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TECHNICAL SESSION - W11

ACCIDENT TOLERANT FUEL READINESS

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WEDNESDAY,

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The Technical Session met via Video-Teleconference, at 1:00 p.m. EST, Joseph Donoghue, Director, Division of Safety Systems, Office of New Reactor Regulation, presiding.

PRESENT:

JOSEPH DONOGHUE, Session Chair, Director, Division of Safety Systems, Office of New Reactor Regulation, Nuclear Regulatory Commission

RICHARD AUGI, Boiling Water Reactor Fuel Product Director, Global Nuclear Fuel

SCOT GREENLEE, Senior Vice President

ANDREW GRIFFITH, Deputy Assistant Secretary, Nuclear Fuel Cycle and Supply Chain, U.S. Department of Energy, Office of Nuclear Energy

DIDIER JACQUEMAIN, Committee on the Safety of Nuclear Installations, Nuclear Energy Agency

A-G-E-N-D-A

P R O C E E D I N G S

(1:00 p.m.)

MR. DONOGHUE: Good afternoon. Welcome to the Accident Tolerant Fuel Readiness Session of the NRC's 2022 Regulatory Information Conference. My name is Joe Donoghue, and I will be facilitating this session today. We will have the pleasure of hearing from key players in the important work being done to develop accident-tolerant fuels for existing commercial reactor applications.

I'm going to ask for all the panelists to show their faces now, for a moment. I just want to introduce the panelists of today's session. They are, besides myself, Scot Greenlee, from Constellation Energy, Richard Augi, from Global Nuclear Fuel, Andrew Griffith, from the Department of Energy, and Dr. Didier Jacquemain from the Nuclear Energy Agency. Thank you to all -- thanks to all of you for being part of our panel today.

All right. Back to me. We'll have time to hear from each panelist, and then ample opportunity to include all of you in a conversation about the status of activities underway to develop and license ATF fuel designs. I encourage you to form questions during the presentations, submit them via the online chat feature. Your questions and comments will form the basis of our panel discussion in the latter half of our session. We'll answer as many questions today as time permits.

Now for my presentation on NRC's activities for licensing ATF fuel designs. Again, I'm Joe Donoghue. I'm the director of the Division of Safety Systems in the Office of Nuclear Reactor Regulation here at the NRC. Among other things, the experts in this division review the safety of fuel designs. Next slide, please.

So what is accident-tolerant fuel? I just want to take a few minutes to make sure we're all oriented on the subject of today's session. ATF concepts gained attention following the events at Fukushima Daiichi. The idea was to develop fuel design features based on new materials and configurations, to improve the ability of reactor fuel to better withstand challenges that could occur during normal operation, anticipated operational occurrences, and accidents.

As you'll hear shortly from Mr. Griffith, Congress has provided direction to DOE and the NRC regarding ATF developments. That is included in the long-term goal of reducing the cost of electricity production. Now, I just want to point out here that the NRC safety reviews do not include cost criteria when we make our determinations. Next slide, please.

The NRC's plans for activities to ensure our readiness to license ATF designs are contained in the ATF project plan. You can peruse the plan at your pleasure via the NRC's website, and we'll provide a link during our session today.

The plan was first issued in 2019, and was recently revised. In short, it explains how the NRC's focus on early interactions with stakeholders in the nuclear power industry, as well as the Department of Energy, to stay abreast of the development of technical information related to the ATF designs. It also explains activities that we are engaging in to maximize our readiness to license new designs.

Our activities span the NRC organization, to include technical and licensing experts in the Office of Nuclear Reactor Regulation, as well as the Office of Nuclear Regulatory Research, Nuclear Materials Safety and Safeguards, as well as others.

As depicted in the slide that you can

see here, we are engaging these stakeholders during the technical development stage of ATF designs, and I'll say very early in the technical development stage. This focus on those activities well in advance of licensing submittals has helped us to gain understanding, to inform our preparations for licensing, with the intent of minimizing the time and resources that will be needed to conduct the safety and licensing reviews.

This parallel processing is different than how the NRC historically considered new submittals. Communication and engagement throughout the development and submittal process is key. We cannot rely on an approach where we wait for a submittal before focusing on the technical and regulatory issues. Next slide, please.

Our accomplishments -- and I'm going to start by pointing to some earlier accomplishments in preparations for licensing ATF before 2021, where, in addition to forming our plan, some things that we completed included issuing guidance for coated cladding, in the form of the Interim Staff Guidance Document, 20-01.

We also conducted phenomena identification and ranking table exercises, and literature reviews for cladding, high-burnup, and severe accidents. We also developed the ATF website, and keep it up to date, to enhance our communication with the public and other stakeholders.

Recent accomplishments, as seen on the slide here, include issuing a paper to the Commission on our plans for rulemaking, covering increased enrichment of conventional and accident-tolerant designs. We also did a more recent revision of the ATF project plan that accounts for recent focus towards high-burnup and increased enrichment.

At the end of last year, the staff issued Research Information Letter 2021-13, which was an update of our understanding of the -- NRC staff's understanding of the information regarding fuel fragmentation, relocation and dispersal for higher burnup.

Early this year, we issued a communication to the industry in the form of a letter regarding our scheduling expectations regarding the licensing of ATF increased-enrichment and high-burnup fuels. In the course of the last year, we've held or participated in numerous workshops, other meetings, pre-submittal meetings for expected submittals, as part of that engagement with -- or early engagement with stakeholders.

Now, as far as plans for the next few years, you can expect our activities will stem from these accomplishments. Most importantly, adjustments that we may need to make to the regulatory infrastructure to maximize our readiness to license ATF for operating plants. These activities will be part of our continued interaction of focus on what is needed for licensing these new designs. Next slide please.

That's a very quick overview of the NRC's ATF readiness efforts. You can see more information at our website that's on this slide here, as I mentioned earlier. You can also contact us directly at the email address on the screen.

All right. Thanks very much for your attention. Now I'm going to introduce our next panelist, Mr. Andrew Griffith. Mr. Griffith is the Deputy Assistant Secretary for Nuclear Fuel Cycle and Supply Chain for the U.S. Department of Energy's Office of Nuclear Energy. In his role, he leads the DOE's research and development on advanced nuclear fuel cycle technologies that have the potential to improve research utilization and energy generation, reduce nuclear waste generation, and limit proliferation risk. Mr. Griffith?

MR. GRIFFITH: Thank you, Joe. And good afternoon, everyone. Or good evening and good morning for those of you in different time zones. Thank you for the introduction. I'm glad to be part of this panel. I have two slides today. One that depicts the historical origins of the accident-tolerant fuel program, and one that depicts the -- shows where we are today. Next slide, please.

All right. This first slide notes the program was established in 2012, as Joe mentioned, by Congress, soon after the accident at Fukushima. The goals that continue today are to establish fuel with enhanced accident tolerance for the existing fleet of commercial U.S. reactors in a short amount of time.

The core attributes for accident-tolerance, as noted on this slide -- developing light-water reactor fuel that can withstand extreme conditions, like those during the Fukushima -- is essential to deploying the next generation of fuel for the existing light-water reactor fleet. Next slide, please.

