UNITED STATES

NUCLEAR REGULATORY COMMISSION

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BRIEFING ON REGULATORY APPROACHES FOR FUSION ENERGY DEVICES (PUBLIC MEETING)

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TUESDAY,

NOVEMBER 8, 2022

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The Commission met in the Commissioners' Hearing Room, First Floor, 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

MARIAN ZOBLER, General Counsel

PANELISTS:

SACHIN DESAI, General Counsel, Helion Energy

DR. RICHARD HAWRYLUK, Senior Technical Advisor, Office of Science, U.S. Department of Energy (DOE)

DR. SETH HOEDL, President, Post Road Foundation

EDWARD LEWIS-SMITH, Head of Domestic Fusion Policy and Programmes UK Government Department of Business, Energy and Industrial Strategy

DR. KATHRYN McCARTHY, Associate Laboratory Director for Fusion and Fission Energy and Science, Oak Ridge National Laboratory (ORNL)

DR. BOB MUMGAARD, Chief Executive Officer, Commonwealth Fusion Systems (CFS)

MEGAN SHOBER, Nuclear Safety Specialist, Wisconsin Division of Public Health

NRC STAFF:

CATHERINE HANEY, Deputy Executive Director for Materials, Waste, Research, State, Tribal, Compliance, Administration, and Human Capital Programs

ANDREW PROFFITT, Project Manager, Division of Advanced Reactors and Non-Power Production and Utilization Facilities, Office of Nuclear Reactor Regulation

DR. JOSEPH STAUDENMEIER, Senior Reactor Systems Engineer, Division of Systems Analysis, Office of Nuclear Regulatory Research

ANDREA VEIL, Director, Office of Nuclear Reactor Regulation

DUNCAN WHITE, Senior Health Physicist, Division of Materials Safety, Security, State, and Tribal Programs; Office of Nuclear Material Safety and Safeguards

P R O C E E D I N G S

(9:00 a.m.)

CHAIR HANSON: Good morning, everyone. I convene this public meeting on the regulatory approaches for fusion energy devices. I think it's important to keep the public informed of the Agency's development in this area of very high interest.

So, I thank you all for supporting this meeting today and I'm looking forward to a great conversation. We'll hear from two panels this morning and then we'll take a short break in between. With each panel we'll hold questions until the end and then we'll hear from Commissioners, where we'll hear from Commissioners and their questions for the panelists. Before we start, I'll ask my fellow Commissioners if they've got any remarks they'd like to make?

Okay, we will begin with the first panel, we're going to dive right in with Dr. Kathy McCarthy, who Is Associate Lab Director for Fusion and Fission Energy and Science at Oak Ridge National Lab. Dr. McCarthy?

DR. McCARTHY: Thank you very much. Now that I have the button figured out, I think I can start. Thank you to the Commissioners to the opportunity to speak with you today. My name is Kathy McCarthy, I am currently the Director of the U.S. ITER project. I was the Associate Laboratory Director up until couple of months ago so I've done both roles, at the same time at one point, and I'm based at Oak Ridge National Laboratory. I'm a member of the National Academy of Engineering and a nuclear engineer by training.

I'm here today to describe the value of National Laboratory's support in the development of commercial fusion, and I'm going to use the capabilities at Oak Ridge National Laboratory as a specific example. But capabilities exist in multiple of our Department of Energy national laboratories, so think of these as representative, not the only ones.

Oak Ridge National Laboratory has over 60 years of fusion experience and contributes to diverse fusion efforts around the world, including the international ITER project, which I lead the U.S. portion, to demonstrate a self-heated plasma of 500 megawatts.

As an expert who has worked extensively in the fields of both fusion and fission at multiple national laboratories, three, I think it's useful to note how fusion differs from fission. Fusion would produce limited long-lived waste compared with fission reactors and that waste is primarily by activation of structural materials. And we do have the opportunity to develop what we call low-activation structural materials, thereby tailoring that waste to some extent. Fusion fuels are broadly available and could promote global energy equity. There is no risk of runaway reactions with fusion and the proliferation risks are considered lower than for fission.

When we compare the current fusion systems to advanced reactor fission systems, we also see substantial differences in their respective stages of development. The technology for most advanced fission reactors has been demonstrated at some scale, typically, often at commercial scale in some form. Multiple qualified or tested fuels exist and some advanced reactors have already been demonstrated commercially.

As a result, there is some range of operating experience with advanced fission reactor technology. In contrast, fusion is not yet at the demonstration stage. While at power-plant scale, even ITER is an experiment, designed to be a science experiment with a strong focus on the plasma physics related to a self-heated plasma. This is essential understanding for practical fusion energy. Fusion fuels may be deuterium and tritium, as in ITER, and as demonstrated in the Tokamak fusion test reactor and the joint European Taurus, or it could be other fuels, such as Deuterium Helium-3 or proton Boron-11.

There are pros and cons with each of these fuel cycles and a complete fuel cycle is not yet developed. A wide variety of fusion reactor designs is under discussion. Different configurations will have different implications for the associated fuel cycle and the operating demands.

The 2021 National Academy's report on bringing fusion to the U.S. grid outlines essential fusion technology performance needs for a pilot plant, from demonstration of safety and economic viability to reliability and availability. And of course, those things are all connected.

As a national laboratory, we contribute sustained R&D to resolve technical challenges and advance technical readiness of diverse fusion systems. We're working on the three major challenges facing practical fusion energy. We're preparing to produce and operate a self-heated plasma with ITER. As a highly diagnosed science experiment, ITER will deliver key data and experience in this area to bring us to commercial fusion.

Second, we're developing materials that can perform in extreme fusion environments. At Oak Ridge National Laboratory, we're building the materials plasma exposure experiment, or MPEX, to provide a platform to test fusion materials relevant for a fusion pilot plant. MPEX represents a shift from the historical direction of the plasma material interaction field, which for many years focused on the effect that materials had on the plasma, but not on the effect that plasma had on the materials. And that's very important.

Third, as home of DOE's national fusion and blanket fuel cycle program, we're preparing the development of technologies that will close the fusion fuel cycle efficiently and safely. We're also involved with long-range planning for efficient, safe, and reliable delivery of fusion energy from source to consumer. And because we have the resources of a multi-purpose, multi-user facility national laboratory, we're integrating advanced manufacturing, artificial intelligence, and modeling simulation for fusion technologies and systems. We know that integration across technologies is critical for fusion systems to be successful.

National laboratories also provide important input for regulatory decisions, as evidenced by fission. Examples include R&D and technology development in the DOE light-water reactor sustainability program, materials in fuel development qualification supported by DOE and/or private industry, and expert input for licensing support. National laboratories work closely with private industry in many areas, making unique expertise and facilities available to solve the challenging problems that private industry faces.

From my perspective in the ITER project, I know that know-how and R&D from ITER is already benefitting the U.S. fusion program and will continue to provide access to essential knowledge and expertise in multiple areas. These are areas such as tools for plasma control and performance, high-power plasma heating, deuterium fuel cycle technologies, superconducting magnets, fusion power handling and plasma diagnostics.

DOE is in the process of establishing a process to facilitate industry access to ITER information of interest, including lessons learned from designing, fabricating, and assembling fusion components. And you can't underestimate the value of that actual construction and assembly, and the lessons learned from that.

Industry participation in DOE programs like Infuse, the innovation network for fusion energy, shows us that private fusion values national laboratories' support for enabling fusion technologies. So far, 65 projects from 19 private companies have been supported by Infuse. Oak Ridge National Laboratory is contributing to 22 of those projects for the following companies: Commonwealth Fusion Systems, Energy-driven Technologies, General Fusion, Princeton Fusion Systems, TAE, Tokamak Energy, and Type 1 Energy.

In summary, Oak Ridge National Laboratory together with the national laboratory system, brings decades of expertise in fusion science and technology, including a variety of confinement approaches and offers important resources for fusion industry and NRC needs. We're working effectively with fusion industry to support enabling technologies and advance the technical readiness of fusion systems. Thank you for your time and I welcome questions that I know will come later in further discussion.

CHAIR HANSON: Thank you, Dr. McCarthy. Next we'll hear from Dr. Richard Hawryluk, who is a Senior Technical Advisor in the Office of Science of the Department of Energy. Dr. Hawryluk?

DR. HAWRYLUK: Thank you for this opportunity to talk with you today. Just a little bit of my background, I've worked in fusion for a long time at the Princeton Plasma Physics Laboratory in various senior roles, including, as is of relevance today, as head of Tokamak fusion test reactor in the 1990s when we did the deuterium and tritium experiments. And I was also on the ITER project as Deputy Director General for Administration. So, it's really my pleasure today to talk to you about the prospects for commercialization of fusion energy. Next slide, please.

Let me talk about some of the recent developments in fusion. Fusion is potentially a global, scalable, firm, carbon-free energy source that can help the United States and the world reach sustainable net zero. Recently, the United States has been forging and changing the fusion landscape and the changes have been substantial and significant. This has been enabled by decades of public investment, which has set the foundations for the science technology but a lot of innovations are taking place currently.

There have been major scientific and technological advances, which I'm going to describe, and there's been a dramatic growth of private investments. You'll hear about that from the other panelists. There's been demand for accelerated strategy for fusion research development deployment, both to maintain U.S. leadership and to contribute to net zero goals.

In March of this year, the White House had a fusion summit which signaled the ambition to realize a fusion pilot plant on a decadal timescale by partnering with the private sector. This was informed by National Academy's report, Bringing Fusion to the U.S. Grid, which I had the privilege of chairing and actually, Kathy was on that panel with me, which was great, and the FESAC long-range plan, which came out around the same time. Both of these documents recognize the importance of public-private partnerships as a key opportunity to accelerate fusion. The Secretary of Energy at that meeting announced the new DOE fusion cost-cutting initiative to develop all of DOE fusion energy strategy. We are now moving ahead aggressively on that. There has been a funding opportunities announcement released to start the milestone-based fusion development public-private partnership program. Next slide, please.

The United States is forging a changing fusion landscape and you can see this in some of the technical achievements shown in this craft. The National Ignition Facility at Livermore achieved 1.3 megajoules, which is a major achievement in the IFE area, and also started a study of burning plasmas in that configuration. Our colleague at the panel here, at Commonwealth Fusion, achieved a 20 tesla HTS magnet demonstration coil, which opens a new pathway to magnetic fusion. Kathy and her team working with General Atomics delivered a central solenoid module to ITER, which is a huge magnet of central importance to the project.

On the right side of this graph you'll see the increase in funding, increasing funding on the public side by a very dramatic increase in funding on the private side, showing the interest in the private sector. Next slide, please.

Fusion companies have raised greater than $5 billion of private capital. Fusion industry associates have formed in 2018, 29 member companies and they span a wide range of different configurations and different fuel cycles. This is very important because this has regulatory issues related to how flexible the framework should be to address the breadth of the community, which is a lot of smarter than it used to be in the past. And these private companies are now building some of the largest fusion experiments in the United States. Next slide.

I'm going to just mention some of the key recommendations from the National Academy report, Bringing Fusion to the U.S. Grid. To ensure the United States leadership and to impact the transition to net zero by 2050, DOE and the private sector should demonstrate net electricity in the fusion pilot plant in the 2035 to 2040 timeframe. At the White House Summit, they declared ambition to even further accelerate this to the early 2030s. DOE should move forward now via public-private partnerships to develop and bring fusion to commercial viability.

As a first step in that pathway, we've announced that a funding opportunity for milestone-based fusion development program. There is obviously a need for urgent investment by DOE in the private sector to resolve the many important scientific and technical issues to realize a fusion pilot plant. And we're working to make that happen.

Let me go to the last slide, which is perhaps the most important for this meeting, how important it is to demonstrate safe operation of fusion pilot plant, which has to be one of its most important goals. For someone who manages a Tokamak fusion test reactor during the deuterium tritium experiments, this was always of paramount importance to me personally.

DOE will support the NRC in developing a risk-appropriate fusion regulatory framework that provides regulatory certainty, ensures public safety, and enables investor and developer confidence by minimizing unnecessary regulatory burden. In this way, it will address equity, energy justice, and environmental concerns. This is extraordinarily important. Fusion is fundamentally different from fission. Kathy discussed that in her previous comments, no special nuclear materials and no concerns about criticality. Therefore, in the Academy report we discussed how 10 CFR Part 50, which is tailored to fission power reactors, is not well suited to fusion technology.

Tritium dominates the source term and mitigation of tritium is key. My experience from TFTR, JET, the National Ignition Facility, and the design of ITER can be leveraged. We've learned a great deal about how to handle tritium, how to handle it safely. I just want to re-emphasize at the end of my presentation here, that the DOE wants to work closely with the NRC and offer technical advice and experience to bring fusion to commercial reality and to make sure we address all the safety and regulatory issues. Thank you very much for your time.

CHAIR HANSON: Thank you, I really appreciate that. Next we'll hear from Mr. Edward Lewis-Smith, he's the Head of Domestic Fusion Policy and Programs with the United Kingdom Government, Department of Business, Energy, and Industrial Strategy. Often we'll have remote participants but this may be the remotest yet. Mr. Lewis-Smith, welcome to the proceedings today and we look forward to your remarks.

MR. LEWIS-SMITH: Thank you very much for inviting me to join you, I hope you can hear me and that there isn't too much of an echo. I've got a few slides but I'll go through them quite quickly to provide an update from the U.K. on what the U.K. Government is doing in fusion regulation. Next slide, please.

So this just gives you a quick outline of the U.K. Government's fusion strategy, which is important context for our work on regulation. And you can all read that, I'll quickly go onto the next one and talk about regulation on the next slide, please.

What we've been doing in the U.K. is publishing a consultation last year which proposed a series of proposals on fusion regulation in the U.K. We've got 58 responses from around the world on this and we published our response to those responses in June. What I will do now is very briefly talk you through those bits of work to hopefully give the Commission a sense of the big themes that we considered in the U.K. Next slide, please.

The aims of that consultation, which are really important, are to look at where the existing regulatory framework would be appropriate and fit for purpose for fusion energy facilities. It's not about developing a new framework but whether the existing one works and what changes may need to be made as the technology matures. Next slide, please.

The objective of that exercise, safety is paramount but of course, proportionality is really important and I will explain how we appraise that proportionality question in our work. Transparency and innovation are also really important for the U.K. Government on this, recognizing that the sector is increasingly diverse so innovation is going to be really important for the commercialization of fusion. Next slide, please.

Very briefly, the way it currently works in the U.K. is that, broadly similar to the NRC byproduct materials approach, simplistically speaking perhaps, in the U.K., rather than the Office for Nuclear Regulation regulating fusion, R&D, it is regulated instead by the Health and Safety Executive and the Environment Agency in England. There are different regulators around the whole of the U.K. A really important thing to note is that the goal-setting approach, the way it works in the U.K., we think that works well for diverse sector, employing lots of different technologies, and those technologies maturing as they are at increasing pace, that goal-setting approach is really helpful for that. Next slide, please.

When appraising proportionality we looked at the hazards, very similar to the work that you're currently doing. Obviously, the safety assessments that are out there are increasingly outdated, but they nonetheless remain really helpful in determining bounding scenarios.

The uncertainties around inventories and things like that mean that we have to take very conservative assumptions but nonetheless we think that there is enough evidence and enough analysis out there to arrive at meaningful conclusions.

The other thing I should note, as referred to on this slide, is that the radiological hazards are really important but they're not the only ones to take into account and we're confident that certainly, in the current framework and with the current activity in the sector, that works well. Next slide, please.

The accident scenarios that I referred to there, a lot of this is detailed online in the U.K.'s public energy authority's technology report. This is in fact referred to in some of the NRC materials, which is really good. I'm not going to go into any of this detail online because we don't have time. If anyone, I should add, from the Commission or anyone else wants to pick up some of the detail, we're very happy to do that. Next slide, please.

The conclusion of that is that our work was quite clear that we should maintain the existing regulatory approach and perhaps learning a little bit from the way that fission is regulated through things like design-stage engagement, perhaps introduce those to that framework. But broadly, the changes we would need to make are about building regulator capability and ensuring clarity in the regulations, rather than fundamental change. Next slide, please.

The majority of respondents agreed broadly with that. Next slide, please. Some important points raised about the need to perhaps be even more conservative around our conclusions given the uncertainties associated with the technologies and the increase in hazard. We're confident that actually, hazard is going to increase but is not going to fundamentally change, as we've heard elsewhere and that, therefore, is not warranted to change in regulator. The increasing capability and capacity is really important but we're confident that the regulators can do that. Next slide, please.

So, that led to the decision, as published in June, that we will indeed be regulating fusion energy facilities in the U.K. under the existing legal framework. There's plenty of commentary on all of the thinking behind this in the publication document in June. And the introduction of new provisions to enable that to happen is already underway. Next slide, please.

This just confirms this approach will apply to all currently planned fusion facilities in the U.K. But as that bottom bullet point shows the Government is, of course, prepared revisit its decision, if compelling evidence is presented to show that the hazard as currently projected would be far beyond that, as we have already assessed. Important to note. Next slide, please.

We are already preparing to put those findings into law to clarify the existing nuclear regulations, which although currently, again, do not apply to fusion, the wording is such that we think some amendments will help really reinforce that to clarify. Next slide, please.

I'm not going to go through all of these things but I think it's important for the Commission to note that in the U.K. we're also looking at many of the other secondary issues such as planning, liabilities, export controls that fusion developers will need to get assurance of as they progress their technologies. Next slide, please.

There are even more of those issues to work through. Next slide, please.

The final point is that the U.K. is working with agencies such as the IAEA and through networks such as Agile Nations to share best practice, our findings, look at the important principles that we think others should look at when considering this topic. Next slide, please, I think it's the final one.

Excellent, those are my links, they're all in the slides already shared, please do check those out. I hope that's been a helpful overview of what we're doing in the U.K. Thanks again for inviting me.

