

**Proceedings of the Nuclear Energy Advisory Committee (NEAC) Meeting
 March 28, 2019
 Crystal City Marriott at Reagan National Airport
 Arlington, VA 22202**

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Attendees

There were sixteen (16) members of the Nuclear Energy Advisory Committee (NAEC) present at the meeting of March 28, 2019 to include NEAC Chair Dr. Richard Meserve and NEAC Co-Chair Dr. Joy Rempe and the twenty-two (22) individuals highlighted in the table below. Of these 16 committee members, three participated by telephone, as shown by the (T) after their names. Two individuals present in the room stood in for other DOE officials. In certain instances, members were in attendance for only part of the day.

Chair

- Dr. Richard A. Meserve, former Chairman, U.S. Nuclear Regulatory Commission

Co-Chair

- Dr. Joy L. Rempe, retired Laboratory Fellow, INL; Principal, Rempe and Associates, LLC.

- John R. Bear
- David Blee
- Dr. Seungjin Kim
- Lisa Marie Cheney
- Dr. Caroline Cochran
- Ralph DiSibio
- Dr. Karen Kirkland
- Maria Korsnick
- Dr. Peter Lyons
- Dr. Regis Matzie
- Dr. Carl Paperiello
- Ray Rothrock ^(T)
- Dr. Alfred Sattelberger ^(T)
- Stephen Kuczynski ^(T)

Office of Nuclear Energy

- Ed McGinnis
- Suzie Jaworowski
- Madeline Lefton
- Dr. John W. Herczeg
- Shane Johnson
- Nancy Buschman ¹
- Andrew Griffith ²
- John Gross³
- Robert (Bob) Rova

¹ In attendance for William J. Boyle

² In attendance for Tracey Bishop

³ In attendance for Sarah Lennon

^(T) Participated by teleconferencing line

Opening Remarks

Ed McGinnis Opening Statement

Good morning. With the round of introductions, I'm really struck that after 14 years in the Office of Nuclear Energy, and coming to these Nuclear Energy Advisory Committee meetings, I've never seen the breadth of representation as it relates to nuclear as we now have on this committee.

It is quite remarkable, in my humble opinion. We not only have our traditional stalwart experts from universities and our experts from the R&D community, from the safety and regulatory community, from the laboratory community, but we now have systems operators' top leadership, top union and trades leadership, top utility leadership, top associations, top developers on the committee developing the new, advanced technologies, and we have top stakeholder leadership.

It is a remarkable opportunity as a committee to bring to fore powerful advice, insight, and views on how we tackle what is a historic moment in the nuclear energy sector in the United States.

We've heard this time and time again, but I believe we need to keep our eye on the ball. The more complicated the issue, the more complex the issue, the more challenging the issue, and the more an intertwined an issue is with others like nuclear energy is, the more important it is as we are progressing through issues such as fuel cycles, or advanced reactors, or human capital to remind ourselves why we are here. What is the "football" that we've got? The "football" is the U.S. nuclear energy sector, it is the U.S. nuclear fleet, and it is the future U.S. nuclear fleet – both infrastructure and human capital.

Our strength is often in the national labs, and the Office of Nuclear Energy brings together that deep bench of DOE experience, but ultimately, we are not here just to do R&D nor just to do regulatory work. Rather, we are here because of that football, the U.S. nuclear energy sector – the fleet and its full life. That's what we are about. That's it. That's why we're here.

We may bring to fore in the Nuclear Energy Office our strengths. Oftentimes, it is our national labs. We have leadership from the national labs here now. We bring together our deep bench of expertise in the Department of Energy.

Ultimately, though, we are not here just to do R&D. And we are not just here to do regulatory work. We are here because of that football, the nuclear energy sector, the fleet and the full life of that fleet. That's what we're about.

We have a fleet that is 39 years old right now. We have 98 plants (units). It wasn't long ago when we had 104. It is remarkable that the utilities with their efficiency and their uprates and regulatory support have been able to maintain 20% even today when we've already had seven premature shutdowns and haven't had any new plant starts or construction in 30

years. That is remarkable that the utilities have found a way to get that much out of these valuable assets. But the fact is, we are beyond half way and we may be accelerating with seeing a significant, substantial decline in our nation's electricity generation coming from nuclear power in this coming decade, in the 2020s.

We need to stay laser-like focused on that (foot)ball, and that is the fleet and getting the new pipeline of reactors coming in and everything you need to go along with it from the test capabilities, from the fuels, from the human capital development, and, yes, the regulatory and the market. If we do not have a market that values [nuclear], or we have half the market in our country that is not valuing the most unique aspects that set nuclear energy apart from other generating assets, we have a major, major problem.

There is no silver bullet. We have to get through multiple gates from technology development to regulatory preparedness to market valuation to human capital readiness to trade. We've seen this in [the] Vogtle [Electric Generating Plant] how challenging it is after 30 years to get that workforce together.

This proposition is not easy what we are attempting to do, but it is incredibly necessary and important, and so I would submit we are at a transitional moment ... We see [the end of] this fleet's life [approaching], and we have to bring in the next generation of reactors sooner than we had planned. We are in a key moment of time.

This is why it is so important to have so many perspectives [including] from one of our top ISOs in our country in John Bear, one of our topic commissioners in Illinois, Southern utilities, and others in the front lines.

The issue is product, the issue is market signaling, the issue is market need. We cannot look in the past and say that we learned a lot about large light water reactors and all we have to do is continue with that. We have to respond to the market needs, and the market needs are absolutely clear. They are more flexible in the choices they have. They have natural gas as a choice. For natural gas, look at the price and the number of folks it takes to operate that plant and where you can distribute it. That is stiff competition. We're not looking to replace but we have to show a competitive choice.

We have an historic penetration of intermittents, which should argue for our value proposition. But we also have a challenge with cost, construction time, and lack of flexibility of multi-purpose aspects that we are going to need in this new market in the signals.

I believe there is a strong and long future for large reactors such as the AP 1000, which in my view is the most advanced commercially available operating light water reactor in the world. I'm proud we've put so much effort in these programs to realize this with the support of loan guarantees, et cetera. But the fact is, we have to focus on what are the products needed today and in the future.

In the markets, they need smaller, more affordable, flexible, and even more inherently safe. If you can get the distributed through without requiring a 10-mile EPZ [Emergency Planning

Zone], you could dramatically open up the market. We've got to get that supply chain workforce prepared for the future.

Product choice. We need product choice. Micro, smalls, small scalable to large. Let's remember that one reactor design is at 12-pack 60 megawatt. It starts out small but the customer has a choice to make it a 720 [megawatt]. It is all about choice and getting the market the value.

A key leg in the table is what we are doing here at the Department of Energy in the research, development, and demonstration, and partnering with industry. To give you a couple of points on what I think are very good examples of what we are looking to do to respond to the market, and then I'll conclude.

On the reactors, pushing and partnering with over two dozen companies that are developing a full array of reactors – molten salts high temperature, sodium cooled fast, light water to micro to small modular to larger.

Supporting advanced fuels, accident tolerant fuels. Different technology and consortia being pushed. We're now pushing hard on the establishment of the front end for fuel supply, in particular with high assay LEU that the new reactors are going to need. High assay LEU demonstration – we are pushing for it in Piketon, we are pushing for it at Idaho National Laboratory and demonstrating no less than two different pathways for high assay LEU. That is for ZIRCEX and for the electrorefining. We are pushing at Oak Ridge [National Laboratory] with INL and other labs state-of-the-art, groundbreaking, highly disruptive additive manufacturing with 3D printing with a challenge of 48 months to have the world's all-components-3D-printed including high assay LEU metal fuel.

We're pushing the envelope and pushing still hard on market reform to get proper market valuation. We are pushing exports. We are pushing all-of-the-above and we are pushing communication. We cannot overstate how important is communication. I had a recent hearing with Senator [Lamar] Alexander and Senator [Dianne] Feinstein, and if you see it, you will see it screams out how vital it is to have your stakeholders with a base understanding. And if they think they are losing that base understanding, we are in trouble.

In my hearing with the Secretary – and I'll close out – by saying what an exciting time. We have never had a better chance and yet still and incredibly challenging task of bringing in our nation's next generation nuclear fleet and nuclear sector. We had Senator Alexander announce yesterday his view of a Manhattan project for clean energy. He had 10 priorities and the first one was nuclear. You can't ask for more support than that. Senator Feinstein expressed strong support, as well.

We have a golden opportunity with Senator [Lisa] Murkowski's Nuclear Energy Leadership Act, as well. That could really go a long way in pushing advanced reactors.

[Fiscal year] 2020 is going to be a key moment for the U.S. industry. If I had to predict, it is looking more and more like Congress is going to make a significant move to give an

opportunity for throwing the ball over the plate for the U.S. nuclear industry to swing at. What I mean by that is real, substantial cost-share technology deployment of first-of-a-kind advanced reactors into the market, once and for all. There is a conclusion that we believe you, we heard you. We have a problem. Time is not our friend. We can't wait until the 2030s. We've got to get the new class of advanced reactors before we have a precipitous, if not irreversible decline in our fleet.

I'm going to stop there. I'm really looking forward to hearing from all of the subcommittees and all of the experts. Thank you, Mr. Chairman.

Additional Opening Remarks

Below are summations rather than a verbatim transcript of the opening remarks by the identified individuals.

Joy Rempe

Thank you to Ed McGuinness and Susan Jaworowski for broadening the background of individuals on NEAC. Thank you also to both current and past NEAC members. NEAC received some good reports and recommendations that will be helpful to DOE-NE in moving forward. In reviewing these reports, I'm impressed with the broader group of people presenting to the committee. This is a testament to the subcommittee chairs who thought about which people should present to their subcommittees.

Richard Meserve

Since the last NEAC full meeting, the committee has lost two stalwarts who were very active in NEAC activities over the years. The first was John F. Ahearne. Dr. Ahearne was actively involved on NEAC for many years prior to my own association with the committee. He was also very active in the broader Washington policy community for many years. A remarkable person, Dr. Ahearne served not only on NEAC but also had a career that included serving as a Deputy Secretary of the Department of Defense and as both a Commissioner and Chairman of the Nuclear Regulatory Commission (NRC). He was an executive with Sigma Xi.

I had many personal interactions with Dr. Ahearne in the context of his work with the National Academies. Dr. Ahearne was a member of over 50 committees of the National Academies and chaired at least 25 of them covering a range of topics from nuclear to defense to energy and many other subjects. He was a remarkable contributor to the policy community here in Washington.