All right. This second slide shows that the accident-tolerant fuel rods, developed by our three U.S. fuel suppliers, have been installed in eight reactors, beginning in 2018. That's four years sooner than the goal originally set in the initial development plan.

So as this slide is up on the screen, I'm going to walk through a number of activities underway in what we're doing in support of this program. So the Department of Energy contributes to the readiness of the industry to deploy accident-tolerant fuel by providing financial assistance in a cost-sharing arrangement to the three U.S. fuel suppliers.

They are also providing unique technical support through the national laboratories. The radiation testing capability at the Idaho National Laboratory and the Oak Ridge National Laboratory provide the industry teams with a range of irradiation conditions, to provide them with the information to develop their concepts and the data to qualify their fuel for use. The Transient Reactor Test Facility, or TREAT, at the Idaho National Laboratory was restarting, in large measure, to enable the collection of transient performance data needed to qualify the accident-tolerant fuel being discussed today.

State-of-the-art post-radiation

examination capabilities and out-of-reactor testing facilities further enhance the information, the data, that the fuel suppliers need. The first test rods from U.S. commercial reactors are now being examined at the Oak Ridge National Laboratory.

We're also developing an institute instrumentation to collect performance data while under irradiation. Investments in advanced modeling and code development at the national laboratories are being used by the industry and the Nuclear Regulatory Commission to enhance the understanding of fuel performance under a wide variety of accident conditions.

The department utilizes the universities to tackle the research and development gaps that they are well-suited for. In recent years, we've established projects in silicon-carbide cladding development, critical heat flux, and modeling and code development.

We also used integrated research projects to address larger issues with multi-university teams. When several universities team up to share information on a common problem, much can be accomplished. The Department also values its international collaborations, particularly with the

Organization for Cooperation and Development, or OECD, Nuclear Energy Agency.

Early on, NEA established an expert working group on accident-tolerant fuel, which brought together fuel experts from around the world to share information. More recently, they established a Framework for Irradiation Experiments, or FIDES, to assign to the shutdown of the Halden Test Reactor in Norway. FIDES is working to ensure that the few remaining test reactors around the world remain fully utilized, meet the broad set of experimental radiation requirements in the absence of the Halden Test Reactor.

And finally, as you can see, accident-tolerant fuel program involves a wide range of program participants all working to contribute to the readiness of the industry to deploy accident-tolerant fuel, and in their future and beyond. When deployed widely, throughout the existing fleet, accident-tolerant fuel qualified to use a higher burnup, will be able to play a major role in our nation's clean energy future. Thank you for your time and attention, and I look forward to the panel discussion. Thanks.

MR. DONOGHUE: Okay, thank you, Andrew.

We're switching back to me, to introduce Mr. Richard Augi from -- there we go. Okay -- the boiling water reactor -- he's the Boiling Water Reactor Fuel Product Director for Global Nuclear Fuel.

He has over 20 years of experience in the nuclear industry in quality assurance, project management, and product management positions. For the past five years, he's been working on strategic projects within Global Nuclear Fuel, focused on growth within the business. Mr. Augi?

MR. AUGI: All right. Thank you very much, Joe, and good afternoon to everybody. Glad to be here representing the GNF ATF team, and want to thank the NRC's leadership and sponsorship for hosting the RIC. Sorry that we're not in person this year again, but looking forward to when we can be back in person and live.

So I just would like to walk through some of the highlights of our ATF program and some of the key points within each of the ATF dimensions. So next slide, please.

So ARMOR is our coating cladding technology, and we're continuing to work on alternatives that can withstand a BWR environment. As has been shared previously, last year, we got our first indication of a performance shortfall from the hot cell examination at Oak Ridge. Ultimately, it's been confirmed that the coating did not survive the BWR environment.

So since the initial hot cell findings, our cause assessment identified many possible mechanisms. However, our consensus is that both dissolution and interface oxidation are operative, and require mitigation.

So we see significant water chemistry dependency as the initial optimal microscopy from the ATF tube irradiation, and PWR conditions revealed an intact coating. So we don't see any significant radiation enhancement. We believe this is all based upon the water chemistry.

So as we continue to evaluate the ARMOR coating as being a significant product, we're working to identify a number of different coating options to mitigate both the mechanisms, and are developing testing methods to accelerate performance assessments. So we're targeting late 2023 to establish the next incarnation of ARMOR, which will be followed by LTAs and an initial reload in the latter part of the decade.

The next technology I wanted to talk

about was IronClad. So since 2018, when we first installed unfueled segments into plant Hatch, we've been carrying two variants of iron-chrome-aluminum forward, one being a low-chrome, C26M, and a high-chrome, APMT.

Originally, they both had -- they had different fabrication pathways, but as we've progressed, we've been able to come to a conclusion that the front end is really -- really the best fabrication path for both is powdered metallurgy, and that the principal difference is the chromium content.

So GE, along with our partners in Sandvik, assessed that tubing fabrication development is mature. We know how to make thin-walled iron-chrome-aluminum tubing, and we're pleased with the fine-grain structure of both alloys. As we've shared in the past, we see that tubing at half-zircaloy thickness results in fuel cost neutrality for a retrofit fuel rod.

So what does come along with that half-thickness is a bigger pellet, which will increase the heavy metal loading. And also, as we consider thin-walled tubing, it's important to keep in mind the minimum thickness for industrial application is a function of the material characteristics and the fundamentals of iron-chrome-aluminum that promote thinner cladding. So laboratory testing to date continues to confirm good performance with significant improvements in fretting resistance and creep.

One of the main things we've been focused on is alpha-prime structures, and how to maintain a low-chrome variant. So the iron-chrome-aluminum with thermally-induced alpha-prime in the lab are showing some reduction in ductility, but have been adequate for the needs of the fuel rod in the reactor.

Our recent experience with hot-cell has been focused upon ARMOR and ascertaining the cause mechanisms. But we do have irradiated iron-chrome-aluminum at hot-cells in Oak Ridge, and also INL, and within the next 12 months, we should be able to establish performance consistent with one cycle of operation. So our objective is to finalize product definition and install preproduction prototypes and lead use assemblies during this next phase.

Next is our LEU+ and high-burnup program. And really, these are -- we've tied these together, and the benefits of high-burnup motivate LEU+, and LEU+ enables higher exposure. But they are largely distinct.

For LEU+, we are mainly focused within our factory. We're proceeding down a two-step pathway for licensing, in which the criticality methods and safety criteria are approved first, and the safety analysis results are reviewed separately. So while it is a serial process, and it does take a little bit more time, it does help eliminate some of the uncertainty in the outcome.

So I'm pleased to announce that our criticality safety analyses are complete, and our integrated safety analyses are proceeding at pace to support a second submittal associated with our SNM-1097 license by the middle of this year. And we are commencing with facility modification in order to get a better handle on higher enrichment, and we are also in the process of analyzing our shipping containers and preparing a licensing amendment for that shipping container later in this year.