CHAIR HANSON: Thank you very much, Mr. Edward-Smith, that was very helpful. Next we'll learn from Megan Shober, she's a Nuclear Safety Specialist with the Wisconsin Department of Health.

MS. SHOBER: Thank you. Good morning, my name is Megan Shober and I'm here representing the Wisconsin Agreement State Program. Next slide.

This graphic illustrates how radiation sources are currently regulated. In the green box, states have authority over electronic sources of radiation including accelerators, and in orange, the NRC regulates special nuclear material via 10 CFR Part 50. Radioactive material in blue is regulated by agreement states under a 10 CFR Part 30 framework. And in NRC space, that Part 30 authority is limited to byproduct material.

Fusion systems are built on an accelerator and involve radioactive material as targets or activation products. Agreement states already have the statutory authority to regulate both the accelerator and any radioactive material that's contained in a fusion system. Our definition of radioactive material, which is broader and much simpler than NRC's definition of byproduct material, comes from the Conference of Radiation Control Program Director's suggested state regulations. Many states use versions of this definition and similar to Wisconsin, already have a framework to license fusion systems, without the limitations with NRC faces with respect to its definition of byproduct material. Next slide.

States have been regulating electronic sources of radiation for decades and in Wisconsin, our authority dates to 1972. In Wisconsin, all accelerators require radiation machine permits and accelerators that use or produce tritium or neutrons require a radioactive materials license. My program has issued radioactive materials licenses for both deuterium-deuterium and deuterium-tritium fusion systems for both research and commercial uses. These licenses include a full-scope radiation safety program, effluent monitoring, financial assurance, and consideration for emergency planning.

In 2009, we issued an R&D license for a small fusion device. In the mid-2010s, our licensee diversified the applications of their technology. In 2018, we licensed a fusion device with a tritium gas target, and in 2019 we licensed a neutron radiography device. We are currently reviewing applications for upgraded equipment including an advanced tritium handling system and we expect these systems to continue growing larger and more complex over time. Next slide.

So, what have we learned? We have had challenges along the way but the most pressing challenges can be solved. Our key needs right now are training our staff and developing fusion licensing guidance. Since NRC has very little experience with fusion-related issues, we are building connections with experts in industry, academia, and the DOE. We have an urgent need for guidance to evaluate tritium handling practices and inventory control, and for the size and scope of environmental monitoring.

We also need resources for evaluating credible accident scenarios. Fusion applicants wants to use a dose calculation to demonstrate that an accident would result in a dose less than the threshold for requiring an emergency plan but NRC's emergency planning guidance in Regulatory Guide 3.67 unfortunately offers little for assessing the dose calculation route.

And finally, we have had issue, a few rule exemptions for fusion licensees. For example, the immediate reporting threshold for lost or missing tritium is 1 curie and for fusion licensees this level of precision on inventory control is impossible. Next slide.

Over the past two years, there's been a lot of discussion on what fusion activities should or should not be licensed under a Part 30 framework. It is critical for us to have jurisdictional certainty over the short and medium term for the fusion technologies that are being tested. Applicants want to be able to determine who their regulatory authority will be and as we proceed with staffing and developing expertise writing guidance, we need to know these efforts will not be wasted.

Getting to regulatory certainty requires thoughtful, practical definitions and decision criteria for any Part 30-Part 50 boundary. Ever since the Nuclear Energy Innovation and Modernization Act passed, the lack of a definition for fusion reactor has concerned us. As have proposed Part 30 boundaries that impinge on activities that states have successfully licensed, like large radioactive materials inventories and licenses with emergency plans.

In Wisconsin, we are invested in fusion and other high-neutron flux technologies. And we want to continue to maintain jurisdiction over the things that we currently regulate, both the accelerators and the radioactive materials licenses. Next slide.

From our vantage point, regulating fusion devices under a Part 30 framework is working so far. Part 30 includes needed regulatory mechanisms, like financial assurance and emergency planning. And we have been able to respond to the challenges. I can't speak to whether Part 30 will work for every future fusion technology, but with small rulemaking modifications, we could better accommodate the foreseeable fusion activities and guidance would help streamline licensing until the fusion industry matures. To the extent that Wisconsin's experience can help the NRC or other states, we are happy to share what we've learned and I look forward to working with the NRC on these efforts as we are able. Thank you.

CHAIR HANSON: Thank you. Next we'll hear from Sachin Desai, who is the General Counsel at Helion Energy.

MR. DESAI: Thank you very much, Chairman Hanson. My name is Sachin Desai, I'm the General Counsel for Helion Energy. I spent my career working on nuclear regulatory matters, including starting at the U.S. Nuclear Regulatory Commission at the ASLB.

I want to first start by thanking the NRC staff for years of constructive engagement on this topic. We've had a very positive working relationship with the NRC staff and look forward to continuing that over the many years we deploy this technology. I'm going to use this presentation to overview a couple quick concepts and then point to materials in the record that might have a little more deep dive. Next slide, if you could put it up on the screen?

In the fusion community, I just want to note to start things off that we are here for one reason, which is the need for clean energy. We need to deploy a gigawatt a day of clean energy on the grid to meet our 2050 milestones. And you have to do that in a manner that ensures energy security across the globe. The future community is ready to meet that challenge. There are 20-plus ventures in the United States alone working on fusion designs, across a diversity of technologies, that have raised $4 billion. Those technologies and that funding has allowed us to meet and set some really ambitious mid-decade milestones for demonstrating our technology and then deploying in the early 2030s if not sooner.

Helion is an example of that community. We want to demonstrate net electricity from fusion in 2024 and in addition, we are actually also a great example of the diversity of technologies that are out there, as opposed to some of the Tokamak concepts that have been discussed, we have a magneto-inertial concept. We form two plasma rings, we accelerate them towards the center, and then compress the final product. We want to use deuterium-helium 3 fuel and a pulsed process. Next slide.

I'll just add that our devices have been regulated by the Washington State as particle accelerators. So, there's a really urgent need to get the regulation of fusion right and the best place to start with that is the safety case. When we're looking between different framework options for how we want to regulate fusion, especially looking at existing options, the best thing to do might be to look at precedent. Our view, or at least my view, is that byproduct materials framework offers the best safety case precedent for regulating fusion devices.

So, in an August 2022 letter we get into much more detail about the regulation of fusion and its safety case, but just to highlight a couple quick points, operationally, fusion devices are very similar to particle accelerators in other industrial facilities. You might say, well, we might have certain expanded hazards, but they're not that different in kind. For example, medical electrons need meters of shielding to deal with much higher-energy neutrons that come off those devices. So, at the end of the day, the shielding requirements are quite similar and we discussed this in our March presentation.

In terms of off-normal incidents, one thing to bring out is the inventory on a device is actually quite limited. This is again discussed in a March NRC staff presentation. One example for Helion is we demonstrated and discussed to the NRC staff that if we were to take an extreme example, we were to take our 50 megawatt plan device and essentially turn the entire vacuum vessel into dust and release it into the air, some of that I have to emphasize is beyond physically capable, the dose to the public at the maximum point is 11.3 millirem, or one-ninth the public dose limit. And the reason for that is fundamentally, the amount of radioactive material in a fusion device itself is quite limited because we don't have a whole core of radioactive material with years of inventory.

Now, there are radioactive material concerns and hazards to address with fusion. For example, we produce tritium in our approach that we have to store safely, but that is fundamentally no different than how irradiators has to deal with millions of curies of radioactive material, how medical isotope generators have to very closely work with radio isotopes that they produced in particle accelerators or other industrial facilities.

I wanted to spend most of the time on that slide, but we can get into more detail. Just to quickly jump to two other slides, as a nuclear attorney I hear a lot about how you classify fusion devices. Fusion has to fit in the AEA at the end of the day and there's no clear statement about fusion in the AEA. I'll just note in that August letter we get into more detail about the regulatory classification. One thing I'll just call out is a perspective. If we were to not think about fusion devices as energy generations, just say that fusion is a technology that we can use for multiple applications, we can switch out the deuterium helium-3 fusion fuel and put in deuterium-deuterium and make tritium and helium-3, a radioactive material that has commercial value as well as helium-3, which has tons of different applications.

There probably would be no real question of that accelerator-driven process that produces byproduct material is under the Part 30 framework. Now, if we switch out that deuterium-deuterium with deuterium helium-3, which actually has less radiological impact than deuterium-deuterium, why do we end up in a stricter framework? Think about that when we think of right-sizing our regulations and being consistent.

The last thing I want to touch on is about the capabilities of the Part 30 framework, that comes up in a lot of different contexts and discussions. In a June 7, 2022, presentation to the NRC staff, we basically asked a question, and admitted there are obviously issues we need to deal with, with any new energy technology, what are the things we want to police in a fusion device?

And so we went through them, access control, shielding, entering and exit, maintenance issues, decommissioning, emergency planning, materials security. And then we looked in the Part 30 paradigm, Part 30 is more than just one section and found that those tools exist in the Part 30 framework today. Under the regulations that exist for irradiator facilities in Part 36 you see a number of regulations that are applicable. And then in Part 30 you see a number of other capabilities.

In addition, one thing that's really exciting about the materials framework is its embracement of diversity and novelty. I really like to point to Part 35 as a great example of a capability that's inherent by addressing diversity in fusion device design or in radioactive materials. And in Part 35, the materials framework, you have different subparts for different types of applications of radioactive materials for medical applications. You also have 35-1000, which is a unique process where if an innovative technology comes in the door, the NRC develops licensing guidance working with agreement states to deploy that technology. That type of different thinking is exactly why the materials framework is not just suited to fusion but uniquely capable of dealing with fusion as it scales.

To just conclude, fusion is game-changing energy technology that has hazards, but those hazards are akin to what you see in the materials framework currently and is used by other industrial facilities, as the U.K. speaker has pointed out. The materials framework has the tools to handle fusion today and over time. I would note that maybe in the near term there's a need to just reply to principles for case-by-case licensing. But when it comes time to develop our proper regulatory framework for fusion, those tools exist and can form the foundation for a strong regulatory framework going forward.

CHAIR HANSON: Thank you very much. Now we'll hear from Dr. Bob Mumgaard. He's the CEO of Commonwealth Fusion Systems.

DR. MUMGAARD: Thank you so much, I'm Bob Mumgaard, Ph.D. in plasma physics from MIT. I spent my academic career in fusion working in various sizes of machines and I also working on machines overseas.

About six years ago MIT asked a really important question of itself, which is what is its role in fusion and where was this going as a field?

There were companies that had spun out, there is the ITER project, strong academic routes, where is this going to go?

And the answer, after a concerted look, was that in order for fusion to make a difference in the problems that are the biggest for the nation and the world, it would have to become an industry, an entire industry, an industry at the scale that is the scale of other energy industries, a scale that is even larger than the existing fission industry.

How does it get there? It gets there one step at a time but never forgetting about where it's going, meaning we build devices but we're always looking to what is the next device. We train scientists but we also think about who is the public, how are they involved? How do we get ahead of any potential uncertainties, how do we get ahead of any potential backlash? And we build an entire system to be able to do that.

As part of that at MIT, Commonwealth Fusion Systems spun out in 2018. Commonwealth Fusion Systems is now the largest of all the private fusion companies. There's about 375 people that are employed directly by the company and about 1000 people that are working on its projects. It is commercializing, meaning not just doing science but thinking about how to build a fusion product, the Tokamak, which is by far the most studied fusion machine, a machine with roots in Princeton, Oak Ridge, ITER, GA, and a long history of 150 Tokamaks have been built.

And we go to the next slide and you'll see the trajectory of where Commonwealth Fusion Systems is today and where we plan to go. This mirrors the trajectory of many of the other fusion companies. As mentioned, there's over $5 billion invested in this space. They start with an idea of a science experiment. In our case, Alcator C-Mod on the left, that was a Tokamak at MIT regulated under the Part 30 framework, run by and funded by the Department of Energy.

It reaches the conditions so that fusion actually happens; it makes many, many neutrons from fusion; it creates activated materials from fusion; it doesn't create a lot of power, it's not designed to do that, but it creates the power of the science that enabled us to know how ITER is going to work but also to know what we should build next. That's coupled with a key innovation, which is happening across this entire field, which is we found things that could drastically accelerate and change the topology of these fusion machines, in our case, a very strong magnet. There's other examples, AI, actuators. That strong magnet allowed us to build a next-step Tokamak that's 40 times smaller than we thought was previously possible, a machine we call SPARC.

This is a machine that will produce copious amounts of fusion energy, meaning at any given time you push a button and it would make about 100 megawatts of fusion heat for about 10 seconds. That's a similar mission to what ITER is doing. That mission shows that fusion is feasible, it doesn't yet show it's practical. So, if we show that slide again, that machine is being built right now, we can show pictures of it.

We're also looking to what the next machine is, a machine we call ARC, which is a Tokamak that you see the scale here, about 400 megawatts of heat designed to produce commercial fusion power and demonstrate this is a practical energy source that can scale. We are currently looking for where to build ARC today and ARC fits within the Biden Administration's decadal plan for showing a fusion pilot plant, an actual plant that's not just a demonstration of science, but a demonstration that this can make power repeatedly in a commercially relevant platform. If we go to the next slide?

This is not some far-off thing that may or may not happen. This is happening today. Here are pictures of the SPARC facility in Devens, Massachusetts, about an hour west of Boston. This facility is about an $800 million dollar facility, it is fully paid for by the investors and Commonwealth fusion systems, which include large energy companies, large financial institutions domestically and foreign, large innovation-based venture capitalists. And this facility in the foreground is a concrete shielded hall, inside there's a Tokamak, underneath there is a tritium handling system, and in the background is a magnet factory to make more of these facilities.

So, if we go to the next slide. We, like other people on this panel, agree on the hazards that fusion poses, which are primarily related to what are the materials and where are they, the tritium irradiation, and is the machine on or is the machine off? Like other fusion machines, they all have very small amounts of fusion fuel inside them, you can't build a fusion machine that has lots of fusion fuels, it's physically not relevant. And so at any given time, a tiny bit of fuel is inside the machine producing a lot of power and when you shut it off you're left with activated materials in a fuel cycle.

Those systems are systems that look like accelerators today, they look like things that are already regulated today. They're slightly modified, maybe they are scaled up but in character they are not different. And we all demonstrate those at a small scale, low throughput in SPARC the same way that ITER is doing it, the same way that JET and TFTR has done it, but we need to know where we're going to go for ARC and we need to know that relatively soon.

These investors who are looking at the challenge of climate change, there is over a $100 trillion energy transition that needs to happen to get to a sustainable carbon-free net-zero by 2050 and they're saying what are other technology mixes that are going to be able to be successful? And the attributes of success come from the fundamentals, in our case, the fundamental fusion reaction which is fundamentally different than the fission reaction. No uranium, no plutonium, no chain reaction, no splitting the atom, no transuranics, which means the approach and the acceptance of this could also be fundamentally different, meaning it could be a technology that could get widespread adoption. And it could go much faster than we previously thought.

That's if we get it right and we don't have to get it right forever, but we do have to get it right for right now, which is, yes, SPARC, that's going, that's understood, but what does that fusion pilot plant look like and how do we get that on the grid within the early 2030s? That means we have to make decisions about what that looks like basically in the next two years. And that's a global decision that almost all these companies are facing and so I really look forward to this conversation as all the technical pieces have come out and we can put it context and also look at the different pros and cons of different options that have been put into the very diligent work by the NRC Staff. Thank you.

CHAIR HANSON: Thank you very much. We'll finish up with our external panel this morning with Mr. Seth Hoedl, he's the President of the Post Road Foundation. Mr. Hoedl?

DR. HOEDL: Good morning, can you hear me?

CHAIR HANSON: Now we can.

DR. HOEDL: Thank you so much. Good morning, Commissioners, and thanks so much for the invitation to present today. Apologies that I can't be there in person. My name is Seth Hoedl and I'm President and Cofounder of the Post Road Foundation. It's a nonprofit dedicated to helping underserved communities build sustainable infrastructure.

To give you some background, I'm originally trained as an experimental nuclear physicist, which I pursued both in academia and as an executive in radiation ecology startup. I'm also trained as an energy law attorney. As part of my work at Post Road, I think of how new energy technologies can be deployed in ways that meet community needs. From an academic perspective, you might think of this work as energy ethics. From a commercialization perspective, you may think that it pertains more to public exceptions or social license. I've applied this thinking to nuclear technologies including fusion in a variety of peer reviewed publications and it's this work that forms the basis of my talk today.

The perspective that I'd like to introduce you to in this briefing is that early public engagement, even in this process of developing a regulatory framework, is essential to build public trust in the fusion industry and eventual regulation. Without such trust, fusion will struggle to achieve the full potential impact on climate change, global energy poverty, our nation's economic competitiveness, and our nation's national security. Next slide, please.

Fusion has the potential to be a transformative technology but it won't be easy. In order to achieve impact, the technology will have to work, be economically competitive, have regulatory approval, a scalable supply chain, a trained workforce, and underlining all of these ingredients, public acceptance.

While it's possible that the achievement of burning plasma is such a great accomplishment that it paves that way for wide adoption, it's not guaranteed. And this isn't a new observation. In 1994, EPRI listed social acceptance as one of the three key ingredients for practical fusion power. Next slide, please.

The reason public acceptance is so important for fusion's impact is that energy technologies that don't have public acceptance stall. They don't achieve their full potential and I represent that here on this graph on the left side of this slide, where technologies that do have public acceptance or social license, is they enter the marketplace that follow this red curve. They grow up and they plateau at a relatively high level. There are technologies that lack public acceptance or that don't have a social license.

They follow this blue curve. They do enter the marketplace but they plateau at a much lower level. And the reason for this difference is that technologies that don't have public acceptance have a higher cost of capital and higher capital cost, they increase litigation risks and costs, and they face increased regulatory burdens.