The second person we lost was Burton ("Burt") Richter. Dr. Richter was a close personal friend of mine both in a NEAC context and because I served as an attorney for the American Physical Society (APS) during Dr. Richter's tenure as APS president. I know that many former NEAC members had the opportunity to interact with him.

Dr. Richter was a Nobel Prize for Physics winner and also was the former head of the Stanford Linear Accelerator Center (SLAC). He was a remarkably highly regarded physicist, as evidenced by his elevation to the APS presidency.

Dr. Richter was a significant contributor to NEAC's deliberations, always speaking his mind and being direct in his remarks. He often presented a contrarian view, and I have to admit he was more often than not correct.

A remarkable person, he had a broad-gauge interest that went beyond being a front-ranked physicist and included authoring a book on climate change for the general public that is available on Amazon, written from a physicist's perspective.

In conclusion, NEAC has lost two remarkable committee members since the last meeting and I wanted to note this fact.

Changing subjects, I second Joy Rempe's comments that the new NEAC members have rejuvenated the committee and brought new enthusiasm that has resulted in the high-quality subcommittee reports to be reviewed in today's proceedings. The reports are both insightful and beautifully written.

Lastly, Mr. McGinnis had mentioned that the aggressive communication and outreach effort on the part of DOE-NE. Susan "Suzie" Jaworowski will make some remarks on that.

Suzie Jaworowski

I want to begin by saying how much I appreciate the time and effort that the co-chairs have put into NEAC. I too am also impressed with the quality of the four subcommittee reports. They contain sound recommendations that will be impactful for DOE-NE's efforts. I'd also like to note the quality and the enthusiasm of the people participating in NEAC. They've produced four reports containing dozens of actionable, realistic recommendations. The breadth and depth of expertise and insight from NEAC is invaluable.

I'd also like to say how happy I am to have the ability to call on any of the NEAC members whenever I see a news media account related to nuclear matters. This ability to talk to those involved and on-the-ground really helps me get out of the D.C. bubble. I appreciate the many opportunities to have relationships with the people around this table. My door is always open if you want to contact me.

As an update, and echoing what Mr. McGinnis said, I too am excited that we are at a tipping point with disruptive technologies and opportunities. I'd like to reiterate Secretary Perry's oft-stated comments about "energy realism." This includes the ability to look around the world and see the role of the U.S. civil nuclear industry, as well as the worldwide vision and opportunity.

This vision and opportunity are great and achievable – and right at our doorstep. We are pushing forward to seize a number of international opportunities such as:

- Building U.S. technology in other countries in order to develop our own domestic pipeline;
- Helping the Vogtle power plant get across the finish line so that the U.S. can reclaim its nuclear power leadership role; and

- Understanding the reality of all of our fuel sources, as well as the attributes of nuclear energy so that we can ensure markets are appropriately valuing those attributes.

Because we invariably get pulled down by day-to-day minutiae, having NEAC gives us the ability to look across the spectrum, see the big picture, and seize opportunities. Having a group such as NEAC with its broad view with communication and feedback is extremely valuable.

The other day, Secretary Perry was down at Vogtle and called it “the real green New Deal.” Having a cheerleader like that on our side, from a communications point of view, is an incredible opportunity. I’m also very, very fortunate to have the team of experts available to me that I do. I like to say that things have been divine in so many ways in the past few years.

A year ago, Secretary Perry said to me that we need to make nuclear cool again. Well, in the past year talented people have been placed in my path who developed our clean, reliable nuclear education and outreach campaign.

We also have the Millennial Nuclear Caucus series that has really taken off with at least 14 events in the past year including one in Japan at the Tokyo Institute of Technology. It was incredible the outpouring of support by young people. Professors came away from that event saying that the United States is really back in the game and we know that we have a great partner in the U.S.

Having these Millennial Nuclear Caucus events hosted at universities, labs, and industry has been incredible, but we are evolving the concept to do clean energy talks so that instead of just pushing the narrative that nuclear is clean, now the aim is that nuclear just *be* clean by being part of the clean energy conversation.

To this end, the Millennial Nuclear Caucus series is being adapted to invite a broader panel to include people from the wind, solar, and energy efficiency fields. To date, seven leading universities across the United States have invited our caucus series to come to their campuses and put on these talks.

Examples have included Dartmouth, George Washington University, and the University of Southern California. In addition, Historically Black Colleges and Universities such as Howard University have also sent an invitation to do a clean energy talk. Creating this conversation around clean energy and how nuclear fits is a huge opportunity.

Internationally, the United States is reengaging with the Clean Energy Education and Empowerment (C3E) part of the Clean Energy Ministerial (CEM), which just two years ago did not include nuclear and Secretary Perry said we need to change that. I am humbled and excited to become the U.S. representative for C3E starting in April 2019.

On Capitol Hill, as you may know, we are doing the “Atomic Wings” lunch-and-learns. Our hope was to have 30 people to show up, but for the last several events, we had to be cut off registration at 175 participants.

These lunch-and-learns are being evolved to also include an “Up and Atom” quarterly breakfast briefing on Capitol Hill. As envisioned, each one will host a different national lab. The first one will feature Idaho National Lab with INL Director Dr. Mark Peter. We will then invite Oak Ridge National Lab to feature their technology and, thereafter, the other labs working in the nuclear space.

We have an active K-12 curriculum development program with the American Nuclear Society that it will introduce in the fall as a sponsor.

For media relations, we are actively pitching stories happening at the labs. We at DOE-NE understand that there is no greater resource than lab scientists who have equity with people in the mainstream media. We’ve had so many story hits. A case in point is an Associated Press article related to the VTR [Versatile Test Reactor] and the TREAT [Transient Reactor Test Facility] that had over 94 million placements.

These things are all coming together, but again, it is a team effort. I know that it is budget season with lots of talk. Some people are happy and some unhappy with the budgets they get. Everyone wants to balance the budget but no one wants to give up anything. Well, let me assure the committee that we are well represented and that DOE-NE is dedicated to everything happening from the broad perspective in order to ensure that there is a strong industry that the United States can put forward domestically and around the world. DOE-NE leadership and your input are both helping to move the ball forward.

I would also like to add that the subcommittee reports are incredible and very helpful.

Presentations

Joy Rempe: Each of these committees does things a little differently. The way we do it here is that we will hear presentations from the speaker, and if you want to make a comment, raise your tent name card sideways. I will try to keep track and call on you accordingly. We will hear first from Ray Rothrock.

Advanced Reactor Pipeline Subcommittee

Ray Rothrock: A few upfront items. First, this is a new subcommittee of NEAC, and we are all getting our sea legs, if you will, about what it means. We had our first meeting on November 9th. There was a lot of email dialogue and phone calls post-meeting, and our report captures both what happened at the meeting and what we discussed thereafter. Steve Kuczynski provided a lot of good material that ended up in the report.

Of my members, Brein Sheahan is on spring break vacation with this family. Jay Faison is also on spring break vacation. David Blee is in the committee meeting room. Steve Kuczynski is on the phone. Caroline Cochran is in the committee meeting room. I did not hear an introduction for Dana Christensen.

The advanced reactor category is huge. This is not just hyperbole. There are scores of companies and lots of activities. This is a very important category for the future. There is a

lot being considered in here. I would suggest to the committee that the title is too broad and we will talk about that.

Instead of deciding ourselves what we thought were the most important ideas, we gathered and collected up many ideas about the issues, discuss our own view of prioritization, and then ask the full NEAC committee for its input. As noted, this is a very broad committee. I think that's a great idea and I applaud that direction we've taken.

There is a lot to consume here, and although we tried to circle the wagon, there is always more to cover. This presentation is high-level. The report was about 14 pages and had a lot of detail to cover. Just keeping it short in and of itself was difficult because there are so many things that can affect the advanced reactor pipeline.

The first slide is the agenda of our initial meeting. We covered topics of our charter, the GAIN initiative and how it interacts with the advanced reactor subcommittee, the nuclear narrative with good comments about that, radiation protection standards – this is something percolating up and as Mr. Meserve may know, this was one of Burt Richter's hottest of hot button issues in the last decade or so. I had the privilege of working with him on a number of projects. And, lastly, we covered the input from the advanced reactor community.

Slide 3. Our Subcommittee Charter. The word "establish" was in our charter originally, but we did not view our role as establishing the pipeline but rather supporting the pipeline, to enable the pipeline to develop. We proposed some word changes and gave it to DOE to sort out. I presume that has been sorted out. The point is, we are not going to establish it. The entrepreneurs and industry are going to establish it. We are just going to help it move along as quickly as possible.

Slide 4. GAIN. This program was stood up three years ago. GAIN stands Gateway for Accelerated Innovation in Nuclear. It is a fairly successful program. It started out with a couple dozen projects and now has over 70 projects. By most measures, it has been successful in attracting and getting some focal point on technology in the advanced reactor world. There is a conversation about financing some of these projects. Our committee touched on that. We talked

Successful program with over 70 projects now. It has a focal point on technology in the advanced reactor world. There is a conversation in a group with me and NEAC member Maria Korsnick and others about financing. Our committee touched on that and we thought we should team up with GAIN and bring them in.

I mention here due diligence standards and processes. In the last 30 years of being involved with venture capitalists, I've seen over 10,000 presentations. They vary in their style. I've talked with some people and the question is, how does an investor who doesn't have a nuclear background get smart on a particular investment? That's a very difficult thing to do. Maybe there is something we can do to assist in putting a framework, a skeleton, together about what that means. We've not done anything yet but it has been discussed.

Slide 5. The Nuclear Narrative. In the business of investing, narratives are critical. In talking about all the activities with universities, this is a really big deal. We talked about this at length in our committee. The nuclear industry has always had a technical narrative, but as Mr. McGinnis pointed out, economics now plays a bigger role than ever. Weaving a narrative about clean energy and economically-sound energy is a very important narrative. Everybody has to participate. It's a big problem from a public acceptance point of view and understanding what is nuclear and what it can be.

We don't have a specific recommendation here except maybe with Suzie's assistance, put together a working group that – in a manner analogous to NEAC or perhaps as a subcommittee. It would really focus on this narrative. We have to get our story bigger and more interesting. “Make nuclear cool again” – I couldn't agree more. We have to figure out how to do that.

Slide 6. Radiation Protection Standards. We stumbled into this at our committee meeting. Mr. [Peter] Lyons was on the phone. He's been around a very long time in this industry and been on the other side of the table. We discussed this. This is something that from an investor's point of view always comes up: Tell me about this thing called source-term and what is this based on? If you get interested in this subject, you dig all the way back to the LNT [linear no threshold].

