certifying the possession and use of special nuclear material enriched to less than 20 percent U-235 for the production of advanced reactor fuels, higher enriched uranium hexafluoride, or $UF_6$, advanced reactor fuel fabrication, and advanced reactor fuel transportation packages for the front-end of the fuel cycle.

For example, the NRC staff is currently reviewing the license application for the TRISO-X Category II fuel fabrication facility and a certificate of compliance application for the DN30-X uranium hexafluoride, or UF-6, transportation package and, finally, the OPTIMUS-L fresh fuel transportation package for TRISO fuel. Each of these applications are notable because, if approved, they represent the first significant steps forward for near-term advanced reactor fuel availability.

The staff's ability to review applications related to the deployment of advanced reactor fuels is a direct result of our pre-application activities for the front-end of the fuel cycle. We expect to engage in additional pre-application activities over the next three years and beyond with prospective applicants, licensees, and vendors, some of whom have already notified the NRC of their intent to submit applications for fuel facilities and corresponding transportation packages. Next slide, please.

Looking forward, staff is focusing on resolving technical issues and seeking ways to enhance efficiency and effectiveness. The staff believes that while these needs exist, they are not an impediment to licensing advanced reactor fuels. Rather, they are technical or operational challenges.

To assist with these regulatory needs, the staff at NMSS has begun to develop the advanced fuels roadmap which will provide a holistic picture linking regulatory, technical, communication, and budgetary activities into one complete planning and action tool. The roadmap is intended to chart both the front-end and back-end of the fuel cycle for all near-term and longer-term fuel concepts by licensee or certificate compliance holder.

With respect to the front end of the fuel cycle, there are potential technical challenges for HALEU feed material and advanced reactor fuels, such as limited critical experiments for higher enriched material, as well as potential operational challenges at fuel facilities. The additional availability of critical experiments for the entire HALEU range, as well as criticality benchmarks would support more efficient and effective reviews. Similarly, there may also be operational challenges such as chemical hazards or security requirements for the possession, use, and transportation of Category II quantities of special nuclear material.

The staff remains ready to review applications relating to the back-end of the fuel cycle for both near-term and long-term fuel concepts based on the information available today. The staff will continue to gather available information and develop guidance, as needed, to enhance the efficiency of our reviews.

We will continue to evaluate the regulatory framework and assess information needs to support our readiness, including potential areas of technical focus such as source term evaluations, criticality and shielding evaluations, thermal performance, material degradation considering both short-term and long-term performance.

Finally, we are encouraged to see external stakeholders starting to focus on the back-end of the fuel cycle. For example, NMSS recently attended a Nuclear Energy Agency workshop on the back-end of the advanced reactor fuel cycle. And we have been involved in discussions with the extended storage and collaboration project headed by EPRI. These activities will facilitate information gathering and will ultimately inform the advanced fuels roadmap. Next slide, please. I will now turn the presentation over to Mirabelle.

MS. SHOEMAKER: Thanks, Jason. Good morning, Chair and Commissioners. I am pleased to present on the topic of international safeguards, implementation of advanced reactor fuels, and international trade. Next slide, please.

The NRC promotes and supports nuclear non-proliferation through the implementation of safeguards on the commercial use of nuclear material and technology. And the objective of IAEA safeguards is to deter the spread of nuclear weapons through early detection of the misuse of nuclear material or technology. Safeguards are a set of technical measures that control and account for nuclear material to ensure it is used for peaceful purposes. Safeguards work hand in hand with security to deter and detect potential loss, theft, diversion, or misuse of material, equipment, and technology.

Domestic safeguards are modeled from international safeguards requirements that are fulfilled through a collection of information through the U.S. national system of accounting for source and special nuclear material. The accounting system, known as the Nuclear Materials Management and Safeguards System, or NMMSS, supports the export controls framework and fulfills reporting commitments under the U.S.'s various agreements.

The NRC plays a technical role alongside other executive branch agencies to implement safeguards across commercial nuclear industry. The inter-agency collaborative environment and frequent coordination allow the NRC to stay on the pulse of improvements and advancements in safeguards. As a result, like in the area of advanced reactor licensing, the NRC is proactive in safeguards implementation instead of reactors developments. Next slide, please.

The regulatory framework is already in place to support safeguards implementation at advanced reactor fuel cycle facilities. The framework can apply to various technologies and types that rely on the use of special nuclear material. The regulatory framework also includes requirements geared towards international safeguards and compliance with IAEA reporting for facility selected for safeguards.

The regulation will focus on tracking, accounting, and reporting of special nuclear material to the NMMSS system, which is operated by the Department of Energy, National Nuclear Security Administration, or DOE NNSA, with NRC support through and interagency agreement. The data currently submitted by licensees will be the same type of data to be submitted by producers and users of advanced fuels. The NMMSS system is prepared to track the location of these materials and create reports to fulfill our safeguards commitments.

Complementary to the regulations, the NRC published guidance for materials control and accounting at Category II facilities in July 2022. The guidance is specific to licensees that possess special nuclear material of moderate strategic significance. And the general performance objective is rapid determination of an actual loss of a significant quantity of special nuclear material through a high level of safeguards awareness training and conservative limits on item control and shipper/receiver differences that are commensurate with the attractiveness of the material at these facilities. These measures uphold principles of domestic safeguards and complement existing guidance for Category I and III facilities under the graded approach for material control and accounting. Next slide, please.

International engagement is growing in importance as advanced reactors and advanced fuels enter our international trade. NRC has been and continues to be actively engaged with our interagency partners and international counterparts on safeguards. NRC staff is working with DOE and national lab staff on the ongoing technical work related to MC&A approaches for advanced reactor fuels and new facilities for advanced reactors. The DOE work is focusing on challenges presented for MC&A by advanced reactors where the fuel is not contained in straight assemblies, such as some molten salt designs.

Now as Chris mentioned earlier, Oak Ridge National Lab prepared a report for the NRC in March of 2020 that provides a model of an MC&A plan for pebble bed reactors, as well as the basis, methodology, and process for development of an MC&A plan, outline, and analysis. Insight from these DOE analyses are helping to inform NRC staff in review preparations and pre-application engagements with developers.