We see these effects in a variety of energy technologies, we see this with transmission lines, we see it with windfarms in a variety of contexts, and perhaps most pertinent for this panel, we see it with nuclear fission. Fortunately, fusion is so young that it can distinguish itself from these technologies, not just in a way that uses physics but also in a way that approaches society. It can follow the red curve, it doesn't have to follow the blue curve and have impact. Next slide, please.

Also, fortunately, there are established methods for achieving public acceptance and these methods are easier than achieving a burning plasma; namely, social license, ethical review, and responsible research to innovation. These methods all have insights for fusion. Importantly, these methods go far beyond a scientist's or an engineer's default approach to public acceptance, which typically focuses on technical change, complying with regulation, and engaging in better communication or education.

It's been remarked for over forty years, these approaches on their own are unlikely to facilitate public acceptance, more is needed and that's what these methods provide. Next slide, please.

The social license is the most prescriptive method and so I want to highlight some of its elements here. It's really a process of meaningful engagement, it opens expertise to new questions and perspectives and addresses what people actually worry about rather than what they should worried about. It engenders trust, it's transparent, it protects human health and safety, and it's more than education, public relations, or letting the public see the experts at work.

I want to note that protecting human health and safety is essential, in some sense the motivation for this briefing, but it's only one of the six elements that are needed with the social license method to achieve public acceptance. The process of securing human health and safety, if it doesn't engage the public sufficiently, then the fact that the public health and safety, that fact alone will not be enough to achieve public acceptance. Next slide, please.

You can think of the social license method as an iterative two-way conversation between technology developers and the public. And this iterative process both builds public acceptance and strengthens outcomes. It identifies problems that experts miss, it's sensitive to social and political values that experts may not share, and it creates a sense of procedural justice and a positive feedback loop that enhances trust.

It only works if the public trusts the industry and government regulators that ensure the public safety. If there's no trust from the beginning, conversation goes nowhere, public acceptance never happens, and the energy technology stalls.

I don't think the NRC should be responsible for this two-way conversation or for fusion to achieve public acceptance. But the NRC does have a critical role to play in building trust in fusion and fusion's regulation during this very early phase of fusion's development. Next slide, please.

Bringing these insights into the topic of the briefing today, the public needs confidence that the NRC adopts a regulatory framework that has the authority to manage the full range of risks that concern the public. Then there's an accident and fingers crossed, it's a very small accident. The public needs confidence that the NRC and the industry didn't overlook risks when developing the regulations. If the public comes to believe that shortcuts were taken, it will undermine trust in the industry and the regulators to the detriment of the long-term viability of fusion.

Of course, the regulations themselves need to have such authority in order to work, but the process by which the regulations are developed is equally important. That process needs to be transparent, based on the full range of risks that concern the public, and undertaking meaningful public engagement.

Just a few final thoughts on potential practical steps. First, actively solicit public concerns from communities nationwide, not just public meetings like today's. Today's is important but more needs to happen. This solicitation will be expensive, it will be time-consuming, but it will be worth it in the long-run for fusion's viability.

Second, on the basis of this solicitation and also expert input, address the concerns that are identified through a transparent high-level health and safety analysis, perhaps before selecting regulatory framework.

Opaque expert-only assessments and regulatory choices are likely to be counterproductive. Use this analysis perhaps to make a catalog of risks that the regulatory framework needs to address to satisfy experts and the public, and then transparently craft the regulatory framework to manage these risks.

Third, support independent health and safety assessments. This point is more to the fusion industry has made to the NRC but it never hurts to have a second opinion on the risks that fusion might pose and the strength of a regulatory framework to manage those risks.

To summarize, the degree to which the public is meaningfully engaged in the development of the regulatory approach and the eventual licensing of fusion reactors, whether through Part 30 or otherwise, will have a profound impact over long-term public trust in and public acceptance of this technology. Public input is essential, even at this very early stage. Thanks for your time.

CHAIR HANSON: Thank you very much, Mr. Hoedl. We'll begin this morning with Commissioner Crowell, but before we do, I'll note that we've got a really large panel here so if my colleagues need to take a little extra time, they should feel free to do so.

COMMISSIONER CROWELL: Thank you, Mr. Chair, and thank you to all the presenters today. This has been extremely informative and it appears to be an exciting time for fusion and we've been waiting a long time for this.

Dr. Hoedl, I really appreciate your presentation, I'm not going to ask you any questions other than to say I agree with you and I think a point you made that the public needs confidence that the NRC and other regulators adopt a regulatory framework that has the authority to manage the full range of risks that the public cares about is critically important in this process. The public does not appreciate the difference, every person does not appreciate the difference between fusion and fission, they just see it as nuclear and then that comes along with a host of impressions based on your experience with nuclear in the past, be it weapons, fission, other uses of nuclear. So, we need to keep that in mind as we move forward.

I'm going to ask Dr. McCarthy first and I'm sure someone else will want to chime in here as well, but what makes this discussion about fusion today different than the one we've had over the last 10 years, 20 years, 50 years? Because we've all heard it before but I feel like we're more on the precipice this time than in the past, but I couldn't articulate that. So, if someone could help with that, I'd appreciate it?

DR. McCARTHY: I'd be happy to do that. I went into fusion in graduate school, which was quite a long time ago and at that point, there was a lot of research going on, but there wasn't really the energy around it that there is right now.

Why is that? We have seen results from recent experiments in the joint European Taurus, prior to that in the Tokamak fusion test reactor, which actually did deuterium tritium shots that were predictable with the codes. That's a very important thing as well. We've learned a lot in terms of modeling and simulation and our ability to predict has gotten quite a bit better. That gives us confidence in terms of maintaining and controlling a plasma.

We are also seeing progress in terms of assembly of the ITER project. We're developing an industry, we're able to write specifications the industry can deliver on that will meet the French regulator requirements. So, that's another piece of it. You also see investment by private industry, that's new and you saw that on the chart. Private industry will typically look for things that give them a return on investment. I think that's a really important indicator that there's really important things that are coming out of fusion, ultimately clean fusion energy. So, I think those are some of the reasons why.

COMMISSIONER CROWELL: Mr. Desai or Dr. Mumgaard, do you want to chip on this?

DR. MUMGAARD: Kathy's exactly right, there's a scientific basis that's been established and you can't underestimate that but on the other side of this too is there's a saying, when will fusion be ready?

It'll be ready when the world needs it and we've developed this science but now we've seen the pull-down, the reach-down to pull that science up from investors and for other people, saying now is the time because of climate, because of the energy transition, because the other technologies that have gotten so much better that have never been applied to fusion.

And I think also an additional point is you're seeing a changeover in the field. You have entirely new people coming into the field.

CFS is 375 people. Only about 10 percent of that came from fusion, all the other people came from other fields, they came from launching rockets, they came from building biotech, and came from manufacturing electric vehicles. Because fusion can have a very, very big difference in the world, it's attracting talent, it's attracting ideas, it's attracting a diversity of viewpoints, it's attracting new technologies. And that centralizing function is hard to put your finger on but it's easy to feel when you go to a fusion conference today and compare it to where it was 10 years ago.

MR. DESAI: I'll just quickly add that in the case of the Helion example, it's a story about enabling technologies. Our approach to fusion fundamentally was thought of in the 1980s. There are black and white pictures we have in some of our slide decks about formation of FRCs and acceleration. However, we couldn't do this approach in the 1980s, we needed high-power semiconductors. We actually needed fiber optic cables in order to send the signals to the different magnets in time.

What happened actually, it's been kind of an unsung hero about fusion's advancement is a series of advancements in enabling technologies over the past 20 years that have indirectly, then substantially contributed to the growth of fusion. Now we have fiber optics, now we have power semiconductors that can send currents to our magnets in sufficient energy to cause fusion to happen and now we have modeling, now we have high-power magnets and other things that weren't there 20 years ago that are there today. That's brought a lot of exciting physics concepts that were put to the side 20 years ago and made it possible to do fusion today.

COMMISSIONER CROWELL: Thank you all for that response. I think it also highlights that what was known about fusion from a scientific perspective and a regulatory perspective 20, 30 years ago was different than what we know 10, 20 years in the future is going to be different than what we know now and that is why we need to have a nimble, adaptive framework that prioritizes safety, but also is manageable from the industry perspective to navigate.

And I think that's going to be an evolution and as long as there's willingness to evolve with the technology and with the learning curve, then this will end up in the right place but that needs to be kept in mind as we move forward.

I'm a little concerned about some of the differences of opinions I've read about regarding the waste profile of fusion technologies and I would like any of you, and maybe this is a DOE question or an Oak Ridge question, I'm not sure who is best to answer this, but there seems to be different opinions as to whether it's long-lived waste or short-lived waste, whether it's high-level or non-high-level. And I think that's important to understand and have a grasp of from a regulatory perspective and in ensuring safety for the public now and in the future. I don't know who wants to take that one first.

DR. McCARTHY: One of the things with fusion that we're able to do is, to some sense, decouple the structural material from the plasma itself. It's not quite that simple, but I mentioned in my opening remarks about low-activation materials.

First of all, it depends on which fuel cycle you choose. A deuterium-tritium fuel cycle produces 14 MeV neutrons. There are other fuel cycles under development that would produce fewer and in some cases close to zero.

So, a lot of it depends on that. I would also say with each of these fuel cycles, there's challenges, none is the clear winner. For example, with the deuterium tritium fuel cycle producing 14 MeV neutrons, something has to stop those neutrons and that is the structural material. So, if you're looking at, for example, steels, you can get some longer-lived activation products, not talking about transuranics, but it could potentially be greater than Class C in the current definitions.

There has been a lot of work previously, it's slowed down a bit, it had slowed down a bit when the Department of Energy really pivoted to the underlying science program for fusion, now we've got to look at technology because we don't necessarily have clear winners. We don't have a clear winner in terms of materials and fuel cycle and that's important for commercial fusion. So, these low-activation materials potentially could activate less and that would impact what the waste is.

So, your question has to be answered on a case-by-case basis and there are actually multiple papers that have looked at this sort of thing and I believe there's something coming out in Nuclear News specific to fusion waste that I think will be useful was well as well. It really depends on the specific technology chosen.

MR. DESAI: I may add, one thing that's interesting about the Part 30 framework is that it does have decommissioning financial assurance requirements and in many ways are actually stricter than what you would see in the utilization facility framework. And under the utilization facility framework, licensees can put money into a trust over time to meet anticipated future requirements. Generally, under much of the Part 30 framework, licensees have to post financial assurance at the start.

So, talk about a public trust mechanism, we have to actually put in the money to deal with long-term waste. We don't have long-term waste but the long-term decommissioning profile at the start. That's going to be a really powerful driver over time to make sure that we keep our waste profiles as limited as possible and to build public trust that no matter what waste we do produce with future companies, we're going to actually have the money set aside at the start of operations to deal with it.

DR. MUMGAARD: I would add a conceptual framework around this. In a fission system utilization facility, the waste is inextricably tied to the fuel. It literally is the product of the fuel. You have uranium, it splits, you have fuel rods with transuranics in it. That's what we call the waste. You don't actually call the activated materials in a fission system the waste.

In fusion, as Kathy said, they are completely decoupled. The fusion process itself has no nuclear waste, it makes helium, but what you choose to build the machine out of, that gets hit by neutrons and gets changed, becomes radioactive, and you have the choice of what materials to put in there. So, you have intrinsic trade-offs. If you put materials in that are higher-performing economically but maybe have a longer lifetime of radioactivity.

The key thing is it's a choice and it's a choice that will change with time, meaning the materials we have today are unlikely to be the materials we'll use in the future.

And so often times it can look like a disagreement about the character of the problem, it's actually a disagreement about the timing of the solution, meaning the thing you build today produces X amount of waste if you build it this way like ITER or like DEMO. Versus no, the plan is to build something that's a bit different, it's a different material with a different volume in it because we have the ability to do that now and also, in the future we have the ability to develop new materials. Nothing precludes that, we just haven't worked on it that would be even different.

And so that's one of the reasons we need a flexible system that looks at these activated materials as not a prescriptive solution but as an incentive solution that says let's get less and less and less of these as we go.

COMMISSIONER CROWELL: Thank you. Mr. Chair, one more question, if possible? The other area that gives me a little bit of concern as I read more about fusion is the risk profile and the differences of opinion that I see from different parts of industry and academia and Government on the safety risk associated with fusion. And I think in terms of managing public acceptance of fusion, we need to sort that out quickly and clearly because if we don't have trust that we're managing safety appropriately, then we're sunk from the start.

Perhaps Dr. Hawryluk or Mr. Lewis-Smith can comment on this, but I was reading in the Advisory Committee on Reactor Safeguards letter that there's some inaccuracies in the NRC staff White Paper with regards to the safety risks associated with commercial-scale fusion, specifically citing DOE report from I don't know when, maybe even as far back as the ‘90s and some international studies on the safety risk. I was wondering if someone can comment on that?

DR. HAWRYLUK: I'm glad to comment on that and have others comment further. If you read carefully a lot of the studies, what you realize is that it depends strongly upon the level of safety barriers and what people do as far as engineering controls.

On TFTR, we had 2.5 grams of tritium in process, 5 grams on site; ITER is going to have 4 kilograms. In both cases, very detailed safety analysis indicates there was no emergency planning required. But you go, well, what's the difference? You've got almost a factor of 1000 difference in the tritium. And the answer is engineering controls, the safety protocols, the segregation of tritium, and these are the underlying engineering assumptions that they place which have to be taken into account in the detailed engineering design and how you handle the tritium.

There's plans underway to come up with ways to reduce the tritium inventory for future machines. There's plans underway to deal with maybe using alternate fuels when you don't have as much as tritium or any tritium on site. But this has to be done carefully, but it can be done, an experience we've had ranging from TFTR, JET, and ITER shows that it can be done but it has to be addressed consistently and thoroughly in your regulations and in your engineering practices. Thank you.

MR. LEWIS-SMITH: If I may comment? I will briefly mention just a couple of points to add to that. The work the U.K. Government has done with its technical advisors to arrive at accident scenarios is very much based on bounding scenarios. It is not a definitive assessment of fusion risks or fusion hazards, it's very much, as I said, a bounding scenario to arrive at worst-case estimates and everything the previous speaker just said absolutely is applicable.

The other thing I would say when we're talking about safety implications is something that our work tried to do, which is invite comparison or at least talk to a potential accident, a very, very worst-case accident, let's say a very large chemical plant. We talk a lot about radiological implications of accidents on humans and the local environment, but it's important when we're talking to the public, that we'll associate fission with fusion to also conceptualize fusion within the broader industrial hazard context. Of course, there are very specific radiological implications but nonetheless, I think if we don't be a bit more holistic when we talk about safety, we run the risk of confusing people.

COMMISSIONER CROWELL: Thank you. Mr. Chair.

CHAIR HANSON: Thank you, Commissioner Crowell. I want to pick up on this theme that Commissioner Crowell introduced. But before I do, first of all, I want to say thank you to everyone for your presentations. It was very informative and also a very diverse set of views.

I guess I want to pull the thread on a couple of things that I saw in the material around the DT fuel cycle and the technology around that and risk analysis and so on and so forth. I agree with the overall tenor that it's important to come up with a framework here that provides enough predictability for technology developers to proceed through their work in the next 5 to 10 years, but also is transparent and ensures safety and so on and so forth.

I take seriously the comments I think, Ms. Shober, you gave us about Part 30, that Mr. Desai, Mr. Mumgaard gave us about Part 30, and yet, I think about these devices in almost a Part 50. I still keep coming back to almost a Part-50-type framework in terms of accident analysis and so on and so forth.

In some of the materials we got there was a paper included by Hersch, et. al., that referenced superconducting magnet failure. But there wasn't a lot of context in here about how that works and what magnet-crunching really is and what the results of that are. We all know when we look at risk there's the probability of that and then there's the consequence, the likelihood and then the consequence of that. And it's not a criticism of the paper at all but I'm hoping we can start, Kathy, with you and then proceed through others to explain what this phenomenon is, how often we've seen it, et cetera.

DR. McCARTHY: Superconducting magnets, and of course, I'm talking about magnetically-confined fusions, depending on the design have a significant amount of stored energy. And let me go to what we've seen as we've been testing the central solenoid modules at General

Atomics in California. So, there we have had a situation where we've had a quench which dumps a significant amount of energy, it has to go somewhere. So, what that means is you have a potential energy source that could mobilize radioactive material.

Let's talk about Tokamak dust. One of the things, and I think it's mentioned in the ACRS paper, I think the staff talk about it as well, back when I was in Idaho in my early career, that was with the Fusion Safety Program and one of the things we did is we looked at Tokamak dust. We collected dust from all over the world and analyzed it. So, what your first wall is made of, what the plasma sees is what will be in the dust. Some plasma-facing surfaces absorb tritium, so in addition to the activated material, you can have tritium. That dust can be very fine and it can be mobilized. So, when we talk about the potential for a quench, that's what we're talking about. So, there's actually a code that was developed back in Idaho and I can't remember the name of it but looked at several of those scenarios.

So, again, it's just an important thing to consider in terms of when you're evaluating the risk, and details can be found in those early papers but it's something that has been looked at. And the one final thing I want to say is you can't completely decouple the plasma from the material, the plasma-facing material because there are interactions because the two and certain plasma-facing materials can pollute that plasma. And then you lose confinement.

CHAIR HANSON: Dr. Hawryluk and then Dr. Mumgaard?

DR. HAWRYLUK: Just a brief comment, the issue that

Hersch raises about a quench releasing helium was actually looked at in the EAR safety case. So, this is a known thing, it's been analyzed and addressed as part of that activity.

CHAIR HANSON: OK. Go ahead.