I was unaware but apparently the House passed the bill H.R. 589 that is a huge win to engage the DOE Office of Science for reevaluating radiation protection standards. These standards start with LNT which, apparently, has little scientific basis. This is a perfect activity for DOE to engage in and for industry to help support. This is not going to happen quickly and perhaps committee members will have something to say in the discussion. But I think it is critically important and every investor, if they get serious about making an investment in this space, they will get to this point in time.

Slide 7. Advanced Reactor Community Topics. Fortunately, Caroline Cochran is on our subcommittee. And Steve Kuczynski. We had a rich discussion. Jay Faison is also on the subcommittee, and he came with a prepared list of topics. In our report, we gave a paragraph or two on each of these topics: Fuel, data, test reactor, financial wherewithal, materials science, government deployment, licensing, and public-private partnerships. This is a large, broad section any of which could have its own NEAC subcommittee.

In our report, we talked about the perishable shelf-life of data. This country and DOE did a lot of research into advanced reactor technology in the 1980s that has perished. The data is lost or the people who did it have moved on or passed away. This would be a very easy win for DOE with the backing of NEAC in a recommendation to appropriately build a library of information whether as video interviews or any other form.

From personal experience, there are a lot of entrepreneurs in the advanced reactor field have gone to meet these people. I'm not trying to judge what is the most important here because they are all important, but I would hope that we would have a short conversation with NEAC to help us get some prioritization.

Slide 8. Conclusion and Discussion. We'll get the charter fixed if people agree. We need this prioritization. There is an overlap with GAIN but that is an opportunity. Engaging not just with GAIN but also industry, particularly the advanced reactor start-up companies, in our conversation is really critical.

I appreciate the feedback we got from Joy Rempe and others on our report. I think Caroline is in the room. If she or any other members of my subcommittee would like to offer up their views on the priorities or what our next steps should be. With that, I finish my formal remarks.

Post-Presentation Discussion / Q&A

Joy Rempe: Are there any additional thoughts from the subcommittee members in the room?

Caroline Cochran: We probably sound like a broken record at this point, but just coming from the trenches, what we need in order to build the first reactor is fuel to power it and data to qualify it to get through the licensing in order to build it. Ray illustrated it well.

On the matter of perishing shelf-life of data, people might ask, "Why would it go away?" As Ray mentioned, the people who worked on the data are retiring or passing away, and we're losing these critical human assets that can review the data. That is needed for quality assurance on the data.

We are planning on using a specific set of data for the licensing, but I would venture to say that almost every advanced reactor company would need to use some sort of legacy data to qualify their reactors unless they plan to build one and use data from that one before they can even start licensing. That's a difficult financial proposition for many of them.

There are different pathways that different companies are considering, but we would still hate to lose many decades of incredible work by DOE just to people retiring or otherwise not being available to seek out their knowledge.

Richard Meserve: Ray and Caroline, a lot of this data is embedded in individual reports, theses, and documents all over the place. The crucial thing is to link this to get a coherent picture of where the knowledge is. Do you have any suggestions of how actually to do that?

Ray Rothrock: The web was originally created originally to do exactly that. That was Tim Berners-Lee's whole point of linking it all together. Steve Kuczynski is on the phone for this meeting, and he said that a lot of work has been going on recently tying the current work to work archived out there from others in decades past. I talk about this in our report.

We need a focused effort by someone at DOE-NE whose job it is to collect, assemble, and index this information up in the cloud and make it available broadly. This happens a lot in finance, it happens a lot in software development. We should not reinvent wheel. We should do what works with other industries.

Caroline Cochran: A lot of work has been done at Argonne, specifically, about creating a methodology for collecting data. It sounds grueling, but having a quality assurance plan for how to collect the data from the papers and get it into electronic format, which has its own procedure. The data base itself has to have its own quality assurance and then making it available to companies.

But how to know where these things are can be very difficult. Some of the work that DOE is doing now to assemble lists, I don't know if that was done previously for things labeled as applied technology. GAIN recently made a list of those titles available. But sometimes titles can be very vague. It could just be an update report, and you don't know what kind of data you're going to get. However, there are recurring things from reports that have essential data. This gets back to the subject matter experts that can do the quality assurance on the data, but they also know where to look so that we don't have inexperienced people just going through folders.

My view is that the work done at Argonne in this area either can be replicated at other labs or they can all use the same database that has already been developed. There is a wheel that doesn't necessarily have to be reinvented.

Regis Matzie: If you appreciate the timeframe of much of the legacy advanced reactor work, it was pre-computer, pre-databases, and you have to go beyond the national labs. All the major vendors, some of whom do not exist anymore such as Combustion Engineering and the B&W Group that did reactors, and of course, Westinghouse and General Electric, that data and those analyses are not in retrievable form.

Everything you said with respect to the national labs, you also have to consider going to the people who did all that work in the past. Whether it is the analysis of pressure vessels for liquid metal reactors or whatever, it is an extensive effort. But I think it is very valuable to see how you can collect it from not only national labs but also from the people who did the analysis, that is, the actual commercial vendors.

Peter Lyons: I agree with the comments that have just been made about making available archival data. I wanted to add the suggestion that DOE might want to consider how that data is shared in ways that primarily benefit U.S. companies. That data was generated in national laboratories and companies. I would suggest some care be given to, for example, not putting it in the cloud where it might be available for the world but having some sort of fairly carefully thought-through means of dissemination and control.

Joy Rempe: I know the gas reactor data and some of the sodium reactor data were designated as applied technology.

Caroline Cochran: Pete, you make a good point. Right now, the database has a requirement of who makes the request and provide access with a certain log in that can expire. Joy, to your point, the benefit of these applied technology label is not necessarily meant for export control but for use by U.S. companies. The forward use of applied technology was eliminated.

There is a new process for accessing applied technology data. It can take some time but there is a way for U.S. companies to get access to it.

To my knowledge, what was done in the past is have a review process to see if all the data could be made fully public. I'm not sure if that accomplishes all the goals of what our country wants, but it does make it available to the companies. It's a trade-off.

Joy Rempe: It seems like this is an important topic. Are you planning for your next meeting to have someone from Argonne who has this process in place to come and brief you, or maybe someone from DOE to talk about what they are doing?

Ray Rothrock: This has been a helpful conversation in terms of focus. We're looking for what is going to help the industry – what do we need to focus on? Data is clearly one issue, as are fuel and regulatory issues. But, yes, if our consensus is that this is a critical thing, we will focus on it in the next meeting and bringing in the appropriate resources, as well as a different industry expert on how they've organized their business. If that is the consensus, that is what we'll do.

Seungjin Kim: There have been an effort in the thermo-hydraulics division at ANS led by Mike Corradini – it surfaced about two years ago – in which we tried to gather some data in the way the subcommittee is recommending. That may be the place to start looking. There has been an effort in the research division to collect all this data not only domestically but also internationally.

Maria Korsnick: In reflecting on Ray's presentation, my hat is off to you and your subcommittee for covering such a broad breadth of information. My challenge to us is how do we take this to the next steps from a NEAC perspective? You've said that we've essentially asked you to solve world hunger as it applies to advanced reactors, and I agree with you, there is just a lot there.

[Given how we are trying to make progress on these many fronts simultaneously, I don't know if the proper approach is a mixture of prioritization or a mixture of breaking this into other new subcommittees or groups that report to the subcommittees.] It feels as though this conversation is one of how fast do things need to be brought to bear? If there is a speed element – and if you listen to the opening remarks by Suzie and by Ed, that was the message: We have to get to build. What is it going to take to get to build? In this recent NELA legislation that is up for discussion, there is an encouragement about building pilot projects. We are definitely going to be encouraging that conversation, and a lot of what is in this subcommittee is going to be enablers around that.

I guess my concern is that they said there is a broad waterfront, and it is. I do think there is an element of time that we need to be efficient with our time, and it's not realistic that this one subcommittee can pull all that together. Logistically, we should chat about that. I don't know the answer but I feel that it needs some robust conversation. And if you had a different message, Ray, and I picked up on something incorrectly –

Ray Rothrock: Nope.

Maria Korsnick: I was just trying to further what I thought was in your discussion.

Ray Rothrock: Thank you, Maria, that was well-said, Maria, and is exactly what I meant.

Richard Meserve: I very much agree with Maria. There's a lot of groups that are looking at issues associated with advanced reactors, and I think we should be cognizant of what else is going on and focus on our effort on issues that are not being addressed or in areas where we have special capacities that may not exist elsewhere.

I asked the question about the data. I've always heard a lot about the GAIN program as a way to satisfy this need, and this presentation said, well, we aren't capturing it, particularly in Regis's comment about legacy information out there in the world that isn't even computerized. This seems to me to be a topic that I haven't heard talked about much. It seems to me this is something this subcommittee could pursue. But how to do that, how to pursue it, and bringing in the Argonne people, other DOE people, ANS people, that's something for a future presentation. My impression is that a lot of people are looking at the regulatory side. I'll defer as to whether there are gaps there. But that may be an area that we don't need to focus on.

I am knowledgeable that this particular group has a fair number of people who are sophisticated in the financial area. This group has an assemblage of people with unique skills. It could be very thoughtful the pursuit of that. True, this isn't an area that has been missed by others concerned about advanced reactors, but there may be some special skills that are appropriate. That could be an area of focus for this committee.

So, I agree with Maria's comments and I think there are two areas that jump out at me that are worthy of possible emphasis.

Joy Rempe: One thing that we could think about doing prior to your next meeting is that there are working groups for each of these technologies. If you want to focus where the gaps may be. It might behoove you to invite some speakers from the working groups and ask them to address the data, financial issues.

Your comment about Slide 4 on standards and processes, I've heard in other forums the need for standards on technology-specific issues. That may be a gap. I know that NEI has a leadership role in advanced reactors. But it might behoove you to do a poll to see what they believe are the pressing issues. What do you think, Ray and Caroline?

Ray Rothrock: I agree. In fact, Steve [Kuczynski] brought up the working group idea in our meeting and conversations. But I want to go back to Dick's point about the financial skills. This is an industry that has not had much of an entrepreneurial community, but it has a massive one right now. It is a good observation, Dick, about the financial side. Maria and I have had many conversations about this. It cuts across everything, and without financial backing, these things die on the vine. They call it the "valley of death" and all that, which is a terrible moniker, by the way. Speaking personally, and my life as a financial person, it's data

and money. We don't build anything if it isn't built on the shoulders of the giants that came before us and we don't build it without money. The entrepreneurs are plenty working on the technology and we can figure out how to share it better, but as I sit here and listen to this, Joy and Dick, what you're saying resonates with me.