The NRC staff serves as chair of the subgroup on the implementation of safeguards in the U.S. with the Departments of Energy, State, Defense, and Commerce. This group, known as SISUS, allows interagency discussion resolution of practical issues of safeguards implementation in the U.S. for both commercial and government facilities. Through SISUS, the NRC has engaged with the IAEA on priority safeguards considerations for advanced reactors and the advanced fuel cycle. Working hand-in-hand with the IAEA and SISUS, the NRC is able to inform advanced reactor developers about international safeguards, and engage with potential applicants on these topics during pre-application meetings.

In complement to IAEA safeguards, the NRC participates with the Department of State, and DOE NNSA, in the Nuclear Cooperation Authorities Group, or NCAG. This is a forum with our major nuclear trading partners, Australia, Canada, the European Atomic Energy Community, Japan, and the United Kingdom. The U.S. maintains bilateral agreements with each of these members and is committed to tracking and reporting source and special nuclear material received from our trading partners to ensure that the material remains used for peaceful purposes.

International partnerships and interagency coordination have ensured that safeguards are reflected in the regulatory framework and effectively deployed across the nuclear industry to meet international commitments. The NRC has played a pivotal role in connecting global safeguards considerations with the commercial industry by welcoming interagency stakeholders into public meetings and other forums with NRC licensees.

A notable example is the recent U.S. prior government approval memo to Global Nuclear Fuels America, or GNFA, in September of this year where the NRC informed GNFA that its process for tracking foreign obligations on low-enriched uranium is appropriate and upholds principles for foreign obligation exchanges. This approval was granted in less than 90 days after GNFA's request for a review. And that timeline was only possible due to NRC's extensive early engagement with interagency partners.

NRC's role in the domestic international safeguards communities allows us to keep abreast of safeguards policy development and to continue to provide efficient safeguards guidance and reviews for advanced reactor fuels technology. Next slide, please. I will now turn the presentation over to Wendy.

DR. REED: Thank you, Mirabelle. Good morning, Chair and Commissioners. And I'm very pleased to be here today to provide an update on research activities to support efforts related to the future licensing of advanced fuels and fuel cycles. Next slide, please.

So as Chris mentioned, research staff is supporting NRR to develop tools to perform independent analyses for new non-light-water reactor fuel designs. This support includes developing a plan to update the FAST fuel performance code documented in NRC non-light-water reactor vision and strategy, Volume 2, Fuel Performance Analysis for Non-Light-Water Reactors.

Subsequently, staff has completed several of the tasks outlined in the plan, including developing TRISO fuel models, FAST code, and improving existing metallic fuel capabilities to perform code assessments. These code assessments revealed that FAST is ready for metallic and TRISO fuel confirmatory analysis. Further improvements to the code will reduce uncertainty in code predictions.

Recent code development efforts rely on experimental data for developing and validation of confirmatory models. Therefore, staff is monitoring industry-led efforts on advanced modeling and simulation involving atomistic and mechanistic modeling that can inform the need for experimental programs and to identify testing priorities.

Staff also engages regularly with the DOE. NRC staff members participate in DOE's monthly meetings such as the Advanced Fuels Campaign and the Advanced Gas Cooled Reactor Program review meetings, where the latest experimental data is presented and the latest code development efforts are discussed. NRC staff members periodically meet with researchers at the national laboratories to learn more about code development efforts sponsored by the Nuclear Energy Advanced Modeling and Simulation, or NEAMS, program to ensure that NRC's tools include the relevant models for non-light-water reactor fuels.

Keeping an eye toward being ready for future technologies, the staff has initiated a research activity under the Future Focus Research Program on the applications of nanotechnology for claddings in advanced fuel assemblies. These advanced claddings may offer superior resistance to radiation damage and serves degradation to harsh coolants and high temperatures. Next slide, please.

Research is supporting NMSS through a holistic approach to assess technical considerations for advanced fuel cycles. To facilitate engagement and cooperation, research developed an addendum to the Nuclear Energy Innovation Capabilities Act of 2017, the NEICA memorandum of understanding between NRC and DOE. The addendum signed earlier this year, addresses technical coordination on activities related to the safety of advanced fuel technologies and fuel cycles.

Staff has been conducting activities related to the front-end and back-end of advanced fuel cycles. For example, as Jason discussed, Research recently published a preliminary assessment of front-end activities for molten salt reactors, including activities related to enrichment, production, and transportation of fresh salt fuel for reactor sites.

Based on the recommendations in the report, Research has initiated an assessment of technical and regulatory considerations related to the front-end of the molten salt reactor fuel cycle. We are also carrying out an assessment to consider DOE's plans for the production or recovery of HALEU fuel feed material, and options for transportation for the shipment of HALEU fuel feed material to be used in advanced reactor fuels.

And as Mirabelle mentioned, advanced fuels and advanced reactors can introduce new considerations for safeguards and material control and accounting due to their novel designs. Modeling and simulation can help to identify the best MC&A practices for nuclear facilities as part of the design process in a cost-effective, risk-informed way. Staff is examining how modeling and simulation can be used to help assess uncertainty in MC&A measurements at different points in a facility, and prepare the NRC staff to verify and validate modeling and simulation technologies.

In addition, staff is building on in-house work that our staff, including an NRC summer intern, performed to explore the use of modeling and simulation to help integrate the safeguards, security, safety, or 3S, by design approach. Next slide, please.

So, as Jason mentioned, potential longer-term challenges for the back-end of the fuel cycle need to be evaluated. And Research is working to enhance the NRC's understanding of the technical considerations related to the unique attributes of some spent advanced reactor fuel types.

Staff has recently begun work to assess the novel waste streams and potential waste forms that are being considered for molten salt reactors. Planned work includes analysis of off-gas management, include monitoring controls needed for successful operation of the off-gas system.

Staff is also monitoring various advanced research project agency energy, or ARPA-E programs that seek to address the challenges of spent fuel waste management. One such program is optimizing nuclear waste and advanced reactor disposal systems, or ONWARDs. Research management was recently invited to speak at the kick-off meeting in Chicago to provide NRC's perspectives. Additionally, staff engages regularly with the DOE regarding molten salt reactors, and meets periodically with researchers at the national laboratories working on monitoring, census, and instrumentation for these reactor types. Thank you for your attention. Next slide, please. And I'll turn the presentation back to Dan for closing remarks.