DR. MUMGAARD: We've quenched quite a few magnets. What happens is you have a magnet, it dumps its energy inside and the magnet itself gets hot, sometimes parts of it melt. That is very different than breaching confinement of the radiological material. Those are physically separate systems. The magnet is around the vacuum vessel but in order for a magnet to actually produce a breach of the vacuum vessel, that's not something I know of ever seeing or ever being seen in analysis or anything like that. I don't even know what the physics of that would be. But more importantly, that breach of that vessel is part of the bounding case for all of the other types of scenarios that we look at in a safety case. Independent of how you breach it, the fact is if you breach it, you get a certain radiological consequence, that's the thing to hit on.

CHAIR HANSON: So, that phenomenon can be engineered around as part of the system case and it's been evaluated as part of ITER.

Mr. Lewis Smith, just to pick up on what Dr. Mumgaard said, you had mentioned a goal-setting approach in the U.K. and then Dr. Mumgaard touched on this issue of a bounding analysis for accidents. I wonder if you could jump in here and talk about the extent to which you've looked at this and how you're accommodating that within your framework?

MR. LEWIS-SMITH: Sure, I was going to say on the quencher, yes, again this was raised in our consultation exercise and as Dr. Mumgaard just said, it is part of what sums up the bounding scenarios, if it is a contributing factor or not, that would be determined by the safety assessments the developer would have to do.

In the context of a goal-setting approach, in magnetic fusion, for example, the developer would have to show the regulators in the U.K. what the potential consequences would be of components or systems failure and how they would mitigate them. The onus is there is then a degree of weight on the regulator to be able to understand that so that's why it's important, as I said in my presentation, to build technical capability in the regulator.

But with that technical capability, that regulator can then say, yes, you've mitigated that risk to as low as reasonably practicable and in the context of the worst-case bounding assumption, the bounding scenarios of fusion, that is acceptable in terms of regulatory expectations in the U.K., for example. So, it is to show the regulator by assessing all of the different potential causes of accidents, they've been appropriately, sufficiently, and proportionately mitigated. It doesn't go into every single one and provide an example of how that should be mitigated, it's on the developer to explain that to the regulator.

CHAIR HANSON: I see, thank you, very helpful. I wonder, Ms. Shober, if you could jump in and talk about this, again, goal-setting performance-based approach and what your experience is with that in Part 30?

MS. SHOBER: Just in terms of getting to things that are more complex?

CHAIR HANSON: Yes, that's a fine way to approach it, I think.

MS. SHOBER: The Part 30 framework is an additive framework. The Part 50 framework is set up where there's a whole structure and you're basically expected to fulfil all of these boxes and then you have to get exempted from things that don't match what you're doing.

So, Part 30 is the opposite tactic and you start out and there's a whole suite of tools that are available for regulators to exercise when necessary. And so for example, financial assurance, there's a threshold. If your possession limits are underneath that threshold, then we don't ask questions about financial assurance, we don't expect licensees to provide money for decommissioning.

Once you exceed, in that case, a certain possession limit for long-lived isotopes, then that trips the financial assurance trigger and then we look at decommissioning funding plans and we have those tools to incorporate in the license, those higher hazards.

Similar for emergency planning, there's thresholds, if you trip the threshold then you have to exercise those tools. So, I could foresee a similar sort of thing when we're talking about fusion technologies. When you enter in past some kind of threshold, then you have to exercise these other regulatory tools that are available.

CHAIR HANSON: That's very interesting, thank you. You said something almost in passing as part of your presentation and I want to make sure I understand it and I don't want to mischaracterize what you said. But I heard, I guess, was Part 30 is sufficient, it provides reasonable assurance of adequate protection for now. Did I have that right?

MS. SHOBER: Again, I can only speak from the things we've already licensed and so no one has approached us with an application for a fusion energy system. So, our experience in our program, we don't have Ph.D.s in plasma physics on our staff. And so there's a process where if someone were to come in with an application, there's of course a period of time before that would actually come to fruition.

So, there is as learning curve that would need to happen, again, that's part of my hesitation in saying Part 30 is working for now and it may not work in the future. We don't know, we don't have that information yet. No one has approached us with an application for the superconducting magnets. That's not something that we have direct experience regulating.

Again, the framework is there, there are tools available for that, it's just not something that I personally have experience regulating. So, I don't want to cast a blanket over something that is beyond my expertise.

CHAIR HANSON: I thought actually it was an interesting point about adaptive or evolutionary regulatory frameworks.

MS. SHOBER: We do that all the time, we have a lot of complex licensees in Wisconsin that use accelerators, that generate high-neutron flux. It's not all fusion, we have other applications as well. And it's been a learning process with those licensees as well to find out the complications with shielding design and the radioactive materials licenses are not really geared very well to represent the wealth of activation products. Because you can't measure them, they're all calculated, they're theoretical, so radioactive materials licenses, you have this many curies that you're allowed and for activation products it's based on a calculation.

That's not very satisfying. As a regulator, how do you know how much possession you have? And so we've had to explore other ways of bounding those based on accelerator beam-on time. And so it is a challenge to figure out how to wrap our arms around that but again, we've been able to do that with the challenges we've taken on so far.

CHAIR HANSON: I look forward to drawing on yours and others' experience as we go forward. Thank you. Commissioner Baran?

COMMISSIONER BARAN: Thanks to all of you for being here and for your presentations. It is a great panel, I agree with the Chair about that. When I proposed holding this meeting a while back, it seemed like now was the right time to get an update on new developments in fusion and to continue the discussion about what the regulatory framework for fusion should look like.

I think maybe I'll pick up with where the Chair left off, which is it sounds like there's quite a bit of support on the panel for a Part 30 byproduct material approach for regulating fusion. I'm interested in whether the panel thinks there are any updates to Part 30 that are needed to tailor it to fusion systems.

For example, would it help to include provisions about what would be required for a safety analysis that considers the hazards from tritium or activated materials or plasma oil interactions or high-temperature conditions? What do folks think about that?

MR. DESAI: I'll take a crack at that. There absolutely need to be updates to any framework to adapt to a new technology. So, I would think of updates to Part 30, following an approach that scales over time.

To start things off, you're going to need a definition, it seems to be an important thing you would add, content of application requirements. That would just help provide certainty to regulators and then the applicants.

As well, there are things that have been voiced to us by states regulators about what they'd like to see and things they want to learn better, so tritium loss issues, tritium management issues, these are things that, again, states have had experience regulating a variety of isotopes but does want to know more about tritium.

So, maybe for the first licensees that can start off as concepts or guidance but I think over time you would want to develop a framework that is well tailored towards fusion. And then I think what we want to do there is just listen to the Staff and listen to the states to see what they want more clarity on and then we can tailor the framework to match that.

DR. MUMGAARD: In the spirit of creating some certainty, it's not just certainty on the side of the developers, it's certainty on the side of the regulators. So, in the case of agreement states, things like definitions that say, okay, this is what a fusion energy machine is, they could resolve some of the things Sachin actually showed earlier. If you do it for medical isotope production and turn the machine on to then make heat that suddenly is different, we've got to resolve some of that from a definitional standpoint.

Also, I think one of the great things about the byproduct material framework, is that we get guidance, we can share lessons learned from states, there's good connectivity between those states, recognizing that basically every new applicant for the next ten years is going to be somewhat novel. And so let's not be prescriptive in advance, let's have those conversations upfront, identify what the guidance is, build that guidance up in the Part 30 framework, and then once we get some under our belt we can look at it again like we did for irradiators or like we did for well logging, or like we did for the other things. That's very different than deciding today we're going to put some big lines in the sand or we're going to leave it wide open. We have a system that's being used, it's accumulating expertise and with some coordination from the NRC and some transparency, and some tweaks, we think it can continue to work as we actually decide what is the future of this industry in terms of the types of plants to build?

MR. DESAI: I just want to go back to the Part 36 irradiator framework for example. There are a number of tools and regulations in there that are already quite tailored towards the types of issues we see with fusion devices.

And so to Bob's point, maybe you don't want to take that and spend all the work writing it down in a single framework today. But those can form the core concepts and the set of tools you would give as guidance to regulators for the first set of devices. And then as you see what works and what doesn't work, you can use those tools as a foundation for a proper regulatory framework within the Part 30 paradigm.

MS. SHOBER: And I would add to that, state regulators are very comfortable operating from license guidance, that's something we use all the time with all of our radioactive material license types. And so I think definitely in the near term, it would be most beneficial for states to have those big-picture elements that would go into a fusion application, those would be better off in licensing guidance and not yet in the regulation.

COMMISSIONER BARAN: So, let me try to sum up what I think I heard on this. It sounds like in the near-term folks think Part 30 is pretty good for this but that as we're going forward, we're going to want to have tweaks, we're going to want to have more fusion-specific framework or module within Part 30 to lay this out. In the short term, it might be guidance that's more useful about content of applications or other things.

Is that how you all are looking at it? Given the significant uncertainty we have right now, which is pretty obvious, trying to do a rule right now wouldn't make a lot of sense, even for those tweaks. You hold off on even that piece until later, is that how you are looking at it?

MS. SHOBER: I think the one thing that does need to be clarified probably sooner rather than later are some of those really core definitions. Like I mentioned, fusion reactor, what is that? And you don't want scoop up things that are actually quite simple and force them into something that's just really not necessary for that kind of technology.

So, what is a reactor when it comes to fusion, those kinds of questions need to get resolved sooner rather than later, and then some of the other details of specific facility kinds of things, those can come later on.

DR. McCARTHY: Yes, just very quickly, I'm not an expert on the regulation side but I think what's really important is that innovation isn't stifled. You see there are multiple different approaches being looked at, they are vastly different. And what is really important is they're not forced into a certain direction now because we're not sure which is the winner, we don't have a complete system.

And when you look at the hazards, it is important to say there are these hazards, these hazards can be mitigated and studies have shown that based on everything we've looked at to date. But coming clean with the hazards is important.

COMMISSIONER BARAN: And whether we're talking about a regulation, rulemaking, or whether it's guidance, one potential benefit of that is to have a more consistent framework across the country. And I'm interested in your thoughts a little bit about that.

The agreement states are already active in this area, they're more active than we've been in this area, but particularly in the absence of a fusion-specific framework, it could be that different agreement states will take different approaches and it may not be consistent across the country.

Is that something you all as developers are concerned about? And from the agreement state point of view, would that guidance or regulation at the appropriate time be helpful to establish that framework?

MS. SHOBER: At least from the agreement state perspective, there really are very few states that are actively engaged in fusion right now. Obviously, the States of Massachusetts, Wisconsin, California, and New York. And that's really it for right now. I promise you, those states, we are talking to each other, we've had lots of conversations, sharing licenses, talking with license reviewers, that information is being exchanged.

Also, through the CRCPD, we have a taskforce for fusion issues that does include several different state participants and also NRC staff participation. There are forums already there to exchange that information and we're all looking for all the help that we can get. So, I don't foresee too much of a licensing in a vacuum, at least with these kinds of novel technologies in the short-term.

COMMISSIONER BARAN: That's helpful.

DR. MUMGAARD: I think it's important to recognize that we do have a mechanism already with the agreement states that enforces consistency with the national regulations. We saw this, where the review was a different agreement state to be aligned with the rulemaking. So, it's not like we're going to offshoot and not be able to get back on track. There's going to be a herding that's going to happen in the future, and that mechanism already exists.

From a developer's standpoint, the ability to engage locally is really important. At the end of the day, this is a local issue and so having the regulator on the site and seeing the stuff and talking to the neighbors is really, really important.

And the state agreement state model really facilitates that.

The other side of it is, from a developer's standpoint, we don't have certainty that that interaction is going to be exactly the same everywhere.

It was never going to be exactly the same everywhere anyway. The neighbors are going to be different, it's going to be a continual engagement mechanism already. So, we're not so worried about the types of bumps and wiggles that might show up in this learning phase. We're also not building hundreds of these, these companies are looking to build their first one and then maybe their second and their third. Ten years from now we're going to know a whole lot more when we're at the stage of trying to build a big roll-out.

MR. DESAI: One thing just to add quickly is right now we're figuring out our technologies. It would be a significant possible misuse of staff resources to try to write down every rule today. However, there will be a point in time where you can build a framework around the devices of the technology and I think we would actually appreciate that because it would build uniformity.

However, there are some really cool options where you can apply lessons learned from prior Part 30 framework towards this approach. I would like to go back to Part 35. Part 35 actually has different subparts for different applications, so radioactive materials to medicine. It has that Part 35-1000 process I mentioned before that brings in new technologies.

You can imagine starting with guidance now, at some point building the bones of a Part 30-something for fusion, and you would start with basic requirements, build in a process for enabling innovation, technology to come in, and then building more subparts as you identify a concrete need based on applied licenses for regulations around certain types of issues. And so there's a very organic way you can develop that, over a significant amount of time you have to get fusion on the grid.

COMMISSIONER BARAN: I probably could go another 40 or 50 questions but I should stop now. I'll turn it over, thank you.

CHAIR HANSON: We all can. Commissioner Wright?

COMMISSIONER WRIGHT: Thank you and good morning. This is fascinating stuff, I'm actually more engaged in this since sitting here today, and I was already engaged. Holy cow. So, a lot has been happening recently. Yesterday, I think the response to the ACRS letter came out too so I am going to bring it up, maybe you can speak to it if you have anything you want to say to it.

To get started, and anybody can pitch in either online, virtually, or here in person, the ACRS did weigh in on the staff's white paper, on license and regulation of fusion energy and the systems, and one of the recommendations from the letter was that a hybrid byproduct materials and utilization facility framework be pursued, considering potential higher consequences of fusion energy facilities, whatever.

So, I look forward to hearing in the second panel what the staff might add onto that. But I might hear maybe your reactions to what came out and specifically how would the adoption of some hybrid approach impact you specifically and maybe, if not, do you have some concerns about it? Wherever you want to go.

MR. DESAI: Let me first start by saying that I appreciate the strong work the ACRS has done towards ensuring nuclear safety. When I was a law clerk the first meeting I actually went to was an ACRS meeting, so I had the chance to understand how they work from the start and that's been very helpful.

I would say there's a couple of points I would raise. To echo off the bat before we get into the hybrid, the ACRS letter talked about past publications and issuances on fusion safety. I think we should recognize there are more recent issuances on fusion safety by DOE, the burning plasma report, which actually noted that Parts 20 and 30 are well suited to fusion technology, as well as the U.K. analysis, which complements years of work, and concluded that the fusion hazards are akin to more of a Part 30-type set of licensee.

But going to the hybrid framework approach, I think what the ACRS does point out is that in the future, as we're all getting to here, there may be fusion devices that have uncertainties we can't account for. But I think what we have to think about is does that mean that Part 30 can't be scaled to meet that need? I think we should look at is there anything in Part 50 that actually provides some sort of tool that we can't add into Part 30 and provide a consistent single framework for fusion going forward, as opposed to having to choose between two frameworks.

There's actually a note in the paper that says that the issue with Part 30, they say that Part 30 can be scaled for fusion but the issue is it creates a patchwork of regulations, that's at least how I read it. And I don't think it creates a patchwork of regulations, I think that actually creates a path forward. It's scaling Part 30 to eventually meet the need. And the biggest patchwork for us is not knowing which framework we're going to have at the start.

I think when I look at the fusion licensing, we don't need to get every word down at the start, we need to get the principal frameworks right. But I can't go to an investor and say that we could be in Part 30 or we could be in Part 50. Our regulatory offices, we don't even know where we're going to be. And so I think what ACRS points out is there are hazards, we absolutely need to keep counting and evolving that framework but there's nothing in the Part 30 that isn't capable of doing that. We've just got to spend time and attention to develop a proper paradigm for fusion within that framework over time and keep learning.

DR. MUMGAARD: I appreciate the ACRS weighing in on this, I also really appreciate the fact that the NRC really studied this for two years and the ACRS is a briefing and then a paper. And the NRC came up with options and ACRS said Option 3. What is Option 3? We're going to talk about it later but I'm going to try to summarize it somewhat quickly.

Option 3 is we'll draw a line through fusion machines and some of them will be utilization facilities and some will be Part 30 facilities. That's what it is. Does that give certainty? Let's analyze what the problems with such an approach would be.

I think there's four basic problems. One, we just talked about how the hazards of a fusion machine and the operating principles are like all of the other byproduct things. So, if you're going to draw a line through fusion machines, you're going to have to draw the line through particle accelerators, too. Because these things are all really close. To say, oh, it's 10 grams of tritium, well, there's lots of facilities that have 10 grams of tritium. So, there's a challenge, how do you draw that line fundamentally?

Additionally, the things you would use to draw that line almost have nothing to do with the actual hazard to the public. You draw a line on how much power a machine makes. You can make a machine that has lots of power that's unsafe, you can make a machine that has lots of power that's safe. It depends on barriers, engineering judgment, a lot of things that go into the discussion. It's not just about straight up inventory or how long the machine ran or how much power the machine made.

So, it's actually really difficult to draw that line. Then additionally, you would end up building today, two regulatory frameworks for fusion. You would take the utilization framework and adapt it somehow. I don't know how you would do that, I've not seen a really good proposal on how you would do that. And you would still have to do things in Part 30. So you would take the regulator and split them into making two sets of rules. That's a lot of effort that I don't think we can afford. That can actually impact public safety negatively by basically spreading our resources so thin.

And then fourth, really importantly, it doesn't provide any certainty, it doesn't meet NEIMA. It just leaves a big set of open questions of what's the line, who's doing what, where do you go, how do you know if you're above or below the line if you're doing an early design, what if you do the analysis and you end up on one side or the other. There's just a whole lot of uncertainty that basically leads to I think the company is now probably looking elsewhere to places that have done the work upfront to say we have a certain scheme that is going to evolve over time.

COMMISSIONER WRIGHT: That’s very good. Thank you very much for that. Does Mr. Lewis-Smith have any comment on this at all or anybody online?

MR. LEWIS-SMITH: Yes, please, I'll go for it, I know Seth has his hand up as well but if I could very briefly?