Pete Lyons: I just want to comment on Slide 6: Radiation Protection Standards. That issue came up strongly in the [Advanced Reactor Pipeline] subcommittee, and it certainly came up very strongly in our Existing Fleet subcommittee. I just wanted to follow on the last bullet ["H.R. 589 is a huge win (Engaging DOE Office of Science)"]. Thanks to leadership in Congress and leadership in the administration, that act [H.R. 589 - Department of Energy Research and Innovation Act] the President signed it last September and it is now Public Law 115-246. It authorizes the restart of the DOE low doses radiation effects program. So, it has moved beyond H.R. 589 and is now public law. Now, the authorization is for the Office of Science, so this isn't a charge to NE [Office of Nuclear Energy]. But I hope that NE could join in encouraging the Office of Science to take this very seriously, and I hope they are far more successful than I ever was in getting the Office of Science to take this seriously. So, good luck.

David Blee: I think we would be remiss on the finance side if we didn't also mention the DOE Loan Program Office. There is a little bit of dysfunction there between OMB and other parts of the government. Nevertheless, we saw this past week, Secretary Perry formalize the \$3.7 billion for the flagship of advanced nuclear, the Vogtle 3 and 4 units. There are several advanced reactor companies in the queue, they're alive and still kicking, and very, very important to advanced reactors. It is a game-changer in the financial area for advanced reactors because now you're talking half a billion to three billion dollars as opposed to six to twelve billion. Within the DOE empire, the Loan Program Office has been very, very helpful in terms of reaching out to developers in this space.

Ed McGinnis: This has been an excellent presentation. Thank you, Ray and everybody who contributed to this. It is a very, very, very useful set of recommendations and findings. Let me just say a couple of things. First, and I may not be appreciating it, but I really don't think we are asking you to solve world hunger. It's a little surprising to hear the opening presentation saying this is such a broad, broad topic and where do you start? Yes, I understand that there are many, many, many pieces to the pipeline. But I take a step back and think, like Maria said, what is the point of the pipeline? It's getting these new reactor technologies into the market, period. And then it's getting them into the market in a competitive, sustainable way. And then looking at it from a perspective – I was looking at the charge letter I sent. It didn't say "enable" but it did say "establish," so that's a good point – not to suggest that DOE should be in the business of establishing. It's the industry, absolutely.

But what can DOE Office of Nuclear Energy do to enable this new pipeline of nuclear reactors? I think about a few things immediately as far as what can we do to support those developers, some of which are there today with these new advanced reactors – micros, SMRs, larger. Looking at what are we doing now with funding opportunity announcements, other commercial cost share. Yes, data sharing. Making our labs available to GAIN. We're working with the NRC and we had a substantial role.

So, I would take a different perspective on the regulatory. Yes, we should be in the lead for regulatory. But I can assure you that DOE is playing an incredibly important role – recognizing the independence of the NRC – in supporting NRC on the pipeline of new and advanced reactors. We are proud that we drafted the advanced reactor guidelines and for the most part, they were accepted as we presented them. Shane Johnson’s group and others working very closely making the codes adequately available and to be able to rely on them and max out our capabilities.

My point is that perhaps to build on this excellent work, my thought is it would be really good to hear in your next round up of exploration of the issues what are some of the other areas that DOE-NE could be doing to support in an appropriate way these developers in getting through that “valley of death” and into the market? That is probably the single biggest issue next to market valuation. Getting our incredible IP [intellectual property] and innovation technology into the market. We’ve been extraordinarily successful in developing the concepts and ideas in innovative designs. But we’ve not been extraordinarily successful in getting into the market.

We are open to all types of idea on what else can we be doing to help enable? For example, micro-reactors: What are we doing right now? We realize one of the biggest issues for micro-reactors is high-assay LEU fuel. They can’t even do a demo without high-assay fuels. So, what have we done? We’ve gone to Idaho National Lab with Mark Peters’ help and leadership, and we’ve increased to 12-hour shifts the processing of EBR-II [Experimental Breeder Reactor-II] fuel so we can get the necessary amount – about 5 metric tons – of the fuel in time for the first demo to be built at Idaho National Lab. I see that as right in the lane of this Advanced Reactor Pipeline subcommittee.

What are those things we could do to help enable? There are codes and fuels. Secondly, financing and market competitiveness are areas we need to double down on. I have yet to see a forecasted price per kilowatt hour that captures the value attribution of the new class of advanced reactors. Load-following capabilities price in, if you have an exception to the Class 1E system for multiple redundant sensors with the workforce to go along with it and complying with the inspections year after year. Not having a 10-mile EPZ [Emergency Planning Zone] – what does that do the distributed? Whether it is the overnight cost for construction benefit or it is a leveled cost overall, I have yet to see any economic models that does anything except build off of the current large reactor fleet.

In my office, we are working to figure out how we can get some established, credible data that describes through data the economic value proposition of these reactors.

Lastly, in the hearing with Sen. Feinstein and Sen. Alexander, there was a pointed series of questions. Advanced reactors: I want to know just a couple of things. What is the economic improvement? How much cheaper on the advanced reactors going to be compared to the large reactors of today? What is the economic benefit? And then Feinstein asked, “How much safer are they going to be?” And, by the way, if we are going to be throwing all this money

into the advanced reactor pipeline, is it going to do anything to reduce the volume of waste? Those were very top level but very profoundly challenging questions.

Maybe this subcommittee would want to think about that? That's part of the communications. As Senator Feinstein said, I just

want to make sure that if we're throwing in billions of dollars, I'm not going to get the same reactor technology that creates the same amount of waste, that has the same level of safety, and no benefit to economics.

There is so much to chew on and go after in this subcommittee, and I look forward to you building on this great work. Thank you.

Versatile Test Reactor (VTR) Update

Thomas J. O'Connor: Thank you for the opportunity to speak to NEAC. [Slide 2] In terms of where we are, in accordance with some of the president's priorities to revive and expand nuclear energy, the Office of Nuclear Energy has a mission to move forward advanced reactor technologies and reactors. In order to do that, an examination was made and determined that we have a gap in some of our infrastructure capabilities, principally, to provide fast neutron spectrum for material radiation and fuels qualification. To address that, we looked at whether we have a need to do this. On Feb 22nd, the answer was signed by the Deputy Secretary as yes. This mission aligns with previous NEAC recommendations. It aligns with the Senate's Nuclear Energy Innovations Capability Act [NEICA] of 2017.

[Slide 3] In terms of what does Critical Decision [CD]-0 get to us, it established a mission need. But it also provided us some bounding numbers for that. The initial cost estimate was \$3 to \$6 billion and the schedule estimate for completion was in the 2026 and 2030 timeframe. Those numbers include some contingency. The completion date doesn't line up exactly with NEICA, which said 2025. Based on where we are, 2026 is an aggressive schedule. Consistent with that aggressive schedule, it lays out some success-oriented milestones. These milestones don't include contingency, but nonetheless are aggressive and success oriented.

When you look at the milestones, you see one is listed as CD-2/3. The reason they are combined is because for hazard category 1, in accordance with DOE Order 413 which lays out the requirements for capital acquisition, it looks to us for a reactor facility to have about 90 percent of the design completed by the CD-2 timeframe. Based on the need to have such an aggressive amount of engineering done, that would be the time we would look to start some of the long-lead types of procurements and get into authorization for the construction.

[Slide 4] In terms of the next steps bringing us to CD-1. Our efforts will be focused on getting an analysis of alternatives completed. That will form some of the framework for getting the National Environmental Policy Act [NEPA] requirements completed. It will also allow us to make a decision on what the conceptual design should be. This conceptual design will help

us further refine cost and schedule estimates. The design will be influenced by the specific capabilities that we will need.

[Slide 5] I would like to talk to you about some of the specifics on these slides. From a NEPA perspective, where we are in the process, DOE has standing contracts with a handful of firms. We've received a couple of task proposals from them for doing this NEPA work. We are in the process of evaluating those proposals. We hope to have a selection in April and kick off a process in late April or early May.

NEPA is a very challenging set of exercises. The bottom line is that we cannot do final design without a Record of Decision. We can't do long-lead procurements without a Record of Decision. NEPA requires a significant interaction with the public. This will involve public meeting at the Idaho National Laboratory and other locations to be determined.

[Slide 6] In terms of getting to completion, our overall strategy is three pieces. The integration of all the work is being done primarily by the national laboratories. Looking at the reactor concept design and cost estimates, GE-Hitachi and Bechtel are assisting us with this exercise.

Understanding some of the experimental needs, we are working with DOE national labs as well as industry and universities.

To be clear here, one of the things this overall effort will bring us to is an overarching cost estimate that includes fuel, training, experimental interfaces, of which the reactor's cost is the lion's share.

One of the entities assisting us is TerraPower. TerraPower is the designer and developer of the traveling-wave reactor. We believe their expertise will be helpful for us to ensure we put forward the best product.

[Slide 7] In terms of experimental capabilities, we are looking at a host of experiments that could go into it – looking at lead, salt, other sodium concepts, drop-in experiments that are static radiations versus cartridge-type radiations, perhaps having a moving fluid or moving pressure.

We're also looking at the development of engineering systems that keep track of all the moving pieces and parts. How does seismic affect hanger supports, the thermo-hydraulics, and the neutronics? We believe this may have broad applicability to the nuclear industry as a whole to ensure that when a designer is developing a technology that they have a robust and aggressive configuration control.

[Slide 8]. The last slide is on the Memorandum of Understanding [MOU]. It was written by the Idaho National Laboratory with Argonne, Oak Ridge, Los Alamos, PNNL, and Savannah River National Laboratory. It outlines how DOE labs are going to work together. It commits to working in a safe environment and being environmentally conscientious. It has times and schedules.

For me, the most important point on here is that it helps us establish a culture, one that is going to bring about success. I would characterize it as trying to create and foster an *esprit de corps*, the team spirit. It isn't about doing what Idaho National Lab is or isn't doing. It isn't about what Oak Ridge is or isn't doing. It's a collective recognition by the leaders of these national laboratories that this is something the department needs and is something that is essential for the advancement of nuclear energy. It helps establish and manages expectations at the top. It appears to be working its way down through the ranks.

