UNITED STATES

NUCLEAR REGULATORY COMMISSION

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BRIEFING ON NUCLEAR REGULATORY RESEARCH PROGRAM

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THURSDAY,

MAY 30, 2019

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ROCKVILLE, MARYLAND

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The Commission met in the Commissioners Hearing Room at the Nuclear Regulatory Commission, One White Flint North, 11555 Rockville Pike, at 9:00 a.m., Kristine L. Svinicki, Chairman, presiding.

COMMISSION MEMBERS:

KRISTINE L. SVINICKI, Chairman

JEFF BARAN, Commissioner

ANNIE CAPUTO, Commissioner

DAVID A. WRIGHT, Commissioner

ALSO PRESENT:

ANNETTE VIETTI-COOK, Secretary of the Commission

MARIAN L. ZOBLER, General Counsel

NRC STAFF PANEL:

RAYMOND FURSTENAU, Director, Office of Nuclear Regulatory Research (RES)

RAJ IYENGAR, Chief, Component Integrity Branch, RES

JOHN NAKOSKI, Chief, Probabilistic Risk Assessment Branch, RES

HO NIEH, Director, Office of Nuclear Reactor Regulation

KIMBERLY WEBBER, Deputy Director, Division of Safety Analysis, RES

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

EXTERNAL PANEL:

DR. TODD ALLEN, Chair and Professor, University of Michigan, Nuclear Engineering and Radiological Sciences

DR. JEREMY BUSBY, Director, Reactor & Nuclear Systems Division, Oak Ridge National Laboratory

DR. JENNIFER UHLE, Vice President of Operations, Nuclear Energy Institute

NEIL WILMSHURST, Vice President and Chief Nuclear Officer, Electric Power Research Institute

P-R-O-C-E-E-D-I-N-G-S

(9:01 a.m.)

CHAIRMAN SVINICKI: And we will now open the Commission's meeting this morning and briefing on nuclear regulatory research programs. We will begin with a panel of external participants and have a brief break and then have a second panel of NRC staff.

So, I would ask the presenters and participants for the first panel to please come forward and take your seats.

And while you do that, again, I'll just say that the Commission this morning, will hear from the panelists on research topics, and then also the NRC Staff.

We do, as a Commission, hear, somewhat routinely, about the research program of the NRC in the series of examination and public meetings we have on various business line and project activities at the Agency, but the Commission today wanted to have a somewhat singular focus on research as an important, I think enabler, of many of the other missions that we are required to accomplish for the American people.

So, since the external panelists have had a moment to get themselves situation, let me just say that we will hear from four panelists. And I will, I think, introduce them all.

It's my intention to go in the order in which you are listed on the scheduling note that I think you all have seen, so, unless there's any other arrangement, I'll proceed in that order.

So, according to that, we would begin with Dr. Jeremy Busby, who is the director of reactor and nuclear systems division at Oak Ridge National Laboratory. And Dr. Busby, please proceed and welcome.

DR. BUSBY: Great, thank you. Thank you very much for the kind invitation to participate.

As you mentioned, I'm Dr. Jeremy Busby, I'm at Oak Ridge National Laboratory and the director of reactor and nuclear systems, as well as our fission research programs.

I'm excited to be here and talk a little bit about some of the high impact research at the national laboratories, in support of the nuclear energy.

Specifically, I'm going to focus on accident tolerant fuel developments, advance reactor concepts. And also touch on how we've been interacting with the NRC to support and accelerate the deployment of some of these technologies for improved safety, economics and reliability.

And I don't know if you have the slides in front of you?

CHAIRMAN SVINICKI: If you, we have them, and if you'll just give a verbal cue --

DR. BUSBY: Fair enough.

CHAIRMAN SVINICKI: -- they'll be brought up in the order --

DR. BUSBY: If we'll go to the next slide. Thank you.

The national laboratories, there's 17 of them out of the Department of Energy, have a unique role in energy research. They perform both basic and fundamental research. Basic that inspires applied topics as well as applied technology research that helps inspire basic energy research.

I think the real power here is combining the basic and applied, as I mentioned, to accelerate innovation, safety and efficiency.

We also collaborate and partner, as well as directly support the U.S. Nuclear Regulatory Commission, which provides us an avenue for cost and time effective research to make meaningful impacts.

Before I go on I have just a few examples I'd like to walk through. I want to mention, while I'm from Oak Ridge National Laboratory, there are 16 other national laboratories all doing important research, and I'll try and highlight some of those valuable partnerships.

If you'll go to the next slide please. Basic-to-applied research certainly has the power to advance and accelerate reactor technology, development and deployment.

And this is a serious of small highlights from the last couple of years at the national laboratories spanning light water reactors, and I'm going to start in the upper left, sort of work clockwise around, as part of the CASTLE program through DOE, establishing a core simulator, VERA, which is now accurately predicted CRUD induced power shifts in light water reactors.

There has been the redevelopment and reestablishment of the domestic capability test to perform loss of coolant accident testing within the U.S., which is essential to understand how cladding performs in the deployment of new accident tolerant clad materials.

There are new approaches that shorten the development and qualification cycle from material such as TRISO fuel particles in the development of accident tolerant claddings for light water reactor applications.

The example shown here is iron chrome aluminum alloy. I'll talk more about that in just a little bit.

The exploration and development and deployment of new weld repair technics to help remediate the nations aging spent nuclear fuel canisters, as well as demonstrations of advance coolants and advance reactor technologies.

Such as a chloride salt purification loop, which has now been built. And it enables us to make larger batches of salt for testing in development of validated models.

And if you'll go to the next slide. Molten salt reactors are indeed one of the more widely discussed and actively pursued concepts in the advance reactor sphere today.

Actually, there are four companies actively pursuing these new molten salt concepts. TerraPower, Terrestrial, Flibe, and Kairos.

And to date, the interactions between the U.S. NRC developers, stakeholders and laboratories have been positive in developing a common understanding and expectations.

For example, in recent months in a report was issued examining a gap analysis report, what data is missing for the deployment of these technologies.

There are new capabilities that have helped developers successfully develop and license MSRs, including design and licensing workshops.

Just last week there was a large workshop at Oak Ridge where stakeholders from industry, regulators, and labs met for two days to discuss and decide on common initiating events that could be used for safety analysis calculations.

We've also been working to develop MSR specific design criteria through different code groups and other key regulatory bodies. And I think these interactions are essential for continued development and assessment of these advance technologies.

If you could go to the slide please. It's also clear that modeling and simulation will be an important part of deploying these technologies. I should state, modeling and simulation in conjunction with experimental. These have to be validated codes.

Recently the national laboratories, specifically Oak Ridge and Sandia, have been partnering with the U.S. NRC to extend these codes, to attach them, to enable more detailed reviews of accident tolerant fuels, as well as into non-light water reactor spaces.

So, in the example I've highlighted here, the scale code, which is used for reactor physics, has been coupled with MELCOR code for severe accident analysis. And Sandia has also added the MACCS offsite consequence analysis.

And so, the coupling of these provides an opportunity to explore conditions, evaluate new technologies, such as accident tolerant fuel. And, again, these codes have to be validated to provide meaningful understanding, mitigation, as well as helping prevent other accident scenarios.

If you could go to the next slide. Again, highlighting the development of accident tolerant fuel, or accident tolerant fuels and claddings, the national laboratories have been working via DOE since Fukushima, to support and development low-TRL technology readiness level, to deployment through industry support. This doesn't have to take decades.

In the example I've shown an activity partnering ORNL and GE Hitachi, has taken a concept of accident tolerant fuel, so called FeCrAl alloy, iron chrome aluminum, from concept to the development of initial data, limited test reactor data, to its now sitting in the hatch plant in an actual operating LWR.

This cycle took less than six years and represents the first non-zirconium based fuel cladding inserted into an LWR in decades.

In parallel, we've developed the materials handbook, in collaboration with our partners at the U.S. NRC. And this provides a good avenue to help accelerate and deploy these accident tolerant materials in a faster pace.

If you'll go to the next slide. I also want to highlight that the national labs provide a forum to help develop some of the validation tools, if not direct reactor technology.

This is a brand new capability that I'm showing in this slide, actually only weeks old, where we've established a new so called mini-fuel experiment to help provide insights into high-burn up performance without the need for multi-million dollar, multi-decade experimental approaches.

In this case, a new testing capability. The very small capsule is in the upper center. And that will allow us to take small fuel particles, which if you can see the penny in the center, the tiny black dots lined up to the edge of it are the fuel pellets that went into this experiment. Miniature TRISO particles.

So it's placed in the high flux isotope reactor, radiated to high-burn up conditions. We then took the capsule into a hot cell and we're able to develop the first testing of its kind looking at fission gas release from such a small volume in such a short time frame.

We were able to establish high-burn up relevant data in less than a year.

These sorts of tools will help develop and validate our modeling and simulation codes. Again, leading to acceleration of licensing, validation and ultimately deployment.

And if you'll go to the next slide please. And if we take that forward and look at other industries and other areas, there are a lot of advance tools. State of the art has expanded.

New manufacturing technics, artificial intelligence, automated sensors and controls. These provide a new direction, an opportunity to expand what we can do in the state of what's possible.

In particular, the videos have shown are of 3D printed materials, in fact, I have several here that we're free to pass around, where between the advance computational tools and the ability to manufacturer shapes are no longer constrained to cylinders, spheres and plate materials. We can now do advanced topological shapes which maximize heat transfer, minimize accident scenarios and gaps and manufacturing defects.

The video in the lower center is an x-ray tomography scan of the smaller piece that's passing around. That is a hexagon that is silicon carbide 3D printed, filled with TRISO fuel particles and then backfilled.

That's not a simulation, that's an actual scan of every component and sub-millimeter resolution. We now have the ability to know where every defect is in ever component during its manufacture.

Reject them when they do not meet certain criteria, or feed them into a so-called digital twin where now we can apply performance models and predict failure on specific components and specific conditions. It's no longer a statistical approach.

These are new ways of doing things. They're not, there's a lot of work to be done to figure out how to qualify, validate and license these sort of materials and approaches in a nuclear framework.

This is also an opportunity to collaborate with industry, with the U.S. NRC, to identify gaps and adoption of these technologies and methodologies. And in fact, I know a new activity and partnership was just established in the last few weeks that we'll begin looking in some of these areas.

And so, if you go to the next slide. Let me just close. I've gone through a number of areas very quickly, but I think there are opportunities for science and technology research at the national labs, to continue driving new innovation and nuclear energy, advance designs, accident tolerant fuels, a wide range of other areas.

We can also explore state of the art technologies that may help further improve safety, efficiency and economy. And engaging with the regulatory partners is certainly welcome and mutually beneficial. Thank you.

CHAIRMAN SVINICKI: Thank you very much for that presentation. I was scribbling a lot of notes, it was very interesting. Thank you so much.

And next we will hear from Mr. Neil Wilmshurst, who is the vice president and chief nuclear officer of the Electric Power Research Institute.

And Neil has been kind of enough to return. We had him recently presenting on another topic, so thank you very much for being here today, and please proceed with your presentation.

MR. WILMSHURST: Again, thank you for the opportunity, and very glad to be back and help my friends in NRC research with this discussion.

If we move to the first slide please. Okay, the Commission are probably already aware, from previous discussions, about the breadth of EPRIs global participation.

This slide really shows the number of plants worldwide that we interact with. It's virtually 80 percent of the global nuclear commercial plants in the world are actually participating with EPRI.

Which is a wonderful business position for us to be in. But what does that actually tell us?

Actually, if you look into the backdrop, globally R&D resources are consolidating, are being shut down. And we need to make sure that the existing resources are maximized in effectiveness. And they're effective use of those resources is ever more important.

And what we're really seeing is the collaboration between research entities in nuclear is more and more important as these facilities do consolidate or disappear. One great example is the Halden reactor in Norway which recently shut down.

Nuclear is in a unique place to be able to work in this environment. Because of the unique culture of cross-company and cross-border collaboration in nuclear.

So, in this context, actually, what do we see. And we're really seeing that the U.S. history and experience in nuclear is clearly a strong differentiator why all these companies from around the world still come to EPRI, a U.S. based organization for R&D.

So, the U.S. fleet, the U.S. research, the research done in the U.S. does continue to be globally relevant.

So next slide please. So this slide shows the areas of EPRI's nuclear research. I won't go through the list. It's basically the whole waterfront of the nuclear enterprise for our members.

With a notable exception is, we very gentle touch human performance aspects, leave most of that to INPO. But we do touch that from the realm of human reliability analysis and the input to PRAs.

Our focus is to make results deployable. If we do research for our members that just ends up on a shelf, that is not of value to them. Our unique spot in the ecosystem is our understanding of our members plants that business imperatives and the ability to connect the science with their needs.

We do jealously guard our independence, not objectivity. But we do also manage to focus very closely on the business needs of our members.

And we're lucky our advisors keep us strategic enough. They don't drive us just to be tactical, they keep us looking over the horizon.

Once great example is the work on what we term long-term operation, others term second license renewal. We started working on that 15 years ago. Before even being talked about.

The work we did in the background enabled utilities to come to this table and discuss taking the plants out 80 years, other countries to look to taking their plants out to beyond 40, beyond, out to 60 plus years.

Other things we started working on before they became a common discussion, things like the impact of flexible operations.

I did want to highlight some of the things we're working on today. I won't touch desperately on accident tolerant fuels, I think Jeremy has covered that very well.

Jeremy mentioned advanced manufacturing. Imagine a world where large components are made with no welds. We are working with the national labs and with operations in Europe, on powder metallurgy.

We have in our facility in Charlotte a 45 percent scale, NuScale vessel head. Made powder metallurgy, hot isostatic pressed so the metallurgy is actually controlled, the grain size is small and there are no welds. Because this is being made in a can and produced.

Imagine a vessel head with no welds. No welds, no inspection.

Another thing we're working on is taking even larger components, electron beam welding them together. When you've heat treated those components after electronic beam welding, you can no longer find the weld. If you can't find the weld, you don't need to inspect the weld.

So, those are some of the technology advances that are being worked on in collaboration with DOE and others.

Another thing with DOE, looking at high-burn up spent fuel. What are the long-term effects of dry store and high-burn up spent fuel in order to help the industry safely store that fuel.

Some of the learnings there demonstrate that there is significant conservatism in some of the heat limits, indicating tremendous safety margins in that storage regime that we actually weren't aware of previous to these experiments.

And then something closer to deployment, smart chemistry. Imagine a world where you are constantly measuring the chemistry of the water in a plant and actually able to react in a more timely fashion.

We've deployed skids to BWR plants, PWR plants. We have them now in Canada on the CANDU plants.

And that will transform the ability of plants to more appropriately manage their assets going forward, rather than just taking samples every shift or every day, having samples taking every minute or less, depending on what the samples are.

So those are some examples of work we're working on at the moment.

Next slide please. So what is the uniqueness of the EPRI approach? We do some basic research, but that is not our focus.

Our focus is to stay close to our members, and their vendors, and understand what their needs are. And actually reach back into national labs, universities, places outside of the U.S. and understand what solutions are being developed in the basic technology world and then speed up that deployment, either through the vendors or directly to our members, to actually address their problems they have.

And as I've said, we really guard jealously, our independence and objectivity of this as we do these analyses.

Next slide please. I've repeatedly talked here about collaboration. This slide really just gives a snapshot to show some of our key collaborators as we do this.