And also, with these increased enrichments, it does motivate us to transition to full transport glass physics to support future fuel evolution, and this propagates throughout the licensing system. As such, there are a number of regulatory reviews needed, and we have shared our forecast with staff. At this time, we remain on track for our first submittals that were made in December of 2021. So that work is progressing at a good pace now. Next slide, please.

So we are performing design studies to frame the first set of LEU+ applications. And I'll share that fuel rod internal pressure is an important aspect to manage for BWR application. So while we do not see areas of significant technical concern with increased enrichment, the precise timing of first application will depend upon funding, regulatory expedience, and the generalized challenges making significant changes in our industry.

Additionally, the screening of methods requiring further attention at high burnup is being performed using a risk-informed approach. Once those areas are identified, deterministic treatments without the use of risk are being used to develop compensatory measures for the impacted high-burnup methodologies.

And one thing to note, you know, with the increased enrichments, going to the higher enrichments, it will open up the design box for our design team, which will lead to more technological breakthroughs.

We took a similar change 25 years ago, in going from four to five percent enrichment. And as one of our chief consulting engineers, Russ Fawcett noticed, I cannot imagine a world that is limited to four percent. I expect our future selves will say the same thing about LEU+. So we see a lot of opportunity within design space that will be opened up as we expand past five percent. Next slide, please.

So once again, let me say thank you to the NRC, the DOE, and all our colleagues at the national labs, INL and Oak Ridge and Los Alamos, that have been working closely with the GNF team, as we move forward with ATF.

We're very excited about the future of accident-tolerant fuel and where it will lead. We're cultivating ARMOR as our short-term, near-term ATF concept, and IronClad as a next-generation cladding. Both of these technologies will be enhanced by the application of LEU+ and high-burnup. And we're excited to see where this takes us.

There is still a lot more work to do. And we appreciate the industry and the NRC and the DOE working with us as we go through this. So I'll turn it back to you, Joe.

MR. DONOGHUE: Thank you, Mr. Augi. I found the correct button to unmute myself, so thank you very much. I'd like to introduce Scot Greenlee, who's with Constellation. Mr. Greenlee joined Exelon, now Constellation, in 2007, as a Corporate Engineering Director, and was subsequently promoted to the position of Senior Vice President of Engineering and Technical Services in July 2013.

Before Exelon, he had numerous engineering leadership positions in three nuclear utilities, and had previously spent four years as an inspector in the NRC, including two years as a resident inspector at Beaver Valley Nuclear Station. Mr. Greenlee?

MR. GREENLEE: Right. Thank you, Joe. And welcome, everybody. I'm excited to be part of this panel. And I want to provide a little bit of background, just to get my discussion going.

You know, Andy mentioned that the accident-tolerant fuel program was established by Congress in 2012. Unfortunately, the industry really didn't wake up to the concept of accident-tolerant fuel until about the 2016 timeframe, and we discussed it a lot at the ANS Utility Working Conference.

And what we decided, or what we

discovered, was there were various benefits to accident-tolerant fuel, which I'll get into in the next slide, but when you -- in order to offset the cost increase of accident-tolerant fuel, because there is going to be a cost increase, we said, hey, NRC, we'd really like to license higher-enriched fuel, and higher burnups.

And putting those two together, along with accident-tolerant fuel, offsets the cost of the accident-tolerant fuel, and gives us, quite frankly, better performance in our cores. So that's kind of the background. Next slide, please. Next. There we go. Okay.

Why accident-tolerant fuel? And why now? Well, you know, once we woke up in 2016 to the fact that accident-tolerant fuel was going to be a real benefit -- and go to the next -- what we discovered was that we think that accident-tolerant fuel would have prevented the TMI accident. And that's just the coated clad. Now, would that have prevented Fukushima? No. But it very possibly would have prevented TMI. So thank you. Next.

And the cladding, the coated cladding, should eliminate fuel cladding defects. So when a piece of foreign material gets into our core, and it starts scratching at the fuel rod, it's not -- the coating is going to prevent any sort of cladding defect, which is also a really big deal. Okay. Next.

Okay. We have some significant obstacles at the moment to deployment of ATF. We didn't recognize these obstacles until late last year. Go to the next bullet. Joe mentioned that NRC issued a paper on fuel fragmentation release and dispersal. It is extremely conservative, and it's going to prevent us from getting the benefits from the higher-enrichment and higher-burnup.

I mean, not completely, but we're going to have to, for example, in order to meet the requirements of this new paper, we're going to have to put less fuel into our fuel rods, in order to allow the gases to expand. And so that's cutting down on the cost-benefit. So that's a problem. Next.

I don't believe you mentioned the new source term paper, but there's a reg guide which tells us how to determine the dose from an accident. And there was -- the reg guide is in draft. We're still talking about it. But it's, again, it's very, very conservative.

And what it's going to do is, it's going to increase the cost to implement ATF, because we're going to have to do something to reduce the dose to the operators. We're going to have to do something to reduce the dose that you would get to the public if you had an accident. So again, it really reduces the overall benefits for us in the industry in implementing ATF. And next.

We've already talked about this. Rich talked about the cladding issues with the BWRs. So we've got more work to do there. But in parallel, we at Exelon are still planning to move forward with higher enrichment and higher burnup in the first reload for us is going to be in the fall of 2024 at our Peach Bottom Nuclear Site. But right now, like I said, there's some obstacles there. Okay. Next.

So what is the path forward? This is just Greenlee's view of the world, but -- next. One more, please. There we go. xLPR, Extremely Low Probability of Rupture. This was a software development that was developed between NRC and EPRI.

And it's a risk-informed approach, and so what we're intending to do -- and Rich mentioned this in his discussion, and the PWRs are doing very similar work -- is we're going to go through and determine what is really the risk of a large-break

LOCA. And if that risk is so low that we shouldn't really have to -- or we shouldn't really have to assume the large-break LOCA leads to FFRD, then that's going to be a success path.

Otherwise, at the moment, I'm a little discouraged about ATF, just because of the conservatism and the things that we've just added onto the plate. And I really didn't anticipate these when we started in 2016. But I think xLPR will get us there. So anyway, that's it for me. Back to you, Joe.

MR. DONOGHUE: Okay. Thank you, Scot. Now I'm going to introduce our next and last panelist, Dr. Didier Jacquemain. He's served as the Senior Nuclear Safety Specialist at OECD Nuclear Energy Agency since January 2020.

He's a technical advisor for the Nuclear Safety Technology and Regulation Division for the working groups activities under the Committee on the Safety of Nuclear Installations, and for the joint nuclear safety research projects. Before joining NEA, he worked for 27 years at the French technical support organization IRSN, in the nuclear safety research area, and was mostly involved in research projects on fuel safety, severe accidents, and aging.

He earned a DC in physical chemistry from the Weizmann Institute of Science in 1992. Dr. Jacquemain?

DR. JACQUEMAIN: Thank you very much for the introduction. And I welcome all to this panel, and I'm very glad to be here and starting to contribute to the discussions of this panel on ATF. So the objective of my presentation is to provide an overview of the activities and perspectives at the Nuclear Energy Agency, to support advanced fuel technologies dependence.