On March 6th and 7th, we had an integration meeting where all the teams gave us an overview and update as to where they were in the progress, and you saw the comradery, the effort to focus on what needs to be done rather than a parochial "I didn't invent it, I didn't do it" attitude.

Post-Presentation Discussion / Q&A

Regis Matzie: Going to Slide 7 and reflecting on Slide 6, I'm not sure why DOE is looking at all the different coolant technologies when it appears there has been a decision that it is going to be a sodium fast-reactor based versatile test reactor [VTR]?

Thomas O'Connor (Response): If few are going to have an irradiation capability, we need to have as broad a capability as possible. So, in order to ensure this, we need to talk with those vendors and those folks interested in sodium-cooled reactor technologies, those interested in lead fast-cooled reactors. So, what are the unique characteristics of experiments would they would want to run in the VTR? By understanding what are their parameters, constraints, and needs, that we can develop a core that will hopefully meet their needs, but at the same time, knowing that we aren't going to be able to meet the needs of everybody. At least we are going in armed with the designs.

Joy Rempe: Aren't you at least going to have some loops with other coolants? Or you're not sure yet?

Thomas O'Connor (Response): Loops in the traditional sense implies having a fluid flowing outside of the core, outside the reactor. With a sodium-cooled fast reactor, that significantly increases the complexity of the core and significantly increases the size of the core in order to accommodate the ability to put those experiments in and out while accounting for this intrusive piping. You need to be able to work around it, to maneuver around it. The only way to do that is to make the core bigger. But making the core bigger increases the amount of material you need and increase the capital cost.

What we are looking at – and this is where we engage with the universities and vendors – is to try to come up with novel approaches that will provide us with cartridge capabilities. That is, self-contained experiments that are singular and tall and don't include all the external piping but that still provide the kind of flowing fluids necessary to achieve the environment that the experimenter needs. It's a trade-off. Part of what we are looking at is trying to do something as quickly and as cost-effectively as possible. This is why the team with GE and Bechtel were chosen, in terms of trying to be able to take advantage of the extensive amount of engineering work that they've previously done with their PRISM design. Otherwise, we

would be starting from scratch. This establishes some constraints and gives us a solid footprint to keep the cost down and the schedule moving very aggressively.

David Blee: We're very strongly supportive of the VTR. I remember testifying before a former NEAC, and I think NEAC gets some credit for advancing the field. My only comment, and I agree with Senator Murkowski, that if we are going to remain the go-to country for nuclear energy and also the nuclear capital of the world, we can't have a sixty-year old test reactor that is not useful for advanced reactors. To that end, your price tag is already drawing some flack – that upward thing of \$6 billion that is equals the price of three nuclear subs. I would say you should spend more time defining on why we need this. You have one slide there and then go quickly into the weeds. I think you understand, Tom, but we need to have a clear statement of why this is important and what is its mission.

Joy Rempe: Any more questions? How about those on the phone?

Steve Kuczynski: I'll add the utility perspective and the emerging constructor perspective. I think we can make it more streamlined. In the short term, this means looking at those that are developing, those that are nearest. A lot of folks are doing the work, but in my view, there are only a handful far enough along. Maybe getting a forum together to see from a priority standpoint what is most necessary to accelerate that technology. From a utility perspective, I don't see a whole not changing. Utilities are just searching for options and cost is incredibly important. It's going to be technology that wins the day. We could gather up those that are furthest along and see what it would take to accelerate from a financial perspective – How can we attract capital? How to we leverage DOE? What legislation we need? I think that's a doable thing in the next few months.

From the longer term, this should be the higher priority in that if we are really going to change the game, this is the one that ultimately makes and evolutionary change. People ask why is it so hard to build a nuclear plant? Frankly, it's straight civil structure commodities. It's just very complicated. Until we can get to the point where those things can be reduced significantly, i.e., by half, which I think advanced reactors can do, but it needs that change to get there. That's an area that should get more support and be put front-and-center.

For designers and developers, even the VTR, it is important getting the constructor involved early. I would say the way it's been done in the past hasn't been all that effective. There needs to be a better balance between those who are actually going to build it and those who design it. A lot of the trouble we run into now and in decades before is that what looks good to the developers is not that easy to build in the field, and that's what drives cost – time.

Caroline Cochran: To Dave's point on the narrative and on the issue of cost, I think there is another way to look at it. You start looking at the national budget. One of the biggest fights we have – and Ray brought this up – is fighting the “but nuclear is too expensive” fight. Now though, even a lot of groups that have been historically against nuclear are coming around. That being the case, I would just say that cost control on a project should be communicated so that the VTR is a project that wasn't built at the higher end of cost. We appreciate the work

you are doing, Tom, but please keep an eye how that can affect the overall industry if we go over cost budget.

Thomas O'Connor (Response): When a project like this is undertaken, lots of people are going to come to us and ask for specific capabilities. At the end of the day, our mission is to provide neutrons, so we need to keep it simple – to build it cheaply and quickly – and to operate it safely and reliably. We are sensitive to how people are drawing comparisons rightly or wrongly.

Karen Kirkland: Your MOU has six labs involved. Are there clearly defined, non-overlapping scopes? In the past, work has been spread out over several labs. For cost control purposes, is it avoiding duplication?

Thomas O'Connor (Response): It is not, but not to what you asked or thinking. What we have is a team that has been put in place so that each lab is not responsible for discrete pieces but rather we are pulling the best people together. We are not saying who is responsible for this pump or that heat exchanger. We are bringing the best people. Relative to funding it, we have lots of mechanisms to move money out to the labs, but to increase flexibility and accountability, we are moving the money to Idaho National Lab in order for them to subsequently disburse it. This gets DOE out of having to move money around, and it can accommodate schedule and resource needs. Having this national lab-level flexibility is something that should keep cost down. It also gives us the ability to say, Idaho National Lab, you are the belly button and we are poking you. Ultimately, we want one project, not six national lab projects.

Joy Rempe: This isn't being double-taxing on overhead?

Thomas O'Connor (Response): No. There is a modest service charge to move the money but nothing else.

David Blee: I want to commend DOE for establishing a clear point of contact. There is accountability. But question is – given that the U.S. Navy is a big user of the current advanced test reactor – have you had discussions with the Navy and gotten them on board? Is that a source of potential funding collaboration?

Thomas O'Connor (Response): Don't have an answer for that. They are relying on thermal spectrum reactors and they are quite happy at ATR. That might be a conversation that might come up but no answer.

David Blee: That might be something worth looking into.

Joy Rempe: I have a question on the way you're designing your test capabilities. Many of those users have not interacted with the regulators to see if the data will past muster. A user who is a design developer may not be enough to get past the regulator.

Thomas O'Connor (Response): The regulator fits into two spaces. The question is: How are we going to authorize operations and relative to experimental capabilities so that we can

answer what is it that regulators would need? From a broad standpoint, we are trying to ensure that this has broad applicability to industry. Could it be utilized by a vendor? We are imposing a rigorous quality assurance program. We are not just relying on vendors for input, but also working with national labs and universities to ensure what is needed. When we get into exact experiments with vendors looking for specific results, they will have to have the conversations with NRC that can render a licensing decision.

Ed McGinnis: Steve Kuczynski said that one thing that would be useful for the advanced reactor pipeline subcommittee is the time it takes to build a reactor. When DOE-NE funds FOA, I convey to leadership is that time is a premium. Time is not our friend. We are driving to get advanced reactors in the 2020s. The challenge is trying to identify those in the best position to bring quality and a competition as soon as possible. When we select our FOA awardees, we take how soon they can come into the market into account.

I thought it was an effective meeting we had the other day when we had multiple companies in attendance including the utilities and the vendors working on molten salt technologies and they described themselves as the malt-and-salt family. I thought that was a wonderful thing as they were describing where they were in the timeline.

If your timeline is in the 2030s and you're looking for prioritization, please show how you can move that into the 2020s. The ones that can get into the market the soonest are going to get premium consideration. Having the Advanced Reactor Pipeline subcommittee describe what are those developers and what they need to accelerate their development helps since this is going to be the billion-dollar question: Are there reactor companies that are truly ready to deploy in the 2020s?

Senator Alexander said he wants to see advanced reactors built in the next 5 years – so that is the mindset. That being the case, I think it would be incredibly effective if that subcommittee could put together an overview of the landscape and what appears to be the key issues to getting across that goal.

The last point is on VTRs. Lessons learned is key. We must get this on-time and on-budget. For lesser projects like TREAT, we were ahead of schedule and below budget. Remote handling project, too. Thus, we have some good examples.

We want an independent review design team of the feds with Idaho National Lab leading and the GE/Hitachi team, and availing ourselves with TerraPower to do the independent design review. In this way, lessons learned are built in. We are trying to avoid pitfalls.

High-Assay Low Enriched Uranium (HALEU)

John Herczeg Presentation. See PPT slides for overview.

Key Points:

Slide 2: Addressing HALEU Needs

- DOE is working on three options:
 - Electrochemical processing;
 - ZIRCEX
 - Enrichment

Slide 3: NEI Estimated Annual Commercial Demands

Remarks: What are the needs and timeframe? There are eight companies listed so it isn't comprehensive. All of these except one are advanced reactors but one is a LWR. The point is that this chart identifies the time we will take off is around 2023.

Slide 4: Estimated Commercial HALEU Market Needs.

- See Chart

Slide 5: Uranium Recovery and Down-blending Methods

- Electrochemical Processing of EBR-II Spent Fuel
- ZIRCEX Process

Remarks: We have doubled shifts to process this material more quickly as part of our agreement with Idaho National Laboratory

Slide 6: Addressing HALEU Needs – Electrochemical Processing (EBR-II Fuel)

Remarks: We've processed over 2 tons. But it was not meant for using in a reactor. There are lanthanides that need to be cleaned up to be used. A purification process is needed. We will purify it as we go. Our goal is to have 500MT of 19.75 U by 2023. This has some impurities that would not be suitable for LWR but only advanced reactors.

Slide 7: Addressing HALEU Needs – ZIRCEX Process

Remarks: This removes the zirconium. In past when Navy looking at reprocessing, they were using aqueous process with huge amounts of waste. Using the ZIRCEX process, you're vaporizing materials. As temp of chloride goes up, it forms into a gas and condenses into a white powder. Navy was very impressed in demos. This removes the zirconium.

The second step is a minimal aqueous step. Once we get rid of zirconium. Third step is to down-blend it.