MR. DORMAN: Thank you, Wendy. As you've heard, the staff is preparing to regulate advanced reactor fuels throughout the fuel cycle. We are working with our domestic and international stakeholders to increase our capacity to address these new technologies. We are working to ensure that we understand the dynamic landscape in which we are regulating, and we are adapting to be ready to oversee the safe and secure deployment of fuels for advanced reactors.

We continue to encourage early stakeholder engagement with us so that we can stay informed of the industry's priorities and design developments in order to prepare the agency with the needed near-term and long-term tools to ensure the safe and secure use of advanced reactor fuels efficiently and reliably.

I want to thank all the panelists today and the staff who supported the preparations for this Commission meeting, as well as all the staff working in the challenging area of advanced reactors. Thank you again for the opportunity to present today. And we look forward to your questions.

CHAIR HANSON: Thanks, Dan. Thanks everyone on the staff for the panel. We will begin again with Commissioner Wright.

COMMISSIONER WRIGHT: Thank you, Chair. And, again, thank you for your presentations. And I know you had a lot of staff support to put it together, too. So, thank them as well.

This is a very busy agency right now in a lot of different areas. And there's a lot of balls in the air. And I really appreciate the way that you're dealing with it. And, you know, as we're coming out of COVID and getting into just regular routine, so it's recognized. So, thank you.

So, Dan and Rob, maybe I'll start with you. So, you mentioned that we're focused on retaining, you know, developing and recruiting highly qualified staff. Talk to me a little bit more maybe about how you are maintaining an agile workforce and what are -- what kind of tools are you using, especially in this area, where we're developing a diverse landscape in advanced fuels?

MR. DORMAN: So, I'll start at the agency level and then I'll let Rob pick it up to the specific areas. As you know, we've had a high focus on hiring over the past year. And we've made significant progress. But we have a lot of work still to do. And we'll talk more about that at next week's Commission meeting.

But one of the areas that we're looking at as we continue to focus in that area of recruiting and hiring the right talent is the resources available to do that in OCHCO and throughout the agency to support our hiring needs, as well as our recruitment activities. And where we're recruiting and, also, re-looking at our recruitment materials and making sure we're putting the agency's best foot forward as a model place to work. So, that's kind of some,

some high-level general things. Let me let Rob speak to the particular area.

MR. TAYLOR: Thanks, Dan. It's a great question, Commissioner. It's a challenging area. These four that are sitting here at this table, we have a bunch behind them, but we need more. The workload and where we expect it to go, we need to hire to round out our resources and be prepared to be able to do multiple reviews at the same time. We're able to handle the workload that we have today. But if the ARDPs come in, we'll have multiple activities going on at the same time, as well as some others who have indicated.

So, we have to recruit well and hire well. That includes both people with experience outside, so we need to be competitive as we do that. As well as recruit, and train, and develop the next generation as well. So, we're using the NRAN program extensively to fill out our ranks as much as possible. Everybody wants the NRANers they're all great.

So, we've first got to get them in the door, and then assigned, and then get them the skill sets and the training. So, we have a robust training program in advanced reactor technologies that we've been putting together as part of our integrated action plan strategies over the last few years. So, we're executing that. I think we're having training, was it this week, I think, on molten --

MR. DORMAN: Thirteenth through 15th.

MR. TAYLOR: Thirteenth through 15th. So, on molten salt reactors. So, that will bring this type of technology to further enhance staff's understanding and capability. And then we have to retain them as well. This is a competitive job market. So, we're going to leverage the tools through OCHCO to use them to retain our staff. One of the things that's helpful in this respect is that as more opportunities are present and our staffing members increase, we now have the potential to promote staff. That hasn't been an opportunity over the last few years. So, when the skill sets are needed at those grade levels, we're able to post. And we've been successful in internal promotions of staff, which is a very important piece for staff to feel like they have a career path within the agency. So, I think it's a multi-faceted activity, and we're working all the pieces at the same time.

COMMISSIONER WRIGHT: Yeah, thank you for that. And I do, I mean, my interactions with the new people on staff to be onboard, I mean, they are hungry. Right? They are, they are ready, which is really, really good. It's very nice, and it's great to see.

Wendy, let me come to you, Doctor. So, you mentioned that we have a vision and a strategy document for the fuel performance for non-LWRs. Talk to me a little bit about what the next steps are in the plan? And as, you know, are we focused on code development and model simulation or are there other focus areas?

DR. REED: There's other focus areas as well. They're also, you know, looking at analytical tools in general supporting codes and standards development. So there's, I believe there's, you know, severa volumes with regard to vision and strategy. So, you know, a general process for updating these plans is to for the analytical tools and the molten salt. Sorry, for modeling simulation as well, is to, you know, frequently look at our data needs. Where are the gaps in our needs? Look at what models, what data is already out there. And also look for opportunities to collaborate, cooperate with Department of Energy, for instance, to make sure that we're leveraging all the experience we can, that we're not duplicating efforts. And so that is, it's sort of the general process with regards to the plans.

COMMISSIONER WRIGHT: Thank you. Jason, you heard on the first panel had a little conversation with Ms. Wheeler regarding some, I don't know, maybe some that were termed as surprises maybe, especially for the -- maybe, and she talked communication, right, but the surprise probably in the acceptance review document, a standard thing that was out there. And maybe potential improvements in that process, you know, along the way, too.

Do you have any, well, after you heard that conversation do you have any perspectives or anything you'd like to share from your experience or staff's experience?

MR. PIOTTER: Yes. So, I think right out of the gate the staff's perspective is that the entire process itself, the bifurcated process of separating the environmental review from the safety review, it was actually a successful process. It allowed us to do some things, to be a little bit creative with some of the potential gaps that we had in the acceptance review process to find a path forward for that. And having that flexibility, I think, is an important thing to have. Now, it may be slightly different than what we're used to, right? And so I think that's an issue of, somewhat of perception and sort of point of view issues. So, I think that was really a positive thing.