So NEA is operating international collaborative frameworks, so we're based in 54 member countries. And consistently with the last projection of the agency, to work for accelerating the readiness of innovative designs. So with activities that we do in a synchronized way, for agencies to affect -- agencies to affect energy readiness levels and the licensing readiness levels. So next slide, please.

So under the CSNI -- so the Committee of the Safety of the Nuclear Installation -- and the Nuclear Science Committee, activities include development, the review and the assessment of technical bases to ensure that in the review analysis, command mode, offline mode, and accidental situations in reactor and interim cycle operations.

So all of these -- NEA works on development of databases. For instance, for compiling critical and subcritical benchmark experiment data and evaluations, we have the ICSBEP project. That includes data for fuel enriched above five percent, for instance. And there are also some databases for managing the effects of clad-fuel microinteractions in severe accident conditions. So these are the databases that have been developed for severe accident analysis.

So under the NEA auspices, state-of-the-art reports on ATF technology and status reports on high-burnups and high-enriched fuels were actually developed, with recommendations and needed research, including the need for safety licensing. And these were provided by international expert groups.

Also, on ATF technologies, provided news of the experience on the technology readiness level applied to these ATF technologies. And there is a status report on the -- discussing the safety implication of the use of fuel enriched above five percent. This is currently under development.

Some activities are also addressing assessment of modelling tools' applicability to criteria for nuclear fuel safety. There was a workshop on fuel modelling in support of performance and safety that took place in 2017. And a technical opinion paper on the applicability of comparing fuel safety criteria to various ATF technologies was developed in 2020.

Regarding the methods -- or the outcomes of the discussion in the seasonal Working Groups on Fuel Safety, the potential future work to gather experience and datapoints on use of risk-informed approaches. Importantly, the deterministic approaches to fuel safety analysis, including for fuel -- for innovative design.

And there is also collecting international collaborative experiments and research projects to support the ATF developments. An example of this will be given later in the presentation. So next slide, please.

So I'd like to comment a little bit on the main outcome from some of these activities. So though it had been recognized in those activities that many research projects have been conducted, they are still ongoing nationally, and at the international levels, so I think they -- I think they have information on ATF, which was recommended to further enhance the technical bases to fully categorize the properties and performance of the ATF, and later support a fuel demonstration and quantification of larger loads and risk reduction. So, for instance, a report on that risk.

So researches have been identified by type of facility, in a cross-cutting format, illustrating all the research facilities which support the advance of the ATF technologies. So regarding the validity of advanced report for this deterministic model, I consider that that skips over the evolutionary concepts, such as chromium coated cladding and doped UO2.

These are opportunities for collaborative research to advance the validation and prediction capabilities, as we said on the slide. And this research should include fuel and clad detect -- direct irrigation from lead the fuel that's on lead, irrigated in commercial reactors. Also, some facilities testing and testing in research reactors.

Commercial engines are expected to further availability of more of the revolutionary concepts, such as the silicon-carbide cladding, or other in this section, as we said in the slides.

So clearly, the designs, with limited departures from the currently licensed technologies, have logically the least impact on applicability of existing fuel design and performance data. So these are reactors to develop the licensing in certain countries. And as earlier highlighted, collaborative research to keep tabs on the internal intake database to better assess the knowledge and gains in risk reduction to support the development and licensing.

And regarding severe accident modeling, this is -- they are considered adapted for production of fuel, but high-temperature testing is needed to investigate the effect of fuel-clad material interaction for coated claddings, and more revolutionary concepts. So there is clearly a need to collect a lot of basic data. For instance, unprotected formation and the effect of fuel-clad degradation in severe accident conditions. The next slide, please.

Now we're into the existing framework for a research project to support ATF development at NEA. There is an imminent need for more full irradiation experiments, which -- that has been mentioned, 2021, in the wake of the failure of the Halden reactor. So it provides a platform for fuel, including ATFs, and material testing, using a nuclear research reactor of one of the NEA member countries, such as the BR-2 reactor in Beijing, the LVR-15 reactor in the Czech Republic, the LOCA reactor in Russia, the NSRR reactor in Japan, and the TREAT reactor in the U.S.

So in the first phase of the project, ATF testing will be conducted at LVR-15, a fortified ATF facility, and there will be a very high level of investigation planned at TREAT and at NSRR. Further testing is planned in the program well beyond 2024 with, we hope, established facilities for in-reactor concerns and accident development testing. So we guarantee, we are getting to ATF revolutionary concepts, and assembling safety issues for IFMF and IFMP, so for instance, 2020, they're here in FIA. Next slide, please.

So another example is the recently launched QUENCH-ATF project that includes three large-scale bundled tests, containing 21 fuel elements with ATF cladding material. So chromium-coated optimized ZIRLO provided by Westinghouse will be tested, and possibly a silicon carbide cladding provided by General Atomics.

These are done at the KIT QUENCH facility, and testing is designed to cover design-basis conditions and severe accident scenarios with temperatures exceeding 1,200 degrees C, and then the zircaloy chromium reactivity temperature. These were all some of the earlier -- this has managed that. So up to this point almost no international experiments were conducted to address the design-basis accident and beyond-design-basis accident scenario.

So an example is the QUENCH-19 bundled test at KIT with the FeCrAl cladding that was done in cooperation with ORNL, and showed the superiority of the ATF cladding with much less hydrogen production. That will sure shed light on some of the challenges, showing the interest of performing and doing more tests to investigate complex formulas, chemical and mechanical behavior, with conditions that are as prototypical as possible and for constant conditions up to and beyond design-basis experiment conditions.

So the data for such experiments will be used for validation of fuel performance codes, such as BISON, TRANSURANUS, and TRUST. And there's also systems simulating severe accidents that are here, like MELCOR, MAAP, ASTEC, and others. So it's officially shown the ATF cladding is a determination, one of the main characteristic metrics for ATF material, which will be evaluated from these important experiments. So next slide. The last slide.

So to conclude, in looking ahead, NEA will continue to assist its members with promoting international collaboration to support development of advanced fuel technologies with, on one side, ensuring information exchanges between the relevant international initiatives in the field, and also working and updating the research priority for enhancing the ATF technology and licensing regulations.

This will be done integrating, as far as feasible, state-of-the-art knowledge from research and development, and lead assembly testing and implementation plans in NEA member countries.

So NEA will also continue enhancing testing capabilities and developing FIDES as a framework for fuel integrity testing in key research reactors, and will couple the experimentation and advanced modeling and simulation. And another objective of NEA is also to contribute to preserving key experimental data sets to support licensing of ATFs. So thank you very much for your attention.

MR. DONOGHUE: Thank you very much, Dr.

Jacquemain, and all the panelists, for your presentations and your remarks. We're going to transition now -- and I'll just remind everyone who's in the audience to -- we have a couple of questions, but submit your questions via the online chat, and we'll start that now. I think we're all on screen. Yes, it appears that we're all on screen now, our panelists.