We cannot operate as a research entity supporting our members without key collaborations around the world.

EPRI was setup, not as a complex of labs, but as a facilitator of having research done. We identify the needs and then we find the best people and the best facilities in the world to do that research.

We have work going on today in Sweden, in Japan, in Korea, in China, in national labs, everything else. So it relies on this deep and close collaboration.

And as I've said, the uniqueness of the nuclear industry is, even with the resources of the labs globally consolidating. This collaboration, I think, continues to be strong and allows this research to be done and done effectively.

Next slide. One of the people, one of the organizations in that previous slide was U.S. NRC. We have had an MOU with NRC research in excess of ten years.

Which I understand was somewhat controversial when it was initially developed. An outside entity having an MOU to do collaborative research with a regulator.

What I can tell you today is, this is tremendously successful and effective. We have routine meetings with NRC Research Staff, we actually do joint research programs with NRC.

And the key to this is, and I apologize a typo found its way into the slide somewhere, research is done, results are developed on a common research plan. But those research results are then assessed independently.

And what happens is, this industry cannot, with a reduction in facilities, continue to keep doing research twice. There aren't enough experts out in the facilities.

So, collaboration is important to make sure that the right research is done in a timely manner, but then with careful arrangements like this MOU, the assessment, the results, can be independently without conflicting missions.

And final slide please. The graphic there shows capacity factor. If you look earlier in that slide, capacity factors were significantly lower.

And what I can tell you is, a good part of the rise, the capacity factor levels today, is based on R&D results. And the snapshot here shows you some of the areas where ongoing benefits from R&D will be realized.

And the common with things, my colleagues have already said, and I'm sure I'll hear it from the research team. I'll conclude my remarks there.

CHAIRMAN SVINICKI: Thank you very much. Next on this panel we will hear from Dr. Jennifer Uhle, who is currently the vice president of operations for the Nuclear Energy Institute, but certainly well-known to this Commission and those here in the room.

Jennifer, thank you so much for being here today, please proceed.

DR. UHLE: Thanks. Good morning, Chairman, Commissioners. I really appreciate the opportunity to present the industry's views on the safety driven research. Or essentially the applied research program of NRC.

Next slide please. So, I organized my presentation around the specific, some of the specific elements of the research mission, overall, just summarizing researches, mission has developed a technical basis in general for regulatory decision making.

And there are three elements here that I'll talk about today as they are listed. Evaluate new technical concerns that warrant attention, develop and maintain needed tools, including data, computer codes and evaluation technics, prepare for new industry activities, so that the agency is ready to review them and regulate them.

And certainly, the industry understands the important role that research plays. We, ourselves, do research, as you've heard through my previous colleagues here.

But we do have some recommendations on how perhaps the Office of Research could be more effective and efficient.

So next slide. So, starting with evaluating new technical concerns. Certainly the safety of the fleet is, the primary responsibility is that of the industry.

So, the industry is just as concerned about safety as is the NRC. It's a shared role. So, at this point, when we have a new issue, the complicating factor is really separating those issues that warrant attention from those that don't.

And since we're talking about new issues, I'm assuming they're not currently dealt with in the licensing basis or in the regulations.

And so, a quick way, or an effective way to separate those issues would be to look at the issues through the lens of the backfit rule. Certainly if an issue is not safety significant enough to require a backfit, based on the Commission and Staff's input, then it's probably not safety significant enough to do a very detailed research program.

Now, when we first take a look at a new issue we may have to do some low level research to determine the safety significance. And when we do so, then we should be making sure their research program is realistic and prototypic of what we see across the fleet.

And unfortunately, we've seen cases where that's not been the practice. And an example would be in the high energy arching fault area that is currently being looked at right now.

So, we recommend that there be more collaboration with the industry. Of course, NRC maintains its independence, as Neil has indicated.

And in that way, the research programs are truly realistic and are representative, or truly represent the industry. And the configuration of the plants.

Now, last point on this slide, I would say going back to applicability, is that it is the industry's viewpoint that international research programs that are not applicable to the industry, have very limited applicability to the industry, should be off the fee based.

Having been in the Office of Research for over a decade or more, there have been many times where there's been participation in research programs, collaborative research programs through OECD, IAEA, that were not applicable to the industry.

And that, of course, side tracks the staff and time and attention of the agency away from those issues that are applicable.

So, next slide. Talking about the tools. Jeremy discussed a number of tools DOE is developing. Neil also hit on this issue.

So bottom line is, there is the whole tool suit that the staff develops and maintains. I was one of the developers at one point for the thermal-hydraulic set, so I appreciate the fine work that gets done.

However, the industry has its own set and the DOE has its own set. And over time the validation and the functionality of these tools have overlapped. And we're certainly duplicating effort.

So, perhaps it's a good time as, again, Neil alluded to, to take a step back and do a top to bottom review of the tool set and figure out if there's a more efficient way through perhaps sharing of these tools. Defraying the cost to the U.S. as a whole.

Again, independence comes up as an issue. But as we indicated before, NRC would be conducting its own analyses and drawing its own conclusions.

As in the case with any tool, using a code outside its applicability range is certainly not something to do, however, we do see that there are times when the staff does that. Use the example of human reliability analysis tools.

They were developed primarily for inside the control room, actions within short time frames and validated through data from the Halden project through other programs inside the control room. But we used them outside the control room.

And to give you an example, during a recent significant determination process evaluation, the NRC used the HRA tools and concluded that during a shutdown event, when the decay heats low and there are a lot of operation staff onsite, that Clinton would not have been able to restore AC power over 11, roughly an 11 hour time period.

And 11 hours, it was essentially how much time it would take for the water level in the core to get to the top of the active fuel.

And this situation stemmed from a valve being mispositioned after maintenance on a diesel generator. And the other diesel generator was out for maintenance. And the staff postulates if there was a loss of offsite power there would be no AC.

Now, there are three different success paths that could be used to restore AC power, if this were the case. Including adjusting the valve on the diesel, which was a very simple action, cross-tying to another available diesel and relying on FLEX equipment.

And in fact, what is nonsensical about this situation, is that the utility brought in operators from other plants and they ran through simulations. And these operators were not informed of the mispositioning of the valve.

They went through the procedures that of course they aren’t trained on. And of the five operators, the slowest time to find the valve and position it was 32 minutes.

They also looked at how long it would take to cross-tie to the other diesel generator, and it was an hour and a half. Then there of course is the FLEX equipment.

So these are procedures and they are trained on. And through the systematic approach to training, which NRC has approved. But we're not getting credit for these types of actions.

We're still in a situation where after spending $4 billion on FLEX equipment, we don't have a clear clean path to getting credit for FLEX in these types of SDP. Significance determination process cases.

So, instead of using a more practical approach by just say looking at, hey, what did the trial runs tell us, we're using tools that are not applicable.

So my last slide is really focused on new industry initiatives. And obviously industry plans to deploy a number of new technologies, you've heard from my colleagues.

To give an example of some, accident tolerant fuel. Certainly we're getting ready for advance reactors.

And the NRC does a great job at maintaining awareness of where the industry is heading. I think there could be more efficiency in developing the infrastructure to be ready for the actual review and conducting the review.

There's a bit of a cultural issue about anything new that comes to the plants. That's not necessarily, or that comes to the NRC, it's not necessarily associated with research, but the whole process could be made much more efficient and effective. And perhaps further collaboration with industry could help.

We've also seen numerous cases where the industry, or the research program has grown beyond scope. We tend to start research and continue research instead of once the original goal is achieved ask ourselves what is the remaining regulatory question that needs to be answered.

So, again, further collaboration so that we have a whole different set of eyes looking at a research program may be, may help in affecting change.

So, to end on a good note, we do appreciate the agency's research programs and infrastructure development on advance reactors and we look forward to further collaboration.

CHAIRMAN SVINICKI: Thank you very much, Dr. Uhle. For the final presentation on this panel I will now turn to Dr. Todd Allen, who is the chair and also a professor at the University of Michigan Nuclear Engineering and Radiological Sciences Program.

Thank you very much, Dr. Allen for being here today, please proceed.

DR. ALLEN: Great, thanks. And I appreciate the invitation.

So I thought I'd use the time to try to explain the importance of research by telling three short stories. Cases where we did it wrong and cases where we did it right.

So if we can go to the first slide please. I'm going to start with one where we didn't do it right. I call it the Coriou effect.

If you go to the next slide. I apologize to those that didn't want to get too geeky this morning, but it's a simple graph and it just shows that in alloy material they use to build steam generators, when you have too much nickel it will crack in service. So that's to the right of the graph. And I put a no there to indicate you don't want to be there.

If you have less, it doesn't crack. So I put a yes there to make it easy to follow.

And in retrospect you'd say, you should operate in the yes zone, not the no zone. And that seems obvious, but it turns out that we got this one wrong in the early days.

So if you go to the next slide. It turns out that in 1959 there was a scientist at the French CEA, who's in charge of their Aqueous Corrosion Lab, his name was Henri Coriou, and he noticed that the alloy that everyone was using for steam generators cracked.

And no one believed him. They thought it was a French unique situation, that there was something a matter with his data and they sort of ignored it.

In the history of this that Philippe Berge wrote, I found this interesting, center statement that said, an American colleague had suspected Coriou of being a KGB agent spreading false rumors to raise doubts about the reliability of American nuclear submarines, right? So for those of you that are big fans of NCIS research as a TV show, it's interesting.

But the point is, we ignored the indications. We didn't do the research. And about ten years later, in operational service, alloy 600 started cracking.

And in the end, we ended up having to shift a lot of plants over to 690. And on the French side, 52 plants were built before they decided to move it over.

So here's a case where there were research indications that were not followed, they were not believed, and it actually cost a lot of money, right. And it was sort of the wrong answer because you didn't have a vigorous research program to make sure you understand that, what's going on.

All right, so go to the next slide. The second case is, I think, one where it was done right where you got the tools done in advance.

And if we can go to the next slide. On this parallel, it's a different image, but it parallels something that Jeremy showed.

Which was, in the mid-'90s the NRC started to allow its codes and tools to talk to each other, right. The cross-section codes and the neutron flux solvers and the temperature calculations were being linked so you could do more complicated analysis of what was going on in the plant.

I think this is the right thing to do, if you fast forward about 20 years, next slide please, there were questions about power rates, and could we do them and still be safe.

And the fact that these codes had, the research had been done to allow these codes to talk to each other, to build a modern platform, allow these types of questions can be answered so that the Commission and the industry could work towards moving the power higher in the plants and still feel that it was safe.

So in this case, 20 years of advanced thinking, puts you in a position where you are ready to answer important questions for the industry. All right. So I'd say that was a case where it was done correctly.

And we'll go to my third story. And this is one that I think it's the need to be forward looking.

And I should say, so I'm on the faculty at Michigan so I'm using Michigan examples, but I don't mean to imply that these are uniquely Michigan, there's lots of interesting work being done in other places.

But if we go to the next slide. We now have a faculty member whose working on advance x-ray tomography highspeed image capture that would allow you to look at flow and complex components.

Well, why is this important? Well, if you think about the codes that I just talked about, and Jeremy mentioned the same thing, your ability to validate them, take the uncertainty out of them, is very important to your confidence.

So, building in new tools that allow you to understand, with great fidelity, what's going on in a complex engineering system is very important. And you're not going to get there if you don't figure out how to build the advance tools.

And I didn't put this in my slides, but if I listen to what Jeremy and Neil both said, we're not looking at things like advance manufacturing, advance sensors, data analytics. This gets into questions of cyber physical security, cloud computing versus edge computing.

There's a lot of interesting things going on where I start to see my colleagues trying to figure out, how can we bring these advance technologies into nuclear.

If you don't have a vigorous research program that understands the implications, right, of how to use these tools, where the advantages are, where the limitations might be, then you're not in a position really to answer these questions and be ready to evaluate the technology. And if you're not in that position, then you don't advance the field of nuclear industry, which I think is important.

If we go one more slide. I'll just point out that, and this is especially true, at least from the University perspective, that research results are only part of the value.

So if you go to the next slide. My obligatory smiling gun faces slide.

Research is kind of the gateway drug for a lot of people to get interested in this, right? I'll go back and look at some statistics about what's happened over the past two decades at the University level.

So around 2004 or '05, the number of students that were interested in studying nuclear engineering jumped by about a factor of four. And it just stayed there.

We have saved nuclear programs, we have started new programs in places that didn't exist. We have places like Penn State, which is taking its nuclear program back out of mechanical and forming a standalone program.

There is a strong amount of interest in the students in nuclear technology. We see it at the universities and it's not a blip, it is a consistent trend.

And I think for a lot of students, that ability to do research at the PhD level certainly, but the ability to engage in research as an undergraduate gets them involved. And the pictures I showed you were people who happened to jump from Michigan to the NRC. And in a lot of case, it was the research that brought them in.

The last thing I'll point out on the people standpoint is that this year was also unusual at the universities on the faculty side. We had about 25 open faculty positions, which is, say, four times normal.

And there's this combination of growth in nuclear, along with retirements. And this strong interest of people in being in nuclear that's drawing people to your universities.

And I will end by saying, at both the student side and the faculty side, that over the last two decades of success and growth, the NRC programs and fellowships, which are very flexible and very helpful to us in not only bringing students into the programs but keeping them in and protecting that investment, as well as the support for young faculty in getting their careers kicked off so they can be successful in this field, we tie a lot of that back to the support that the NRC has provided.

So, helpfully those stories will give you an indication of why research is important, in bringing both people in and advancing the field and keeping nuclear technology the cutting edge. So thanks.

CHAIRMAN SVINICKI: Thank you very much, Dr. Allen, and to all the presenters. But thank you in particular for mentioning the people part of this.

As we always say at NRC, we really can't do anything here without our people, and it is the most important thing to begin and end with, so thank you for that.

I want to apologize to my colleagues in the busy morning in affirmation, I neglected to ask them if they wanted to make opening comments at the meeting, but I'm sure that they'll have the indulgence of the Chair if they want to have a little extra time in this opening round to make some background commentary. And we will begin today with Commissioner Wright.

COMMISSIONER WRIGHT: Good morning. So this is my one year anniversary.

CHAIRMAN SVINICKI: Is it?

COMMISSIONER WRIGHT: Today. I got sworn in, you swore me in right there a year ago today. Mom held the bible, it was a big day. And I talked to her this morning, she said hello.

(Laughter.)

CHAIRMAN SVINICKI: Well thank you for that. It's important to acknowledge these milestones. And I say hey back to her.

COMMISSIONER WRIGHT: Yes. So thank you for being here. I know some of you had to travel a long way to get here and I appreciate your willingness to participate on this.

You know, we've talked here a lot about transformation, and we continue to do that. And I've said a lot. I don't want to transform just for transformation sake, we got to kind of know where we're going, what we want to be, what the vision is going to be.

So at a high level, I see that using our knowledge and our expertise and our experience, you need to use it the right way to regulate more efficiently. Because when it's done the right way it really works. It's very effective.

And by the way, my reactor TA did some reason, Dr. Allen, and found out that Clemson and Michigan have never played football against each other.

DR. ALLEN: Lucky for Clemson.

(Laughter.)

COMMISSIONER WRIGHT: That's what Alabama said. So, we've won about 1,700 games combined but we've never played each other. I found that really astounding. Two great programs. It's just hard to believe.