I think we're a lot closer, a lot more closely aligned than one would expect out of the gate in that I think we all have the same goals with the acceptance review. I think there's, again, different interpretations. But at the end of the day -- and I want to come back to this because I think this point is very important -- that communication piece for acceptance reviews is incredibly important. And I think you mentioned it as well, that over-communication in particular. When you're dealing with a novel fuel facility, or any novel activity that we're working on, having those early and often communications and in-depth communications are absolutely crucial so that you can get past some of these perceptual differences.

COMMISSIONER WRIGHT: Sure. Great. Thank you. And part of the conversation that we had on the first panel had to do with on the back-end of the fuel cycle. Right? So, talk to me a little bit more about the timing of having that pathway on the back-end. Is an applicant going to have to know how they're going to dispose of their fuel on day one, or is this something that can be done later in the process?

MR. PIOTTER: So, as we currently operate now, it's later in the process. There's not a requirement in any of our processes for licensing and certification that requires a specific date for availability for disposal.

COMMISSIONER WRIGHT: Okay. Thank you so much. So, Chris, before the panel started, Rob said that you were the guru on some of this, and that I should let you have the questions.

MR. VAN WERT: Thanks, Rob.

COMMISSIONER WRIGHT: So, you know, HALEUs was discussed a few times in Jason and Wendy's presentation. And I'm curious if you had any insights regarding how the staff's, how they plan to handle reviews of HALEU and what makes it different or more challenging from a regulatory and technical perspective?

MR. VAN WERT: Of course. Yeah, as you heard this morning, it's HALEUs on everyone's mind, Department of Energy, us, industry, et cetera. From a reactor licensing perspective, there's not a huge challenge there because we don't have a lot of specific regulations tied to it. The only place in Part 50 where a by weight percent enrichment limit is mentioned is in 50.68, which is related to spent fuel pool criticality. That is a regulation that you can choose to follow, and it provides a lot of benefits to an applicant or to an operator. But you can also, instead, use the Part 70 requirements that are kind of associated with it. So, it's not a requirement to follow 50.68.

So, once you take that out, then you come back to what are maybe some of the technical challenges. And those mostly revolve around validation. I think you heard a lot about that this morning, so.

COMMISSIONER WRIGHT: Right. Very quickly, I've got just a few seconds left. In the discussion of generic guidance, right, you mentioned the important role of developers in demonstrating that their fuel behavior is well understood, right, and can be predicted.

MR. VAN WERT: Uh-huh.

COMMISSIONER WRIGHT: Can you elaborate on how developers are going to be able to achieve this understanding in cases where reactor designs are still, you know, preliminary?

MR. VAN WERT: Yes. Yes. And it depends to some extent I would say on what technology they've chosen to proceed with. Some technologies have quite a bit of history behind them, you know, TRISO being one of them. And with that in mind, maybe they want to extend, you know, say, a hypothetical design wants to extend the operation outside of the past history. They would be able to leverage the pervious history and then maybe do a limited set of testing to develop that database necessary for the desired operability range they have.

For a more novel approach, a new design that maybe we haven't considered in the past, before they come in for licensing, of course, they're going to be doing their own internal testing program to just identify the characteristics of the fuel which are most important to safety. And by doing that they will identify those characteristics. And that information will help them go through the process.

And I mentioned NUREG-2246, which is kind of a technology-inclusive approach. And using that, they will help identify maybe missing data areas. And then that will dictate the further testing that they will need to support their licensing efforts.

COMMISSIONER WRIGHT: Okay, thank you.

CHAIR HANSON: Thank you. Commissioner Caputo.

COMMISSIONER CAPUTO: Thank you all for being here. It's quite a big panel, but certainly we appreciate all your contributions. Mr. Van Wert, I'm going to start with you. We have one operational uranium enrichment facility here in the U.S. If that facility chose to pursue 19 percent enrichment, that would be a Cat II facility; correct? Or maybe Mr. Piotter?

MR. VAN WERT: That would be more of a Jason question.

COMMISSIONER CAPUTO: Okay, Jason.

MR. PIOTTER: Yeah. Correct.

COMMISSIONER CAPUTO: Okay. So, would that mean that would require a new application or would it be a license amendment?

MR. PIOTTER: As I understand it right now, it would be a license amendment.

COMMISSIONER CAPUTO: And how long would it take the staff to review that?

MR. PIOTTER: It depends on the quality of the application, but typically 30 to 36 months is a rough timeframe.

COMMISSIONER CAPUTO: Okay. Thank you. I'll just stay with you, Jason.

MR. PIOTTER: Sure.

COMMISSIONER CAPUTO: And perhaps Rob. So we heard from Mrs. Wheeler one of the things that she mentioned was the staff's request for supplemental information during the application acceptance review and how detailed those information requests were.

Rob, I know that this is something that we struggle with in application space in general, but between the two of you, how are you managing the request for additional information process in general in terms of making sure that questions are only asked once? In this case, I hope since they were asked in acceptance space, they're not going to be asked again now that you're into the review.

And how are you also looking to tailor the scope of those to ensure that the questions that are being posed are actually necessary to make a safety or security finding?

MR. PIOTTER: Yeah. I'll go ahead and start. So I think, you know, initially, when we're -- when we're looking at RSIs in particular, there are several layers of review that happens. You know, the staff obviously produces them, they get reviewed at the branch chief level, and depending upon the actual application that we're looking at, sometimes they go up to the Division Director level.

So there are several layers of review, multiple branch chiefs. That process, I think, helps us to sort of weed out some of those questions that may not rise to the level of RSIs. They may be too technically focused or they may be something that we need to address as an observation. So that's one way that we sort of meter out what we're doing with respect to the scope of the questions themselves.

In terms of whether or not they get into technical review space, it sort of depends on what the answer looks like and what the process that we're following is, because I think if you look at, in this case with TRISO-X, some of the acceptance review activities have actually bled over into the technical review space, just by using some of the flexibilities in the acceptance review itself.

So there will be some things I think that get addressed in technical review space that weren't covered fully in that acceptance review phase. And so that, again, was part of that flexibility that was sought to be able to accept this. And I think the one area that was brought up was digital I&C, for example, where the entire design wasn't present at the time that the application was submitted, and that we're going to be pursuing additional activities during technical review space to resolve those -- that particular issue.