Just to echo what Sachin was saying, in the letter I noted that it said the NRC staff has not identified specific technical limitations associated with byproduct material framework that would preclude establishing requirements...et cetera. I think that actually is very similar to something we've been looking at in the U.K., which is the Health and Safety Executive is establishing a new consent authorization process within the existing framework.

In other words, there's no change to the law, no change to implementing regulations. However, they have introduced a new process that requires an operator of future fusion facilities, for example, to submit a safety assessment to the regulator. That will then come be inspected by specialists and then a consent would be granted. That's much more oversight than is now but that's nothing to do with the change of the regulations.

It's that kind of enhancement of evolution of the framework that can happen within existing regulations and I think that's just to illustrate perhaps what Sachin was trying to allude to. It's very much certainly how we're doing things in the U.K.

MR. DESAI: Yes, I think that's right, we have the ability to scale the regulations over time to meet the need. I'll also just add I believe that the other members of the industry may provide responses as well to that ACRS letter over time.

COMMISSIONER WRIGHT: And Mr. Lewis-Smith, I'm going to stay with you for a second here, you're leading fusion regulator and you've really looked at pros and cons and different regulatory frameworks for fusion. I'd be interested to hear if you have any suggestions or tips that you might have for the NRC as we go about considering these different regulatory approaches?

MR. LEWIS-SMITH: Thank you. The one thing I would say, I don't want to make too much of comparing the U.S. and the U.K. approaches, we do things very different in terms of our legal apparatus but one of the things I said earlier about the goal-setting approach, the requirement for that fusion developers to explain to the regulators how they assess the risk and mitigated them as far as reasonably practical.

We think that kind of fundamental approach is really beneficial. How that is then implemented at state or federal level or through which regulation is less of an issue. It's the fundamental of how the framework works, which for us is really important. But otherwise, I think everything we've heard from the panel today and I hope things that I mentioned in my presentation about trying to define those bounding scenarios, enabling flexibility and acknowledging there are uncertainties. If you can arrive at a conclusion that has done all that then we think you will have been on the same journey as we've done.

COMMISSIONER WRIGHT: And with the time I've got left, Mr. Chairman, I want to talk to Ms. Shober for a second. First, I'm very happy that you're here, I'm very grateful for your comments, too. At the CRCPD meeting that we had earlier this year, you were on a panel with Duncan White and I believe Jeff Semanchik from Connecticut, I think. And you all talked about this and what the states were trying to do. I've been very impressed with what I heard then and especially what I heard today.

I kind of wish you all were the second panel because I would like to, based on what you've heard today so far from the panelists here, I just wondered if there's anything you'd like to add or something you think we need to further look into or consider as we go through this, even though you don't know what the next panel is going to say. It would be interested in that because the whole agreement states program is an amazing program working with the NRC and I see you all, it looks like you're going to be huge players on this.

MS. SHOBER: Thank you for your comments. I think what I'll toss in here is I think that the agreement states at this point have more fusion regulatory experience than the NRC and that puts us in a bit of an awkward position because you guys are the ones that are making the decisions about what framework we're going to end up with.

But on the research front, the people that have come to us that are applying for fusion licenses at this point, they aren't coming in with a fully formed giant facility project. So, we've had the luxury of starting small on things that grow over time. I know that what CFS is doing is a little bit different on the time-scale but we've had years to run into these obstacles to figure out how to climb over them to figure out how to streamline things to identify those challenges.

And so I guess one of the things that's hard for me as I'm listening to this about the hybrid approach is we could very easily end up in a situation where all of the R&D pieces happen with agreement states. We have this many-year relationship with our licensees, we understand how they operate, we understand their systems, and all of the sudden they cross a line and now they're a utilization facility and they're regulated by the NRC.

And so I think in that case, that's a challenge for you as a utilization facility regulator because you don't have that knowledge that's built up with all these years of working with an applicant. And then it's also very hard for the fusion companies because now all the training they've given us, all the many conversations and years back and forth, they would basically be starting over with a different set of regulators. And I think that duplicating that effort and all that, there are consequences for that as well. And so I understand the position that you're in considering these issues and trying to figure out where to draw the line or should you draw the line.

I'm glad I'm not the one doing that. From an agreement state perspective, we understand the licensees that we've been working with and we are developing the capabilities like everyone else in the country to regulate more complex and larger and different, evolving systems.

MR. DESAI: Actually, you reminded me of something I wanted to raise which is with regulations we can change and modify regulations over time so you can take one framework and build it up. The harshness of that Part 30-Part 50 switch is actually, you're also changing the statutory requirements. You're moving fundamentally from one regime that has a set of very flexible statutory requirements to a regime that has a completely different set of statutory requirements, and that would be something that would be nearly, almost impossible to make that transition.

The beautiful part about scaling up the Part 30 framework, for example, or building a custom framework within the materials approach is that you have the same set of flexible statutory requirements you can apply to fusion licensees and applicants, but you still at the end of the day have the same adequate protection standard.

So, you meet the same federal standard but you have a set of statutory requirements in place that's consistent over decades and allow for the Agency and states to have the most flexibility on the path they want to pursue.

DR. MUMGAARD: I'll just put in the point of SPARC relief. If we had done TFTR under the hybrid approach, what it would have meant is we ran TFTR for 10 years under one regulator and then one day the same exact facility, we decided to run it under a different regulator. And then the next day we went back. That's because these facilities evolve over time, you can put different fuels in them, you can run them with higher power or lower power, it's part of the innovative cycle to be able to do that. And that's much better done by a team of local experts that have been there for a while than by throwing it over the fence.

CHAIR HANSON: Thank you. Commissioner Caputo?

COMMISSIONER CAPUTO: The difficult thing about going last in questions is so many of the good questions have already been asked, so maybe I will end up being a little more concise and not using my full time.

I do want to try and create a little bit of clarity around a lot of the discussion that we've heard better using Part 30. Let me just start with Mr. Desai and Dr. Mumgaard. It sounds like for the nature of what you're planning to do in your companies, you really need regulatory certainty within the next two years or perhaps less. And you clearly stated your comfort with Part 30, perhaps with some modifications through guidance.

Dr. Hawryluk, given the other technologies out there, and maybe Dr. McCarthy as well, the universe of technologies that we know about now, is it your sense that those would probably fit under Part 30 as we have it today but perhaps with some guidance modifications?

DR. HAWRYLUK: I think for the near-term experiments that people are working on, I'll give an example as SPARC that we talked about and others which are in the pipeline right now, I think Part 30 will work just fine. There are some questions that need to be addressed as to what additions and modifications to Part 30 are needed for the future pilot plan. And we're in the process, some groups hope to do it faster than others to get to a preliminary design to define this. By the time they're at the preliminary design, they have to have some fairly concrete assurance as to what the regulatory framework will be and what the expectations are.

So, each machine, each concept is probably slightly different on the time scale but I think we're talking about several years, but there are some near-term things that Part 30 will work on. Downstream you probably need to modify that, in some cases it's a perhaps, I think it's a perhaps, to address some of the issues that the ACRS raised.

COMMISSIONER CAPUTO: I'll just stay with you for a minute. What I want to try and get a better understanding of is what's the time horizon here for some facility that's envisioned that needs to come in with a regulatory framework that somehow warrants regulation outside Part 30 or a significantly different Part 30 that would warrant us going through a rulemaking process?

Because I think certainly, in my experience, no matter how narrow of a modification to our rules is, the rulemaking process itself is quite time-intensive. So, we talked about if it's a hybrid approach, what kind of a threshold would warrant something more significant? Can you, given your attempt to find a milestone schedule for fusion development, give us an idea of when you see a potential device that might need to go beyond Part 30 with some modifications and into rulemaking space?

DR. HAWRYLUK: Going back to the NASEM study, we were talking about the preliminary design for these fusion pilot plants in about five years, which is about four years from now if you look at when we issued that report. And so at that stage, it would really behoove us to have the regulatory framework fairly well-defined. At that point, switching from a byproduct utilization facility, I can imagine and people here, Bob and Sachin should really comment on this further, we would find it very disruptive. So, I think that's talking about the fusion pilot plant, it's not talking about near-term facilities such as SPARC.

DR. MUMGAARD: I'm happy to provide a timeline of how we think about the problem. We're building a machine right now and that machine is under existing rules. That machine, you turn it on in 2025, operate it, at that time I'll need to have a materials license, that process is underway.

Then you think about a pilot plant, a pilot plant is what the NASEM report recommended, it's what the decadal plan is aiming at. There's an FOA to get money out from DOE to actually build such pilot plants to multiple award winners.

Those plants, that timeline, basically are all let's have a conceptual design of that pilot plant in about 18 months. So, at that point you know what that thing looks like, you know its size, you know its power output. It's a pilot plant, this is not an experiment, this is a machine that's designed to get through environmental cycles, it's designed to show some commercial implications. It's not just prove a principle.

So that means in 18 months we probably need to know where we're headed on these regulations. When do you actually start construction on such a plant? By the time you start construction, you have to know what the rules are, otherwise you don't start.

The Loan Program Office doesn't get you a loan, DOE doesn't get you past CD whatever, and investors don't give you the money to do it. So, you have to know before you start construction.

Various companies here are looking at starting construction in the next three to four years of such a thing and if you look at the bounding of the NES report, it's not more than five years, six years away from what the decadal plan says. That gives you a sense of when that window is. We think those pilot plants could be within Part 30 with some modifications and definitions. but we'd have to know what that looks like at that time.

MR. DESAI: Just to highlight, we're planning to start construction on our first commercial facility in the near term in a similar time scale, which means we actually have to start pre-application engagement with the appropriate regulator next year, essentially. So, we're looking at it to understand the framework in the very near term.

If I may make a strawman suggestion, taking some of the feedback from this conversation, it sounds like there will be a couple applicants coming in in the next year or earlier to start pre-application engagement. Those applications will be the test case for fusion and we can do that and I think it's actually broader than that, we can do that under the Part 30 framework with guidance or limited rulemaking based on what the states and the NRC staff think is the most appropriate.

At that point, that's going to be the threshold, when you have initial experience with a couple license applications to start building a framework for fusion. You also have proven that fusion works so there will be a lot more attention on this from funding and availability to develop a proper framework.

I'll note that 10 CFR Part 38 is an empty part of the regulatory code and so may or may not be a good place to start getting the bones of a fusion framework. And again, I'll take the 35 analogy, you have basic rules in place and you build subparts and you build in a process to intake new technologies as it comes along. And so I can see that as being a multi-step process that proceeds with the technology to build a framework that can scale for fusion.

COMMISSIONER CAPUTO: I'm going to ask a slightly different question. Getting into liability and insurance, fission reactors have to join the Price Anderson framework under law because the liability of a nuclear accident exceeds the value of insurance that's commercially available.

So, I'd like to ask the both of you do you see yourselves needing access to that framework or do you see the liability resulting from a possible accident scenario being bounded by the insurance that you find commercially available on the market?

DR. MUMGAARD: It's a great question.

I think a lot of the studies that have been done in the U.K. and elsewhere have shown that the bounding scenarios here for an accident are not what we think about in fission because you don't have uranium, you don't have chain reactions, you don't have transuranics. It's just a different reaction altogether. And it actually shows up in the insurance markets, so SPARC is an insured facility that's on the commercial market. I believe even

ITER is on the commercial market for insurance.

And so that says that we don't think Price Anderson makes a lot of sense to apply across those technologies, they're too different. In effect, what you would be doing is one technology would be subsidizing another technology when, at the end of the day, they're actually completely opposite reactions.

MR. DESAI: I can say we do not anticipate, nor do we want to be under the Price Anderson framework. We believe and we are confident we can develop an insurance market for fusion devices. It's actually a project I've undertaken working with an insurance broker to go and introduce fusion to a number of insurance companies.

Actually, and also, this was at the International Nuclear Law Association conference a couple weeks back, where I posed this question to nuclear insurers about what do you think about fusion devices needing insurance. And a number of them came back to me and said I don't see any need for a Price Anderson or a particular government regime to apply fusion commercial markets can cover you.

I think one thing we should recognize is the commercial market in the 1950s and 1960s for insurance was a lot different than the commercial market today. And fundamentally, because we're pursuing a particle and cellular approach in which the inventory hazard within the device is quite limited compared to the external materials hazards, there's a lot of experience dealing with that type of set of hazards in the commercial insurance space.

COMMISSIONER CAPUTO: Thank you for your participation and contributions today. Clearly, this is a very vibrant discussion, it's an exciting time, a nascent industry for fusion, which I find absolutely fascinating. So, thank you all for your contributions today and that's it for my questions.

CHAIR HANSON: Thank you, Commissioner Caputo. Let me echo her comments, thanks again to all of our panelists this morning and also, particularly to our remote participants, Mr. Lewis-Smith from the U.K. and Dr. Hoedl. It was a pleasure to have you with us and with that we'll take a short break. We'll reconvene probably just at 11:02 a.m., 11:03 a.m. so we can get started with the NRC staff panel. Thank you all again.

(Whereupon, the above-entitled matter went off the record at 10:57 a.m. and resumed at 11:04 a.m.)

Welcome back, everybody, let's get rolling here on the second panel. This second panel is the NRC staff panel and it will be kicked off by Cathy Haney, the Deputy Executive Director for Materials, Waste, Research, State Tribal Compliance, Administration, and Human Capital Programs. Cathy?

MS. HANEY: Good morning, Chair Hanson, and Commissioners. It's a pleasure to provide an update on the NRC Staff's efforts to develop options for licensing and regulating fusion energy systems.

Consistent with national energy priorities, the Administration has stressed the importance of creating a regulatory environment that supports continued research and development and progress towards commercialization of fusion energy.

Additionally, the Nuclear Energy Innovation and Modernization Act, or NEIMA, requires the NRC to develop a regulatory framework for fusion reactors, which the NRC staff refers to as fusion energy systems.

While the NRC has a mature regulatory framework for fission reactors, its regulations do not explicitly address fusion energy systems. Developing an appropriate regulatory framework that meets the NRC's safety and security mission is essential for providing regulatory clarity and predictability to an advancing fusion industry.

As directed by the Commission, the NRC staff is developing options for regulating fusion technologies while enabling research and development in the eventual safe commercial deployment of fusion energy. To that end, the NRC staff established a fusion energy system working group consisting of a diverse array of agency staff. Two members from the Organization of Agreement States were included in the working group to provide insight into the states' current experience with licensing and regulating fusion activities.

The working group's insights are reflected in the NRC staff's September 2022 white paper, which the staff issued to inform discussions with the Advisory Committee on Reactor Safeguards and to gather feedback on potential regulatory approaches for fusion energy systems. Based on feedback received on the white paper, the NRC staff continues to refine these options and our supporting rationale.

For example, the NRC staff is developing a detailed analysis of whether and when a fusion energy device should be considered a utilization facility as defined in the Atomic Energy Act, and is assessing past mission decisions where non-reactor technologies were determined to be utilization facilities.

The NRC staff is also evaluating whether any legislative changes or additional statutory authority are needed or desirable to facilitate an appropriate regulatory framework for fusion energy systems. This thinking and other changes that address the valuable feedback from the Advisory Committee on Reactor Safeguards will be incorporated into a notation vote paper that the NRC staff will provide for the Commission's consideration by the end of this year. Next slide, please.

On this panel, you will hear from Andrea Veil, who will discuss the NRC's development of a regulatory framework for fusion energy systems, Duncan White, who will give an overview of fusion technologies under consideration, and they're associated risks and hazards. Andrew Proffitt, who will discuss the options developed by the NRC staff for licensing and regulating fusion energy systems, and finally, Dr. Joseph Staudenmeier will provide an overview of the NRC staff fusion research activities and our efforts to ensure the NRC's continued readiness to efficiently license and regulate fusion energy systems.

I'll now turn the presentation over to Andrea.

MS. VEIL: Thank you, Cathy, good morning, Chair and Commissioners. The NRC's principles of good regulation including independence, openness, efficiency, clarity, and reliability anchor us in accomplishing our safety and security mission. These principles have guided our decision-making and helped us to adapt to evolving landscapes for fusion technology.

This morning I'll discuss how we incorporate Commission and Congressional direction and leverage insights from the current regulatory treatment of fusion research and development activities. These insights reflect both domestic and international perspectives and assisted the NRC staff in developing actions for licensing and regulating fusion energy systems. Next slide, please.

The NRC staff is currently preparing a recommendation for a regulatory framework to support commercialization of fusion energy systems. In 2009, the Commission asserted regulatory jurisdiction over commercial fusion energy systems whenever such devices are significant to the common defense and security or could affect the health and safety of the public. However, they directed the NRC staff to wait until commercial deployment of fusion technology became more predictable before expending significant resources on developing a regulatory framework.

In 2019, NEIMA directed the NRC to complete a rulemaking to establish a technology-inclusive regulatory framework for advanced reactors including fission reactors no later than December 2027. For advanced fission reactors the NRC staff is well on its way to developing this framework with the 10 CFR Part 50 rulemaking. We remain on track to provide the draft framework and proposed rulemaking package for the

Commission consideration by February 2023 and to issue the final rule by mid-2025.

Consistent with the Commission's direction on the Part 53 rulemaking plan, the NRC staff is developing options for fusion regulation as a separate effort to ensure predictability and reliability. Our progress is consistent with the maturity and readiness of the technologies. Following a Commission decision on the notation vote paper on fusion and consistent with NEIMA, the NRC staff plans to develop the regulatory framework for fusion for near-term fusion energy systems by the end of 2027. Next slide, please.

To date, fusion research and development in the U.S. has largely been carried out under the purview of the Department of Energy. Additional research and development has been performed under the jurisdiction of the agreement states using authority assumed through their agreement with the NRC or their general authority.

The NRC staff has been engaging DOE to understand the operating characteristics and treatment of fusion energy systems under their purview. The NRC staff is also learning from DOE's international activities including its collaboration with 35 countries on the international thermonuclear experimental reactor, or ITER, located in France. ITER, which is pictured on the left, will be the world's largest fusion experiment when completed.