But on a more important topic for everybody here, we've heard some great examples today of how good things can happen when the NRC works collaboratively with organizations like IAEA and EPRI and NEA and NEI and others around.

So my question for anybody on the panel that wants to weigh in, is whether there are other organizations that we should consider partnering with or doing collaboration with?

Anybody that we're not talking to that we should?

And that would be either, I guess internationally or domestically. Do you have any thoughts on that?

DR. UHLE: I'll jump in. I'll be the sacrificial lamb here.

(Laughter.)

DR. UHLE: I think that as an industry, as a whole, we tend to think that everything in nuclear, we're siloed in nuclear and so we don't necessarily talk to the other industries that may be using very similar materials. Perhaps in similar environments, maybe not.

So I think there's probably a role where the industry, as a whole, could take a look at other industries to determine if there is something we can learn.

I know we do a little bit of that in digital I&C. And in the case of PRA. But I'll, Neil, you want to add anything there?

MR. WILMSHURST: Well thank you for that. And really, that is what we're seeing as we interact with our members, both in the U.S. and globally.

As there's an economic pressure on many of our members, the appetite for deploying technology is increasing. And that technology is being seen as having safety benefits and commercial benefits.

And it needs R&D in order to understand the deployment challenges and the deployment issues. And in some cases, as Jennifer said, other industries have already done it.

And we tend to quite rightly view nuclear special, but there are cases where even we can maintain nuclear being special but still learn from other industries.

And there are opportunities abound for all the research operations in the nuclear industry to reach out to those other groups. For example, look at the aero-engine industry and what they do with remote monitoring and sensors. Tremendous lessons there for the nuclear industry.

COMMISSIONER WRIGHT: Thank you. So, in the last several years we've had a number of reactors that have permanently shut down.

So this question, are we, DOE or anyone else, doing anything to study the material condition of those reactors?

I'm wondering if we can learn something about component aging that we could use to help us review applications for subsequent license renewal. Could this be a unique opportunity maybe to perform testing on components in a way that we don't do on the operating fleet?

MR. WILMSHURST: I'll go first, and I see there's another volunteer to follow me here.

So, it's a great example. And as we did the work to support second license in the long-term operation, the question of concrete aging and primary materials aging came up.

And at the time, there wasn't a plant of the right vintage in the U.S., but collaboratively with DOE and NRC, we identified the Zorita Plant in Spain was a valuable place to go and harvest samples. And that is just what we did. We took concrete samples, material samples from Zorita Plant.

So, that activity is going on. At the moment, I'm not aware of any activity around harvesting anything from U.S. plants, but globally that is definitely an option that is being explored.

DR. BUSBY: There are actually, in the last year or so, some more active programs on the DOE side, under specifically light water reactor sustainability.

There has been an effort to harvest concrete core specimens from the Zion Plant, as well as a section, the RPV midline, I'm sorry, beltline weldments.

Those materials, it's complicated into the decommissioning process, but we have rescued a number of high value materials. They were transferred to Memphis and are now sitting at Oak Ridge.

There have been inquiries and explorations around harvesting high value materials from San Onofre. And I think there are some other initial discussions ongoing.

COMMISSIONER WRIGHT: Thank you. Did you have any?

So, Neil, let me stay with you real quick in the couple of minutes we've got here. Can you describe the benefits of collaborative research conducted by the NRC and EPRI?

And you stress that our organizations reach independent conclusions, and I think, Jennifer, you backed that up earlier. Are there examples where NRC and EPRI have teamed up on a research project and reached different conclusions, and if so, how was that handled?

MR. WILMSHURST: Jennifer brought up the high energy arch fault. That's probably the nearest term disconnect I can talk about where there's an ongoing discussion about the scope of the actual R&D plan as to whether the R&D plan going into it is representative of configurations in existing plants.

So that's an example of a disconnect. And there's ongoing dialogue, and it's healthy dialogue. And is there frustration that it could be resolved faster, yes, but I think we're in a better place because of the MOU to have that discussion.

On the results of the research, I don't know that there's ever been a disagreement on the results because the assessment is done independently and every organization has its own right to make its own conclusions.

So I think the front end constructive dialogue is where those disagreements are worked out.

COMMISSIONER WRIGHT: Thank you. So, Dr. Allen, I'm going to come back to you to finish up here.

One of the challenges that we're faced with right now is a shortage of younger folks at our agency. My understanding is that we're at about two percent of our workforce under the age of 30.

And I'm not sure exactly what the right number is, but I know it's not two percent. So what are you seeing at Michigan, is this an NRC issue or is there a shortage of talent elsewhere in the nuclear field?

And I guess to follow-up with that, in your opinion, what would be the best way to attract younger people to the nuclear field?

DR. ALLEN: So, I think right now we're in this very interesting competitive recruitment for people. So even though I said we went up by a factor of four, if I look at what's happening at the universities, what's happening at the national labs, there's a retirement boom that overlies growth and everyone is competing for the same people.

Whether it's mid-careers where it's especially hard, but even with younger people. So even though we've jumped up, it's pretty competitive right now.

I do find that the people that are the most effective at recruiting students out of the universities are those organizations that get to know them early. So if you show up at the last second and say, hey, you just are graduating now would you be interested in the NRC, they very likely have other suitors.

And so I think it's showing up early, being visible, getting them into your spaces because they talk to each other, I think is critical to all of it. And I think that, yes, the people that do that well and show up well are the ones that win the recruiting battles.

COMMISSIONER WRIGHT: Thank you. Thank you, Chair.

CHAIRMAN SVINICKI: All right, well thank you very much. I will guess next with some questions. And some of these are fairly general so I think if someone wants to chime in. Hopefully there will be a willing victim and not a sacrificial lamb.

But you talked about some themes that I think are, resonate strongly with me in terms of where the nuclear R&D enterprise is today, both in the U.S. and globally, compared to where it was when I began my nuclear career with the U.S. Department of Energy and activities associated with what was then the Idaho National Engineering Lab and is now the Idaho National Lab.

And I think that consortia is the new model and has been that way for some time. I think that the more stove-piped your funded by one funder to do something without other principle investigators and other participants.

It's partly for reflection of the fact that nuclear research that involves actual nuclear materials has limited locations at which it can be conducted. And it's expensive because there's a lot of controls on it.

But I get a growing sense that if we were to contrast with how the U.S. developed its early nuclear power program in Idaho, building 52 different prototype reactors out on the desert of Idaho, I think that now for the federal investment there's an increasing imperative that work be conducted with a consortia model.

And that, my experiences with that, not just here at NRC but in other positions, and this congressional staff, has created a strong conviction with me on the topic of independence, which a couple of you mentioned, is that if collaboration and collaborators are all involved at the beginning and the design of the research, it's my conviction that independent analysis decision making at the end is absolutely possible. I have just a strong conviction about that.

Now, that early part is important because you can't just be handed a bunch of papers of data printouts if you don't, it's that early participation. And so, I note that NRC, I think as we look at accident tolerant fuels in advance reactors, is realizing that that early engagement is very important, both with the vendors and designers of new technologies.

But just generally I think to have our independent and fully informed safety conclusions at the end of the day.

The other firm conviction I have is that the tools and progress that have been made across the research enterprise, not just in nuclear but also finding utilization in nuclear, can and have enhanced safety significantly.

I know many of your organizations are focused on operations issues and other things, but NRC, at the end of the day, we want to know that our safety conclusions are even more firmly rooted.

And the further penetration of some advance technologies have a high probability, in my view, of enhancing operational safety at plants. And so, I do worry a little bit about young people have a perception that nuclear, it's very hard to penetrate nuclear programs with innovative and advance technologies.

So I know that there's a shared concern across addressing that perception. In some cases, it's probably a reality that that it is happening.

So, I appreciate what all of your organizations are doing. And next when we hear from the NRC Staff, I think that they're doing some really, really interesting and creative things as well, but we'll hear from them shortly.

One thing though that is important, I think to anyone concerned about safety, is that there are many tools. The rise in kind of computing power and things has been kind of mind-blowing over the last 30 years.

But it is important that there be experiential validation because you can get a lot of decimal places but is it meaningful in terms of real-world phenomenology. How would any of you characterize the computing power and the analytics versus the rooting it in real-world phenomenology?

Do you think that the experimental work has kept pace?

That can be the more expensive thing nowadays, so how would you characterize, not just the power of the tools but how well they reflect reality?

It's a little philosophical. Maybe Oak Ridge will leap in and --

DR. BUSBY: Yes. And let me share a caveat. I'm an experimentalist --

CHAIRMAN SVINICKI: Oh.

DR. BUSBY: -- by training in nature who now manages 100 or so modeling and simulation folks.

I think you said it very well. Experiment and modeling have to go together, hand-in-hand. And they're mutually beneficial.

Modeling and simulation can point us to the highest value experiments. Experiments can point us to flaws in our modeling logic or structure. They have to go together to end up with a validated tool that we can trust and believe. To extrapolate out into situations when we need to do that.

One of the, I think there's several difference levels of modeling. Are we talking about atomistic modeling, are we talking about engineering scale modeling.

And I think that the experimental engineering scale experiment can keep up with the modeling and simulation. And we're at an atomistic level, that's a little more challenging because we discover we don't understand the physics and it takes two to three years to figure out the experiment to get that fundamental materials or physical constant that goes into the model to make it make sense.

So I think at the engineering scale, which is perhaps the most relevant to rapid deployment and accelerated deployment of safety and operational features, we can keep up.

But there's another challenge here. Is that the modeling and simulation crowd and the experimental crowd speak different languages.

And they have a different training, a different experience. And getting them to understand and appreciate, and to interact fluently with each other is perhaps the bigger obstacle than funding and pace.

And so we're working very hard to embed and get them to translate to each other.

CHAIRMAN SVINICKI: Thank you for that. And kind of to pivot a little bit, Neil, you talked about the infrastructure around the globe to where the experiments and research can be conducted.

And we have seen a consolidation and a contraction. We've seen university programs close their research reactors, not so much now but in the '90s and early 2000s there was a wave of the U.S. lost a lot of those research reactors at university programs.

But when we talk about consortia and kind of forcing people to work together, as Jeremy was just talking about in bringing people together, consolidation of the number of places at which to do something could actually be beneficial to that. And it might say that we're going to have to be more streamlined and we're going to have to come together for the physical infrastructure that we have.

So there is benefits and negatives. Could you talk about though, are there areas where we're going to becoming, globally the enterprise is developing gaps and capability, or we have vulnerabilities and weaknesses given the contraction and the physical infrastructure?

MR. WILMSHURST: Probably the one that comes to mind, most frequent in discussions, is test reactor capability to support the global efforts in maximum tolerant fuel.

With Holden shutting down, other capabilities being constrained, that has become a priority for OECD-NEA, to try and understand what capabilities are there, what their workload is and what their availability is.

And then you throw the political dimension in there because some of the key remaining facilities are in Russia, for example. And will people be able to test in those facilities.

So, that is probably the main one that comes to mind at the moment. Suitable reactors for testing for the accident tolerant program.

CHAIRMAN SVINICKI: Todd or Dr. Allen. I feel like since I went to Michigan you could have been one of my professors a long time ago, so I'll call you Dr. Allen.

Would you like to comment in terms of students today being able to have access to hands on experimentation in nuclear?

DR. ALLEN: Yes. I think we do something very well and others maybe not. So, maybe three comments.

So, the labs have generally been pretty good about operating what I'll call a user facility model. Where they've got these big capabilities, they know that they are the sole owners of them and they try to make them available and welcoming. To faculty, to students, to other research staff. I think that works out fairly well.

I think a second point, which is maybe a subtlety of your question on consortia, that could be useful is that, typically when people go in and say, well, let's do a consortia, they're thinking about a bigger team, bigger member. And because of that there's an institutional commitment to longer periods of engagement.

One of the things that I think really harms us in all of this is that we whips off from one thing to the next. And you don't have the time to build up the expertise to be able to bridge the gap between the modeling and experiment with people because you're constantly being flung off in some other direction.

So I think Jeremy pointed out some of the benefits of consortia, which I think are obvious. But I think one of them is that there's an inherent commitment to longer engagements on projects, but I think it's actually very useful. Whether you're a young student all the way up.

And then I think, the third thing I'll point out is that, and this actually goes back to the recruiting question, the labs that are good at recruiting are also the ones that make their facilities available to students early on.

And so, you have this conductivity that just works well. And the ones that don't do that well then, they suffer on that engagement.

CHAIRMAN SVINICKI: Okay, thank you. And Jennifer, if I may, I'll just close with this comment.

I appreciate your insights. Your unique insights given your background about kind of linking the NRC's licensing work to the research that is conducted, scoping problems and issues correctly.

This is kind of odd because it's the next panel, but I have an awareness of what the Staff will present, and they have been making efforts in recent years to improve that fidelity between the two and integrate that look at it on kind of some sort of routine basis to make sure that if you scoped a problem one way, is it still relevant to the regulatory outcome.

So I'll just maybe highlight that. That there is, I think the NRC Staff has a focus on that. And I don't claim perfection and I don't think the NRC Staff claims perfection either, but I think that we have an internal recognition of the need to do that. Okay. All right, thank you very much.

Okay. And next we will hear from Commissioner Baran.

COMMISSIONER BARAN: Thanks. Well, thank you all for being here. I think it's been a good discussion so far.

Several of you mentioned, mostly briefly but with a little bit more discussion, about advance manufacturing technologies. I was interested in hearing a little bit more about that.

What advanced manufacturing technologies, or process, are getting the most attention for potential use at nuclear power plants and when do you expect those to be introduced?

MR. WILMSHURST: The one I mentioned was hot isostatic pressing for large metal components. If you think about large valve bodies, traditionally they've been cast inspected, defects discovered, defects ground out, weld repairs done.

And if you, one of the main challenges during an outage, in an existing plant, is the inspections of those components. So, there's a tremendous advantage in these hot isostatic pressed components.

You can manage the grain size, you can actually make them near-net shape and you can get them to a place where there's no weld repairs.

And we have been working, that is now in the ASME code. And there are reactors, not in the U.S., that are actually operating now with HIP material valves in place.

So, that is an early deployment technology. And as I mentioned, the work we're doing with DOE and others around SMR vessels, that could conceivably cut the time to manufacture a reactor vessel by 50 percent, reduce the cost by 50 percent, and then have the through life benefits of reduced, maybe effectively zero inspections as well.

So, from the EPRI perspective, that is the technology we're seeing with the biggest return at the moment.

COMMISSIONER BARAN: And what time frames are people talking about for deployment in the U.S. of technologies like that?

MR. WILMSHURST: Overseas the SMR is tied to the SMR program, which we're all aware of. For the other valves, most, it's really tied to a commercial imperative for people who are getting into the business and manufacturing.

At the moment, with the economics of the nuclear plants in the U.S., there's not really a tremendous drive to change. But outside of the U.S., people are picking up this technology and starting to work with it.

So, there are limited capabilities to reduce components in these HIP vessels in the U.S.

DR. BUSBY: So, I was going to lead in with a similar example. I think the time to deployment is a bit of a risk reward opportunity.

Perhaps these technologies are demonstrated on components well outside the core. A valve, a pipe, any number of other secondary functions, versus jumping right into 3D printed fuel. That will take a little longer.

However, I'll also say that the national labs are working on, within the next two years, printing a core structure. And within four years, having that fueled and perhaps even turn it on as a demonstration of what's possible.