With respect to RAIs, we have created a culture within DFM to be very, very sensitive to the fact that we only want to ask a question once. We don't want to miss it in the first round of RAIs and then have to ask it in the second round of RAIs. And we don't want to belabor a particular point if we don't need to. And, again, that goes to that same level of review at multiple levels within DFM, to ensure that we're not either being duplicative or asking questions that are out of scope.

COMMISSIONER CAPUTO: Okay. Thank you. Dan and Rob, I'm going to ask you a quick high-level question, given that staffing has come up. Considering the agency finished out fiscal year '22 with $92 million in carryover, clearly resources are not a constraint in hiring. Can you just briefly discuss the factors within the scope of this area, considering that there is a lot of -- a lot of work going on here, and that this work is potentially critical path for advanced reactors themselves. Can you just discuss the factors that are constraining your ability to staff here?

MR. DORMAN: Yes. I think Rob touched on the competitive nature. You know, there are 17 developers in pre-application discussion, as well as the existing fleet and a number of other entities that we're competing with for the same talent. So that's a factor. I see --

COMMISSIONER CAPUTO: Do you have enough

flexibility in our hiring practices to offer the levels of compensation that you believe you need to to compete?

MR. DORMAN: We have -- we have both resources and processes to apply to that, and I think I'll let Rob jump in on any specifics.

MR. TAYLOR: So a couple things to your question. It's a really good question, Commissioner. There are flexibilities and tools and we're executing them. So, you know, when it comes to negotiating salary, that's a huge thing with folks. We have tools that allow us to assess and adjust the salary offer that we make to individuals to be competitive. We have also adapted to enhance the ability to use full-time telework in our recruitment processes, which is very important to a lot of people that we're recruiting today. So we're adding those flexibilities to those things.

To the execution and the dollars, the understaffing that we had in fiscal year '22 did require us to prioritize work to some degree. We emphasized ongoing licensing work as our highest priority. So things like the Kairos review and the pre-application engagement where we're trying to approve topical reports and get feedback on white papers, it has caused some slips in some guidance that we had hoped to have finished. But we made the conscious decision to apply the resources elsewhere because we still felt we had the time to do the guidance where we needed to do it.

So we have had to make some decisions here and there based on staffing levels relative to it. We haven't missed any major milestones yet, but we certainly need to hire and staff to make sure we can do all the work that we do plan to have on our plate.

COMMISSIONER CAPUTO: Okay. And since you mentioned telework, we heard from two panelists earlier about the importance of having in-person meetings --

MR. TAYLOR: Agreed.

COMMISSIONER CAPUTO: -- when dealing with complicated issues. When you are utilizing this telework flexibility in hiring people, how are you balancing the need for adequate in-person time given the technical nature of this work?

MR. TAYLOR: So part of the agreement is there is an expectation to come to the office when it's presence with a purpose from the standpoint of

COMMISSIONER CAPUTO: Thank you.

MR. TAYLOR: -- engagement. Yes.

COMMISSIONER CAPUTO: Ms. Shoemaker, I have an MC&A question. So just had an announcement from BWXT that they have restarted fabrication of TRISO fuel, and we now have an application under review for TRISO-X. So I have questions about just the nature of MC&A procedures. Are the procedures that are in place for BWXT -- will they fully translate to TRISO X, or is there further MC&A work that's going to need to be done to support the licensing of that facility?

MS. SHOEMAKER: Sure. So I haven't seen the specifics of this one, but what I can speak to on MC&A is that the staff put out the guidance for Cat II facilities. So the approach for MC&A review will be to apply Part 74 requirements, depending on the attractiveness of the material at the site. And we believe that the requirements for current light water fuel technology can still apply to the advanced reactor technology types under the current regulations.

COMMISSIONER CAPUTO: Okay. But we still need to do research on MC&A in general, so I'm looking for some clarification here. Are we sort of covered in terms of fabrication facilities and our MC&A work is focused on reactors themselves and the nature of, you know, tracking the difference between fresh and irradiated as these materials circulate in a system?

MS. SHOEMAKER: So if I understand your question -- and, if not, I will take it back to the MC&A staff. I think you know our team is five folks, three that do international safeguards and two that focus specifically on the domestic safeguards application. So I'll take it back if I don't fully answer your question. But we're working -- in terms of research, we're working with DOE to leverage current research underway for advanced reactor technology types. I don't have more, you know in-depth knowledge on --

COMMISSIONER CAPUTO: Okay.

MS. SHOEMAKER: -- the BWRX application. So I'll take that one back --

COMMISSIONER CAPUTO: Okay.

MS. SHOEMAKER: -- to our staff.

COMMISSIONER CAPUTO: All right. Jason, I'll come back to you with another question, just about criticality. But, first, I'd be remiss if I didn't start this question by saying Go Badgers, seeing as how you're sporting your Hawkeyes spirit today.

(Laughter.)

COMMISSIONER CAPUTO: Just sort of slide that right in there.

MR. PIOTTER: I'm from Wisconsin.

COMMISSIONER CAPUTO: Well, what went wrong?

MR. PIOTTER: Madison didn't like me very much.

(Laughter.)

COMMISSIONER CAPUTO: Well, that's too bad. So Mr. Griffith mentioned in the previous panel that he thought there was adequate nuclear criticality data. You mentioned the need for nuclear criticality data as a foundation for licensing decisions with regard to HALEU. So do we have the right capabilities and capacity to review licensing submittals? Do we have enough of what we need in criticality space?

So when I look across all of these applications, whether it's, you know, transportation, fuel facilities, reactors, et cetera, you know, there are a lot of criticality analysis needs here. Are we going to have the data and the people that we need? Because this is one heck of a specialty.

MR. PIOTTER: It really is. And so, you know, to start with, I'm going to answer the question as, yes, we have what we need. And even our criticality reviewers for both fuel facilities and for storage and transportation echo that sentiment.

I think what we're talking about in terms of challenges really comes down to efficiency and effectiveness of reviews, not the ability to actually do the reviews themselves. So we do have an application in-house for up to 20-weight percent for TRISO-X. We have an application in-house for $UF_6$ transportation package for up to 20-weight percent enriched. So we have the capability to actually license those at the current time.