So now the fun part of our session begins. So the first question is really directed to the panel, but I'll try answering the easy part, and then see if the panel can help with the tougher part of the question.

The question is basically, they heard about -- the questioner's heard about FFRD. And that is Fuel Fragmentation, Relocation, and Dispersal. This was mentioned in our presentations today, and I guess, you know, in other meetings. It appears to be a concern for fuels in the reactor for a long time. And the questioner would like to know exactly what is being done to address it.

So I'll, like I said, try the easy part, what FFRD stands for. Again, Fuel Fragmentation, Relocation, and Dispersal. So the first part of it, fuel fragmentation, is the fuel pellet over the course of operation, as the fuel is burned at higher burnups, the fuel pellet itself will start to develop cracks and start to fragment.

And this has been -- this has been a phenomenon that the industry, the NRC, that we've been aware of, I'd say -- I think even before maybe 2010 or '12. It's not a new phenomenon. So staff's been aware of it. In fact, the staff has considered it for a while.

And licensing reviews, as fuels have increased in their burnup -- they're allowed more time in the core, for a fuel rod or a fuel assembly, it's measured by burnup -- and over time, the NRC's approved applications for higher and higher burnups for certain fuel designs. Now what we're addressing are even more extended, higher burnups than what's currently in operation. And it's now known that the fragmentation can become more extensive.

And then the RD part of FFRD, the relocation and dispersal, is the potential for, under accident conditions, if the cladding were to fail, then the small fragments of fuel being relocated and dispersed throughout the reactor coolant system. So that's the source of the concern, is the fuel after it fragments in an accident could be moved outside of the core. You could lose the configuration that the fuel was originally in.

So you know, I know that there's work going on to better understand this testing, and that you've heard a little bit about it today in the presentations so far. It's being done at DOE facilities and overseas in international test programs that I'll ask the panelists to be ready to talk about a little bit more here. But the work continues.

Now, the research information letter that was recently issued, that you've heard mentioned a couple of times from our panelists here, was the NRC just updating, with the available information that we have, our understanding of the technical issues related to that. Now, it's really -- it's not a regulatory guide, it's not a regulation, it's not anything like that.

It's an internal document that now we and so what -- part of the NRC is what we're going to do about it -- part of the question here. The NRC's using that information to take steps needed to start -- and I think I mentioned regulatory infrastructure, including looking at our guidance, and what additional guidance makes sense, and working with the industry to do that, to put out the appropriate guidance.

I think you'll -- and I'll stop in a minute, because you've heard Mr. Greenlee mention that there's a potential to look at the probability of different accidents, and how severe they could be to, you know, challenge fuel cladding.

So these are a number of things that I'm aware that are going on out there. I know experts here in the panel have more detail that they can share. So I'll see if any panelists are ready to supplement my answer.

MR. GRIFFITH: Yeah, I'll just reemphasize that DOE is looking to establish some experimental capabilities to better understand the phenomenon and the conditions by which that may occur. And so we still have some work to do there, but I think there's still, you know, other ways of addressing the challenge that Scot, I think, mentioned earlier.

MR. AUGI: Yeah, just from the fuel side, we are looking at it within our LEU+ and high-burnup program, and determining the impact of the research information letter and what we can do within our analysis and within our fuel rod design, if need be, to make changes.

MR. DONOGHUE: Thanks.

DR. JACQUEMAIN: Well, I think, from the NEA side, I could comment that in the Working Group on Fuel Safety, this is clearly an issue that is of interest for the fuel safety community. And this has been discussed extensively in the recent state-of-the-art report on LOCA, on one side, and area on the other side.

And as you probably already know, these are subjects that are under investigation, at least for the NEA sort of accidents. So this is some issues that I've looked at intently. And as you mentioned, the activity of -- they're getting more relevant for high-burnup and -- high-burnup fuel. So this is a -- I think it's something that is of interest, and that is going to be looked at and investigated.

MR. DONOGHUE: Thank you. All right. So I don't think any other panelists were going to add to that question -- respond to that question. So I'll move on to the second question, which is directed to the NRC, so I'll do my best to respond.

The question is, how does the NRC work with stakeholders to approach technical disagreements in the interpretation of research activities? So I think that this question is probably prompted by the research information letter that's been mentioned.

And I think Scot had mentioned in his remarks how there are stakeholders that consider it quite conservative. And you know, how do we, NRC, deal with those disagreements? So the regulatory information letter is really an internal document from the experts, the technical experts, to allow us and staff to use that information to take the appropriate regulatory steps.

Now, what we're not doing is taking that research information letter and translating it directly into a regulatory requirement or guidance, because we realize the information in there is an update, and there's other considerations besides just the -- there can be other information that can be provided by other stakeholders, that the NRC for one reason or another -- maybe it's proprietary information or -- as research is continuing to be developed, to supplement our understanding.

But also, there's other considerations. I think in Mr. Greenlee's presentation, he discussed a tool, the xLPR software, that's being explored as a means to apply a risk insight. That's one avenue, to apply risk insights to the potential for that relocation and dispersal that I mentioned.

So but just generically, the NRC takes that kind of information. We are embarking on considering what guidance -- existing guidance or possibly new guidance -- would make sense to address the technical concerns here, to make the -- to make the right framework -- to put the right framework in place to support future licensing and regulatory decisions.

So when we would do that, we're required to take steps to ensure public interactions. We would invite public comments on any regulatory, you know, draft regulatory documents. One example that you heard about today was the regulatory guide that's under development, the update to the regulatory guidance on source term that Mr. Greenlee mentioned. And we've had lots of interaction with the public on that. We can do further interaction.

And so any other guidance that we would put together, we would be taking those steps and addressing other comments, disagreements. But in the end, the NRC has to make the appropriate reasonable assurance determinations. And that's our responsibility.

All right. I'm going to go on to

Question 3. This is directed to Mr. Griffith from the Department of Energy. The question being, what performance is observed for quenching? And what kind of material characterization is carried out for ATF? I can repeat that. What performance is observed for quenching? And what kind of material characterization is carried out for ATF? That sounds quite technical.

MR. GRIFFITH: Yeah, I'm not familiar with any of the work we've done recently on quenching. But I would like the other panelists to see if they're aware. Yeah, I think particularly, that was of concern, really, for the silicon carbide technology. So I don't know if we're quite there yet.

MR. DONOGHUE: Okay. I'm not sure if any of the other panelists are able to give us insights on that. Wait a second. Okay. Thank you. Question 4 is directed to Mr. Greenlee. And I'll read it a couple times, just to make sure you hear the whole question, Scot.

The example that you cited of TMI is quite interesting, but it seems that the advances produced by ATF for the moment don't really increase the tolerance of fuel efficiently to face accidents -- or maybe effectively -- to face accidents such as

LOCAs. Indeed, as you mentioned, source term and tritium issues are not so easy to deal with. What is, in your view, the deadline to implement industrial and -- I'm guessing, on an industrial scale -- ATF in the U.S. fleet?