Slide 8: Potential Path Forward – ZIRCEX

Remarks: We are looking to a quarter scale pilot test by 2020. We take "cold" – i.e., unirradiated – material. The next step would be to go forward with a hot demonstration. The scale is TBD but could be large enough for a whole assembly. Need to find a hot cell large enough. This will not be cheap. It is better to do experiment in a hot environment than to design a facility and have to retrofit it. Our rationale is move forward with a hot test and are working with INL on this.

Slide 9: ZIRCEX Pilot Plant (1/4 Scale)

Remarks: This is the INL plant. Hoping to have start-up testing by August 2019. The scale is small. It has a small footprint.

Slide 10: Enrichment

Remarks: This provides us with limited quantities of material in two ways. There are logistics problems. Some is in dry cask storage, some is in liquid pools. To make it available, we've been working with [?] reactors. We believe we will have 4 to 5 tons of HALEU material going forward. These are limited in supply, so we went back and looked at enrichment – driven on premise that we needed a long-term sustainable approach to HALEU in a way that makes the commercial industry producing material for the industry to use. The first slides show that there is a big upswing in need in the 2023 – 2026 timeframe.

Slide 11: Demonstration of US HALEU Production Capability

Remarks: We own a facility in Piketon, Ohio. Opportunity to demonstrate HALEU through uranium enrichment.

AC100 started in 2012. Turned over to NNSA at end of 2013 and closed down project. They identified some technical issues with the AC100. Technology not ready. They developed a new centrifuge at ORNL . Time frame is for availability in the 2034 timeframe. They will design and small-test testing. Cost will be \$4 to \$14B.

We worked closely with the experts at ORNL who oversee enrichment – “the three wisemen”

Consulted with them to see the state of the AC100. They claim that American Centrifuge has done a lot of design work to resolve the three issues – and have come up with a new centrifuge called AC100M at TRL 8. Purpose is to move to TRL 9 and commercialization that sends a signal to the market.

Slide 12 – Addressing HALEU Needs – Enrichment.

Remarks: We would like to put a contract in place in 2019 ... Still working on this. A bit slower than we want. Hope to have it in place soon. Trying to mobilize the DOE facilities for the pieces we need for transport from ORNL to Piketon to assemble in 2019. Plan is to produce gram-quantities in 2020 ... After NRC approval, there will be a one-year test out and shaking to see if they can run for 9 months. At that point, commercialization is over and it is up to industry.

Slide 13 – DOE Facility

Remarks: The key points are as follows:

- The picture here is the facility in Piketon, Ohio. It was going to be decommissioned. It is worth \$1.5B if it were replaced today. So, a factor was let's capture an existing facility with all the infrastructure in place. The cost of the demo is therefore limited.

- This place also holds an NRC license to run centrifuges of non-HALEU material. It has started process of deactivating its license by July 2019.

Slide 14 – Process Building Layout.

Remarks: Interior picture of building. In the background, you can see the supporting equipment (diesel generators, heat, air). What will be required to build 16 demo units? DOE owns 8 of those at ORNL and will build 8 more. This “cascade” will then be plumbed to produce HALEU by 2021. It is not in our plan or charter to build this material to supply industry ...

Post-Presentation Discussion / Q&A

Regis Matzie: Would this facility be made available to a commercial entity?

John Herczeg (Response): Yes, it would be.

Pete Lyons: I understand how important it is the moving ahead with high-assay LEU and that there are several paths to ensure success. But a point you didn’t make – and looking ahead to the NEUP [Nuclear Energy University Program] presentation – is that there is a significant reduction in the NEUP budget and those funds were transferred to the enrichment program. I have concerns with solving the enrichment problem at the expense at the universities. I know it’s a done deal this year. I am concerned looking into future if there are more CRs [continuing resolutions]. I’m concerned that as the enrichment demo moves ahead in a three-year program that there needs to be discussions to ensure that universities are protected in the subsequent years. The NEUP budget reduction has been a blow to the universities. Our Existing Fleet subcommittee report refers to universities as the gold standard of the world. This is an area where the United States is the envy of the world, and I’m concerned with cuts to the NEUP program. Given where we are, and given possibility of more CRs, are there discussions ongoing to protect the universities?

John Herczeg (Response): Yes, but I think I should turn this over to Ed McGinnis.

Ed McGinnis: We have finite funds and we have to prioritize. Before, I mentioned the football. That football is the health of the industry and the advanced reactor pipeline. If we don’t have a nuclear sector, then what do we have? We are not terminating our NEUP. We are still doing nearly \$40 million, which is more than in recent years when it was as low as \$30 million. Of course, human capital is the top priority, but so is the fleet and the pipeline and the pipeline is not going to get there without the fuel.

The current funding of nearly \$39 million is a lot. I know that at its peak, it was \$59 million. And I know how much you love NEUP and the IUP [Integrated University Program], but in years past, we have seen them funded at zero. And I am not the only one makes this call. I’m hoping that we don’t have to revisit this. I am hoping we put this in the budget next year and we told the Hill we don’t *have* to make tough trade-off choices. But reducing the program from \$59 million to \$39 million doesn’t mean that we don’t think it isn’t top priority. Having said that, we need a pathway for high-assay LEU and without it we are in trouble. Yes, I wish

there was a better answer, but that's where we are. I take your point about the CR. We have pointed to the Hill that if we are back in the CR, we will have this issue. But I will do what I can to avoid it.

Caroline Cochran: OK, I have three questions. First, are you aware that there is a dollar cost target for the project?

John Herczeg (Response): We've been trying to calculate that and having trouble coming up with that number. We have done calculations on the per ton basis, but the basis from which we are calculating, it is very difficult to get an answer and the numbers would have such a large error bar. I can't say with confidence. It is what industry wants to build and charge. But when you go advanced LWR and advanced reactors, it costs more. It is also a function of the number of units built. Once up and running, then it is just electricity, maintenance, security, water.

Caroline Cochran: So, there isn't a target? I would encourage that there be a target. While there are no U.S. sources, there are international targets and in trying to make the U.S. more competitive, please keep that in mind.

Secondly, the timeline of EBR-II fuel recovery indicates 5 megatons of high-assay LEU by 2023. That timeline is later than 2022 mentioned in the FOA for the Westinghouse eVinci reactor. My question is, how is that evaluation done by DOE for this timeframe? I don't even know the NEAC panel can talk to this matter. But I would suggest that with FOAs, we should be cognizant of what we are funding and the timelines to align with each other.

John Herczeg (Response): I can answer part of that question. When we first did our calculations for when the material would be available, we did not take into account the need to purify the overall material. If you add the purification step, it's not difficult to do but it does cost a significant amount of money. And it increases the time you need. But we want people to be able to do this work in boxes, not in hot cells. That reduces your cost. If you had to go into the hot cell to manufacture the fuel, that would be much more expensive. So, yes, there is a delay, but it gives you material you can use in a fast reactor.

Caroline Cochran: My third question: Is DOE also funding efforts on transport? How is transport capital being captured in this?

John Herczeg (Response): We have been working with NEI, which has expressed a strong desire that we move quickly on cask design and qualification. We have tried to identify the right path forward but haven't done that yet. But the laboratories can help in the qualification. We can build these but we would work with a cask vendor and help them qualify that cask for shipment in the United States. There is a German that has been qualified for a higher percentage.

Don't forget that DOE moves material around all the time, but we have very special casks because it's usually very high enriched material and plutonium. Our casks are not the physical size you need. So, yes, we are interested in working with industry, and I've asked

this question at NEI meetings. We will work with vendors but it is up to vendors to provide the design, and we'll have the laboratories help them with the R&D to make sure that it meets NRC's standards to be shipped in the United States.

Caroline Cochran: Thank you so much, John. We appreciate the crosscutting work you and Ed are doing so that all these fundamental things are met so we can have new builds and move forward on technology. I do want to mention that we'd like to see more funding go toward crosscutting efforts like transport and not have to rely only on only giving funds to individual companies.

Ed McGinnis: On the transportation casks, this is not something that is deeply in R&D space. We know casks and we understand what would be required, as does industry. If industry decides to develop them, this is something that is doable.

I would just encourage any industry that is interested in casks for high-assay LEU to think about the FOA process. Yes, ultimately, it is going to get to specific companies, but that is one pathway. Companies can apply at any time – you can apply today – via the FOA with cost-share proposals – and high-assay LEU transportation casks fall within our mandate.

On the 2023 date, I've been pushing as fast as possible. Once they realized there was a cleanup, they said 2024, but I said we want to get in front of that maybe by more shifts. It might be that if we see the progression where we see they are really moving toward a 2022 target for a license, we might be able to revisit further accelerating. But acceleration costs money. So part of it is technical and part of it is cost.

We need to keep our eye on the progression of micro-reactors and if they look like they really are going to hit the 2022 market. John and I will keep an eye on that. I don't want to go out and burn a lot of funds to get a 6-to-8 months delta if it ends up not being needed. Also, the target prices, that's the key point of market signaling with the high-assay LEU markets. It is industry that will lead this. It gets challenging if we start trying to divine the price point. We should have some sense of cost competitiveness, but ultimately it is going to have to be the enricher who makes that call on the price point.

Lisa Maria Cheney: Two questions. First, a comment. When you mentioned the delicensing? Have you put the brakes on that?

John Herczeg (Response): Unless we get a contractor in place, it's on hold. We have asked NRC to please be patient and not shut it down immediately and those discussions have been positive. The answer now is no, it won't be shut down. But, yes, the license would go away with the lease.

Lisa Marie Cheney: Are you looking at the repurposing of MOX facilities?

John Herczeg (Response): We are not looking at that. If the people at NNSA have a unit, they could look at it. I have some uses of MOX that I will talk to you about privately.

Lisa Marie Cheney: I agree with Ed that if we don't drive our technology so that we are once again a key provider and leader, then all the education isn't going to be worth it because we aren't going to be the ones driving the future. There has to be a balance. I think DOE's decision is a near-term is probably a wise one but long-term, once we're back in the seat being a respected leader – I mean, we're still a leader but we're not the producer anymore – then at that point, we can bump up what we do in our education.

Regis Matzie: Regarding Slide 4: Estimated Commercial HALEU Market Needs, have you thought about the NNSA program? I am referring to conversion of high-powered research reactors from AGU. That will also have a significant demand for high-assay LEU.

John Herczeg (Response): That's under the purview of NNSA. We have commented on one of their reports that we have some misgivings about that conversion. But no, we didn't. They have stocks to downblend from LEU to high-assay LEU so they have enough to do it. But they could run out of it because they have a need for tritium.