That doesn't mean that it is licensed and qualified to generate power for 60 years, but it's a start and an example that we can then learn from, about how to take these technologies from a demonstration into an industry deployment scenario.

DR. UHLE: If I can add quickly. At NEI we have a group that's working on advance manufacturing.

And we've prepared a document that really is talking about the regulatory pathways. And we'll begin interacting with NRC around that here shortly. So there is a definite interest that is growing.

In the case of operating reactors, it would be those components that they can't replace small pieces or parts. But in advance reactors, small module reactors, I would say the door is wide open. Provided there is the regulatory approval.

COMMISSIONER BARAN: What about the increased use of sensors and analysis of the resulting data at nuclear power plants, where do you see that heading in the next few years?

DR. UHLE: I can take it. So at NRC, excuse me, I still do that after three years. Anyway, at NEI we have what's called delivering the nuclear promise.

And that is coming up with ideas on ways to do things more efficiently. And where recently we're looking to pivot that and get more into new technologies.

There's activities through DOE with the LWR sustainability, we're there. And EPRI plant modernization. So we're trying to get everybody together.

Areas that are being looked at would be in the, essentially machine learning area. And that could be using machine learning to take a look at condition reports to determine which ones need more attention, which ones don't.

There has been trial cases of that. And that based on your learning data set, you can get a really high accuracy rate.

There's also being areas of remote sensing. Could remote sensing replace rounds associated with rad protections with now people taking samples. Could that be a more effective way of performing that same work and making it as, ensuring safety to the same level.

So, those are just some ideas that are being pursued.

COMMISSIONER BARAN: Can you give us a sense of, particular in the sensors, how far long is the thinking on that, how far along is the research on that?

DR. UHLE: Okay.

COMMISSIONER BARAN: You know, if our research program is trying to figure out, when would we need to be ready for people to come through the door with a technology like that or a program like that?

Are we talking a couple years, a few years, longer term, what's your sense of that?

DR. UHLE: I would say a year or so. Some of the activities would not require regulatory approval. They would be, it's more of a performance-based regulation and be at the licensees' own risk using this approach.

But others would. And in those areas that would, we will be interacting with NRC to ensure that there is an awareness.

DR. ALLEN: And if I used a simple volume of the conversation metric around this, I think there's a good comparison to what Jeremy talked about relative to advance manufacturing.

So, the volume of conversation around advance manufacturing a few years ago was a good thing. And now you're working two to four years from trying to print a core, I would say the volume of conversation around sensors and data analytics is about a couple years behind where that was.

But it is becoming a much louder conversation and people are getting very interested. And I would be very surprised if you don't hear some more things about demo platforms at the labs and how you do that and how it ties into cyber physical and things.

So, I think there's a very strong trajectory there. ARPA-E just had a big workshop on that. I think it was last week or the week before.

COMMISSIONER BARAN: If we kind of take a step back and think big picture, if you put aside accident tolerant fuel and non-light water reactors, do you think that advance manufacturing and sensors data analytics are probably the biggest things we should be looking at just a tad bit over the horizon, I guess?

DR. UHLE: Yes. So, when people say sensors, you can use that for data analytics and that way you're putting sensors on equipment. And they do this in GE turbines in aircraft to determine vibration, to give the health of the turbine in the plane. In the engine.

So that is being looked at. That is being discussed a lot. And people have, and plants have invested money to try to start seeing if this is a way to go.

I don't think that will be the first thing that comes in. I think it will be smaller chunks, like the use of machine learning or sensors, for the replacement of the particular tasks.

And in that way, there will be a familiarity that will build. And I think a comfort level that would build. Because there is an investment needed to adopt these technologies.

MR. WILMSHURST: And I think this is, we mentioned it earlier, this is one of these areas where we all have to be cautious not to view nuclear as being unique. Many of these technologies and technics are already deployed with great rigor in other industries and we really have an opportunity to learn from these other industries on what they did and how they did it.

One example is, one of the biggest challenges in the nuclear plant has always been, well, how do I get the data from the sensors back to the computer. Well, there's technology developed in the '60s that used in sport stadiums and large ships, which allows basically cell phone technologies to be distributed around the building a lot easier than wireless.

And we've demonstrated that. And the coverage actually is far better in large concrete structures.

So we're going to start seeing the enabling technologies be deployed almost ahead of some of the technics. Because there's no point deploying the sensors until you get the information to somewhere.

So we're already seeing utilities deploying this, distribute their antennae system as one of those precursors to the technology arriving.

COMMISSIONER BARAN: Thank you very much.

CHAIRMAN SVINICKI: Thank you, Commissioner Baran. Commissioner Caputo.

COMMISSIONER CAPUTO: Good morning, thank you all for attending. Let me just start by saying, Todd, you and I have worked together in a variety of capacities during our careers, so I'd like to congratulate you on your new position as department chair.

Question your judgment a little bit about leaving the University of Wisconsin to go someplace like Michigan, go Badgers, but I congratulate you, nonetheless. It's nice to see you here.

Dr. Uhle and Mr. Wilmshurst. I'd like to start by, I know we've had a lot of discussion about collaboration and so on this morning, but I'd like to start with a question.

Do you feel like you have a good transparent understanding of the activities that the NRC is researching or do you think that more transparency in stakeholder input could help refine our direction, our priorities, focus our connections more toward regulatory decision making based on the direction the industry is headed?

MR. WILMSHURST: I'll take this one first. What I can tell you is the MOU we have with NRC research, as I said, it's over ten years old.

I can tell you, that relationship today, and historically, has been very strong. It just goes from strengths to strength.

Earlier this morning we're discussing with the director or research, our next face-to-face meeting where we get together at least once a year and we discuss what our research priorities are and NRC research discuss what their priorities are.

And from my view, complete transparency on what programs are, what plans are. And it makes a tremendous difference to our scope to be informed what those priorities are.

So from my perspective, it could always be better, but it's actually in a very healthy place at the moment.

COMMISSIONER CAPUTO: Okay, Jennifer.

DR. UHLE: Yes, I would just echo those comments. NEI looks to EPRI and to the owner's groups to, and the vendors really on the research side. So we don't have direct communication with the Office of Research.

I think there are pockets based on interactions with EPRI.

Pockets where the communication could be improved because the MOU doesn't cover everything that NRC is working on.

And I would say I have a pet peeve, if I can just add one more comment, and that would be in the international research arena, that that's not as clear what's being worked on and why.

COMMISSIONER CAPUTO: So if it's, I was going to ask if you could give me a couple of examples, but if it's not clear, do you know what examples you could give me?

DR. UHLE: Okay, sorry, I'm going to be a traitor here. Having been the division director in charge of this program, I think that we continue to work in the area of source term. And in particular, iodine, ruthenium release, cesium release and that chemistry.

And we continue to work in that area without a real clear regulatory need. Or at least the regulatory need isn't clear to us.

Now, my information is probably a year old so that things may have changed. But that would be an area that I think we, the NRC likes to participate to support other countries programs so that when there is a program that NRC wants to start, that there is support for that program.

And that's fine, I just don't think that the utilities should be charged for that, it should be off the fee base like other international program activities.

COMMISSIONER CAPUTO: Okay. Back to you again, Dr. Uhle and Mr. Wilmshurst.

So, for, Mr. Wilmshurst, you indicated on Slide 6 that EPRI and NRC collaborate on digital I&C research. Do you feel that there has been enough research and now it's time to deploy or do you think there are still research areas that we have to finish up?

MR. WILMSHURST: Digital I&C, there is a very healthy discussion. And one of the items in there is the whole risk informing and understanding of the hazards and the system approach to digital I&C.

And that's an example of the healthy exchange of research and understandings. Which has led us to, I believe, a very good joint understanding of digital I&C, how the design processes, deployment processes, should work.

I think we're close to being ready to deploy. I don't know there's a significant amount more R&D to be done.

I actually think now it's more a development of the joint understanding of the state we're at and the confidence that we're in the right place.

So, to briefly recap, not significant amount of R&D. There's more time to reflect on what's being done and get a joint confidence that every things in the right place.

COMMISSIONER CAPUTO: Okay.

DR. UHLE: I would say that no more research is needed. I think at this stage we just need to sit down and iron out some of remaining positions that are not aligned.

And of course, NRC is the regulator. And your decisions will trump any input provided by the industry.

However, I do think that we are talking past each. And to the best approach is to sit down with some clear examples and go through them and take the time in a public setting to really work through them. Because I think we're really on the same page but there is still a lack of, or there is miscommunication occurring.

And we are proposing that to NRR in a public setting. And we're hoping that can take place soon.

COMMISSIONER CAPUTO: Thank you. Jennifer, back to you for one last question.

So you stated that a top to bottom assessment of NRC's tool set would be timely. One of those tools, obviously, is computer codes.

And as you know, we spend a considerable amount of time and funds maintaining and upgrading these codes. Could you just describe how you think that kind of an assessment could be conducted and maybe some examples of codes that may have lost their usefulness over time or outlived their usefulness in some way?

DR. UHLE: Well, the first thing I would say is that in the development of codes, or computer codes or any tools, you are also developing skills of the employees. And you're retaining employees that are very strong in phenomenology that is sometimes necessary for certain licensee submittals.

And so, there can be a case where the maintenance, or a little bit of development is ongoing, but it benefits the agency as a whole.

I do think though that, I just take a look at it from a 100,000 foot level and it really is a shame that DOE, industry, NRC will all sort of using the same validation base and the same capabilities and yet we continue to invest a lot of money.

But in the case of advance reactors where we're starting with a clean slate and we are looking at sharing these tools and perhaps developing them in concert.

Same thing in the probabilistic fraction mechanics area with the extremely low probability of rupture code I think that is not as high priority at this time because of 690. Alloy 690.

But there are some areas, I would say the SPAR models would be an example. We've been looking to see if there can be a portal through EPRI for NRC to get access to the utility SPAR models, or excuse me, PRA models, instead of maintaining the SPAR models.

And that would give, hopefully, the NRC the same access to what they currently get with the SPAR models.

I mean, it's hard to say off the top of my head what else to highlight, but certain going through them and asking the question, is further development needed or is this something where going forward we can participate in a collaborative effort development on a new tool.

The downside of course is getting the Staff comfortable with a new tool. And that is an investment that has to be considered.

COMMISSIONER CAPUTO: Thank you.

CHAIRMAN SVINICKI: Well, thank you again to each of our panelists for participating this morning. We will now take a five minute break, until 10:30, and reset.

If the staff presenters could please be coming forward. Thank you. We'll reconvene in five minutes.

(Whereupon, the above-entitled matter went off the record at 10:26 a.m. and resumed at 10:34 a.m.)

CHAIRMAN SVINICKI: If I could ask everyone to please take their seats or begin to do so. And I appreciate we have all of the NRC staff presenters at the table, but I know research is so fascinating that we've got a rowdy crowd, so it's taking a moment for the room to come to order. Okay. Silence is restored.

Okay. Well, thank you. Now we will hear from a substantially large, for us, group of presenters from the NRC staff. So thank you all for the presentations that you're going to be giving this morning. And we will be led off today by Mr. Steve West. Thank you for kicking us off and, after you give some opening remarks, please just hand the panel over, as you all traditionally do one to the other. So please proceed.

MR. WEST: Thank you, Chairman. Good morning, Commissioners, Chairman. We appreciate the opportunity to share with you the latest from our Nuclear Regulatory Research Program, including current activities, focus areas, challenges, and the changing environment in which we carry out the program.

It has been a number of years since we have had a Commission briefing on the research program. I think the last one was 2007. And we look forward to the dialogue today.

During this meeting, the staff will present the strategic direction of the research program, how research results are used by our business lines, how the Office of Research collaborates when conducting research, and how the office helps enable agency innovation through the development and use of engineering and risk tools.

Our research program strives to prepare the NRC to be ready and to enable the staff to make risk-informed decisions to support our common safety and security mission as new information and technologies become available. You'll hear us reinforce the Be Ready theme throughout our presentations this morning.

This morning, you will also hear about the essential role of research to our regulatory mission. I have seen the value that the research office brings to a variety of activities, and I'll start with just a couple of examples that were much different than what you heard about this morning.

The Office of Research provides necessary leadership to maintain the transfer of knowledge management through hosting agency-wide research seminars. Seminar topics help to not only provide awareness of NRC activities, they also promote external awareness by providing industry and academic stakeholder perspectives through their participation in our seminars.

The Office of Research even adds value to our corporate support business line. For example, value is currently being added by having the Office of Research specialists with expertise in organizational sociology by helping us prepare for our innovative NRC Futures Jam, which is going to be held in mid-June.

Slide two, please. Our first speaker this morning is Ray Furstenau. Ray is fairly new to the NRC and is our Director of the Office of Nuclear Regulatory Research. In his short tenure, Ray has shown us new ways of doing things and has made a number of positive and innovative changes to the research program. This morning, he will present the strategic direction of the research program. He will also discuss our outreach with stakeholders, something we have been doing a better job of under Ray's leadership.

We will also hear from Ho Nieh, the Director of the Office of Nuclear Reactor Regulation, also new to your new job, and he's going to talk about ongoing research activities and their benefits to the operating reactor mission.

Kim Webber, the Deputy Director of the Division of Safety Analysis in the Office of Research will discuss ongoing cooperation and research supporting the advanced reactors and accident tolerant fuel.

Raj Iyengar, the Chief of the Component Integrity Branch in the Division of Engineering in the Office of Research will discuss how research integrates knowledge into engineering solutions.

And, finally, John Nakoski, the Chief of the Probabilistic Risk Assessment Branch in the Division of Risk Analysis, Office of Research, will discuss how risk analysis tools and methods are helping the agency continuously improve our focus on our safety and security mission.

So with those introductions, I will turn to Ray.

MR. FURSTENAU: Okay. Thank you, Steve, and good morning, Chairman and Commissioners. I really appreciate the opportunity to talk about the research program at the NRC. I've been here for about a year now, about the same time that Commissioner Wright and Commissioner Caputo came onboard, and I've thoroughly enjoyed my first year at the NRC and really look forward to the future.

And then speaking about the future, we talked about our age demographics and stuff, so I'm going to contribute to raising our statistics on the under-30 crowd and introduce our summer hires. Most of them are here, and they volunteered to sit in the front row here so we're going to see them. And they're really key to what we do in research, as well, because it takes effort on their part, as well as ours, to get them involved in NRC activities. But I've talked to many of the people in research who host these folks, and they get as much or more out of it than the students do, I think, so it's --

CHAIRMAN SVINICKI: Can I just interrupt to say that it's sad that it's noticeable. I noticed them there because it was a group of younger individuals all in a row, but that's probably not a good thing to admit that that's so noteworthy around here. Thank you and thank you for bringing them.

MR. FURSTENAU: Oh, okay, all right. So maybe I introduced that a little oddly. But, anyway, that is our future. I mean, I think we all recognize that we need to do more. The last panel talked about that, to get new blood interested in coming to the NRC and nuclear in general.

In my years, I was with DOE for about 31 years, and the far majority of that time was spent in overseeing nuclear facility operations, certainly not power reactors but test reactors, hot cells, that type of thing, and nuclear R&D programs that the Office of Nuclear Energy managed. And when I look back and compare that, one thing that really impressed me when I came here at the NRC, in research in particular, is the technical capabilities and competence of the people that do research and the understanding of really the fundamentals of the importance of research and what we do.