Now that focuses on, obviously, TRISO fuel in $UF_6$. Further down the road, we may need to reevaluate that to see additional information that we need. But I think Mr. Griffith pointed out quite well that if we have the opportunity to expand the database of critical experiments, we would be remiss not to do that, because what it allows us to do is it allows us to be more efficient in our reviews. It allows us to take away some of the uncertainty that we have in those reviews, and then also perhaps remove some of the margin that we have had to add to account for the fact that we don't have those critical experiments through the full range of HALEU.

COMMISSIONER CAPUTO: Okay. Great. Thank you very much.

CHAIR HANSON: Thank you. Commissioner Crowell?

COMMISSIONER CROWELL: Thank you. Thank you all for the presentation today. It is you and your staffs that are going to make this heavy, heavy lift possible, and I want to make sure you have all the resources you need. I'm not planning on asking any questions about workforce, but I did want to make a comment on it before I jump into my questions.

Picking up on Commissioner Caputo's question about telework, I think there's an implicit understanding that people on telework will be in the vicinity of headquarters or a regional office, so that they can come in as needed. And I think that's going to artificially limit our ability to recruit from a limited pool of talent out there. Do I have that correct?

MR. DORMAN: Not quite. Even before the pandemic, we have employees who have been on full-time remote work agreements from outside of any geographic area in which we have offices. So, in that sense, there are exceptions.

So as we work with NRR in their recruiting needs -- and as Rob mentioned, are looking at having location TBD in some of our postings based on the challenges we have experienced -- there is the potential that we would have experts that we would hire who are outside of the geographic area. But going to the point that Commissioner Caputo raised, management has the prerogative in all of those cases to say, "For this meeting with the licensee, we're going to get in a room and roll up our sleeves, and you're going to come to the meeting." So it doesn't preclude that.

COMMISSIONER CROWELL: And I know it comes at a bit of a burden to the employee and a cost to the agency, but I think it's worth it if they need to be here and -- to do that and have the talent. So --

MR. TAYLOR: It's part of the hiring agreement is when you put the full-time telework in place, it says that you need to be able to come to the office for routine and important meetings. So we emphasize that as we do our work.

COMMISSIONER CROWELL: Thank you. And just -- it's all within the realm of -- there is no one-size-fits-all to solve this issue.

A couple table-setting questions that I have been hoping to ask. And, Dan, I'll give these to you. You can farm them out to whomever you think appropriate. But do light water SMRs use advanced fuels as defined by NRC?

MR. DORMAN: I'm going to go to Chris and make sure that I'm right on this. But I know -- I know, for example, one of the selling points that GE has for the BWRX-300 is they are using a qualified fuel. NuScale, I think if it's not, it's well within the range, and we have already completed the review on it and approved it. So I think there's not these kind of challenges when we talk about the LWRs that are in front of us. I'm not sure where we are in the Holtec, SMRs and maybe others. Chris?

MR. VAN WERT: Yeah. So I think, in general, when you think of light water reactor SMRs, you are looking at more traditional type of materials. You know, you're looking at a zirconium-based cladding, UO-2 fuel pellets. I am aware peripherally because it's not my background, but I'm aware that there are some discussions of maybe using ATF in the future. But to the best of my knowledge, none of the applications that have come in to date have any sort of advanced -- or something close to advanced reactor fuel in a light water reactor environment.

COMMISSIONER CROWELL: So in those cases, would those light water SMRs be considered advanced reactors?

MR. VAN WERT: Do you mean if they used ATF fuel?

COMMISSIONER CROWELL: No. In the ones that --

MR. VAN WERT: Oh. No. No, that's --

MR. TAYLOR: We typically use the term advanced reactors to refer to non-light water reactor technologies. The international community uses SMRs to cover both light water and non-light water technologies. So it's a distinction only that we make. It doesn't matter. Our approach as to how we're going to do the reviews and the activities we're going to do, we're applying all the same principles and concepts, whether they are light water SMR or non-light water. It's dealing -- we'll just deal with the fuel type and what the performance standards of that fuel type need to be for that technology.

COMMISSIONER CROWELL: Okay. It's still confusing to me, and I think it's confusing to the external world, to understand the difference between traditional reactors and advanced reactors. But let's continue to work on it and get it a little bit more crisp.

That said, you teed me up nicely for my next question to you, Rob. In your presentation, you said the current regulatory framework is adequate to review and regulate the near-term use of these fuel designs, including review of the applications. If that's true, why is Part 53 necessary?

MR. TAYLOR: So it's adequate, but it doesn't fit perfectly. It's 50.46, the requirements in Part 50.52 are very prescriptive, right? And the technologies, they are designed for zirconium clad, five-weight percent fuel, and they provide very specific performance criteria for the fuel during accident conditions. Those aren't going to be applicable to non-light water reactor technology. So we'll set those aside and use the exemption process and other techniques to be able to set the performance standards for those reactors.

So one of the things you heard in the first panel is set what the PDCs -- principal design criteria -- will be for those technologies, what do they need to demonstrate early on in the review, and then you review them against those standards and the performance. You go to the data. You go to the testing to demonstrate that they can do it. So the tools work, and we're to set aside the requirements that aren't going to be necessary for those reactors and apply the right standards for safety relative to that. So that's what I mean by that.

So we'll have the infrastructure of the research, the testing, the things that we're doing, the codes, to be able to do all that work, we'll just apply a different regulatory standard based on what is really appropriate for that technology.

COMMISSIONER CROWELL: And you'll give guidance to the applicants to which regulatory pathway they are -- is most appropriate for them to pursue.

MR. TAYLOR: Well, they can choose to use any -- 50, 52, or 53 will all be voluntary. They can choose whichever pathway they want to. They will -- they may choose for business reasons one has a different benefit over another. But we can give them guidance about how to move through the process and what would need to be demonstrated. That's what we're talking about with the pre-application is, okay, tell us about your technology. One of the first things we want to do is go through what the applicability of the regulations are to your technology.

COMMISSIONER CROWELL: My understanding of Part 53, though, is that it incorporates the elements of 50 and 52 into one of the two frameworks.

MR. TAYLOR: The licensing process -- so whether you have a construction permit or not, you can do that in Part 53. Absolutely. Or whether you want to go with a combined license. You can do that in Part 53.

MR. DORMAN: But not necessarily the prescriptive requirements in Part 50.

MR. TAYLOR: Not the prescriptive requirements.