The NRC staff also closely coordinates with the agreement states to gain valuable insights based on their experience regulating private and academic fusion research and development facilities under programs compatible with the NRC's regulation for byproduct materials.

Pictured on the right is Commonwealth Fusion System's SPARC facility that is currently under construction in the Commonwealth of Massachusetts. Both ITER and SPARC are Tokamak designs; however, SPARC and the planned commercial version, ARC, are significantly smaller in size than ITER.

Additionally, the fusion energy systems working group that Cathy mentioned engages in extensive discussions with the broad spectrum of stakeholders, including technology developers, national labs, and industry groups. The working group also cooperates with a wide variety of international regulatory partners to share technical and legal insights, good practices and lessons learned for mutual benefit and experience. Andrew will discuss our stakeholder engagement in much more detail.

Consistent with the NRC's approach to evaluating safety for advanced fission technologies is essential to appropriately consider the significance of fusion technologies to public health and safety and common defense and security, and to apply an appropriate regulatory framework commensurate with the significance of the risk and their hazards.

Fusion technologies could be safely regulated through a utilization facility licensing framework, byproduct materials framework, or hybrid approach of the two depending on the significance of the risk and hazards posed by the particular design.

Throughout our outreach efforts the NRC staff has learned that designs and technologies have evolved substantially from the concepts considered just a few decades ago. The NRC staff believes that near-term designs based on their operating characteristics, anticipated material possession, and associated radiological hazards could be appropriately regulated under a byproduct material framework. However, as the fusion energy industry further matures, designers may develop fusion energy systems that have new or greater hazards than near-term concepts and may be more appropriately regulated as utilization facilities.

Thank you and I will now turn the presentation over to Duncan White, who will provide more detail on the technologies, risk, and hazards of fusion energy systems and get some water.

MR. WHITE: Thank you, Andrea. Good morning, Chair and Commissioners. This morning I'll provide an overview of the diverse near-term fusion energy system concepts discussed and associated hazards, which differ from operating fission power reactors, and the potential for using NRC's byproduct material framework as the foundation for the regulation.

The NRC's byproduct material framework is well suited to address the hazards at proposed fusion facilities based on the expected operating characteristics, material possession, and accident sequences at these facilities. Next slide.

As you heard in the first panel, the fusion industry believes recent technological breakthroughs will enable demonstration of the feasibility of fusion energy in the mid-2020s and support deployment of commercial fusion energy systems in the 2030s. While there is no generic fusion power-plant, the NRC Staff has a practical understanding of the major fusion technologies, including most near-term concepts and variations across different developers.

The NRC considers both commercial and research and development fusion energy systems that are currently contemplated for near-term deployment during the development of options for a regulatory framework.

While fission splits heavy elements such as uranium-235 into two smaller elements releasing energy and neutrons, fusion combines two low atomic number elements or particles releasing energy along with charged particles and neutrons. Fusion energy systems can produce tritium, neutrons, and neutron activation products that need to be properly contained to protect public health and safety. There are several different technologies being commercially pursued for fusion energy systems. These technologies can be grouped into three general plasma confinement approaches, magnetic, inertial, and magneto-inertial confinement. These methods generally seek to create an environment with adequate density, temperature, and energy confinement, time to enable sufficient fusion reactions to produce a net energy gain.

Most designs used the deuterium-tritium, or DT, reaction because it has historically been seen as the easiest path to an energy production breakeven point. However, some fusion technologies may use aneutronic fuels such as proton, boron-11, or deuterium-helium-3. While aneutronic fuels do not produce neutrons as part of their reaction, they do produce radiation including neutrons produced in secondary reactions. Therefore, commercial devices are expected to require shielding and barriers to radiological releases to protect public health and safety.

With magnetic confinement, a high temperature, light nuclear fuel plasma is contained by a strong magnetic field using superconducting magnets within a vacuum vessel. They operate in a steady-state mode with only a fraction of the size of the tritium inventory present in the plasma within the vacuum vessel at any one time. A large portion of the tritium inventory will typically be in the tritium handling system where the tritium is recovered, processed for injection, and stored.

The Tokamak magnetic fusion approach has historically been the focus of most research and development within the fusion energy community and has been the most studied. With inertial confinement, a capsule of light nuclear fuel is compressed by laser beams or other means within a chamber to increase the density and heat the material.

Although the general conditions for releasing energy from the fusion energy system are essentially the same for inertial confinement as for magnetic confinement, inertial designs require higher plasma densities than magnetic designs because the energy confinement time is much shorter.

Finally, the magneto-inertial confinement designs involve some combination of magnetic and inertial approaches. Generally, these designs use magnetic fuel to combine and initial plasma that is then compressed and heated directly to fusion conditions.

Both inertial confinement and magneto initial confinement designs are pulse-powered designs that seek to achieve energy gain on each pulse. Given the diversity of designs, a technology-inclusive, performance-based approach to fusion energy system licensing and regulation is critical. Next slide, please.

Understanding the hazards associated with proposed fusion energy systems is a key component in applying the appropriate regulatory framework that is commensurate with the risk they pose to public health and safety. Although several concepts have been around for decades, near-term designs have evolved and so has our understanding of the risks.

The designs being pursued for commercialization are smaller than the large Tokamak concepts that had been the focus of international government back fusion programs such as ITER.

While many studies of fusion technologies over the decades have evaluated the potential risks of these larger historical designs, the NRC staff has been careful to focus its attention on the current state of the technology.

There have been advances in plasma physics, superconducting magnets, high-powered lasers, and computer capability. These advances have and are expected to continue to enable the design and operation of fusion energy systems with less fuel and with better control of the plasma as compared to historically studied systems.

Changing inventories, particularly active inventory in the fusion device, are expected to be smaller. For example, historical designs are expected to have an active tritium inventory of approximately 1 kilogram, while near-term commercial designs are expected to have active inventories of less than 100 grams.

The quantities of activation products in near-term commercial designs are also being addressed to the development of structural materials with lower neutron cross-sections; therefore, while historical references are important to consider, near-term concepts are expected to be of lower radiological risk based on different designs, structural materials, and inventories of radioactive materials.

The most significant radiological hazards are driven by the inventories of reactor materials at the site, radiation produced during the operation and thus produced in the vacuum vessel. This includes tritium and neutrons from fusion reactions, activated components including dust, and gamma emissions. Confinement of these materials and shielding of the radiation are key areas of focus for protecting workers and the public.

The characteristics of the tritium produced or held on-site are important for radiation safety purposes. Tritiated water, gas, and dust particles can be present, contribute to the source term for potential offsite exposures, and must be tracked and monitored. Tritiated water and gas can be readily absorbed into the body and components, including metals. Components activated by neutron bombardment must be managed appropriately. Activation products and facility components will depend on the specific materials being used.

The quantities of activation products will build over time, which will increase the reactor material inventory. Dust which may contain tritium and activation products and be chemically reactive is generated in the vacuum vessel by energetic plasma surface interactions.

Like activation products, dust will build up over time. These activated components and dust can have implications for certain accident progressions, waste disposal, and decommissioning, and will influence financial assurance requirements.

Fusion energy systems also have non-radiological hazards which are design independent. The NRC staff will evaluate these hazards and their ability to impact radiation safety during routine operations and accident scenarios. Some non-radiological hazards including high magnetic fields, thermal shock from plasma disruption, loss of vacuum, hydrogen and dust explosions, chemical hazards, cryogenic releases, and high-powered lasers. The NRC staff will coordinate with other federal and state regulatory agencies to ensure oversight of these hazards. Next slide, please.

As discussed on the previous slide, the radiological hazards associated with near-term fusion energy systems are expected to be driven by the possession and use of byproduct materials such as tritium. As such, the NRC staff is considering the potential for NRC's byproduct material framework to serve as the foundation for regulating fusion energy systems. This framework is currently used to safely regulate fusion research and development and some commercial activities.

Materials made radioactive by particle accelerators is considered byproduct material if it is used for commercial, medical, or research purposes. Fusion devices operate in a similar manner to particle accelerators, as they create conditions conducive to fusion reactions by accelerating charged particles through electromagnetic interactions in a vacuum and discharge the resulting particle and other radiation into a medium. These characteristics are consistent with the regulatory definition of particle accelerators and therefore, the reactor material produced by fusion devices could be considered byproduct material.

Additionally, the NRC's byproduct material framework is suitable for licensing and regulation of fusion energy systems from a technical standpoint. It is scalable, technology-neutral, and capable of addressing a broad array of fusion energy systems and their hazards.

The NRC's byproduct material framework includes high-level licensing that address design, safety, and security considerations relevant to fusion energy systems including emergency planning, financial assurance, decommissioning, physical security, training, facility design, radiation safety, and environmental protection.

Many features of the proposed fusion energy systems have been successfully regulated under NRC's byproduct material framework or are analogous to devices or a facility regulated by the NRC in agreement states using a byproduct material approach. Several planned fusion devices will use or produce tritium which the NRC and the agreement states have a long history of regulating, including large quantities as byproduct material. Devices that produce neutrons using the DT reaction for neutron generators, explosive detection, and well logging have been regulated under NRC's byproduct framework for decades.

It's important to note that while the NRC's byproduct material framework is protective of workers and the public for a wide range of uses of reactor materials, it may not be appropriate for the commercial fusion energy systems with different risk profiles or higher hazards than the proposed near-term concepts.

Separately, most designs which use aneutronic fuel may only generate reactor materials incident to their operation and may not meet the current definition of byproduct material. Without amending the Atomic Energy Act, the radiological hazards and fusion concepts using aneutronic fuel would fall outside of NRC's jurisdiction and reside with the states.

I will now turn the presentation over to Andrew to give an overview of the options for licensing and regulating fusion energy systems developed by the NRC staff.

MR. PROFFITT: Thank you, Duncan, and good morning, Chair and Commissioners. This morning I'll provide an overview of our stakeholder engagement on this topic, discuss options for licensing and regulating fusion energy systems, and detail how the NRC staff is evaluating these options to make a recommendation for the Commission's consideration.

As Andrea mentioned, the NRC staff has determined that fusion technologies can be safely under a utilization facility framework, byproduct material framework, or a hybrid approach leveraging both frameworks. Next slide, please.

The NRC staff has proactively engaged stakeholders over the last 18 months to inform the development of these options. Through our engagements, the NRC staff sought to better understand the state of fusion energy technologies, projected pathways and schedules for commercialization, and the potential risks and hazards associated with these systems. We also solicited stakeholder perspectives on the appropriate regulatory framework for the NRC to employ.

Some examples of this extensive outreach include six NRC-staff-led public meetings; a joint public workshop sponsored by the NRC, the Department of Energy and the Fusion Industry Association; the NRC staff participation in the White House Summit on developing a bold decadal vision for commercial fusion energy and the follow-on DOE workshop; international engagement through bilateral interactions and IEA activities. We coordinated with the organization of agreement states and, as mentioned, included agreement state representatives on the NRC's fusion energy system's working group.

We also held technology introduction meetings with private companies seeking to commercialize fusion energy and conducted three briefings on the Advisory Committee on Reactor Safeguards. Next slide, please.

Informed by stakeholder feedback, the NRC staff has developed three options for licensing and regulating fusion energy systems that are consistent with Commission and Congressional direction.

These options include a utilization facility approach, a byproduct material approach, and a hybrid approach that would introduce the decision criteria based on the potential risks and hazards to determine whether a specific concept should be licensed and regulated under a byproduct material or utilization facility regulatory framework.

The first option would treat all fusion energy systems as utilization facilities. To do this, the NRC staff would initiate a rulemaking to develop a single new regulatory framework to specifically address the hazards and risks posed by fusion energy systems, separate from NRC's current utilization facility frameworks.

As part of evaluating this option, the NRC staff is assessing whether currently contemplated fusion devices meet the definition of utilization facility in the Atomic Energy Act by making use of atomic energy in such quantity as to be of significance of the common defense and security or in such a manner as to affect the health and safety of the public.

The NRC staff's current analysis of near-term fusion energy systems indicates that these systems are unlikely to meet the common defense and security criterion of the Atomic Energy Act definition of utilization facility. The NRC staff's analysis is based on our consideration of the potential for radiological sabotage, need for material control, or risk of proliferation. For example, near-term designs do not use, possess, or produce special nuclear material, nor can they be readily adapted to do so.

Additionally, tritium and fusion device sales and exports are not currently subject to domestic and international safeguards programs and do not currently appear on the trigger list associated with the Treaty on the Non-proliferation of Nuclear Weapons.

The NRC staff's analysis of near-term fusion energy systems also indicates that these systems are unlikely to meet the public health and safety criteria of the Atomic Energy Act definition of utilization facility.

The NRC evaluates potential impacts to public health and safety by assessing operational risk and accident risk. Radiological risk from operations is controlled for all NRC license activities through compliance with 10 CFR Part 20 and isn't a salient factor in determining if a fusion device is a utilization facility.

The NRC staff's analysis of accident risk and non-radiological operational risk is based on consideration of operating characteristics, potential offsite consequences, and the contribution of the device to the radiological consequences of potential releases.

As part of its analysis of near-term fusion energy systems, the following device characteristics were considered holistically to support the NRC staff's conclusions that these systems are unlikely to meet the public health and safety criterion of the Atomic Energy Act definition of utilization facility. Fusion devices will not use fissionable material and thus cannot achieve nuclear criticality, a self-sustaining chain reaction that requires positive means to stop.

Fusion devices are expected to immediately cease energy and radioactive material production during an accident scenario. Only the material and energy present at the initiation of the event are available to contribute to a potential release. As such, implementation of extensive safety systems to prevent significant continued production of energy and radiological material in accident scenarios is not necessary.

In the case of a total loss of active cooling, low residual heating precludes melting of the device's structures in a potential release and offsite consequences during credible accident scenarios involving the fusion device are expected to result in low doses to the public without the need for extensive controls on the device.

Given the lack of common defense and security considerations, the low potential offsite consequences, and the lack of significant contribution of the device to the radiological consequences of potential releases, fusion devices need not be broadly classified as utilization facilities.

However, given the flexibility of the statutory language in the Atomic Energy Act, the Commission could decide to classify fusion energy systems as utilization facilities based upon its own consideration of the statutory criteria.

To implement such a decision, new provisions would need to be developed to ensure appropriate prevention and mitigation of radiological releases, recognizing that fusion technologies do not pose the same types of hazards as fission technology currently licensed under NRC's utilization facility frameworks.

This could provide the NRC staff the opportunity to develop a holistic, technology-inclusive, risk-informed and performance-based regulatory framework to specifically address the unique hazards and characteristics of fusion energy systems.

However, categorizing all fusion energy systems is utilization facilities is widely viewed by developers, non-governmental organizations, and agreement state representatives as a burdensome option.

Categorizing fusion energy systems as utilization facilities would apply specific requirements in the NRC's regulations and the Atomic Energy Act. Examples of these include financial protection of the Price-Anderson Act, restrictions on foreign investment and ownership, mandatory hearings during the initial licensing process, specific export controls, operator licensing requirements, and prohibiting agreement state delegation.

These stakeholders also believe that a utilization facility approach would create regulatory uncertainty as the NRC staff initiates an extensive rulemaking to tailor a framework historically developed for fission reactors to the hazards posed by fusion technologies.

If the Commission decides that fusion energy systems do not meet Atomic Energy Act definition of a utilization facility, the second option for regulating fusion energy systems would employ the NRC's byproduct material framework.

If pursued, this option could build upon the licensing framework in 10 CFR Part 30 through a limited scope rulemaking along with the development of supporting regulatory guidance. This approach including references to 10 CFR Parts 30 through 39, 10 CFR Part 20 and other applicable parts of 10 CFR, could provide a broad scalable framework for regulating the use of byproduct material produced by fusion energy systems.

This approach has been successfully applied to current fusion activities by our agreement state partners and has historically been used to regulate radiological hazards from an extensive spectrum of uses of byproduct material, from low-risk portable gauges to higher-risk panoramic irradiators that contain millions of curies of cobalt-60.

However, larger higher-hazard commercial fusion energy systems that differ from the characteristics we have described may require exemptions, license conditions, or orders to appropriately regulate under this approach, and may ultimately be determined to be utilization facilities.

The final option is the development of a hybrid approach that could address the differences in potential radiological hazards associated with a wide variety of fusion technologies and designs. A hybrid approach would introduce decision criteria to determine the appropriate regulatory framework using either byproduct material or utilization facility approach based on the potential risks and hazards.

Such decision criteria could be developed as part of a rulemaking process with significant stakeholder engagement and would need to be grounded in the Atomic Energy Act criteria defining utilization facilities.

This option would provide a graded approach for addressing potential risks that could encompass the full range of possible commercial fusion energy systems.

This approach would apply the appropriate set of requirements to safely regulate a given fusion technology commensurate with its risks and hazards and would include criteria to transition from a byproduct material framework to a utilization facility framework.

A drawback to the hybrid approach is the potential introduction of regulatory uncertainty for designs that approach the design criteria.

To successfully implement this approach, the NRC staff would need to work closely with developers prior to the submittal of an application to affirm the appropriate licensing framework for a particular design.

In developing its recommendation to the Commission, the NRC staff is evaluating these options based on several key considerations including consistency with the Atomic Energy Act and Commission regulations and policy, framework scalability from current research and development facilities to expected commercial fusion energy systems, radiological and non-radiological hazards associated with operations and the radioactive material inventories for a variety of designs, ability to leverage requirements within existing regulatory framework that can legally and technically encompass proposed fusion energy systems and their associated hazards. And applicability and flexibility in certain programmatic areas such as financial protection under Price-Anderson, foreign investment, licensing process, and others.

I will now turn the presentation over to Dr. Joseph Staudenmeier to update you on the NRC staff's research efforts in preparing to regulate fusion energy systems. Joe?