I do think we can do more in research to really enhance or better the relevance of our research and increase our engagement and transparency, as there was questions with the other panel about how can we do a better job of that. There is always room for improvement in that, and I want to improve that and increase that transparency both internal and external.

Just quickly on our research budget, it shows here it's close to $80 million and that includes 208 FTEs. We're using FY 19 numbers here. But we have about 198 - 199 folks onboard in research right now, so we have

41 million in contracts, as well as the 208 FTEs. And this number is not including the $15 million for the Integrated University Program. And our majority of our efforts support the decision-making in the advanced reactors, as this pie chart shows, and a big reason why we're having my colleague to the left talk about relevance of our research study operating reactors.

So regarding new technologies, Steve West mentioned before our theme of being ready, and the NRC research, I think we should lead the agency readiness efforts for innovative technologies and support the resolution of those key technical safety and security issues that we really need to get the NRC ready for new technologies, and that's an important part of what the Office of Research does.

And without proper planning and readiness, I think NRC will become critical path in licensing and agency assessment and new technologies that our stakeholders will be requesting now and in the future. And we don't want to be in that position. We don't want to be on critical path.

Important to how we prioritize research, it's important to prioritize our research, what research to start, beginning research with an end in mind, and when to stop it. When have we done enough research from a regulatory standpoint to fit into our regulatory decision-making process? Our research mission supports both forward-looking readiness and provides support for licensing reviews through our confirmatory evaluations.

The importance of external engagement, it's been brought up on the previous panel and we'll have that theme here, as well. We really can't do research in isolation. It's not the right thing to do, and we can't afford it. So progress is made, I think, through external engagement, collaboration with knowledgeable experts across our stakeholder community, both domestically and internationally.

When Congress, last fall when they passed the NEICA, maybe the less well known of the NE acts, the Nuclear Energy Innovation Capabilities Act, it was pretty clear that Congress expected DOE and NRC to cooperate and coordinate on research activities and sharing technical expertise. It was clear on this type of stuff what we wanted to spend government money once, if at all possible. And I think this can be done, as was mentioned before, in early-stage R&D and development programs, that we can do this without jeopardizing our regulatory independence. I think engaged research, NRC research, engaging early in the development process is essential to ensure we're ready to assess new technologies.

The research program is broadening our outreach to stakeholders. Outreach helps to ensure our efforts have appropriate value and benefit. We really do want to take the mystery out of research done by the NRC to all of our stakeholders.

Next slide, please. So performing research that matters. We're working to improve our research process and provide better value to our customers. It's our internal and external stakeholders. We're focusing on research that matters and adds value. We're meeting with our business lines, the ACRS. We're starting a biannual review with the ACRS just last month again. They provide valuable input to the research programs. So there's other interested stakeholders through our research program reviews.

Our strategic alignment focuses on efforts to ensure we're doing the right research at the right time with the appropriate priority. And, again, this includes knowing when to adjust or even when to stop ongoing research programs when they no longer add value to the regulatory decision-making process.

And slide eight, please. To conclude my remarks, research needs to support timely and informed agency decision-making. That's really what we're here for, from user needs, operating experience, experience internationally as well, and partnerships with our other stakeholders internally and externally.

Research outcomes need to enable the success of the program offices, that's our main mission, and assist and the agency in focusing its energy on the most important issues.

I think the forward-looking innovative research is about finding out what we don't know and reducing uncertainties and improving realism. That's what research is about.

And with that, I'll turn it over to Ho Nieh. He's our major NRC office director/stakeholder for our research activities. Ho.

MR. NIEH: Okay. Thank you very much, Ray. Good morning, Chairman. Good morning, Commissioners. I'm really happy to be here today to tell you about some of the benefits that the operating reactor business line receives from research. You know, about 80 percent of Research's work is done in support of the operating reactor business line, and NRC's Nuclear Regulatory Research Program can play a key role in the decision-making in the operating reactors business line. And it does so by giving us additional confidence in the technical evaluations that we perform, and it also helps us by minimizing uncertainties in our analyses and models. So my slides this morning all highlight a few examples along those lines.

Next slide, please. Generic safety issue 191 probably brings a smile to some of us here in the room or a groan to others. But this has been a generic issue that was opened in 1996 in response to concerns over potential blockage of emergency core cooling recirculation sumps at pressurized water reactors. And over the last two decades, the scope of this generic safety issue had actually expanded to beyond sumps to also include downstream effects and also reactor in-vessel effects.

Having said that, what we know today is that there have been significant safety achievements that have been realized in the operating PWR fleet due to installation of larger and better recirculation sump strainers, implementation of containment cleanliness programs, and also removal of some problematic insulating material types. And, of course, over these years, we've done a lot of analysis, testing, and evaluations to help us better understand phenomenology of materials that could get past the strainers and the chemical effects and in-vessel effects.

So based on the safety gains that have been achieved already and the knowledge that we've gained through research, NRR very recently made a risk-informed decision and concluded that no further actions are required under generic safety issue 191, and it's time to close out the GSI. The Office of Research helped add confidence to that technical decision by performing some supplemental analyses using the NRC's thermohydraulic code TRACE. These supplemental analyses provided us with further information and confidence that boric acid precipitation and the potential for complete flow blockage inside the reactor vessel is no longer, not as significant of a safety concern as we had once considered.

So with that in mind, NRR is now proceeding to finalize its technical basis. We're writing a technical evaluation report that will support the closure of GSI 191. We expect to have GSI 191 closed out in the July time frame.

I do want to note, while GSI 191 is on a closure path, there are some licensees that will still have to engage with the NRC to close out their specific Generic Letter 2004-02 regarding performance of their sump.

And I should have mentioned, if you put this slide back up, the picture on the slide just shows an example of the improved strainers that have been installed. These are the strainers that are at the Palo Verde plant in Arizona. In fact, Ray and I are somewhere in the white suits in the picture. We had taken a trip out there. So I think it was good to have the research director see some of the things that we've achieved over the regulatory process on this issue.

Next slide, please. As you know, all U.S. operating nuclear power plants today have additional mitigation capabilities installed at their site to better cope with the effects of a beyond design basis event, such as those that might be driven by an extreme natural hazard. And the capabilities were put in place by the NRC following our response to the nuclear accident at Fukushima, and the industry has implemented these mitigation capabilities in what is referred to as FLEX equipment or FLEX strategies. And these FLEX equipment generally consist of multiple types of portable cooling water pumps and portable electric power supplies. And what's shown on the slide here are actual real examples at nuclear power plants today. In the left large oval is an example of a portable spent fuel pool cooling pump with its hoses. The large right oval shows a portable auxiliary feedwater pump, and the smaller center oval shows an example of a portable electric generator.

I do want to point out that the safety benefits of this FLEX equipment go beyond mitigating beyond design basis events. In fact, the

FLEX equipment can provide significant risk reductions when permanently installed safety equipment are unavailable during normal operations. And how regulatory research is helping NRR right now is that they're doing some work that will help us better characterize and model the deployment of FLEX in looking at how we apply probabilistic risk assessment modeling, PRAs.

So research is gathering data on operating experience, looking at human reliability analysis, so that we can better characterize the success probability of the human actions required to deploy FLEX. This will help the NRC give a more accurate and realistic assessment of the ability to deploy FLEX and the success of having FLEX in achieving some risk reduction in PRA space. So we're treating this as a high-priority area in the business line, and the work of Research will help us better evaluate and credit FLEX in PRA models going forward.

The last point I wanted to mention on how research benefits the operating reactor business line decision-making is the work that Research is doing in support of the reactor oversight process, or the ROP. Office of Research continues to maintain and improve the standardized plant assessment risk models, or analysis risk models, the SPAR models, and they were mentioned in the earlier panel. And Research also supports us by maintaining the related SAPHIRE codes. These codes and models, the SPAR and SAPHIRE, I consider to be essential tools for the NRC to independently assess the safety significance of findings in the ROP, plan events, and also emerging issues as well. And we've heard as in the earlier panel and we've heard over the years feedback from industry stakeholders that have suggested that the NRC discontinue using the SPAR models and instead rely on licensee PRA models.

The NRC staff believes that these SPAR models continue to be improved to become more realistic and that they are a very cost-effective way for us to be able to perform independent assessments of the safety significance of issues. So we have no plans or intentions to discontinue using the SPAR models. We use them quite often, and they're a key component to our decision-making on a variety of issues even beyond the ROP.

The other point I wanted to mention on the slide here is that the Office of Research recently helped NRR in providing information in support of the ROP enhancement project. We had asked Research to do some analysis and assessment on what the current level of safety is in the operating fleet today, and the Research staff had gone out and looked at various safety performance indicators, such as scrams, transients, events, collective dose, also internal events CDF. And the insight they provided us was that, overall, the level of safety in the fleet today is much better than it was 20 years ago when the ROP was put in place. So that helped NRR have additional confidence in formulating the recommendations that we're preparing right now that we hope to send to the Commission in the June time frame on improving the ROP.

So before I turn my part of the presentation over to Kim Webber, I just want to underscore that the research does benefit decision-making in the operating reactors business line. There are a lot of areas looking forward, such as accident tolerant fuels that were already discussed, long-term operations and materials, as well as advanced manufacturing. We think we would continue to derive benefit from the work of Research.

So thank you. And I'll turn it over to Kim Webber.

MS. WEBBER: Good morning. Thanks, Ho. Good morning, Chairman and Commissioners. I'm really excited to talk to you about our cooperative activities in the advanced reactor area and in accident tolerant fuel. It is an exciting area for all of us, and I think, as the previous speakers alluded to, we are preparing ourselves to support the Regulatory Office in this case, Ho's office in both of these areas, as NRR and NRO merge.

So as you know, the Office of Research works closely with our counterparts to identify the necessary analysis tools, expertise, and capabilities that support a wide range of regulatory decision-making activities, which include the development of technical basis for rulemakings, performing confirmatory analysis to augment licensing activities, and conducting safety studies to form the bases for regulatory decisions.

So could we go to the next slide, please? So we're going to Be Ready. That was the theme that Ray interjected, and that's a theme I think we all believe in. Although we're in an uncertain, variable, and changing environment, our mission now more than ever has to be to support the regulatory offices. I think we know that, and I think that we are striving to do that even better than we have in the past.

We know we need to do our research differently and embark on more Be Ready strategies. This means that we need to deliver the tools, the expertise, and the information in a cost-effective manner so that the advanced reactor and accident tolerant fuel licensing actions can be completed on time and with the allotted resources. Thus, we've been working closely with our colleagues in NRR and NRO to identify innovative ways to support their needs, and one of those ways is through cooperation with external organizations. This is a critical element of our Be Ready strategy.

So to reduce costs and duplication of efforts, we have been investing our time and energy in building even stronger partnerships with external organizations in these areas. For example, the NRC has been involved in complex multinational research projects through the Nuclear Energy Agency and through their bilateral or through multilateral negotiated agreements.

Overall, those partnerships produce experimental data and information that yield a significant average return of about 10 to 1 on our investment. One example that I'd like to highlight is in the fuel performance area. Over the last five years, we are one of ten international organizations conducting research through the Studsvik Cladding Integrity project. This project produced experimental data to investigate the dominant cladding and fuel failure mechanisms.

While the total cost of the project was about $15 million, the NRC's contribution was about $1.1 million, or about seven percent of the total cost of that project. This is a pretty common cost arrangement when we're dealing with international projects such as these, and most of the international projects that we deal with are through the Nuclear Energy Agency, although we do have bilateral arrangements with individual countries.

Domestically, through our cooperative development of computer codes with the Department of Energy and even through a senior executive rotation to the DOE's Office of Nuclear Energy, we have been building stronger, more strategic partnerships with other federal government agencies, such as the DOE and with the national laboratories. We believe our partnership with DOE will accelerate the development of our analytical tools by not having to develop our own potentially duplicative codes. I think this was a theme that was brought up in the last panel and is one that we have been proactive in and started over two years ago to try to realize a vision that I'll talk about shortly. These partnerships also help develop in-house staff expertise to support licensing of advanced reactors.

So NRC participation, such as with those organizations showed on the slide -- if you could just show the slide, please -- enable better use of taxpayer dollars and also lead to cost-savings because, as I mentioned, for example, we can reduce duplication of experimental programs and reduce duplication of code development activities, which is new to us. Working cooperatively with these external organizations but also working with the public who come to the table with different perspectives will promote the generation of new ideas that can result in more effective regulatory processes and products.

Next slide. Regarding accident tolerant fuels, this is an area of high interest in the industry and in the NRC as a whole. Over the last few years, NRC has had numerous interactions with the fuel vendors to better understand their plans for designing for testing, qualifying, and analyzing the safety of those accident tolerant fuels. In advance of the licensing submittals, we've been using methods like developing phenomena, identification, and ranking tables which help identify the most safety-significant phenomena and also developing guidance which will focus us on the most important safety issues.

Additionally, one of the key assumptions of the accident tolerant fuel project plan is that the NRC will not do its own confirmatory experiments, and that is we're relying heavily on experimental data and information produced by DOE, by vendors, and other organizations in a timely manner to support the licensing of ATF concepts. The NRC has been working with DOE to understand their schedules for conducting experiments and producing data needed for the development of the safety basis that may be used for licensing ATF.

Additionally, through a memorandum of understanding with DOE, we hope to obtain experimental data from Idaho National Lab's advanced test reactor and the Transient Reactor Test, or TREAT, facility to support the validation of our computer codes that will be used to enhance and focus our safety reviews on the longer-term ATF concepts. Through a collaboration with the Electric Power Research Institute that began last year, we will learn more about fuel fragmentation, relocation, and dispersal, which is a phenomena that may affect the coolability of operating reactors under certain design basis accidents. This important collaboration will provide information that supports our understanding of high burnup ATF fuel behavior.

Additionally, a recently-issued EPRI report on the safety and economic benefits of ATF gave the staff some additional insights on the safety benefits and operational flexibilities associated with the use of ATF. These activities have given us perspectives on the condition of ATF and the potential operating conditions ATF is likely to see. This will allow us to be better prepared to review industry submittals.

Lastly, through an international collaborative research project proposed by the NRC staff and organized by the NEA, our staff is gaining insights on international fuel safety criteria for near-term ATF concepts, such as the Cr-coated, Cr-doped fuel, and FeCrAl clad fuels. These cooperative arrangements are a part of a cost-effective strategy that will help us license ATF.

In today's environment of smaller budgets, our Be Ready mission needs to include more strategic research plans that transform the way we conduct our research activities. Through a stronger understanding of DOE's programs and the people responsible for those programs, we are strategically identifying DOE and other federal agency program assets that will enable us to develop the regulatory products that support the aggressive licensing schedules being proposed by the advanced reactor community.

This is an area that we see a real opportunity to innovate our research programs. We see the Nuclear Energy Innovation and Capabilities Act as a strong enabler to obtain experimental data, computer codes, important physics correlations, material property data, and other information at lower cost to the agency than ever before. For example, with substantial support from DOE, Idaho National Lab, and other national laboratories, we're developing a code suite called the Comprehensive Reactor Analysis Bundle. It's shown on the slide on the top right, otherwise known as CRAB or the blue CRAB. And there's some humor behind the selection of the name for this in that the DOE codes that are included in this vision of an NRC computer code suite, they name their codes after animals, so we have Bison and Pronghorn and Mammoth. So all of their codes have animal names, so we thought we'd play along and call ours CRAB.