COMMISSIONER CROWELL: And I'm going down this pathway because I don't understand that well, but also because I'm worried about our workload. And if you have Part 50, if and when Part 53 gets finalized, and yet Part 50 and 52 are still open for business, I don't think that helps our effort to get things done. I think it makes it a more confusing -- like pick-your-own-adventure regulatory framework, and I don't think that helps when we don't have a lot of staff to do this stuff. So I'd -- just take that under advisement. I don't necessarily need an answer to it. But it doesn't make sense to me necessarily. You're off the hook for the moment.

Jason, I'm very interested in the back-end of the fuel cycle and what we're doing there to be prepared for the back-end on the advanced reactors. Let me say advanced fuels, use of advanced fuels in whatever kind of reactor. Do you have any plans in your shop for new regulations related to management of the back end of the fuel cycle for advanced reactors?

MR. PIOTTER: Regulations?

COMMISSIONER CROWELL: For advanced fuels. Yeah, regulations.

MR. PIOTTER: For regulations, we do not.

COMMISSIONER CROWELL: Okay. Do you think they are going to be necessary at some point? Can you envision it, depending on as you learn more about the technical aspects of the fuel and demonstration, et cetera?

MR. PIOTTER: I don't think we can rule it out, but I think the way that we're phasing our prioritization with respect to what are known technologies that are coming down the pike, such as metal, fuels, or TRISO, we're focusing on those first. And then, of course, molten salts coming on -- behind that, and we're focusing on the front-end of that.

So as we phase in these new technologies, as they become available, we'll have to look at that. I think we need to be careful of not jumping too soon, if we don't know that we're going to need back-end either transportation or storage for those particular technologies.

So it really is highly dependent on what kind of communication and demand signals that we get from industry as to what we potentially need to do. But our goal is to actively monitor whatever the situation on the ground is with respect to new technologies. And if we see something where we're going to need to make some changes, we will actively pursue that.

COMMISSIONER CROWELL: Okay. Along those lines, and this is either for you or Dr. Reed, have either of your shops reviewed the Stanford letter, the Argonne-led reports on waste from advanced reactors? And, if so, how are you incorporating it into your thinking and review and guidance? Or it just looks like a mess to me of confusion about what the back-end of the advanced fuel and advanced reactor looks like. And I'm just wondering how we're navigating those waters.

MR. PIOTTER: So I'll say that I'm familiar with the Stanford report. I haven't read it personally myself. And we're aware of it, both within DFM and NMSS, as well as NRR being aware of it. And so we'll actively take that into consideration as we're moving forward with back-end considerations.

COMMISSIONER CROWELL: Okay. Dr. Reed, anything to add?

DR. REED: No. Like Jason, I am aware of the report. We haven't had to read it yet, but we are, you know, aware of the diversity of the fuel types and the -- you know, the challenges and the considerations we need to make regarding the varied fuels and novel waste forms that have the potential to be developed.

COMMISSIONER CROWELL: Yeah. Thank you. Thank you, Mr. Chair.

CHAIR HANSON: Thank you. Chris, let me just start with you real quick. You know, I brought up in the previous panel about accelerated fuel qualifications. So I just wanted to kind of get your thoughts about kind of what are the challenges or key technical issues from NRC's perspective with the application of an accelerated fuel qualification model?

MR. VAN WERT: And I think you're going to hear kind of a little bit of the same refrain, in that validation is a key challenge. You know, if you get to a first principle modeling capability, it's great. But how do you know that that model works properly? So you need to have some sort of validation program, and I don't think anyone is saying that they won't have it. It's just what will that validation program look like. So that's going to be ongoing discussion between us and the industry.

CHAIR HANSON: Okay. Yeah. Fair enough. Thank you. I think this -- let me go to you, Jason. I was really interested in this slide about the advanced fuels roadmap --

MR. PIOTTER: Okay.

CHAIR HANSON: -- at NMSS. And I definitely appreciate your answer to Commissioner Crowell's question about whether or not we would actually need any changes to our regulations to be able to kind of deal with the materials issues around these advanced fuels. And yet we're kind of still in this situation where we have to -- and I think you've identified on this slide a number of really good issues that we have to kind of tackle, because if all of our work is kind of on the reactor side, and we haven't done some of this other work on the materials side, well, then, we may find ourselves kind of stuck.

So I -- tell me a little bit more about the roadmap. I'm really interested about what the content of that is going to be, whether it's going to include kind of resource needs and nominal schedules or milestones that are going to be identified, et cetera.

MR. PIOTTER: You described it perfectly. I mean, that's exactly -- that's exactly what it's going to have.

CHAIR HANSON: Okay.

MR. PIOTTER: You know, and part of the goal, I mean, the roadmap is really -- you know, it has been in the making for quite some time, even before I came on in my role for advanced reactors in ATF. It has really been the brainchild of staff that have come before me. What we're trying to do now is actually utilize some of our information tools that we have to be able to look at this information in aggregate and then layer it to see how we might see different effects with budgetary constraints, for example, and then where that -- where that fits with perhaps a research timeline.

And so all of this information is intended or at least envisioned to be in this roadmap that you can then manipulate and see what the effects are, whether or not you have, again, the budget for a fuel facility or multiple fuel facilities, for example, out to 2026 as one example. And so that's the goal for this is it to be all-compassing, to be a repository of all our information, of all of the different fuel types that we might see, all the different vendors that we might see, licensees that we might see coming in, for all of these activities. So, yeah, I think you framed it very, very well as far as what we intend to do with it.

CHAIR HANSON: Okay. I think that would be really helpful. Am I -- if I could provide a little impact? I mean, I think security could be added -- it could be added to the fuel cycle back-end here, particularly if we're talking about different kinds of fuel types that at least in theory, even if they're self-protecting, you could put in your hand --

MR. PIOTTER: Sure.

CHAIR HANSON: -- or in your backpack or something else, right? Maybe it's a robotic hand, I don't know. But I guess I would ask, you know, that as that roadmap gets developed, do you have a timeframe for kind of when that would be completed? I'm sure it's a -- probably an iterative process, but --

MR. PIOTTER: It is an iterative process, and some of it is dependent on what tools are available to us in terms of technology. But we've got a draft of it working right now.

CHAIR HANSON: Okay.