DR. STAUDENMEIER: Thank you, Andrew. Good morning, Chair and Commissioners. I'm going to give a brief overview of our current and future activities to support the development of NRC capabilities to license and regulate fusion energy systems. Next slide, please.

There are many private companies pursuing fusion energy with a wide range of concepts and expected timeframes. Several have plans to demonstrate the feasibility of their designs in the next few years. As this happens, some fusion companies will shift their focus from demonstration to the task of engineering and designing safe and reliable commercial plants.

The NRC staff will establish an agile and responsive research program that stays current with the evolving technology to support the development of a technical basis for efficiently licensing and regulating commercial facilities. Our initial activities will focus on further enhancing our knowledge of the commercial designs to support the development of risk-informed and performance-based regulations and guidance.

Although there are many different proposed fusion energy system designs, there are important technical areas that are common between them. For example, most of the designs will require a system to process and purify tritium. They will also require radiation shielding and have materials performance considerations. Other areas that are important to consider include assessing potential accident source terms, operating waste streams, and decommissioning and waste disposal.

While the NRC staff has information about these areas, we continue to monitor changes that the industry may make as they scale up for commercial operations. Additionally, the NRC staff plans to participate in the development, review, and possible approval of design codes and standards. These codes and standards will increase regulatory predictability and if applicants adopt them, could streamline NRC Staff reviews.

While we understand the hazards associated with the fusion technologies operating today, scaling up those technologies to commercial prototypes will introduce new systems with new technical challenges. The NRC staff will monitor the industry for those potential changes and respond in a timely manner to ensure that our expertise and analytical tools if needed are ready to evaluate the safety of larger commercial fusion energy systems. Next slide, please.

To do that, the near-term focus of the NRC staff is to develop additional expertise on fusion technologies. We intend to mirror the successful approach used for developing advanced reactor expertise. This includes developing and offering training in general technical areas applicable to fusion technology and technology-specific fusion design training for concepts approaching commercialization.

We are also conducting Agency-wide seminars to increase the NRC staff's knowledge base. The NRC staff held the first of these seminars on October 19th. That seminar provided a high-level overview of fusion energy systems, including basic physics of fusion reactions, fusion confinement schemes, technical areas of concern for regulation, materials issues, and environmental regulation considerations.

We recognize there is a wealth of knowledge on fusion outside of the NRC. As Andrew discussed, the NRC staff has held public workshops to collect input from stakeholders and we will continue to engage with the fusion community to leverage their substantial work and knowledge related to fusion. The NRC staff will also interact with DOE, the agreement state, university researchers, and the international fusion research and regulatory communities.

Finally, the NRC staff will continue to coordinate with the commercial fusion industry to understand detailed design information and deployment schedules as we develop a regulatory framework to license fusion energy systems in an efficient manner that protects public health and safety.

Thank you, I'll turn it back to Cathy Haney to wrap up today's presentation.

MS. HANEY: Thank you. As we've heard from both panels, it's an exciting time in the nuclear field as fusion energy continues to make significant technological progress towards becoming a viable energy source. The NRC staff has engaged stakeholders and is developing options for Commission consideration that reflect diverse viewpoints and address regulatory needs based on the state of the fusion energy industry.

We will look forward to your feedback on NRC staff proposal and direction to prepare regulatory framework for fusion energy systems. The NRC Staff will continue to prioritize stakeholder engagement while completing the regulatory infrastructure to support that direction.

In closing, I'd like to thank all of the panelists today, the NRC staff who supported preparations for the Commission meeting, as well as the NRC staff and agreement state representatives on the fusion energy working group. Our success would not be possible without them. Thank you again, Chair Hanson and Commissioners, for the opportunity to present today and we welcome your questions.

CHAIR HANSON: Thank you, Cathy. We'll begin again with Commissioner Crowell.

COMMISSIONER CROWELL: Thank you, Mr. Chair, and thank you to all of our panelists today for all the information you provided. Talking about a regulatory framework for fusion may not be as exciting as talking about the science and technology readiness of our first panel, but it's equally as important to get right. So, that's why everyone from the first panel stuck around. I think my first question is probably to Ms. Veil.

Can you, for my benefit, tell me from a safety, environmental, and public health risk perspective how currently proposed fusion energy facilities compare to advanced reactors, particularly non-light water advanced reactors?

MS. VEIL: Yes, you heard in the panel earlier and we stated it here too, fusion technologies and fusion energy systems don't use, possess, or produce any special nuclear materials. So, inherently, risks associated with that, hazards associated with that are expected to be lower because there's no special nuclear material.

For advanced reactors they're still using special nuclear material and they're still underneath the Part 50 or Part 52 framework because of the hazards that are associated and the whole framework that's built around new and advanced reactors. Whether they're close to current fission reactors or they're completely different, they're still using special nuclear material.

COMMISSIONER CROWELL: But if I understand it correctly, a fusion reactor could be nefariously used to create nuclear materials that cause a proliferation risk, is that correct?

MS. VEIL: I wouldn't characterize it that way because I don't think that fusion facilities could even easily be adapted to be nefarious. There's no triggers in terms of imports or exports, domestically or internationally, for fusion energy systems. So, they are fundamentally different. I don't know envision a scenario, I'm not an expert but I have not heard of any literature or any expectations that fusion energy systems could be modified for nefarious intent.

COMMISSIONER CROWELL: When a fusion energy system loses power, my understanding is that it's passively safe so to speak. But how does it come back online? It's not like you can just use diesel generators like traditional light water reactors. So, what happens in the event of power loss at a fusion facility from the perspective of grid stability?

MS. VEIL: I'll start at a high level and that may be a Duncan question, to give you some details on how they come back. But my understanding is if there's some type of accident with a fusion energy facility that the plasma reaction is just going to stop. I talk with my hands so I'm going to show you.

The plasma will collapse, the tritium that's inside of the fusion reaction is going to be a fraction of what's on-site, but the energetic possibility of even getting something offsite is going to be so much lower because you already have a small fraction of tritium and then the reaction stops. You don't need special engineer features to cool down that system. Now, in terms of coming back on mine, I'd have to pass that over to Duncan.

MR. WHITE: Yes, as Andrea said, the reaction ends within a few seconds. If you have a disruption, it will end. So, you would just have to go through the startup sequence again to start the system back up again. You would have to start all over again, you would have to create the plasma, you'd have to inject fuel into the plasma and achieve conditions. One of the things that would happen if there was a disruption, yes, you will have decay heat the system will have to calibrate.

Again, it's a complex industrial apparatus and it has heat involved with it that will dissipate. So, I would assume that they would have to reach equilibrium before they would probably start up again.

COMMISSIONER CROWELL: So in layman's terms is that hours, days, weeks?

MR. WHITE: That I don't know, it's very design-specific, I'll have to defer that to the developers.

COMMISSIONER CROWELL: As we think of fusion and fission from a low-carbon but also base load power perspective, it's important to know how long you're going to be without that base load if something should happen in the system.

I'm sure there's probably limited ability for a fusion system to go offline and that's probably the more important point, but anything can happen. And it's something to think about and be interested in more as we learn more on that point. Thank you, Mr. Chair.

CHAIR HANSON: Thank you, Commissioner Crowell. I think you raised a good set of questions. This connection to the grid, on the fission side we have this issue where if the secondary trips, we trip the primary in a lot of cases. Is there anything in a fusion energy system, whether you're talking about a DT system or some other thing, where it trips on the heat transfer side or the power generation side that then would impact the primary? From a safety perspective, not just from a flipping the switch perspective.

MR. WHITE: Like any complex system like this, complex energy system, you're going to have things that might trip the reaction. Again, to maintain the plasma in continuous mode is going to be a difficult thing to do. And again, there may be something that happens, it will trip. And again, what those causes could be, it could be a number of different things, sequenced things that could happen involving cooling or magnetics or something along those lines. There could be a number of different things and again, once you disrupt the plasma you lose your ability to generate neutrons, which in turn --

CHAIR HANSON: That's not considered to be safety-significant?

MR. WHITE: Again, these near-term systems that we've seen and studied, we have an understanding that they don't need special safety shutdown systems or require them to shut them down safely, they inherently will shut down by themselves.

CHAIR HANSON: Got it. So, one of the themes I think we heard in the first panel was the need for definitions and so how is the staff approaching that, either in the paper that we're going to see or subsequent to that?

MS. VEIL: So one of the things that you've heard in the first panel, and it's critically important, is to have clarity. So you've heard all of us say that these facilities could be regulated under a Part 30 framework, but Part 30, and neither does the Atomic Energy Act, have any definition that talks about fusion energy systems. It doesn't exist.

So getting those definitions in there are extremely important. There is also content about the applications. We are always trying to be as clear as possible and set expectations up front so applicants know what to provide for us. So all of that will be detailed in the SECY paper, but it's critically important, and you heard about limited scope rulemaking, we need definitions. So that would be a part and the content of applications will be a part of limited rulemaking.

CHAIR HANSON: Okay. Thank you. I think it was Mr. Desai who in the previous panel had mentioned this Part 35.1000, which I think was we just had a Commission paper on this for emerging medical technologies, if I am not mistaken, as a potential model. So given the recency of Commission action on that front I was kind of curious if the staff had any reaction or thoughts, maybe even preliminarily, about a framework for addressing new and evolving technologies.

MS. HANEY: All right, I'll start. I actually can go back to when 35.1000 came to be in Part 35 in the '80s.

CHAIR HANSON: Yes.

MS. HANEY: It really was for that reason that we heard, was there were a lot of new emerging technologies into place. It didn't fit into the existing Part 35 so the question was posed how could we create a regulatory framework to bring these technologies into play. It was exactly as described in an earlier panel. We would get applications in and we would start looking at them, deciding what we, you know, what as a regulatory agency we needed to have to move forward, to basically to issue that license such that we could go safely and we were assured of safety and security for the public as well as the workers.

So the same situation really could apply here, you know, as described philosophically is that, you know, it probably wouldn't be, it wouldn't be a 35.1000, obviously.

CHAIR HANSON: Right. Yeah, no.

MS. HANEY: But that aspect of we have technologies that is emerging, industry is learning, we are learning, we are all getting smarter every day, even, you know, if you go back to when we wrote the White Paper to where we are right now. We are learning more, we're getting more informed, and we want to apply that as we develop that regulatory framework. Then as you get more, become aware of what you need, like, you know, we start with guidance, and then you can move into a regulatory framework. So that model I think would be, you know, definitely worth considering and philosophically I think it can be applied here.

CHAIR HANSON: Okay, yes. Thank you. Sometimes adjacency is helpful as we think about these things rather than a complete blank sheet of paper, but I think that's been part of the theme here, too, is where does this fit into things we already know and things we know how to regulate, so I think that's important.

Cathy, I think you mentioned, and maybe in passing or very briefly, that staff is evaluating whether additional statutory authority might be needed under the Atomic Energy Act to facilitate the kind of appropriate regulatory framework. Do you want to kind of elaborate on that?

MS. HANEY: I think I am going to actually defer to either Andrea or Andrew who has been a lot more involved in the discussions than I have been, but it would be clearly something, a lot of discussion in that particular area and depending upon which path that we go down it adds clarity and transparency to where we are going. So, Andrea?

MS. VEIL: Sure, I can start. I saw Andrew raise, so he can add some detail as well. I mentioned earlier that the Atomic Energy Act has certain definitions in it. It doesn't say anything about fusion energy systems, but on the other hand it's also very prescriptive about what a byproduct material is. You heard it in the panel earlier. It talks about material that is made radioactive and used for either medical, commercial, or research.

So if it doesn't fall into that framework, like you heard Duncan mention about aneutronic devices, it's incidental energy that is produced and that energy may not be used for anything commercial or research or medical.

So then that falls outside the jurisdiction of the NRC because of a definition. So that could be easily, well I'm saying easily, but theoretically that could be revised.

We talked about Part 30, just a few minutes ago, of how the definitions need to be in. Similarly, if we could make a recommendation for a legislative change it would make it that much more clear that fusion fits into the framework because, again, it doesn't, there is nothing that talks about fusion energy systems.

MR. PROFFITT: Yes, and I will just add I think Cathy and Andrea said it well, but also with regard to the classified fusion energy systems as a utilization facility you would still run into this issue because the Atomic Energy Act current definition has for byproduct material a criteria for material that's made radioactive through the use of special nuclear material.

So that's what brings in material that is made radioactive at commercial fission reactors. So you would still, the change would still be desired to ensure all this material was brought under NRC, clearly under NRC jurisdiction, regardless of which framework you went under. So it's not only a byproduct material issue, it would be also classified as utilization facilities.

CHAIR HANSON: Okay. Thank you. Yes, I appreciate the discussion this morning and the staff panel and I appreciate the constructive approach that kind of everybody is taking to kind of this reasonably complex set of problems. I think it's really incumbent on us as an agency that we are not an impediment to kind of technological innovation in this area while we uphold our safety mission, you know.

You guys hear me talk a lot of about chicken and egg problems, you know, fusion has a lot of the same ones that, you know, deployment of new fission does and I do think it's incumbent upon us as an agency to, you know, address those chicken and egg problems within our purview as much as we can, as expeditiously and clearly as we can, so thank you again. Commissioner Baran?

COMMISSIONER BARAN: Thanks. Well, I wanted to start asking about a different but related definitional question actually, which is on particle accelerator. In the White Paper the staff did, the staff raised the concern that some fusion designs might not meet the definition of particle accelerator, which as I understand it is really determinative of whether or not you could use Part 30 as written for a particular design.

Can you all talk a little bit about that? What kinds of designs might fall out of that definition? Are those ones that are being thought about in the near term?

(Simultaneous speaking.)

(Laughter.)

MR. WHITE: I'll start. I think with regard to -- I think we have touched a little bit about this already about particle accelerators and byproduct material because they are both, you know, for proprietary, they are tied together, tied together, and I think we have talked, we've had discussion, talked a little bit about why it's important that the definition of particle accelerators have to be used for commercial, medical, or research purposes and we've talked about, you know, the limitations associated with that.

One of the key things that may happen with that definition and why particle accelerators, you know, inherently may present a challenge there is that the, for like particularly with aneutronic fusion you may think the production of radioactive materials is not needed for, it's incidental to the overall reaction, it's not needed for the direct reaction.

Because of that it's -- So it doesn't meet the definition and because it doesn't meet the definition it provides a potential regulatory gap and this is why we have been, you know, talking about them, maybe the need to address the Act, change the Act, because if it's in the Act we can't fix it by regulation, obviously.

So that's really part of where we are coming from with regard to why that is. And, again, particle, you know, as I said, when the rulemaking back in, you know, for the Energy Policy Act and then the subsequent rulemaking in the mid-2000s we weren't thinking about fusion devices at that time. So it wasn't on either the Congress' mind or the staff that developed the regulations, oh, we shouldn't have to incorporate fusion devices into the regulatory, you know, framework and sort of trying to, so now we're left, you know, several years later trying to see how we can fit that in.

COMMISSIONER BARAN: Okay. Option 2B in the White Paper talks about a limited scope rulemaking, which we've talked about quite a bit, to explicitly address fusion in Part 30.

Can you talk a little bit about what the content of that rule would look like? Is it purely -- Is that just basically the definitions and content of application-type issues or is there something beyond that that the staff is contemplating when they think about Option 2B?

MS. VEIL: It is mainly the definition because no matter what framework we choose the definitions are important. So that limited scope would be definitions and then specifics on content of application. That really is the main focus of that limited scope.

We may pull in other things that are more minor, nothing, you know, monumentally different, but if we're going to open it up and do a limited scope we might as well get all of this clarity in there, but not anything that's beyond just clarification.

COMMISSIONER BARAN: Okay. And when you are talking about content of application does that get at, you know, what would be required for a safety analysis for the hazard specific to fusion, is that part of content of application when we talk about it that way?

MS. VEIL: We weren't contemplating getting that specific in the limited rulemaking.

COMMISSIONER BARAN: Okay.

MS. VEIL: It would be more so the definitions, content of application, and then we'll probably get to this later, but I'll go ahead and introduce it now, that if we were then talking about a hybrid approach what would be design criteria to kind of trip that threshold.

Those are the types of things that we would think of in a hybrid approach, but for Part 30 itself it's the definitions and the content of applications not specific to safety hazards and things of that nature.

COMMISSIONER BARAN: So just to clarify, so if we were talking about, let's put aside hybrid for a minute and just talk about kind of Part 30 and a limited scope rulemaking on Part 30 for more of a fusion module there, would there be clarity provided in such a rulemaking about what would need to be shown on a safety analysis or is that simply not relevant for Part 30? I would think it would be, right. You'd have to -- Whether it's tritium or whatever the other hazards are, activated material, to provide some real certainty and predictability to potential applicants about what do you need to show on those in an updated, you know, Part 30 approach.

MS. HANEY: I think it's more likely you're going to see that in guidance development.

COMMISSIONER BARAN: Okay.

MS. HANEY: You know, because typically in the rule if we're putting anything into a rule about what needs to be in a license application it's at a very high level. But really what the end users, including our staff, are interested in the guidance, the examples of what we are looking for, again recognizing there is a difference between guidance and a rulemaking, but I think that level of detail you would see more in guidance.

COMMISSIONER BARAN: Okay. Yes?

MS. VEIL: And I would just add to it at this phase it may not even be very prescriptive guidance, because remember we're kind of focusing on the near-term. To get to the type of analysis for maybe future fusion energy devices, we would need more certainty, more time, more operating experience, what have you, before we try to put out something that prescriptive, but we're not really concerned about that for the near-term devices.

COMMISSIONER BARAN: Okay. Yes, when we talk about near-term, I think on the first panel both Commissioner Caputo and I were trying to get at this a little bit, you know, what are you thinking about in terms of timing? What is the timing you are envisioning for a limited scope rulemaking if we went down that path?