So this particular suite of codes combines NRC codes, which is difficult to see on this slide, but, pictorially, the NRC codes are shown in yellow and then the DOE codes are shown in light blue so you can see that there is an intention to intercouple the NRC and the DOE codes to make them fully usable for the advanced reactor licensing applications that we see ahead.

I think the resulting code suite that I just showed you could be used for safety studies to gain insights on the most safety-significant topics prior to the licensing applications being submitted, which is a real advantage, I think, because I think that will help us focus our licensing review activities on the most safety-significant things. Additionally, a code suite such as that can be used to perform confirmatory analysis when we obtain the licensing application at a later date, much later date.

Additionally, through our strong relationships with DOE, we believe that we'll be able to gain access to DOE-funded experimental data to validate those codes. You heard from the previous panel that validation was an important part of our use of codes, and so that's what we intend to do.

Our recent engagement with DOE's versatile test reactor program has provided us with several opportunities, including expanding our understanding of and developing staff expertise in sodium fast reactor technologies. Additionally, we think we will be able to gain insights and lessons learned on some of our regulatory guidance through INL's use of the licensing modernization plan in Draft Guide 1353 and the advanced reactor design criteria found in Regulatory Guide 1.232. Additionally, if requested by the department, we may provide technical and regulatory expertise to support DOE's authorization of the versatile test reactor.

The Office of Research relies heavily on coordinated research activities also through bilateral agreements for which we achieve significantly leveraged benefits. One of those examples is that the NRC has had substantial engagement with the United Kingdom's regulatory authority, the Office of Nuclear Regulation, over the past few years and has obtained significant amounts of information, data, and operational experience on graphite aging and degradation. This information has led to the acceleration of our own knowledge of the behavior of graphite under high-temperature and high-radiation environments, which is typical in high-temperature gas reactors.

And now I'll turn the presentation over to Raj Iyengar.

MR. IYENGAR: Thank you, Kim. Good morning, Chairman and the Commissioners. In the next few minutes, I'll present some research examples that will underscore the themes and key messages here from the previous speakers.

Most of our research work stems from the work requests that we get from our customers at NRR, NMSS, and NRO. And we bring in the extensive pool of in-house knowledge and expertise of our researchers to accomplish, they are fully utilized to accomplish such needs and the milestones that our customers need.

The short-term projects, you know, we have short-term projects, as well as long-term projects. The short-term projects are fairly easy to control and bring to a closure. The longer-term projects are a little bit more complex and a little bit challenging to sunset. So what we do is we build in some hold points and checkpoints on those projects to reassess the scope and whether we have accomplished what we need in terms of our regulatory outcome. So these are some points that will help us sunset or bring a research project to closure.

One example is the research project on the Consequential Steam Generator Tube Rupture, which is a fairly extended project. And we had utilized one of the hold points to reassess and descope the project and bring it to a satisfactory closure.

Another example is the research and the performance of neutron absorber materials in spent fuel pools, and this project is set to conclude in fiscal year 19 when we've accomplished the technical basis that's needed for the regulatory outcome.

I also want to offer another request that came from NRR was for us to perform an in-house assessment of surface stress modification techniques, such as peening, to mitigate against stress corrosion cracking. So after we performed the assessment, we concluded that there was no need for other confirmatory research in this area and we provided a recommendation to NRR. NRR agreed with our recommendation. The information and operation experience we have obtained from our Japanese colleagues was, in part, crucial to bring to this conclusion.

Our staff integrates information knowledge from a wide variety of sources into useful solution that facilitates some of the risk-informed decision-making. We engaged with the domestic and international technical community to anticipate emerging trends, technical issues, that may have a bearing on reactors safety. A case in point is provided in this slide. In anticipation of potential applications of subsequent license renewal, our staff coordinated with the researchers from Department of Energy and Eclectic Power Research Institute to, under an applicable memorandum of understanding which you heard, to proactively identify technical issues that may surface during the long-term extended operations, and this effort resulted in a report summarizing the major technical issues that impact extended period of operation. Subsequently, the Commission identified via staff recommendation requirements memorandum four of the most technical, four of the most significant technical issues related to degradation of reactor pressure vessel, vessel internals, concrete, and cables.

In response to the SRM staff worked with DOE and EPRI counterparts to develop and implement giant road maps with milestones, specific milestones for cooperative research with separate and non-duplicative research programs. These programs aim to better understand the technical issues and potentially to solve or mitigate the effect of these issues. The results of these technical activities reduced uncertainties related to materials aging during extended period of operations and augmented the technical basis for updating aging management programs called AMPs and associated regulatory guidance.

We are applying risk-informed approaches to reactor component integrity and material aging. Probabilistic approaches are useful in incorporating the effects of uncertainties. As the cartoon in the slide shows, the uncertainties in the input parameters are properly quantified and propagated through a probabilistic model to yield a distributed output. And for improved realism, these probabilistic models need to contain validated physics-based equations or empirical equations so that you would get the said outcome.

We had implemented the use of probabilistic fraction mechanics approaches to assess component integrity and to risk inform reviews of relief requests for reductions in in-service inspections. The staff's effort will afford the licensee flexibility in their methods and increase efficiency of regulatory reviews, as well as the predictability of regulatory outcome, when probabilistic fraction mechanics is used as part of technical basis for a licensing action.

As part of research, past research activities, we developed a probabilistic fraction mechanics code called FAVOR, along with Oak Ridge National Laboratory for reactor pressure vessel assessment. The use of this code has yielded significant benefits. The industry has used this code a lot.

In-service inspections of reactor pressure vessel circumferential welds were successfully reduced at many sites through application of FAVOR-based risk-informed methodology. This code was also used to conduct a thorough and timely analysis of the potential impact on U.S. fleet of the hydrogen flakes, such as that found in the Belgian reactors Doel 2 and Tihange 3. Additionally, the use of FAVOR code enhanced the quality and efficiency of the pressure temperature limit reviews for new reactor applications.

Research and EPRI staff have jointly developed an assessment tool called Extremely Low Probability of Rupture, which Dr. Uhle had referred to earlier. It's a probabilistic code for piping integrity assessment. This code accounts for degradation effects of fatigue and primary water stress corrosion.

xLPR represents a first-of-a-kind in probabilistic fraction mechanics technology. This flagship code represents many firsts because this is the first time they partnered with EPRI on a significant software development under a memorandum of understanding. This is also the first time the component integrity assessment code was built to rigorous and modern quality assurance standards. This was also the first of a challenging, I must say, complex code distribution agreement the NRC and EPRI have signed.

Our staff is working with NRR counterparts to develop their acceptance review of the code for leak-before-break applications. They have provided in-depth training on all of these codes to the agency staff, enabling them to use these codes in their application reviews.

We are in the forefront of evaluating the applicability of new technologies to reactor safety, thus forging the future for the agency. I will provide some examples.

We are actively supporting the agency's readiness for licensing advanced reactors. Material selection and qualification for these new designs are long lead items and also design-limiting consideration. Our focus here is to assess the performance needs and issues for materials and component integrity and support the development of regulatory framework. We are adopting a multi-prong approach expeditiously, yet judiciously, to be ready. Our activities cover mining of applicable international and domestic operating experience, identifying technical issues early, and facilitating a resolution through active coordination with Department of Energy and EPRI and developing flexible approaches to material qualification, including the potential endorsement of American Society of Mechanical Engineers Section III Division 5 Code, as well as alternate approaches to material qualification and selection.

To support increasing use of risk insights, we have completed reports on international operating experience on sodium fast and high-temperature gas-cooled reactors and another report on the technical gaps for materials issues for molten salt reactors, which we worked with Oak Ridge National Lab on that.

We had a well-attended technical session at the 2009 Regulatory Information Conference on international operating experience for advanced non-light water reactors. The panelists included experts from France, UK, and Japan. These efforts have received positive feedback from early vendors and designers, as well as our international counterparts.

Another area of engagement involves advanced manufacturing technologies, such as 3D printing, Hot Isostatic Pressing, which you heard, and Electron Beam Welding. These technologies offer great promise in producing replacement parts for the existing fleet with a very short turnaround time and also new and complex parts for SMRs and advanced reactors.

The picture on the bottom shows a thimble plug device made by 3D printing. Westinghouse is planning to use this as a non-code class low-risk component in the reactor water environment under 10 CFR 50.59. Because of the rapid technology development possible implementation, our staff is engaged with NRR and NRO staff to proactively position the agency to respond appropriately to industry on the safe use of such components.

The impact of electromagnetic pulse events also has received considerable attention recently. The picture on the right shows the potential continental impact of an air burst nuclear EMP, as illustrated on the little cartoon above the red arrow. The interaction of gamma radiation with intense burst, from intense burst of energy with the earth's magnetic field lines creates such strong electric fields at the earth's surface. In response to the President's executive order on EMP, staff is validating a prior work indicating the components needed to maintain core cooling and provide make-up water to spent fuel pools and will be able to perform their safety functions. For nuclear power plants, a large EMP could potentially lead to an extended duration of loss of off-site power due to damage of electric grid. We will continue to consider new information and identify the needed research in this area.

In closing, I want to offer an analogy. Indian mythology talks about a bird called Pramahansa or the Supreme Swan, which has the rare ability to separate milk and water. Likewise, our researchers are very skilled at sifting through the technical information, voluminous data, and simulation results to extract what is needed and what's sufficient, leaving out what's redundant, to meet the engineering challenge for a specific regulatory outcome in mind.

Thank you. Now I turn over the presentation to John Nakoski.

MR. NAKOSKI: Thanks, Raj. Good morning, Chairman and Commissioners. I appreciate the opportunity this morning to share with you some of the research we are doing to advance risk-informed decision-making consistent with the Commission's 1995 PRA policy statement.

We have a long history of using risk tools, tools that include software like SAPHIRE, PRA models, collection and analysis of operating data, research on internal and external hazards, human factors and reliability, and application of probabilistic methods to more realistically understand plant response from challenges to system structures and components. These tools have improved our decision-making by systematically considering results of scientific and engineering analysis in an integrated approach that factors probabilistic information directly into the process to better characterize risk.

Risk research has enabled us to develop the skills, knowledge, and ability to make risk-informed decisions for operating new reactors and to prepare us for advanced reactors. This capability supports our review of licensee applications to adopt a risk-informed approach to treating structures and systems and components under 10 CFR 50.69.

Further, the risk analysis we perform for the proposed rulemaking on containment protection and release reduction strategies for boiling water reactors supported, in part, the Commission's decision not to pursue rulemaking.

Looking ahead, one of our objectives, what success looks like, is to have the tools and skills available to risk-inform issues and areas when the need arises. For example, we will use risk to prioritize reviews of digital instrument and control systems and we will develop tools to credit recovery of permanently-installed equipment during event response. And as you heard previously from Raj, risk research supported NRC's work in the materials area on fracture mechanics.

Research is being done to understand the benefits of expanding the use of our risk tools in physical and cybersecurity. Risk has been used for security, for example in establishing target sets. And many of the risk concepts used in security and safety are the same. The challenge is often communication.

Through the ASME and American Nuclear Society Joint Committee on Nuclear Risk Management, or JCNRM, we are collaborating with security and safety subject matter experts from the nuclear industry, academia, and other federal agencies to address the communications challenge and to build a consensus framework through which risk tools can inform our decisions on physical and cyber security.

The understanding of severe accident risks is being enhanced by the Level 3 PRA project. Improved insights are being developed on the margins to the quantitative health objections, and we are benefitting from advances in methods, models, data, and analytical tools.

These gains will be useful to us for new and advanced reactors in areas such as multi-unit or multi-module risk, emergency planning zone size, and integrated multi-source site risks.

Knowledge of severe accident progression and off-site consequences is being enhanced through the State-of-the-Art Reactor Consequence Analysis project, or SOARCA. Insights from this project were used in the review of the APR 1400 in NuScale and in the review of severe accident mitigation alternative contentions for license renewals.

Insights from the project are also being applied in areas like the Level 3 PRA project and international cooperative research programs. And we added the SOARCA source terms to the NRC's Radiological Assessment System for Consequence Analysis code, or RASCAL, used in incident response.

The use of risk tools helps us focus on issues important to the NRC achieving its mission of protecting the public. For example, by participating and developing and PRA standards and methods to assess PRA acceptability, we support the use of the results of licensees' PRAs and licensing actions. Our standards development work also supports regulatory decision-making in areas such as new PRA methods, Level 1 and 2 PRAs, PRAs for advanced reactors, and risk-informed approaches for external hazards. Research on multi-unit and integrated site risk, dynamic PRA, and human reliability for advanced control rooms helps prepare us for advanced reactors and embracing new technology.

Knowledge management is an important piece of the puzzle, enabling us to use a risk-informed approach. We hold knowledge management seminars and training on risk-informing our decisions. Through rotations, research staff gain regulatory experience and regional and program office staff gain hands-on experience with our risk tools by working on the Level 3 PRA project, performing risk assessments for the accident sequence precursor program, and updating our PRA models.

NUREG/KMs have been used to document events that have shaped the nuclear industry, such as the accident at Three Mile Island and the Browns Ferry fire. Other NUREG/KMs document concepts that we may take for granted but not fully comprehend the complex history of how we ended up where we are today. For example, the NUREG/KM on defense-in-depth.

This commitment to knowledge management undergirds our ability to understand the impact of changes in decision-making as we move forward with expanding the use of risk insights, supports preparation for advanced reactors, and provides our legacy for the future. With this background, Research is working with the program offices to encourage the use of our risk tools by technical staff and their work. The focus of this activity is to develop a common understanding of what risk tools bring to decision-making that complements our traditional engendering and scientific analyses.

Advancing the capabilities of our risk tools supports efforts to transform from relying heavily on our traditional deterministic approach to a more risk-informed approach that focuses resources on issues that are most important to our mission.

While we have made progress in using our risk tools, improvements should be made in their use to make our processes better and to ensure that we fairly place burden on licensees consistent with our understanding of the risks. Research to improve realism supports this by better characterizing uncertainties, margins, human reliability, and advances in operational capabilities.

Our risk tools are more able today to account for changes in plant capabilities and to account for human performance. For example, SPAR models were updated to account for the improved performance of new reactor coolant pump seals installed in pressurized water reactors, and, as you heard earlier from Ho and others, we recognize that FLEX has substantially improved the capability to respond to events and are able to credit it in response to the extended loss of AC power in our PRA models. Further, we expect that FLEX could be used more broadly by licensees for event response and to compensate for short periods when permanently-installed safety-related equipment is unavailable.

As licensees proceduralize their approaches, show us the capabilities and reliability of FLEX equipment, and that the operators can use it, we will be exploring how to appropriately expand FLEX credit for other events and conditions during which it may benefit safety while providing improved operational flexibility.

We are collecting information on operator performance in the control room to enhance realism in characterizing human failure. Also, we are exploring approaches to better understand and, where practical, provide appropriate credit for actions outside of the control room. Related to this is the research on human reliability for longer-term mitigating strategies that bring pre-staged equipment on site to respond to events. Success for human reliability research is being able to more realistically characterize operator response in our risk tools.

To reflect operating experience, we are conducting research with the Electric Power Research Institute to improve realism in prior PRA models. We also collect component failure data with the Institute of Nuclear Power Operations, so we can develop generic component reliability information used in NRC and many licensee PRA models. This data will also be used to develop site-specific component information for more realistic assessment of the risk from events or conditions identified by our reactor oversight program.