So I'll read it one more time. I kind of stumbled through the wording here. The example of TMI is quite interesting, but it seems that the advances produced by ATF, for the moment, don't really increase the tolerance of fuel effectively to face accidents such as LOCAs. Indeed, as you mentioned, source term and tritium issues are not so easy to deal with. So what is, in your view, the deadline to implement ATF on a large scale in the U.S. fleet?

MR. GREENLEE: Okay. Well, like I said, for Exelon -- or for Constellation -- got to get used to the new company. My apologies. They're planning to implement starting in 2024. We want to ask GE to do -- and we're also engaged with Framatome and Westinghouse and their designs. But yeah, most of a big part of our fleet are BWRs, and so we've asked GE to really hunker down and, you know, start getting full core reloads, starting in 2024.

Now, again, that's just going to be

higher-enrichment, higher-burnup at this point, until we can figure out the new coated clad. But as soon as that's available, we'll put in the new coated clad, too, because it's going to be very beneficial, and like I said, eliminates fuel defects, et cetera.

So, you know, I think by the end of the decade, I would generally like, you know, all of my BWRs to have higher-enrichment and higher burnup, and we'll see where the coating falls in. But I would really like to get that as quickly as we possibly can, too. Hopefully that answers the question. Thanks.

MR. DONOGHUE: It does, thank you. I have a question myself for the panel, including myself. So I'll answer my own question to start with, and then I'm going to ask you to weigh in. So the NRC is aware that there's -- you know, I think you've heard it in several remarks, including, most recently, this morning, the EEO's, about the challenge we have in keeping our expertise base, keeping our human capital resources, you know, the people, the experts that we need -- technical and regulatory experts here at the NRC -- to be ready to do the work we need to do.

So in the area of fuel development, I

think it surprises a lot of people that fuel technology's changed over the years. It has not been static at all, even before ATF appeared on the horizon. So there's a lot of people that have gained a lot of experience, but some of them are leaving professional life.

So I'm just -- yeah, the question that is in my mind is, you know, what are the prospects for you? How difficult has it been to get new people on your staff that you need, with that kind of expertise?

I'll just say, for the NRC, it's been a challenge. We have some really promising talent that has joined the NRC recently, so I think for the immediate future, we're in good shape. However, you know, I think that there's a lot of other -- there's other opportunities that people have besides the NRC. Maybe working for some of you. So I just want to sort of ask you, the panel, what kind of challenge do you see in that part of the business?

MR. GREENLEE: You know, Joe, I'll go first. It's interesting, as I'm thinking about your question, because, you know, my organization's very, very large, and a big -- I probably have about 177 -- 100-plus fuel engineers.

And we've been actually able to maintain the staff we need in fuels. We're having problems in other parts of my organization, but in fuels, for whatever reason, we seem to be able to attract people and keep people, because, you know, one of the things we're doing, which -- I know GE's probably not real happy with me on this one, but we're bringing our methods -- we call it vendor independent methods -- in house, so that we can do our own core designs.

And that excites the engineers. They really are excited about being able to do the core designs, as opposed to, you know, just kind of overlooking, you know, GE or Westinghouse or Framatome. So it's not been a problem.

MR. DONOGHUE: Thanks.

MR. GRIFFITH: Yeah, I'll go next. Our Nuclear Energy University Program has been an outstanding pipeline for young talent in the fuel area. And as I had mentioned, our research projects at a number of universities have been involved. That was an excellent application -- or use of both that expertise for -- from the universities. And I've seen a range of outstanding young talent across the various fuel suppliers, as well.

So I think the future's bright, but yeah, the time is right now, so that these periods of the more -- the later career folks to share their knowledge and experience with the new generations. You know, we're probably going to -- it's transitionary period that's really important, so that that experience then can be transferred.

MR. DONOGHUE: Thanks.

MR. AUGI: I think I'd echo what Andy said, as far as, you know, recruiting younger talent into the organization. You know, it is going to be that knowledge transfer from the more experienced personnel, and allowing that to transfer to the younger workforce that's coming up.

And what it's going to do and has been doing is opening up opportunities for those newer employees to step into technical leader roles or managerial roles that probably are, you know, a couple of years ahead of where they would be. So it's actually propelling them forward.

And I think that's a good thing, because it is giving them a little bit more responsibility, a little bit more learning experience, and the opportunity to really show what they can do.

So you know, it is difficult, finding those mid-level and later-level career individuals to pull into our organization. But, you know, we do continue to look out there in the industry, and, you know, hope to continue to expand, both in the midlevel and the entry-level.

MR. GRIFFITH: I'll just add that, you know, one of the challenges we're facing in the DOE programs is because of the very high degree of focus on the accident-tolerant fuel program for the same light-water reactor technology.

The more advanced fuels area has suffered, because funding has been reduced in those areas. And again, that's the kind of technology that does excite young talent. And we've lost a lot of early-career people in our advanced fuels R&D areas as a result of that reduction in funding. So I just wanted to share that part.

MR. DONOGHUE: Thanks.

MR. AUGI: Likewise, in the NRC, there's, you know, a talent pool, and they get assigned work in a number of different areas, and, you know, that competition for people's attention, some advanced reactor efforts, has become a more and more apparent all the time.

MR. DONOGHUE: All right. So thanks for going along with that surprise question. But I think it's important, you know, it's important to us at the NRC, you know, we're talking about readiness to license, and we need to have people to do it -- the right people to do it. So it's important to us. All right.

The next question I have here is directed to Mr. Augi, and Global Nuclear Fuel. When do you think the types of advanced fuels that you've discussed will be available industrially -- I guess on large scales -- for full reloads? When do you think the types of advanced fuels that you've discussed will be available for full reloads?

MR. AUGI: For full reloads, you know, when we look at the ARMOR technology, we're looking at the late 2020s. And IronClad would probably be a couple of years behind that. So you know, we would like to have ARMOR ready for a reload by 2028. And then we would love to be able to follow that up with an IronClad reload shortly thereafter.

LEU+ and high-burnup, as Scot said, we are targeting 2024 to get that out there. So, you know, we'll have that out in anticipation of the ATF concepts catching up to them.

MR. DONOGHUE: Thanks.

MR. GREENLEE: And of course, Rich is

going to try and improve that schedule on the -- yes.

MR. DONOGHUE: Okay. Yeah, and you know, I just say that -- you've been talking about the NRC's readiness. You know, coat cladding is something we -- that was one of the early areas where we engaged. There is guidance available now that was issued by the NRC. So I think, you know, the focus lately, for us, as we kind of the pivot to include higher-burnup and increased enrichment, as well.

And that's actually the focus of the next question, to you, Scot, Mr. Greenlee. You identified -- I think, you know, we discussed this a little bit, but I'll ask the question to see if you want to add to what we've discussed, Scot.

You identified the NRC's recent RIL and the draft regulatory guidance as challenges for license and ATF. They don't provide requirements -- the question is pointing out that these don't provide requirements or dictate specific approaches. So I guess, you know, there's flexibility. I'm trying to read the question quickly.