MS. VEIL: So if we went down the limited rulemaking path we're looking at about 18 months to get something in place for limited scope.

COMMISSIONER BARAN: Okay. Eighteen months for a proposal or --

(Simultaneous speaking.)

MR. PROFFITT: I was just going to add we're --

COMMISSIONER BARAN: That sounds so suspiciously short.

MR. PROFFITT: So we're certainly on the clock with NEMA to provide something by 2027. So the different paths we have looked at for the different options we have assessed, you know, how we could get to that point over the next several years. But certainly that's our goal is to meet the NEMA requirement of having a framework in place by 2027.

COMMISSIONER BARAN: Okay.

MR. WHITE: Yes, and that would include both rulemaking and guidance. Guidance, you know, would you have to be developed in parallel with any rulemaking. Guidance could be probably done quicker than the rulemaking if it was done by itself. That could be our 18, that in itself might be about 18 months just to do the guidance.

COMMISSIONER BARAN: Okay. Well, and that sounds like, 18 months sounds like more in line with potentially folks coming in to start pre-application discussions, right, to have that guidance in place. That's how you are thinking about that?

MR. WHITE: Yes. In fact, with regard to guidance and reviews if we use the byproduct materials framework we have a good template in place with NUREG-1556, you know. It's scalable to a wide range of different uses from gauges up to panoramic radiators, there is particle accelerators in there, so there is plenty of basis to get started with and thinking we would pull in other, you know, guidance as needed, you know. There is separate decommissioning guidance and different NUREG and stuff like that, so it certainly would provide a good starting point to do that and it's very comprehensive, too.

COMMISSIONER BARAN: Okay. Well, and Joe talked a little bit about this in his presentation, but let me ask about NRC's capabilities and expertise when it comes to fusion.

Historically we haven't really focused on fusion because we have only ever licensed fission reactors. This is a broad question, but I'll ask it. It's the kind of thing you can answer in two minutes, I think.

(Laughter.)

COMMISSIONER BARAN: What technical expertise do we have now, what expertise do we need and when do we need it?

MS. HANEY: All right, I'll start with that one. So what we need is we're really looking at the engineering fields, the structural, the electrical, and the materials, the chemical, health physics, nuclear engineers. That's if I just do a very broad brush on what sorts, or what are the big, you know, kind of the big hitters, and then there is, of course, a subset under that.

We do have those skillsets in house right now. They have been working on the project. Today you have heard what's going on in research. We have been involved with research. We have been involved domestically, as well as internationally, the different engagements. We have been working a lot in this area. Moving forward we probably need the same type of skills, but, you know, do we have those skills right now, do we have a gap.

I think, again, we are continuing to learn. Given the engagements that we have. I don't think there are any specialties we need to go out and hire or retain right now. Obviously, you know, I might give you a different answer in 2027, but for right now I think we just need to continue to grow the skills that we have right now, the individuals that we have right now, and make sure that they are getting the experience in fusion that we'll need them to have going forward.

COMMISSIONER BARAN: Okay. Well, thank you all for today's discussion. I thought it was good. Thanks for the White Paper. I am looking forward to the upcoming Policy Paper, and I know you are all hard at work at that, so thanks.

CHAIR HANSON: Thank you. Commissioner Wright?

COMMISSIONER WRIGHT: Thank you. Thank you very much. Good morning, or good afternoon, to each of you and thank you for your presentations.

This is a lot of information and there has been a lot as you know going on and I am trying to kind of get things in the right order perspective and understand where things really are.

So, you know, you had the White Paper that came out in September. It was widely reported in the Trade Press and it even felt like you had kind of settled on maybe an option or a direction.

You've had numerous drop-bys and conversations and meetings with, you know, people internally and externally where the White Paper was concerned and there seemed to be general alignment, you know, with what had been reported in the Trade Press and with the conversations that the staff seemed to be aligned with the external stakeholders and some others as well on that and then we had the staff's response to the ACRS letter of yesterday.

So I am trying to understand just a little bit more. The conversation that you had here with Commissioner Baran was really good. That helped put some of that in some perspective, too.

So a couple things. One, can you speak a little bit about where you really are right now regarding this decision, okay, and which option to go, what framework to go, how to do this. Then, I am also wanting to understand, based on what I heard in the first panel there is a need to get the basic stuff done now so that they can get involved in pre-application and they can get moving on some stuff.

But then they are going to have to know at some point certain here that it's going to be under Part 30 or Part 3X or Part whatever, you know, because once you get, if you start mixing, as I heard in the first, you mix Part 30 and then you go to Part 50, you know, that you're changing the rules of the game, right. So kind of speak to me a little bit about where you are right now on that on everything.

MS. VEIL: Sure. I can start and then others may want to add as we move forward. So Cathy kind of mentioned this earlier. First of all, I'll say what the first panel said, we appreciate ACRS' thoughtful consideration of this topic.

So I will be very clear on the things that we agree with and the things that we have disagreements with. The NRC staff and ACRS both agree that near-term, either, you know, facilities that are research or facilities of that nature, no question, they could be regulated under a Part 30 framework, right. We also agree that there may be a threshold of where a fusion energy system is no longer a byproduct facility, it's a utilization facility. Where we disagree is what that threshold may be, right.

However, what you have heard today, Cathy mentioned it, the panel mentioned it, I mentioned it earlier, for the near-term fusion energy facilities that we have been studying for two years, that we have information on, and that we have been coordinating with our Agreement States, international partners, IAEA, we don't have concerns with the near-term fusion energy systems that with some tweaks, as you've heard for Part 30, that they could be regulated under a Part 30 byproduct material framework.

COMMISSIONER WRIGHT: Right.

MS. VEIL: But you also heard from our Agreement States speaker, who spoke very eloquently about this, we don't know what we don't know. We have an opportunity here. If we are going to go forward with rulemaking, we can also have an approach that sets a framework, as you heard Sachin say, that later could be scalable. What Part that comes under we need to really assess that and look. But we have near-term and we have what comes in the future.

Certainty is important for the near-term. You've heard a number of us say for near-term we don't have concerns about risk, we don't have concerns about common defense and security, proliferation, the kinds of import/export things we talked about earlier.

So the certainty in my opinion is there, but that doesn't mean that if there is something that has a higher risk, higher hazard, or some design that comes down, you know, in the future that we can say definitively right now that it will never be a utilization facility.

COMMISSIONER WRIGHT: Right. So I guess -- And you've gone to where I wanted to go a little bit. So if I understand right, if we go to a limited scope rulemaking, right, you're going to try to address these things early on some of this stuff and when you get to the more complex stuff or changes in design or changes in materials or changes in whatever comes down the pipe later, you're not going to hold things up and put it under one rule. You're looking maybe at doing a dual path, am I correct there?

MR. WHITE: Right.

COMMISSIONER WRIGHT: Okay. That's --

MR. WHITE: Right.

COMMISSIONER WRIGHT: Okay.

MS. VEIL: Yes. And I would characterize it even further to say that we would have specific decision criteria so that we're not making it up at the time when we get those applications.

COMMISSIONER WRIGHT: Right.

MS. VEIL: We're trying to have that certainty up front, but, again, we're not concerned about near-term fusion energy systems.

COMMISSIONER WRIGHT: Right. That's very helpful. Thank you. It brings a little clarity to me. Andrew, do you got anything to add to that?

MR. PROFFITT: Well, I was just going to add, you know, and if fusion succeeds, as I think many people hope it does, I don't think this will be the last Commission meeting or the last Commission paper on the topic.

COMMISSIONER WRIGHT: Correct.

MR. PROFFITT: I mean if we have a fusion energy industry in this country, you know, we'll be actively engaged and then, well, probably half that book maybe about fusion.

COMMISSIONER WRIGHT: Yes.

MR. PROFFITT: So I think starting now and focusing on near-term and given that certainty and meeting, sort of meeting the technology where it is and continuing to grow that framework that it is currently regulated under probably makes a lot of sense.

COMMISSIONER WRIGHT: Yes. And based on what we heard two years ago versus what we are hearing today, it's light years, right. If they are truly trying to hit it ahead of schedule like it appears they are I mean there is a lot we got to do, you know. To Commissioner Caputo and Commissioner Baran's points, we need to, you know, the timing is really important for us to be, we want to be in front of this, right, I mean we certainly do. Thank you for that.

So, Duncan, just quickly for you, given that your Agreement State, you know, history and how well you, in your experience and working with our partners, do you have any additional thoughts to maybe what was added to what Megan talked about in the first panel at all?

MR. WHITE: Well, I think first I think I want to reiterate, you know, our engagement with the Agreement States has been valuable to, you know, get insights on the technology, you know. So they have been taking the lead on this and we really have learned an awful lot from them. As we work and develop options, you know, it was mentioned earlier, but we have had two State people on the working group, very, very helpful, very great input. We've had four government-to-government meetings. We've had actually talked to a number of different States and heard, you know, where they are with all this.

Again, many of them, you know, Megan mentioned earlier there is a limited number of States now actively engaged, but a lot of States are curious, you know, because it may, you know, be in their jurisdiction in the coming years and they want to learn more about it. So I think we've got some really good insights on that.

So I think in terms of – and we also -- I think there is a great deal of interest, you know, that Megan brought up and others, you know, we've heard from the previous panel about regulatory predictability.

One of the things that I think the State Representatives are really interested in is, you know, the NRC get involved and be involved with, you know, develop guidance for emergency plan, accidents, accident assessment, and emergency, all the things that, you know, that are kind of, it's like, we really don't have anything in this area. We need this type of guidance in place so we can have some level of certainty going forward with that.

And, again, and this is I think the last thing, that we need to continue engaging with them. Again, you know, whatever path we take forward they will be sitting, you know, in the room with us, you know, working on that guidance or working on that rulemaking in the future.

COMMISSIONER WRIGHT: Yes.

MR. WHITE: I mean that goes without saying, because, again, from a national perspective they have, you know, they are the experts right now.

COMMISSIONER WRIGHT: Well, thank you for that. Thank you so much, Chairman.

CHAIR HANSON: Thank you. Commissioner Caputo?

COMMISSIONER CAPUTO: Hi, there. Thanks again for all your work preparing for this meeting. This is a pretty exciting time for us in a topic like this that, as my colleagues have mentioned, we haven't spent a lot of attention on historically.

But I have to admit I am still struggling with a little bit of clarity here. So it sounds like what I am hearing from you is for the near-term technologies we can use Part 30, yes?

MR. WHITE: Yes.

COMMISSIONER CAPUTO: Okay. So then stepping beyond say the near-term, are the foreseeable technologies, technologies that we have heard about, studied, talked with, do we expect that those will also be able to fit under Part 30 or do we see some candidates that we think may exceed the bounds of what we can do under Part 30?

Because Andrea mentioned we don't know what we don't know and I am trying to figure out what we know because -- I am trying not to be comic here, but saying we don't know what we don't know really isn't much of a basis for doing what Andrew suggested, which is crafting a new rule by '27. So help me figure out what this middle ground is of the technologies that we are familiar with or know are out there and, you know, somewhat credible, not just ideas on the back of a cocktail napkin, but for the designs that we know are out there, are we seeing some that would challenge the paradigm of licensing under Part 30?

MS. VEIL: I'll start and then anybody else can chime in. So for what we have seen and what we have been engaging in in the last two years, all the literature, all the interactions that we have seen, we don't have concerns about the Part 30 framework.

However, if we didn't take this opportunity to look at some decision criteria that could be offsite dose, as our UK speaker said they are doing a bounding type of assessment because, again, they don't know what's going to come in the future.

If we didn't take this opportunity now, which as Andrew said, it could be refined later. We are doing this to be able to have the framework in place if we do get something that challenges that, but from what we have seen we don't see challenges at this point.

COMMISSIONER CAPUTO: So have we done the bounding assessment for Part 30 enough to know the technologies will fit within that bounding assessment or are you talking about a bounding assessment that is theoretical for technologies that we really haven't seen and haven't considered?

MS. VEIL: We have looked at the bounding assessment for Part 30 in terms of how we are going to move forward with some decision criteria. We are going to have more information in the Commission paper of how we are looking to do that, but in terms of something theoretical or going out to some other framework that's not what we are proposing.

We are proposing to have design criteria for anything that may be beyond that. I know that's not a satisfying answer, but that's -- We don't have concerns about the near-term technologies. That's about the best way I can put it.

COMMISSIONER CAPUTO: Okay. So in looking beyond the near-term technologies then, obviously I think we should be very focused on making sure that whatever we do is risk informed. Have you considered a graded approach like the integrated safety analysis used in Part 70?

MS. VEIL: Yes. And I know either Andrew or Duncan can provide more detail on what we considered.

MR. PROFFITT: Yes. So I think any framework that we were to build, you know, obviously I think we're talking about for near-term facilities proposing a limited scope rulemaking to bring them within Part 30 and learning that as we go. Certainly without any licensing experience or any operating experience or even, you know, maybe at this point a proof of concept of a design not happening for a few years now, I think the staff feels like it would be premature to set out and try to establish a full new framework to address fusion energy systems.

So I think that's part of our recommendation, bringing in -let's continue under Part 30. The current designs that we see out there can fit under a byproduct material approach.

There is not necessarily a technological limit to what Part 30 could do, you know. Right now it covers a broad spectrum from, Duncan mentioned, you know, low-risk portable gauges to a higher risk panoramic radio with a significant hazard.

So we don't see a potential unnecessary cap. The difficulty comes in when you are trying to apply fusion in the right place with the Atomic Energy Act that doesn't mention the word "fusion" within the Act. I think that's where the struggle comes into play and assigning it to a framework that neither one was built originally to accommodate fusion energy systems. One aligns well with the hazards and the materials and the types of equipment that is there at those facilities and that's where they are being regulated now. I think growing that framework and allowing it to scale as the industry matures and evolves could serve us well.

COMMISSIONER CAPUTO: So is the integrated safety analysis approach in Part 70 a possible option for doing that scalable graded approach?

MR. PROFFITT: I think so. I think we would certainly look at, you know, what we have done in Part 53, what we have done in Part 70, areas where we have brought risk information, and the ISA, as you mentioned, and bringing that into a framework as we develop a more full framework that would support a fusion energy industry.

COMMISSIONER CAPUTO: Okay. Thanks. I think that makes a fair amount of sense and that's certainly a technique or a process that we certainly have a fair amount of experience with.

Dr. Staudenmeier, I want to indulge my inner geek here for a moment. I have a research-related question. Obviously, the Office of Research has been conducting future focus research. This technology I think is probably a candidate for some of those efforts. I want to ask you in particular about something. I noticed an article last week from MIT on how they are using machine learning to anticipate turbulence at the periphery of the plasma.

I know Office of Research has been starting to look at AI. Is this, you know -- The most interesting engineering challenges are always at the periphery, which this is. Is this issue something that is important simply for the function of the machine or does this become, understanding this phenomena become important for us in regulatory decision making; and if so are you folks looking at the nature of how they are using machine learning here to better understand those phenomena at the edge of the plasma?

DR. STAUDENMEIER: Thank you. I have actually seen that article I think that you are talking about, or some version of it I've seen. I don't think we're really too interested in the plasma physics models, excuse me, but we are interested in the effects that the plasma can have on the material interfaces and generating of dust. Another thing I know people use AI for infusion is to try to prevent disruptions, which can cause damage to the first wall also.

COMMISSIONER CAPUTO: Mm-hmm.

DR. STAUDENMEIER: So that would be a possible accident initiator that we would have to consider if we were looking at a safety analysis. So there are applications I think that are related to us but maybe not directly the plasma physics but the consequences of the plasma physics.

COMMISSIONER CAPUTO: Okay. Maybe particle transport? I am thinking of just the interaction with the walls of the machine.

DR. STAUDENMEIER: Yes. Well, the type of particle transport we'll be more interested in other than the materials interactions at the edge and we'll be interested in experiments that are looking at that and how the plasma affects the edge and generates dust or possible melting of the first wall material.

COMMISSIONER CAPUTO: Okay. All right, fair enough. I am going to take a minute, since I have one minute, and just ask a quick question.

We focused a lot today on regulation and we focused a fair amount on safety. What we really haven't talked about much but Commissioner Crowell sort of broached the subject a little about security.

So, obviously, not really much in the way of safeguards considerations because there is no special nuclear material, but is there anything that sets physical protection differently for fusion energy devices than we would see for particle accelerators under Part 30? Are there any different considerations here for physical security?

MR. WHITE: I'll take a crack at that one. We did have discussions with NSIR regarding the physical security in fusion facilities.

As you know, Part 37 was developed for a very particular, for RDDs and Radiological Exposure Device, REDs, and there is IAEA literature out there and documents that do have a look at a broad breadth and include additional isotopes, including tritium. Again, tritium was never considered under Part 37.

So going forward and looking at a security standpoint we would have to, you know, start with what IAEA has and do that assessment, do that security assessment, with regard to what is going to be at these commercial fusion facilities and take a look at those and determine if we do need to have some sort of, you know, threshold values or something associated with that where physical protection is needed or something like that and we'll have to do that assessment.

Again, there is information just to get started with what we have to go through and do that assessment to come up with --

(Simultaneous speaking.)

COMMISSIONER CAPUTO: Okay. But considering the types of materials present in a lot of particle accelerators I assume this kind of a review would be risk informed based on --

MR. WHITE: Yes.

COMMISSIONER CAPUTO: Okay.

MR. WHITE: Yes.

COMMISSIONER CAPUTO: Thank you. That's all I have.

CHAIR HANSON: Thank you, Commissioner Caputo. All right, thank you, everyone for a very, very good discussion. Thank you again to our external panelists, very wide ranging and I think very informative and I really appreciate all of the constructive engagement.

And, as always, thanks to my colleagues for their insightful and thoughtful questions. With that, we're adjourned.

(Whereupon, the above-entitled matter went off the record at 12:27 p.m.)