Operating events have shown us that we need to understand not only internal hazards but external hazards, as well. So we have conducted research on hazards such as earthquakes, floods, and high wind events to improve our understanding of these events and the uncertainties of their effects on safety. The research we've completed on earthquakes and high winds has supported incorporating seismic and high wind models in many of our plant-specific PRA models. When we complete the work on probabilistic flood hazard assessments in the next couple of years we'll be able to do the same for external flooding.

Assumptions and limitations in our state of knowledge and the ability to model complex systems contribute to uncertainties. We have taken steps to understand the uncertainties to the extent we can and provided guidance on how to consider them in decision-making. By using a systematic approach to building PRA models, we better understand the uncertainties that are tied to the assumptions and limitations and can clarify our understanding of the margins we have.

Much of our risk research can be applied to new and advanced reactors. Research on passive systems, understanding operator response in advanced control rooms, dynamic PRA, and insights from the

Level 3 PRA project enable us to more realistically model and assess the risk of advanced reactor designs.

Building off our risk research to refine our understanding of uncertainties and improve realisms, we can continue adapting our regulatory framework to assure that we achieve the mission to protect the public while adjusting the regulatory burden to be consistent with our evolving understanding of the risks.

Thank you for your attention. And with that, I'll turn it over to Steve West to continue your presentation.

MR. WEST: Thank you, John. Chairman and Commissioners, as you heard this morning, our research program emphasizes a Be Ready approach to future regulatory activities by developing and delivering tools and technical solutions for the staff. These activities support all aspects of our agency from research technical staff who support licensing reviews and oversight activities to research staff who facilitate the preservation of knowledge and assist with knowledge transfer.

Our overarching goal for our research program is to continue the focus on the most important activities in support of our safety and security mission. We continue to assess and adjust our research strategy with the goal of positioning ourselves for the future while maintaining our core technical capabilities to carry out our work.

In closing, I thank the staff throughout the agency who support our research program and who contributed to the research and regulatory activities we highlighted this morning in our presentations this morning. This concludes our presentation, and we are ready to address any questions that you have for us.

CHAIRMAN SVINICKI: Well, thank you again to each of the presenters and to the teams that work for you and with you and that contributed to the materials that you presented here today. We will begin again with Commissioner Wright.

COMMISSIONER WRIGHT: Thank you. Good morning. Thank you for your presentation. I think it's the first time that I've seen six people at the table. I know we've gone five before, but six is a lot and a lot of information.

So I guess, Ray, I'm going to go with you. In the first panel, I think Neil Wilmshurst talked about the arch fault issue in response to a question I had. So what I want to ask you how that research is going. My understanding and the reason I ask that question is that there were some strong differences of opinion between the NRC and the industry on whether the testing was realistic. So have we been able to work through those differences, and what differences remained? And what's the path forward?

MR. FURSTENAU: Thank you for the question, Commissioner. As obvious from the last panel, you know, the HEAF and the consequences of HEAF are a popular topic, let's say. And there were areas of disagreement. I think we're working through those. I think anytime where you have testing that you might get some results of the testing that maybe weren't expected that you then, okay, what does that mean and what do you have to subsequently do to develop, adjust your test plan to be more realistic? And I think that's where we're at now.

I think, in any of these type of things where you have issues like that, communications is a key to that. And I think my team, as well as EPRI and industry, in the past several months have gotten together more often in public meetings to discuss what issues remain with HEAF testing and the subsequent stages of that. And I think we had tests that were completed in September '18. There's more tests planned for September of '19. And all along the way since those initial tests we had involvement. I think Neil acknowledged with EPRI, as well with others, about how do we make these tests as realistic as possible and reflect real plant conditions? And a lot of that centers around defining the zone of influence.

So I think we certainly haven't reached any conclusions yet at this point with regard to any type of regulatory action. We're just not there yet on that. But I do think the communications has gotten much better. We are incorporating it into future test plans that reflect industry, as well as EPRI's input to that.

COMMISSIONER WRIGHT: So aligning everybody's interests, you all are really getting into that a little bit better now?

MR. FURSTENAU: Yes, I think so. I think it's gotten much better.

COMMISSIONER WRIGHT: Okay. I guess I'll stay with you, but anybody else can pitch in if you want to at all. But do you have a sense of how much money the NRC is spending versus what the industry is spending on research? And then do we have a sense for how much other regulatory agencies, like the FDA or FAA, are spending relative to the industries that they regulate? Do you have any --

MR. FURSTENAU: I don't have an answer for that directly. I'd be only guessing. I would, from my experience, I'll relate my experience with DOE on this one.

When I came to the NRC, and I'm going to be a little sarcastic here because I'm kind of dry sometimes, but I came and started looking at the research budget. I said there's got to be a zero missing here somewhere. And, obviously, you know, DOE is more of a promotional of just the R&D budgets and the Office of Nuclear Energy, they probably put forward about 450 million just for maintaining facilities and another 500 - 600 million or more on R&D activities.

So they're quite large, quite large budgets. But we have a different role to play I think. I'm not really, I really haven't judged yet whether our budget is too much or too little. I think we need to obviously focus on what's in demand from our users, our main users. But looking ahead, I think we, for more forward-looking research, I think we could do more in that area. It's part of our Be Ready theme. But I think being driven by user need for the most part has worked pretty well for the near term and maybe short-term need. The longer-term needs maybe not so much, and we might need something in that area.

MR. WEST: If I can just add a little fine point. You know, since Ray has come onboard here at the NRC, he has started making some changes in the research program. And one of the things he has started to do is having program reviews with the business line leads. I went to the first meeting, which happened to be with Ho, and they have an opportunity there to kind of get some of the questions today about talking about what is the real research being done, how is it going to be used. And in that meeting at least, there was a lot of very transparent and open discussion about the research needs, and I think some things were being questioned. But I could just see, you know, over time, that that's going to help shape the research program to where really what the business line leaders are saying they need is what's going to be getting done and other things may fall off the plate.

COMMISSIONER WRIGHT: Thank you. So I guess, again, the next question, anyone can weigh in, if you want to here. So what are some specific steps that regulators should take to maintain an understanding of emerging technologies? And my concern is that we stay abreast and develop some of these areas but have limited money and many technologies that may or may not be pursued. So I know that the NRC, the staff and managers, they attend various conferences and workshops, but are they finding things that we should be doing in this area that we're not doing, or are there things that we're doing that we may want to stop doing because they're not adding value? Do you have any insights?

MR. FURSTENAU: I want to then start and then Ho can correct me or add to it. But I think the kind of the external awareness, I think, is important. NRC just can't stay in a vacuum. We got to pay attention to what's going on around us. In some respects, you know, we have to follow the money. Where is money being spent?

I think all of those areas and many of the areas that were talked about by Dr. Busby and Neil and Jennifer, you know, are some of those things we recognize. We've got to go forward, we've got to pay attention, and that's some of the more longer-term research that we ought to be doing from a regulatory standpoint. As we see those technologies developing, what are the issues we're seeing with respect to regulatory issues? And we need to share those early on. We ought to not sit back and wait for some sort of a licensing action to occur before we start thinking about it, and that's the point of research many times for the longer-term issues.

MR. NIEH: I'll add to it. I'm not going to correct him because there's nothing to correct there. So as Steve mentioned, I'm new but I'm not new. I've been with NRC for a long time. But I've only been back eight months, and for a little over three years before returning I was working at the Nuclear Energy Agency in Paris, France, which is part of the OECD. And in my portfolio there, I was responsible for a lot of the multilateral joint safety research projects.

So one specific step that I think the NRC can do, building on what Ray said, is to maintain our external awareness and really work with our international partners to leverage these joint multilateral research efforts because they really give us a lot of bang for the buck. The leveraging aspect and partnering with other countries to share the resource costs are pretty significant, I think.

From working at NEA and the projects I've seen, one thing I would advocate for when we participate in these things is make sure that the projects we're participating in are projects we want to get something out. I mean, there are a lot of projects that we've been going on years and years with and we have to stop and ask ourselves do we still need more data from this research project? Is there another area that perhaps could be more relevant for us to move on?

For example, at NEA, we were trying to get a lot of things going with accident tolerant fuels. I think another area that's kind of ripe is looking at advanced manufacturing. There's not an existing project that's currently being developed right now with the NEA in that area, but it could be as other countries also are going to be perhaps using products coming from vendors that are going to be made using advanced manufacturing technologies.

As Neil mentioned in his presentation, you know, EPRI has a very robust network of engagements with other organizations. I think the Chairman, you mentioned early on in your remarks about early collaboration and still being able to achieve regulatory independence. That's the model that's happening in the rest of the world. You have regulators, industry, research organizations getting together up-front so there are no surprises in the end when the regulators got to make an independent decision.

So I think that model is happening elsewhere in the world, and I suggest the NRC continue to leverage that approach.

COMMISSIONER WRIGHT: Thank you so much.

CHAIRMAN SVINICKI: Well, thank you again. I get so geeked up about the research stuff, so I confess that, you know, prior to coming to NRC, my work was always in and around federal research initiatives, whether it be for the U.S. military or for DOE. And, Ray, I've known you almost 30 years, so I'm just going to say I know that you didn't come here chasing zeros. And the sobering thought is that, whatever the size of NRC's research portfolio, the rest of it can't be successful if we don't have what we need to make the independent safety conclusions and have the input and be able to convey that confidence to the American public, whether it be for currently-operating reactors or for novel technologies that we see. So the effectiveness of whatever the dollar amount is, is pivotal to the rest of the enterprise.

And so there has been, I was kind of deciding whether to make this comment or not, but there have been a few comments about, you know, declining resources and budgets and things like that. I just want to be clear that, from my standpoint, if there are things that we need for NRC's unique role, an investment that we need to make, yes, we need to be collaborative, yes, we need to participate up-front, but I'm counting on all of you, the licensing organizations and the Office of Nuclear Regulatory Research, I'm counting on you in that early engagement to be fierce advocates for, at the end of the day, we have to make really important sober decisions about the safety of things. And, you know, we shouldn't be timid in the up-front. We need to show up. We need to be outspoken about what we need, but our obligation is to advocate for that.

And so as this budget, if it gets smaller, if it needs to get bigger, but pivotal in securing those funds, so I'll be an advocate for you, but pivotal to the success of doing that will be the exquisite case we can make for how it relates to what we ultimately have to do. So, you know, I think there may be other research enterprises where you can kind of indulge your intellectual stimulation a little bit more. Here there is a discipline around doing that, but I'm confident that, if we can tie it to our mission, that I think there would be broad support for us getting what we need.

So I want to be clear: it is true that there is an increased look at leveraging the federal investment, but, you know, that shouldn't be a reason why we aren't kind of, we need to look over that horizon for what we need. And I felt really compelled to say that.

I had some other cheeky comments. Kim, I appreciate you telling me why CRAB, because I noticed the proliferation of the Intermountain West mammals. The other thing is that I think swan, I think we ought to be base it on the Supreme Swan because crabs are kind of in aqueous environments maybe. Maybe that's the way we need to go.

But I do appreciate the discussion and even the diagram, which was difficult to see, but how NRC model development and we can be part of an integrated whole, and I kind of want to pivot to the SPAR models. I'm agnostic; I don't know. But we heard Ho come in and take a fresh look and say, wait a second, you know, we have unique reliance, they're useful, they're our product, they're cost effective. We heard on the previous panel someone at least questioning whether or not the maintenance and the use of those by the regulator over the longer term, I don't think it was a retribution of the past, but, you know, is that really sustainable, is that the best way for the regulatory to have risk insights?

And since I don't really know any better, I guess I would ask the question of Ho is part of the cost effectiveness of the SPAR models it that it is the model we have and use? And I think Jennifer acknowledged that you would have to train and get people really conversant and confident, and NRC staff would have to learn something new. There's a cost to that. And so is that some of the cost effectiveness?

And the other thing is that there was mention of could NRC have access to the licensee PRA through an EPRI portal or something else about what's being conceptualized in that area. But going forward, as industry PRA models become more sophisticated, is it something that, you know, not today or two years from now, but, if you looked 15 years in the future, could NRC have a more pronounced problem in that what SPAR and the evolution of SPAR, I was tempted to call it the son of SPAR but that sounds like a sci-fi movie, you know, whatever we had or the spawn of spar or something like that. I don't know what we would have in the future. But would that, like, is there a potential that would be an inferior tool to us because, you know, at some point, there are things where you need to pivot and just do things fundamentally differently.

So I'm a little bit curious about that and if the answer could be in a way, you know, most of what I know about PRA I actually used from CJ Fong when I was sitting in the audience here, but he was willing to talk to me about PRA in a way that acknowledges that I am not a PRA analyst. I know that PRA people love what they do, but a lot of us are not in that priesthood of PRA. So anyone who would like to kind of address that.

MR. NIEH: There's a lot there, so I'll take a stab at that. At the SPAR. I think maybe the most compelling reason, in my mind Chairman, about using SPAR is really the independence aspect.

And you know, that's a prominent principal of good regulation we have. We've got to be able to make independent regulatory decisions based on an independent look at the safety significance of an issue.

You know, when I think about SPAR, yes, there is the element of keeping the skill sets and the muscles strong in applying PRA models. There are some differences certainly in terminology that licensees have in their PRA models.

We get some efficiencies because in all our models use the same terminology. I would say our inspectors are trained on it. So there's an efficiency there.

And furthermore, there have been instances where our SPAR models have found errors in licensing models. And I think that's a pretty important thing for us to have the ability to do. To have that sort of second check.

So, the question, you know, could it be one day that our models are -- maybe becomes really less sophisticated then a licensee's

SPAR model, or perhaps inferior? I suppose so.

But our maintenance costs I think help keep the realism in updating as we're learning more information. I mean, I kind of look at the -- the analogy that comes into my mind with SPAR is like SPAR is like a shotgun and the licensee PRA model is like a sniper rifle.

They'll both hit the target. You know, maybe the licensee's models are really super precise. But we get pretty darn close.

And then what I see the problem occurring now in the actual implementation stage, is we're debating the decimal points. I think somebody mentioned that in their early part of their process.

And then of course, you know, there's -- we have a role. Industry has a function as well. And when we're trying to analyze a safety significance, obviously if we come to a big delta, then that's where the rub lies.

And we're trying to zero in on the decimal points to get it to, you know, where industry wants it, where we see it.

So, I think the model serves its purpose very well for NRC's functions both in the oversight program and how we respond to events. And how we access what to do when an emergent issue comes.

So, I think the research work will help us stay ahead of the obsolescence issue that you're sort of pointing at with SPAR. That's my view on that.

CHAIRMAN SVINICKI: Okay. Thank you very much. That's actually very helpful to kind of step back in that way.

Kim, on accident tolerant fuels, you talked a little bit about the use of PIRT there. And I've heard very favorable things from other participants in this process.

But it strikes me that our success is really depending on that being the right tool and going well. Is there any assessment you can give?

I know we're still kind of in early stages. But, how is it going so far?

MS. WEBBER: Well, so I think we just completed the chrome-coated PIRT panel. And so a report will be coming out soon on that.

We still have a couple other PIRTs that are being planned. One for, I think, fresh fuel. One for high burn up in-vessel PIRT.

So the PIRTs are moving along very well. And I think they are adding some, you know, understanding of the phenomena that are important for safety.