Karen Kirkland: The way the NEUP budget was cut was fairly intrusive. There were topics that were far along and we had colleagues who lost preparing. Continuity is important.

Joy Rempe: My understand is that there were also cuts in the international program, and the manner in how such cuts were made, was disruptive.

Ed McGinnis: We worked with each country to find a secondary support. But the view on Capitol Hill is one of frustration. Maybe we are spread too much. We can't afford just to fund at the levels that we have if we have not seen the progression of the next generation nuclear. I'm just saying that it is they seem to be grappling with. We've already been told that next year's budget is going to be far more prescriptive. They are wrestling with how to have a robust sector.

Karen Kirkland: Universities are not a business, so when we have disruptions, we don't have a reservoir of funds and we have to cut back and downsize.

Shane Johnson: I really don't understand this. All of these awards are future-oriented, so there is no guarantee that anyone who submits anything gets funding. I don't know how this is affecting program admissions that won't be made for months in advance. My question is, how did this DOE decision have an impact on who you admit into the program?

Karen Kirkland: No, we don't feel entitled and we realize it is a competitive process. Rather, we make estimates of what our funding could be. And we admit students in the spring for the fall. In this way, we rely on DOE. We will admit a smaller number of students if we know that we don't have the funding possibility.

Richard Meserve: DOE needs to get an NRC license cask if they want to do this by 2023.

Ed McGinnis: Absolutely. This is something that must happen. And we think it can happen within the time frame we have.

John Herczeg (Response): I believe so, but we need to work closely with NEI and see what type of fuel we need. Are they pebbles? Are they multiple type fuels? We have to understand that because you can't make a generic cask. I think that through the working groups at NEI that I attend, I see that feedback coming.

David Blee: The advanced reactors stakeholders at NRC, of which we are a member, we testified on this very subject back in January. This is very much on NRC's screen. Industry is capable of doing this. It's just that they aren't going to do it on spec.

Fuel Cycle & Infrastructure (FC&I) Subcommittee Report

Ralph DiSibio and Al Sattelberger Presentation. See PPT slides for overview.

Key Points:

Slides 2 – 5: Overview of subcommittee members; topics of the Jan 24 – 25, 2019 meeting; remarks made by NE-1 (Ed McGinnis); and the reorganization of NE-4 office.

Slide 6: Budget and Congressional Highlights

Remarks: In some ways, the budget was concerning, but in other ways, positive. The VTR is fully funded as a top priority. But there are some issues already discussed including about the NEUP (already discussed).

SLIDE 7: Experimental and Testing Facilities Update

Remarks: The two recommendations highlighted in red on this slide now seem obvious but it wasn't obvious to us in January.

Slides 8 and 9: Vendor and EPRI Presentations

Remarks: We had a series of presentations from three of the vendors working on these accident tolerant fuels including Framatome, GE, and Westinghouse, and EPRI.

Our recommendations included constant and upgraded recommendations with NRC, while recognizing they are an independent agency. We also recommended preparation of a roadmap for the business case for commercialization. Without a business case, nothing happens.

The EPRI presentation was more of a historical perspective. A more even-handed presentation would have been better. It was one-sided and we felt as a recommendation that there should be an even-handed presentation (see red comments on the EPRI slide).

Slides 10 and 11 – Versatile Test Reactor (VTR)

Remarks: This is the financial elephant in the room and not much we can add. Let me just say that there was a lot of innuendo with respect to Idaho. A lot of what is going is being

developed there. We talked about the Memorandum of Understanding (MOU) among the national labs. Idaho National Lab is responsible for doling out those dollars.

We aren't sure if the political implications have been vetted. This is a \$6 billion program. The sites such as Savannah River, Hanford, Nevada, Oak Ridge, and Idaho are going to vie for this. The political implications of this could slow it down. We recommend that DOE work toward a procurement process that obviates the tremendous competition that will occur among the labs.

Because of the magnitude of the project, it would benefit from a multi-year funding. Unsure if that can happen but we need a plan.

Slide 12 – ZIRCEX

Remarks: This is old bridge technology in the event the others don't come to fruition as rapidly as they can. We have to keep spending money on it as another arrow in our quiver from a timing perspective.

Slides 13 and 14 - NEUP

Remarks: Why is so much energy devoted to NEUP? It has to do with pipeline of intellectual capacity and human talent. What if all our dreams in advanced reactors come true but then we have to import the talent from China, North Korea, or Iran? We have to think more of this more a priority in all our judgements. This is vital. Yes, it's technical, but without the human resources, technical will never be realized.

Slides 15 and 16 – Nuclear Science Users Facilities

Remark: The Nuclear Science User Facilities (NSUF) is a valuable but underfunded program. The difference between NSUF and other national user facilities is that there is no funding provided to the facilities from NSUF for base support of the facilities.

We suggest NE-5 form a high-level committee to address the four issues listed in Slide 16.

Al Sattelberger: The big-ticket item is VTR. I think the subcommittee is concerned about having a resource-loaded schedule. By next year, we are going to have such a schedule, but it is dependent on an increase in funding. So, what are the contingency plans that need to be put in plan in case things don't go this way?

Also, at Argonne, we are going to have a redesign and expansion of the advanced photo source. This is an opportunity to do additional experiments such as X-ray source one, so this is a wonderful time to get engaged with the Office of Science to see if there is the possible of a partnership to see if the nuclear community could get involved.

Post-Presentation Discussion / Q&A

Joy Rempe: I'd like to elaborate a bit on Slide 15 ["Nuclear Science User Facilities"], the point that NSUF doesn't fund the base operations of the facilities. Recall that in the NEAC study on the VTR, one reason we recommended that DOE go forward with fast-neutron capability was

because we looked at the landscape of thermal-spectrum capabilities and at that time, there existed the Halden reactor, the ATR, HFIR, and the MIT reactor that are primarily used by DOE-NE for irradiations. . But in the last year or so, we've seen that the Halden facility has shut down. There has been an issue with the HFIR down for about a year. So, now we are with ATR and the MIT reactor, and it is my understanding that there have been maintenance issues with ATR. IMIT reactor is basically subsidizing NE research, so we're doing things doing things not on a cost-recovery basis. I'm concerned that MIT could make a decision similar to what the Government of Norway did and say that we're also not going to continue supporting this and we're going to shut down the Halden reactor. How will it affect the NE programs if we continue running NSUF without providing baseload funding for some of the facilities to rely on? This came up after our report was issued. This is something the committee should consider. Maybe we need to think about some facility funding. I know INL has its facilities budget but that might not be enough.

Ralph DiSibio: It is a funding issue as well. On the Halden project, we made a recommendation that we ought to ensure that the skill sets – the actual people associated with that – get absorbed and not let the experience that they had, even though it was in Norway, go to waste and that we absorb that as a human resource and make sure we pay attention to it.

Richard Meserve: I might add to what Joy said, and I don't know the current status of it, but the MIT people indicated to the reactor facility people that they aren't going to continue the subsidy. So, there is an immediate financial challenge. We may lose the MIT facility.

Ed McGinnis: I'm not sure I understand what we mean by "subsidizing." You mean, MIT subsidizing DOE?

Richard Meserve: The university is paying some of the cost for the operation of the facility, but they don't think they are getting a commensurate benefit to the university from the money they are putting into it.

Ed McGinnis: Yeah, and I was really disappointed that they came last year with a letter that said we're going to shut it down if we didn't provide more money. We've already funded them and provided them with fuel. I don't know how we can do much more without owning it and operating it, which we aren't going to do. But I would ask Shane or John if they want to respond to the workaround for Halden and what we're doing about it.

John Herczeg: We've been following what's going on at Halden, and we understand that they are going to keep the people and the resources together and continue the overall program without the reactor to make sure that the knowledge is there and the experimental data is available. We've talked with Ray Furstenau [Director of Nuclear Regulatory Research] at NRC and we are actively jointly making sure that we can have access to that data.

With regard to VTR and Al's question of do you have enough money to get to the next step, that's Critical Decision [CD]-1 and that includes alternative analysis study. The total estimated cost for that is \$120 million. We have \$65 million even with a continuing

resolution and our completion date will be no later than June 2020. So, we can get to the next step but then we'll be running out of money at the end of that, but we will finish CD-1 on schedule, on time, on budget.

Ed McGinnis: It is important to mention the \$3 to \$6 billion range with \$1.5 above or below, so hopefully it's not going to be \$6 billion. We have that range precisely for contingency including for funding. So, ultimately, if we are shooting for a 2026, it is going to cost to get earlier. But the 2026 – 2030 timeframe also provides that contingency. Wouldn't you say that, John?

John Herczeg: Yes, I would. But equally important, the range we give for the cost estimate at CD-0 are just an estimate, and everyone I talk to because of the contracts we have in place and the path we have forward, we believe the number is going to be less than \$4 billion. And if [Kamal?] were here, we would say that if it is more than \$4 billion, we should not be doing that. Now, I'll believe it when I see it, but everyone I talk to tells me it's not going to be \$6 billion.

Comment [Richard Meserve?]: From your mouth to God's ears.

John Herczeg: No, that's talking to General Electric [and] other consortia people who have submitted proposals to us. They said, you do the licensing and we'll build it and the number was \$2.1 billion per reactor.

Ed McGinnis: In addition, that's why we're doing, among other things, the independent, separate design review. Getting that design developed before you start spending a lot of money on construction is one of the key lessons learned. But we're open to other lessons learned that we can build in. We're open-minded. We understand the remark with historical context. It may not give everybody reassurance that \$4 billion is what we hope, but we are doing everything we can to try to learn from past experiences.

Ralph DiSibio: I don't think any of us have any question as to what your intent it and what you're literally putting in place. It's not just a matter of intent. You're putting in place these processes and anticipating these things, and we all want that to occur. The fact that GE or some other commercial entity like the ones I associate with made an estimate, well, let's get this thing rolling. But that's when the price goes up almost by nature. So, that range seems to me to be accurate, particularly in light of the fact that you're putting in place processes to ensure that you'll stay within that range.

Regis Matzie: I just wanted to amplify on the MIT cost issue, Joy and I were part of one initiative to see what you could do there. It's my understanding that MIT is stating that about half the cost of maintaining the MIT reactor is recovered through the various programs for radiation, and so the university is supporting the other half. They did the review a couple of years ago and they are in the process of doing another review to see what can be done and/or to see if the facility should continue on long-term because it is a drain on the R&D budget of the university. So, it is real and it is a potential threat. Don't just brush it off. In their mind, it's real.