We've got this flexibility in the regulatory infrastructure to use other approaches to include other risk-informed approaches and additional information. So what are the industry's plans for providing such additional information to the NRC, so we can fully consider those approaches?

MR. GREENLEE: Well, like I mentioned, I think xLPR is the path forward. So we're actively working xLPR right now, for the PWRs, and expect to have that ready for NRC review by February of this year.

And I think GE's going to actually beat that for me. But GE has just gotten started on xLPR, so the timeframe's not clear yet. But I would expect we should be able to get something using the PWR model, you know, by late this year, maybe early next year, for the BWRs.

MR. DONOGHUE: Okay. Thank you. For those who haven't heard of xLPR -- correct me if I'm wrong, Scot -- that is a way to predict the failure of a component, of a pipe, for example. Right?

MR. GREENLEE: Yes, it is. Yeah. Correct.

MR. DONOGHUE: So it's not -- I just want to make sure people aren't mistaking that. That's the reactor coolant -- it's not the -- it's not the failure of the fuel itself that xLPR gives us. Right?

MR. GREENLEE: Correct. What xLPR does

is it predicts the likelihood of a -- and in particular, large-break and medium-break LOCAs, because we can address small-break LOCAs deterministically. But it predicts that.

Let's just say, for the sake of argument, you know, we come out with a TN-9th probability. You know, we're going to come to the NRC and say, look, this is a really, really low probability, and we'd like to not have to assume those large-break and medium-break LOCAs when it comes to FFRD, because it's the LOCA that drives the FFRD, and that's where it becomes a problem.

And that's why we're struggling a bit at the moment, because with the new RIL guidance, like I said, GE's going to, you know, reduce the fuel content in the fuel bin in order to prevent the FFRD.

MR. DONOGHUE: Okay. Thanks. I'm going to move on to the next question. This is directed to you, Dr. Jacquemain. However, I think that maybe others on the panel could address it, as well. It's very short.

What kinds of in-pile and out-of-pile testing is required for verification of ATF performance? So again, what kinds of in-pile and out-of-pile testing is required for verification of

ATF performance?

DR. JACQUEMAIN: I think that in one of the slides I had proposed -- there's a recommendation, actually, from the experience separate from the ATF, and the sort of thing that would be needed. So really, there is in-pile testing that would be needed for, as they say, the more complicated commissions. And that's what is going to be addressed, I think, in the FIDES framework.

But we use the FIDES framework, as we could see there would be, essentially, some testing on the chromium-coated cladding for the time being. And these are the first -- actually begun the work of essentially building -- establishing, actually, the testing facilities for doing some hot-cell testing and accident testing.

And while this is being -- has been established, and second phase after this, there will be some testing that's rather more on the transient and accident conditions. And I believe that is the most recommended, actually, type of testing that should be performed.

And there are some, in particular, some really -- also, things that, when the QUENCH-ATF projects, they are complete, some testing that will be performed to investigate what is going to go forward for not only the design-basis accident conditions, but also the beyond-design-basis accident conditions, because their mesh is very indicative. And so there's a need identified to perform that sort of testing. So I don't know if that answered -- if it answered your question, but --

MR. DONOGHUE: I think it's very detailed. Any other insights from DOE or industry representatives?

MR. GREENLEE: Nothing really to add. Thanks.

MR. DONOGHUE: Okay.

MR. AUGI: The only thing I would add is, you know, fission gas measurements are going to be important, especially for the high-burnup activities. So that is one thing that does need to be considered and accomplished, in order to reach some of our goals.

MR. DONOGHUE: Thank you. The next question is for the NRC. Could the NRC's Be RiskSMART program be used to identify and create licensing efficiencies for ATF, increased enrichment, and higher burnup?

I'm going to say yes. And it has been.

Again, first of all, I'll say that the NRC, for a long time, has applied risk insight to its designs involving different fuel designs. In fact, over the course of, I'll say, a generation or so, there are programs in place where there are, I think, relatively minor changes made to fuel designs that don't even require a licensing review.

For a higher burnup, which we are involved in now, you know, and higher enrichment, you know, I wouldn't put those in the category of minor. Those are important. But you know, applying the RiskSMART program includes, you know, looking at what could go right, what could go wrong. So just looking at how the NRC put together its ATF project plan, we asked ourselves those questions.

You know, just trying to -- as I mentioned in one of my slides, having this early interaction as the technologies are developed, there's actually a balance that is struck between the resources that are applied to look at information and pre-submittal environment, but very early, before submittal is even necessarily contemplated by a particular vendor, where we, the NRC, want to understand the particulars. And that, it's an efficiency, from a resource standpoint.

So but that is outweighed, we think and that's why we're taking this approach and this new paradigm in the plan. So we ask ourselves those questions. What are the ups and downsides of taking an approach like that?

I'll go further and say, you know, we've asked ourselves questions, and we're doing it right now, taking that regulatory information letter -- and there are -- you know, I'll agree with Scot to this extent. Yeah, there are points being made in there that appear to be conservative, but there's other aspects that are raised in the RIL that we think are potentially ways that could mitigate the effects or -- the effects that are seen in this new information.

So the NRC, you know, is applying RiskSMART when we're looking at the path that Mr. Greenlee's mentioned, and I think there's other paths available that could, from an analysis point of view, be applied to -- apply risk insights and risk-inform our reviews. And we're asking ourselves those questions in a RiskSMART framework.

The next question is for Department Energy, Mr. Griffith. What are the promising ATF candidates for deployment in the near future?

MR. GRIFFITH: Yeah, the

near future really is the high-burnup, higher-enriched, coated cladding fuels. And those are the -- that's the technology that is nearest the market, most mature, likely to be deployed in the 2020s. However, we are looking at the silicon carbide, to the extent funding permits, as well as the FeCrAl technology, which is -- or does require some additional work.

MR. DONOGHUE: So that's long --

MR. GRIFFITH: Yeah, those are the longer-term technologies.

MR. DONOGHUE: Thanks. The next question is for Dr. Jacquemain. Do you know approximately when the 2022 NEA technical report you mentioned will be issued? You mentioned a report under development.

DR. JACQUEMAIN: So which report are you referring to? Because --

MR. DONOGHUE: Well, I'm not sure which report the questioner's addressing, but I think you mentioned one in your remarks that's under development.

DR. JACQUEMAIN: Yeah, one report is dealing with the safety implication for high-enrichment UO2. And this will be produced at the end of this year, so it's expected to be released next year. And regarding -- you may be aware of, so referred to, the ATF report. That's a report that is providing some recollection on the applicability of safety criteria to various ATF designs. And this is a -- this is under publication, and it's supposed to be released this year.

So maybe, aside from this one, it's actually focusing on the five different sorts of ATF. So this type of ATF were considered either the most developed, or the most valuable, so they do a part on the carbon-coated ATF, the carbon to coat. There is then a part on silicon carbides, a part on doped UO2, too, and a part on uranium silicide. Of course, uranium silicide and silicon carbide are considered longer-term ATF than the other concepts.