And so we'll use that information to update our codes as appropriate.

CHAIRMAN SVINICKI: So the selection of PIRT is kind of a primary approach for eliciting the right phenomenologies and then their relative importance and things like that?

You would give an assessment that we seem to have a sense that this was the right approach?

MS. WEBBER: Yes.

CHAIRMAN SVINICKI: Okay.

MS. WEBBER: That would be my conclusion.

CHAIRMAN SVINICKI: Okay. Thank you on that. And then it's interesting to hear about the -- the kind of performance reviews that are being done now with the business lines from -- by the Office of Research.

I think again, that helps to create this nexus and connection to the relevance of an issue, and how it was initially scoped. Versus where we are today.

And as Raj talked about, kind of the sorting through the milk and the water. And figuring out what the relevance is to the regulatory decision that we need to make, and the information that we need to support that decision.

One other element though is that the ACRS has provided the Commission a review of the research program on a regular basis. And I know that ACRS has struggled to try to make that the most useful type of review tool for the Commission's needs.

I think in the past they've even met with individual members of the Commission. And said, is the review we're providing beneficial?

It would be interesting as the staff makes additional efforts in terms of its periodic assessment of research and its support. I know we have NRR here today.

But for NRO and NMSS, you know, as well, looking at the fidelity of the research program supporting the mission space.

It might be good at some point to kind of loop back through and think about how could the ACRS then either leverage off that? Or benefit from that?

And maybe provide an even more targeted and strategic assessment for the Commission. I think that at some point, I'm not saying that that's relevant today.

But I think that intrigues me as you bring more governance tools into what you're doing. That might be something to think about.

And with that, I will turn to Commissioner Baran.

COMMISSIONER BARAN: Thanks. Well, thank you for your presentations and for all your work. Ray, I want to start with a couple of bigger picture questions for you.

Can you talk a little bit about your vision for striking the right balance between user need research and anticipatory or more forward looking research?

What is your sense about how much of NRC's research should be anticipatory?

MR. FURSTENAU: On that question, when I first came here, the terminology of confirmatory versus anticipatory, and I've been struggling okay, where is -- what falls under which line?

And I guess going back and putting a number on it, I think the -- we had some folks look at when was the last time that was done to try to draw that line?

And maybe in the early 2000s. And anticipatory was maybe 20 percent of the research budget.

But I think maybe looking ahead, another way to look at it is, I think user needs are actually pretty good. Our program plan is pretty good for near term, you know.

Or what's in front of us with regards to licensing decisions. And even for ATF, you know you could argue maybe ATF is anticipatory research.

But, we're looking short term, you know, one to three years on that. And I think that methodology works pretty good.

But, where I think we fall short, is the beyond. You know the four or five years and beyond that.

I think a nominal amount needs to be dedicated to keeping us aware of what's going on. So we can look at, from a regulatory standpoint, what -- how are these new technologies?

How are these new fuels going to affect us in the long term from a regulatory standpoint? That's where I -- that's the separation point for me.

COMMISSIONER BARAN: And how -- I mean, it sounds like you think we're not doing that much in that area right now.

MR. FURSTENAU: No

COMMISSIONER BARAN: I mean, how do you, you know, and your colleagues figure out, what are the areas we need to be looking at for four or five years in the future?

And how much of that work should be done? And what are the gaps we should be thinking about filling now?

So, as you kind of termed it, we don't become the critical path a few years from now when something comes in the door.

And we say wow, this -- we really need research in this area that's going to take five years. Wouldn't it be great if we had started that five years ago?

MR. FURSTENAU: Yes.

COMMISSIONER BARAN: I mean, how do -- that seems kind of tough to figure out where you -- what to do there. But pretty important too, to figure that out.

MR. FURSTENAU: Yes. I think it is too. You know, and I think a lot of the areas that were mentioned, you know, maybe how much do we use modeling and simulation in lieu of testing?

I mean, that comes up in the short term as well. They talked about AI, big data, that sort of stuff.

And lots of it's, you know phrases right now. What does it mean to everybody? What do we see coming on the horizon?

I haven't had, you know, a lot of detailed discussions on that with our customers in the business lines. But, I think that's important to do.

I of course again, supporting licensing actions, the near term, that's the top priority. But to be ready, we need to think more about what do we need to put some, you know, reasonable amount of resources on the more forward looking innovative stuff.

COMMISSIONER BARAN: Well, I could just see there would be a certain amount of tension there, right? Because there's always going to be pressing needs.

MR. FURSTENAU: Yes.

COMMISSIONER BARAN: And it's easy to see them just kind of squeezing out anything that's more, you know, forward looking or over -- a little bit over the horizon.

And you know, if we're not intentional about that, it just seems like that part's just going to get dropped off, right? In the face of kind of present day needs.

MR. NIEH: It's a great question. And the gears were turning in my mind when you asked it. And that had been something I had been thinking about.

And I'm glad that Ray's taking some initiatives with research looking at the big picture. And I do think what you point out is an important aspect.

And I think if we did have a systematic process in the agency where we're building on our external awareness. I know we don't have crystal balls.

But we -- what you're getting at is, we need to be ready for disruptive technologies that may have legs in the market. And that we don't want to be in the way.

So, we'd like to do those things in advance to understand what's maybe coming down the road. And that's kind of hard to do, as you sort of pointed out.

But I could in my mind, envision a systematic approach that the agency could take in getting information from organizations like EPRI, or NEI, and the industry. Or perhaps even other.

Look at what's happened. What technology is being brought into other industries that could benefit the industry that we're regulating.

So, in my mind, being let's say a recipient of the work of research. Like obviously there's user needs that I'd need on an immediate basis if there's a gap for a decision I need to make.

And I don't have that information. But, I think we do, we should look at how we could have something systematic in place to anticipate things that might really disrupt us in the future if we're not ready.

COMMISSIONER BARAN: On the first panel we heard a fair bit about advanced manufacturing, and sensors, and data analytics. Or just sensors and that's maybe separate from data analytics, or with it.

How much are we doing in those areas? What are we doing there? And are we doing enough?

MR. FURSTENAU: Not a whole lot. Data analytics, we have started in research kind of looking at, you know, literature searches.

Stuff with working on. Also with CIO on how -- what's out there? What could data analytics do to help us?

What's going -- what are the trends in data analytics? And how should we play a part in that with our missions as well?

Not a lot. But we have started looking into that.

COMMISSIONER BARAN: In specialized areas of our work, there are times when the workload is low. How do you think we should maintain core technical capabilities in specialized areas during those periods?

How do you approach that question?

MR. FURSTENAU: Um-hum. Well, I'll give you my perspective, Commissioner. I think core capabilities are an important.

I think the last time the, maybe the NRC looked at it formally in research was maybe in the 1998, 2000 time frame. So it's been a while.

I expect a lot of those core capabilities are still valid. But I do think it's part of what we're doing with the strategic workforce planning, and looking at the future.

That kind of gets inherent in that. So, I'm not sure we need another dedicated effort in that. But, we've rolled it into the strategic workforce planning.

And how to maintain for those, there's -- we look when we maybe lose expertise. We look at, should we replace that internally? Do we still need it? Do we buy it versus make it ourselves sort of thing?

And that's what I think, you know, like myself and my directors, division directors, we need to be constantly, constantly looking at that. What do we need to maintain internally?

And some of that maybe available in the -- in the business lines as well. And that's where you get the importance of doing rotations from research into the business lines, and vice versa.

External assignments help with that. It ought to keep people interested in what they're doing. And I think that's an important part too in core competencies.

You've got to -- you have to have interesting work. And to maintain top talent as well in your core competencies.

COMMISSIONER BARAN: You and your team took a stab at prioritizing all the different NRC research activities. Which I imagine was pretty challenging.

When I look at some of the items listed as lower priority, there are some very significant efforts there, including research related to post-Fukushima seismic assessments, dry cask integrity, alkali-silica reaction, an ongoing effort to stay current on the science of natural hazards.

What does it mean for an item to be characterized as lower priority? Does it mean that it's work we don't need to do?

MR. FURSTENAU: No. I would look at, you know, a prioritization system in all judgements.

You can have a prioritization system that comes up with a number, but you're still relying on judgements of people on what the -- whatever categories you came up with.

So, but we had a process. And we looked at, you know, from that process, where would these activities fit?

We did that within research. And then -- and then worked with business lines to do a sanity check. Does this make sense from what they're referring to?

But, I wouldn't take it as meaning low that it's not necessary to do. But when you're looking at budgets, whatever the budget is, whether it's not enough, or it is enough, what we're -- what are you -- what's most important?

What's going to affect the Agency's mission the most? And so you focus on those based on availability resources, whether it's dollars or people.

So, I guess it doesn't mean that they're not important. It just means the priority of the work.

COMMISSIONER BARAN: Okay. I'll stop there. Thanks.

CHAIRMAN SVINICKI: Great. Thank you. Commissioner Caputo?

COMMISSIONER CAPUTO: Well good morning. Thank you all for your work in preparing for today. It's quite an amazing amount of information to take in.

Steve, you observed that the Commission hadn't had a meeting on research in quite a while. Given the caliber of discussion today, and the importance of research in support of the mission, I believe that it would be useful for the Commission to have a meeting annually with research.

Just to stay abreast of the changes that are coming. And the work that is being done.

So, just to follow on, I think, a little bit with Commissioner Baran's question on setting priorities. Is it perhaps also a factor for some things that may be listed as low priority, that they're -- that the level of priority given at a particular point in time may be reflective of the fact that a large body of work has been done fairly recently on the subject?

And therefore is perhaps not as important as other issues at this time, based on the caliber of work that's recently been completed?

MR. FURSTENAU: Yes, Commissioner. I think that's a fair -- a fair point. That that, it is a factor in the relative priorities.

COMMISSIONER CAPUTO: Okay. Thank you. Ray, last summer when both of us were new, in my trying to gain an understanding of the nature of the work going on in the Office of Research, I talked with you about the importance of having -- of the Research Office being able to articulate and produce a list simply of the projects that are underway.

I just want to say that the list I've seen so far, I think reflects a considerable amount of effort and thought. It's a -- I commend you for the effort.

I think there is probably a lot of staff work that went into that. And my compliments to you and your staff for that hard work.

I'd also like to commend you for your commitment to external engagement, outreach transparency in an effort to forward the work of the Research Office. I think that's also very important.

So, and I will shift gears a little bit. One characteristic I think of a healthy research organization is knowing when to close out a research project and be able to redirect resources to advance knowledge in a new or different area.

So, I noticed earlier this year the IG completed an audit of our processes for developing and coordinating research activities. So, one of their recommendations was earlier involvement of senior managers in developing research requests.

I know that you are stepping up efforts to coordinate with the business units in an effort to have those sorts of discussions. I definitely compliment you on that.

I think that's probably going to be extremely fruitful. The part of the response to the IG recommendation was to improve facilitating alignment on the priority strategic outcomes schedule and proposed budget for research activities.

So I guess my question from that is just this effort to pursue alignment, will it also include what constitutes completion of a research request so that there's a clear understanding of when that research project has reached its conclusion and can be terminated in favor of redirecting those resources to a new activity?

MR. FURSTENAU: And I'll start it. And then maybe Ho, if you can help from your perspective.

I think, you know, the IG's observation is -- I agree with it. I think in developing user needs let's say in developing those, I think it's important.

You know, research sometimes you don't know what you don't know. And you're trying to figure that out.

So, you've got to be flexible in that standpoint to develop a user need based on a -- on some unknown or some uncertainty that the user office wants to address and wants research to address.

I think it's important to develop, you know, milestones that okay, at this point we're going to relook at the scope.

Maybe off ramps if you want to call them that, in developing that there's checks and balances along the way, so it just doesn't become an endless research project.

Again, we have to have the end in mind. So, I think that's important in developing the user needs that research gets from the business line.

And that I pay attention to that when I sign off on them, as well as the business leads. And I also think it's part of what we do in the program reviews.

To give a perspective of what's going on in this particular activity. And is it getting the business lines what they need?

And the advantage of a program review is you're less, less siloed if you will. That you have maybe a bigger picture look at across the business line, the research that's being done, and where the priority.

And we may say, or maybe say, hey enough. We don't need any more of this from a -- from a decision making, a regulatory decision making point of view.

It might be nice research, but let somebody else do that. We're done.

COMMISSIONER CAPUTO: So, given your list of activities and the program reviews that are going on, do you have a feel for, or are you getting a feel for how many of these user needs, activities have sort of outlived what was originally envisioned in the user need request?

MR. FURSTENAU: I'm really not at that point yet. I think getting the list of activities, getting a look at what we've spent on them, what we're getting out of them.

I personally, I haven't made judgements yet on the value of these. But I think that has to happen.

COMMISSIONER CAPUTO: Fair enough.

MR. FURSTENAU: Yeah.

COMMISSIONER CAPUTO: Fair enough. Mr. Nakoski, on slide 22, I talked about how knowledge of severe accident progression and offsite consequences is enhanced through state of the art reactor consequence analysis, or SOARCA.

And this is work that's gone on for a number of years. I know this was particularly timely in the wake of the Fukushima accident.

My understanding is that we now have three separate NUREGs on SOARCA. And that the Office of Research is now working to develop a NUREG that combines all three.

I guess my question is, is it really necessary? How much time and resources end up dedicated to simply taking three documents that already exist, and combining them into one document?

And is there a benefit to doing that, that really warrants the time and effort?

MR. NAKOSKI: I'm actually going to defer to Kim.

COMMISSIONER CAPUTO: Okay.

MR. NAKOSKI: Because she's got the -- more knowledge on that than I do.

MS. WEBBER: Yes. So you're right. The severe -- the SOARCA analysis and the project itself has been around for quite a long time.

And out of that we've produced quite a number of reports about severe accidents and their consequences.

As far as I understand, the last particular NUREG that is being completed now on the severe uncertainty analysis, is going to be sent up to the Commission in June.

And then the remaining activity is to produce a summary report of all of these uncertainty analysis and deterministic analysis for the three different plant designs that were evaluated.

There's a lot of material in each of those individual studies. And for anyone to wade through all of the material that is there, it's pretty heavy technical material.

And so the intent of this summary report is to bring it up at a higher level so that people like me, who aren't experts in those fields, can understand the outcomes and the ramifications of the results, and insights that were found through those studies.

So in my mind, it would be a tool that would enable other people to understand those insights.

COMMISSIONER CAPUTO: Okay. I'd like to compliment you on your focus and your presentation on the Be Ready mindset.

I think that's hugely timely given all the advanced technologies that are coming down the pike. And I think it reflects a huge amount of leadership by everyone here, and all the staff, to recognize that.

Because I think that stands in a striking contrast to items that were also raised today, like GSI-191. I think there was a mention of neutron absorbers and spent fuel pools.

I remember that being discussed my first year out of college in 1997. So, I think the shift in mind set, the shift in culture toward a be ready mind set, and preparing to tackle sort of a broader range of new challenges, I think is enormously important.

And I think reflects a significant amount of leadership. So, I commend you all for that. And with that, I have nothing further.

CHAIRMAN SVINICKI: Okay. Well, on behalf of the Commission, thank you all again. I think this was a good discussion, and informative.

There was a lot of content. So, I think it was a lot to take in. And it was very, very helpful.

So, thank you all again. And with that, we are adjourned.

(Whereupon, the above-entitled matter went off the record at 12:14 p.m.)