MR. PIOTTER: And we're working to build that up over time. We don't necessarily have a timeline, but it is a high priority within our division to get a draft of that completed and get it operational.

CHAIR HANSON: Okay. You know, it -- I'll leave it to you about when the -- when the ripeness of that draft is ready, but I think delivering that to the Commission would be helpful, and actually having a CA brief on it as well about that roadmap would be -- would be greatly appreciated on this. So thank you.

You know, it's funny, I'm at this place again where I guess, Mirabelle, I'll just go to you real briefly. You know, one of the things that -- one of the slides I think we didn't get to with Dr. Lyman at the end of the last slide was about safeguards by design. And I'm interested in that, about how those principles are going to kind of be reflected then, in design reviews, whether we're talking about design certification or whether we're actually talking about design reviews, reactor systems analyses, you know, in Part 53 or 52 or 50, or whatever. So could you talk to me a little bit about that?

MS. SHOEMAKER: So the staff agrees with the Commission about having these conversations about safeguards by design early with developers. The principles are not articulated directly in the regulations, but -- so they're not considered under the application review, which is a challenge.

And that's why, as we said earlier in our presentations, that we're looking towards utilizing those in-person meetings and having early discussions with the developer, so we can underscore the importance of safeguards by design considerations early on. It promotes the safety principles, but it also -- it actually facilitates the application of safeguards more early on. Since safeguards follows the process, the flow of material, these considerations could happen on the front end, and then it makes the application much easier on -- once the site is operational.

CHAIR HANSON: Well, I'll just put you on the spot and kind of ask you, I mean, as you noted, right, safeguard by design isn't in the regulations. Should it be? You can defer to Dan or anybody. You can -- you can phone a friend on that.

(Laughter.)

CHAIR HANSON: I'm sorry. That's what --

MS. SHOEMAKER: There are superiors who have had that conversation well before me to consider.

CHAIR HANSON: Yeah.

MS. SHOEMAKER: I mean, at this point, safeguards -- domestic safeguards follow international safeguards protocols. And our domestic safeguards are very adequate and robust, and they inform our application of --

CHAIR HANSON: Okay.

MS. SHOEMAKER: -- international safeguards in '75. So I would say right now, you know, we are prepared to be able to license and implement safeguards at -- for applications that we receive, and, you know, whatever happens down the pike, I'll be here to support it, but -- yeah.

CHAIR HANSON: For the record, I have no -- I have no problem with that answer, right, because of all of the other things that we've heard about today about how we're accounting for these issues in other places that kind of, in a sense, add up to a safeguards of security by design, almost kind of review, right, where we're -- when we're talking about MC&A and other kinds of things. So I don't want you to think that -- that I was -- it was a genuinely honest question for you on that. With that, I will just -- I think I will -- I will surrender or otherwise yield my time to Commissioner Baran.

COMMISSIONER BARAN: Well, thank you for your presentations and for your work to get NRC ready to review advanced reactor fuel applications. It has been a good discussion, so I also will try to be brief and get folks to lunch. Chris, you mentioned NRC's collaboration with the Canadian Nuclear Safety Commission to develop a joint position paper on TRISO fuel qualification. I think that kind of technical cooperation could be very valuable. Can you give us a quick update on that effort?

MR. VAN WERT: Yes. So, so far we have released two interim reports. I believe we are finishing up the third interim report right now. I know we provided a draft in the last advanced reactor stakeholders' meeting. I believe the schedule for the final report is sometime next year, so we're well on our way for that.

And, yes, it is -- I saw the hand reaching for the -- so the -- I would say that we found it to be very useful from the standpoint that we're able to leverage the experience of experts on their side of the border as well as ours. And then it also provides a benefit to the applicants who might want to license a reactor on both sides. So --

MR. TAYLOR: Yeah. So the schedule is the third interim report by the end of this month, and then trying to tie it all up by March of next year. And this is a great example where we've expanded the MOC just a little bit and invited our O&R colleagues from the U.K. to observe this activity, because there are TRISO uses envisioned in the U.K., although the form is slightly different in what they're going to do in U.K. So it's a good opportunity to continue to foster international cooperation.

COMMISSIONER BARAN: Great. Let me ask a broad question about research, and this could be Wendy or Rob or whoever makes sense. You know, there's obviously a lot of research going on outside of NRC on advanced reactor fuels. We heard a bit about that on the last panel. Does the staff see any research gaps that NRC needs to fill in the short term to be ready? Is there research we should be doing to better prepare for the applications we are expecting? And I don't know whether the shutdown of Holden has any kind of effect on that outlook. Any thoughts there? Any gaps we're seeing?

DR. REED: I can take that question. Well, as you know, the advanced reactor environment is extremely varied. You know, the different designs, the different stages of development, and so it's a very dynamic environment. So to answer your question, it is very hard to pinpoint something that, you know, is near-term. I mean, we are constantly -- because of this dynamic environment, we are constantly revising our research priorities and our research needs. You know, we are obviously looking to leverage as much information, coordination, that we can.

For example, we have utilized a lot of data from the molten-salt reactor experiments which operated in the 1960s at Oak Ridge, but we are also leveraging DOE programs on metallic fuels and TRISO fuels that are ongoing now, so that, you know, we have the best information to make good decisions regarding research priorities.

As to your question about Holden, the NRC's, you know, Research is looking for opportunities to get -- you know, other places to get irradiation data. One good example is the NEA International Framework, FIDES -- I hope I have pronounced that correctly -- the Framework for Irradiation Data, which really seeks to help that gap with fuels and materials testing data and to facilitate coordination and the utilization of international facilities throughout the world to collect experimental data.

COMMISSIONER BARAN: Okay. Great. Well, I could go on, but I'm not going to. I am just going to stop there, and we can move on with our day.

(Laughter.)

CHAIR HANSON: It's a target-rich environment. I completely agree. Well, thank you all very, very much, for a set of very engaging presentations, a lot of really good information. I think, as usual, we have -- we have touched on a lot of really important issues from staffing to data requirements to requisite analytical capabilities, international cooperation, et cetera. Thanks again to our external panel. Very much appreciate everyone's participation and engagement today. With that, we're adjourned.

(Whereupon, the above-entitled matter went off the record at 12:29 p.m.)