MR. DONOGHUE: Okay. Thank you. This question is directed to the NRC, but after reading it, I'm going to ask the panelists to weigh in, as well. The question is, are the high-burnup, high-enrichment economic considerations outweighing the safety enhancements of ATF?

I'll just say that, in my remarks, I think I said one of the goals for ATF that's set by Congress, when it directed the DOE and NRC to engage in these activities -- one of the goals was to reduce the costs of electricity. So that leads into trying to address the cost of the fuel.

The NRC's solely focused on the safety of these new fuel designs. And I'll just add, we're not focused on increasing safety. You know, that's a goal, but for us, it's -- whatever the design submitted to us for licensing is, that we make sure that's going to maintain safety under the current regulations and guidance.

Now, the NRC does not include cost criteria in our reviews. So I think that the question about the, you know -- are the economic considerations outweighing safety enhancements of ATF? That might be better addressed by others on the panel.

MR. GREENLEE: I'm just going to -- I'm just going to say that from my utility perspective, you know, we're a business. You know, we have to justify our costs to our shareholders, et cetera. So we are a business, and so cost is important in our business.

We're not a -- Constellation, at least, is not a regulated utility. We get some support from two of our states. So, you know, with some regulated piece in there. But, you know, the bottom line is, we owe it to our shareholders to, you know, get our costs where they're supposed to be, and maintain safety at the same time.

And right now, my deal is, our nuclear plants are some of the safest, you know, facilities in the world. I mean, we've evolved a lot since TMI. And so they're already extremely safe. And now we're going to make them safer by adding ATF, but in order to add the ATF, we really need the higher enrichment and higher burnup to offset the costs of the coated cladding.

MR. GRIFFITH: I'll just add that the coated cladding concept does -- helps provide potential depth, and clearly no one's interested in compromising safety.

MR. DONOGHUE: Thanks.

MR. AUGI: I would just --

MR. DONOGHUE: Mr. Augi?

MR. AUGI: I was going to say, just to add to that, we are -- you know, one of the things that we have to keep in mind as we go through fuel designs and new products is the economic viability. We cannot put something out to market that the market's not going to support. So that is one of our goals, as we go through, is to make sure that whatever product we're developing is going to have a market, that it is economically viable.

You know, and enhance, as we look at -- you know, IronClad, the FeCrAl alloy, is a longer-term solution. But one of the things we're focusing on is, how do we make it cost-neutral or even better, to make sure that there is an incentive for utilities to want to go to accident-tolerant fuel?

MR. DONOGHUE: Okay. Thanks. All right. We're getting down to a few minutes. I think we have time for a couple more questions. Apparently, we have participants that are very interested in hearing from us. So that's great.

Richard, since you're still on, this one is directed to you. But I think we can also expand it to the rest of the panel. Is it worth -- it's kind of along the same lines of the previous -- is it really worth continuing development of coated ATF concepts?

MR. AUGI: You know, I think it is. And part of the reasoning behind that is, not every reactor site is going to adopt LEU+ and high-burnup. And not ever reactor site is going to be able to go to IronClad. There are technical considerations that are going to have to be addressed, whereas coated cladding is -- I don't want to say easier, but it has a clearer path to being implemented at almost any site.

So, you know, there are limitations, I guess I would say, on -- you can't say every site is going to be able to go to LEU+ and high-burnup, and eventually to, like, the IronClad cladding. So you really need that coated cladding to get the other sites to, you know -- the accident-tolerant benefit, the defense-in-depth benefit, for debris failures.

So I think there definitely is room for coated cladding, you know, as a short-term bridge, and then potentially for longer-term for the sites where it just does not make sense to go to the other technologies.

MR. DONOGHUE: Thank you.

MR. GREENLEE: I'm just going to say, I'm fully bought-in on coated clad. I think there's good benefits there. The accident tolerance, the debris shredding, you know, not having those cladding defects. So I'm still fully bought-in to coated clad.

MR. DONOGHUE: I think we have time for, really, one more question. And I'll warn you, Mr.

Griffith, it's directed to you. But I'll weigh in from the NRC's perspective, as well, as much as I can.

How does ATF fuel R&D efforts integrate and overlap with other DOE fuel R&D programs? How does the DOE show that fuel R&D efforts are not duplicative across fuel types, specifically for long-term ATF and advanced reactor fuel concepts?

MR. GRIFFITH: Yeah, I think the light-water reactor application is -- you know, squarely keeps this approach or this technology separate from that fuel that's being developed for, say, sodium fast reactors, or high-temperature gas or salt reactors. However, I will say that there are some material -- there's some cost-cutting material development opportunities, I would say, for coordinating with the other fuel types.

But I should back up and start by saying, you know, if it wasn't for the advanced fuel R&D work that has been done over the past several decades, we would not have these types of concepts under development for application today.

And that's why, you know, going back to a point I made earlier about the reduction in funding for our advanced fuels R&D program, the things that were going to be static in our implementation of fuel technologies is -- we're just fooling ourselves. Clearly, the existing generation of light-water reactor fuel has improved significantly through evolutionary improvements over the decades, to where the failure rate is just so low.

You know, credit going to the fuel vendors and the work that they do. EPRI and Exelon. But these concepts, including the FeCrAl and silicon carbide, the more advanced concepts being considered for light-water reactor fuel applications, they didn't come out of nowhere. They came out of work that had been done in the broader advanced fuels R&D area.

MR. DONOGHUE: Thank you. I would just say --

MR. GRIFFITH: I welcome any additions you have, for sure.

MR. DONOGHUE: Okay. Yeah, I'm just going to add that, you know, from the NRC perspective, there's a lot of activity in advanced reactor fuel preparations, along with ATF. And those people in the NRC communicate with each other.

And specific to some questions that have come up here, you know, we're going to be open to any views that might be applicable to operating reactor fuel. For example, to help risk-inform our approaches. So we don't do those -- those efforts are not being conducted in isolation. All right. So we're down to -- go ahead. We're almost done, though.

MR. GRIFFITH: Yeah, let me just add another small plug. I know we're short on time. The experimental capabilities today are just really phenomenal. The lower-length scale type of close-radiation examination capabilities, coupled with the high-performance computing, as I said earlier, and also with the in situ instrumentation, where we can see, real-time, the material performance under irradiation.

These are all things that are going to make the fuel programs more predictive, and then shorter to market, if you will, from initial concepts. You know, it's just really important to maintain the momentum in those areas. Thanks.

MR. DONOGHUE: All right. At this point, I want to thank all of you, all the panelists, especially Dr. Jacquemain, who's working overtime, to the participants today -- tonight, for him. And thanks to all the audience for your questions. I wish we could do this in person. Looking forward to next year where we can do that.

And I'll ask that the final slide be -- there it is -- final slide to be put up. Again, you can contact the NRC at that email address. You can also read more about ATF, the NRC's activities on ATF, high-burnup and increased-enrichment fuel there on our website. Again, thank you all, and have a great day. Enjoy the rest of the RIC.

(Whereupon, the above-entitled matter went off the record at 2:29 p.m.)