Ed McGinnis: Regis, when you say “recovered,” is that recovered costs from users such as from industry?

Regis Matzie: They recover from users and other programs that roll through there such as Kairos Power radiations and the radiations that were done as part of the FHR [Fluoride-salt-cooled High temperature Reactor] integrated research program and materials program. So, yes, recovery is the fuel you guys supply and all the other money they get from those programs.

Ed McGinnis: That was my question. Have they thought about expanding their fee recovery from commercial users or others? It sounded like they were debating what the impact would be if they didn’t have a research reactor on their curriculum and their student body. I certainly hope they would continue this very important test capability, but ultimately, they have to make that decision. I also think it’s important to state – I think this is right, Shane or John – that it’s not just the fuel we’re funding. We are also at times funding and supporting experiments that are going into that reactor.

Mike Worley [in audible on audio tape]: Over the last 10 years, we’ve provided \$40 million to MIT competitively or for research.

Ralph DiSibio: The subcommittee recognizes this recommendation was based upon the result of the presentation we were given, and it’s our job to share that with you and get the feedback we are getting so that we get a balanced representation.

David Blee: Thank you for that presentation. I think you’ve checked most of the boxes, especially on accident tolerant fuels and the Versatile Test Reactor and, of course, the university programs. The only thing I would ask is if this fuel cycle infrastructure or fuel cycle *and* infrastructure? Maybe look a little more broadly, because it was very DOE-centric. It’s whatever DOE is doing now. That’s a good place to start, but I would think a little more broadly. For one thing, our backend infrastructure is non-existent. We’re storing this stuff safely, and they can stay there for some time to come, but it hurts us in international markets.

We don’t have disposition capabilities and the government living up to their contract. It’s one of those omni-present issues in terms of infrastructure. We are actually not even a conversation these days when you go to international fora on the backend because we have nothing to say. If we are going to be involved in the D&D [deactivation & decommissioning] market internationally, which we want to do, we need to have disposition. This is a big gap in our infrastructure.

I would also say that some attention is needed to the supply chain. The supply chain is in need of some revitalization. We can only do 65% of the current reactors in terms of manufacturing forgings and castings. The advantage of smaller advanced reactors is that 100 percent can be done in our country. Some people are already saying we can’t do everything here. Well, we are doing a manufacturing gap assessment on the heavy side, which we’ll share with you.

I think that what Ed is doing with deployment and those initiatives, build it and they will come, are very, very important to revitalization. The other part is the industry FOA. That could fill some of the needs, as well. But the supply chain needs some attention in terms of ensuring we're getting new entrants.

We have a program called Ready for Nuclear where we go around the country and put on programs with supply chain to make sure they remain interested, and they are in general very excited about things coming out of NE-1. But, generally speaking, I would encourage everyone to have a follow-up focus beyond just a DOE generic budget issues.

Ralph Disibio: Those comments are very well articulated and are things we've been thinking about. I will say that Al [Sattelberger] has set up the next meeting on the backend of the fuel cycle in Nevada and the history there and where we stand. It will be presented at that time and play a very important role in the next subcommittee meeting. This is very critical and I'm very sensitive to it, especially as it relates to my background, and it's what I did for a living for 40 years. It is important.

As to the supply chain, I hadn't thought about it, but you're absolutely right. We should take that up as a subcommittee and report back. Those companies that have an "N" stamp are disappearing, and so you are having a more difficult time for organizations that can do this kind of work – not because they wouldn't like to, but fabrication shops and welding organizations that have "N" stamps are few and far between and getting fewer. So, the work you guys are doing with respect to encouraging people to get into that business and go through the certification that are required – I hadn't thought about it, but thanks for bringing it to our attention.

David Blee: As you well know, Ralph, cost of those "N" stamps and programs is very, very expensive. And if you talk to ASME, there are less and less people to keep up those capabilities. That is something we ought to think about: How can we nurture? We don't need a government takeover, but we need to provide some incentivization.

I also was remiss in not mentioning another very important initiative DOE is doing and needs some positive reinforcement is the Transformational Reactor Initiative. I was opposed to it when I thought it was a new reactor but it has nothing to do with that. It is effectively the manufacturing initiative, dealing with additive manufacturing. When you go down to the Manufacturing Demonstration Facility at Oak Ridge, it is really eye-opening what is happening. I saw things such as airplanes from the Department of Defense and other things, and we need to push, push, push if we really think the transformation challenge program is a great vehicle for that and certainly strongly supported by the Senate Appropriates Chair.

Richard Meserve: One of the arguments about advanced reactors is that the safety systems will be such that that nuclear-qualifying equipment may not be necessary and that commercial-grade equipment will be satisfactory for the objectives of the design.

David Blee: Well, in your former orbit, we also need to make sure the NRC gets with the program. Carl Paperiello can talk about that.

Richard Meserve: I'd like to pass along a comment on the ATF program to reinforce what you said about a business case evaluation. I wish that Maria were here as she could be much more knowledgeable in responding, but I have heard through the utilities world that their aspirations for the ATF program over time, at least for the near term, have diminished to make sure they can have higher burnups, and finding a solution for all the severe accidents may be a wonderful long-term goal but is one that is not achievable in a reasonable time frame. It may not make a lot of sense to try to make a lot of money on it.

Ralph DiSibio: As a matter of fact, that was presented to our subcommittee in terms of, it's one thing for the new, smaller reactors to have this better fuel, but it would be a heavy lift to try and convert that into the existing fleet because of cost considerations and other things including what you just suggested.

Richard Meserve: I take that to be one of the thrusts of your recommendation.

Ralph DiSibio: Yes, sir.

Ed McGinnis: What would you say is the reasoning for this shift in utility thinking on going for higher burnups and not trying to go for silicon carbide and beneficial new fuels? Is it cost? I thought one of the big issues was time. The utilities were saying that if you don't bring the fuel in for me to order by X year, like 2024, it's going to be too late. Is it a question of time or are they just rethinking the cost implications even it were ready in 2022 for existing reactors?

Ralph DiSibio: The short answer is, I don't know. I've only heard the cost implications, and that's what was presented to our subcommittee notwithstanding it's not ready yet.

Regis Matzie: Just to amplify on that, I was involved a couple of years ago on a couple of designs for DOE. Most of the suppliers have two tiers. The first tier is closer time frame and very incremental benefits. If you give some benefits are temperature, there is some additional grace time. But for the more advanced ones, it the kind of things like silicon carbide, a different fuel form, which get to the kinds of things you just mentioned, Ed, where you are almost blocking the fuel failure, the advanced fuels. But that's longer term, longer time to develop, higher cost to develop. I think it's that idea that the first wave of ATF fuel is only incremental of what you have today.

Peter Lyons: If I could just add one comment, I agree with what Regis said, and I agree, Dick, with your comment about higher burnup. But I also believe that industry is very interested in looking at even the near-term ATF in concert with things like the FLEX system in order to look at a lifecycle potential benefit. In the meetings I've been in, there remains strong interest in both the near-term and long-term benefits of ATF. But there will be significant questions – and Joy has been instrumental in raising them – that the NRC is going to have to ask for both the near-term and long-term benefits. But there are very much two versions.

Existing Fleet Subcommittee Report

Pete Lyons and Karen Kirkland Presentation. See PPT slides for details.

Pete Lyons: [Slide 1] We thought the charter was very well developed with technology development and policy opportunities.

[Slide 2] Key recommendation: Policy changes are needed. We are convinced of this and that economic sustainability will not be achieved through technology advances. Survivability of the existing fleet is essential if the industry is going to move to advanced reactors. Must save the existing fleet. We are concerned that as the number of reactors falls, there is a cliff. We don't know where the cliff is, but as the number of operating reactors erode, the remaining reactors have to shoulder all the cost for maintaining the infrastructure. We don't know where that cliff is but it could be sooner than we think.

[Slide 3] Membership Existing Fleet Subcommittee. All subcommittee members are in the room and contributed to the report.

[Slides 4 – 8] I'd like to give you a small snapshot that is in our report. By way of a snapshot, in order to guide policy, our discussions fell into two categories. First, there was recognition of nuclear energy for resiliency, reliability, and clean energy, and also recognition that markets are greatly distorted by mandates for renewable power and the power production tax credits that apply only to renewables. We discussed that most of the solutions are coming from the states. We greatly appreciated DOE Secretary Perry's comments on state solutions, but it doesn't change the fact that we need national solutions. It is great to try piecemeal solutions by states but that's not how to get national solutions.

Another aspect we discussed is interest in plants in moving beyond electricity – such as desalinated water and hydrogen production. We think this is very positive.

Our other category was national security. We worked to make sure no overlap with the international committee work. We looked at Secretary Perry's statement "energy security is national security" and looked at CSI report *Back from the Brink*. It is absolutely vital in the Navy and those were to use extremely important considerations. There are many reports that substantiates this. When talking about national security, those are also national interests. You must look at National Security Council thinking. I think this is joint work with international committee and solutions will have to involve efforts that rise to the level of the NEC

The Navy uses light water reactors [LWRs]. All our existing plants use LWRs. While we are as enthusiastic as any about advanced reactors, but this fact suggests that it is LWRs are supporting the national security including for the Navy.

Out of this, we developed policy recommendations. [Slide 4] Policy Recommendation 1 of 2. The first bullet is that a White House senior director for nuclear energy domestic and international programs should be created.

The fourth bullet: The suggestion that the Secretary of Energy and other senior administration officials need to have a strong voice in talking about importance of maintaining a strong nuclear industry. We are concerned that in some states where there

has been discussion, it has been the fossil and renewable industries that have stood up and said don't support nuclear. Those are contrary to a policy of DOE's policy of fuel diversity.

When there are papers about 100% renewables, that is dumb. It is at the secretarial level to stand up and say this doesn't make sense.

Last bullet is: "Administration should develop legislation or propose a FERC rule" to ensure that any state or federal mandate for specific energy sources do not discriminate against other sources with comparable emissions attributes. We're unsure if FERC or legislation would be required for this. It would be good to propose it to avoid those that only say renewables and not clean energy.

[Slide 5 - Policy Recommendations – 2 of 2] More on the importance of the administration working with FERC. This is a powerful way of addressing sustainability. The third goal – the expansion of existing programs to assure that the university community is more involved in issues relevant to sustainability. The Halden issue is an issue to discuss with the university community.

We've discussed other items on the bullet. We share the concern that we effectively ceding leadership to Russia and China, and that's not smart from any perspective.

About NEUP, we understand this can't be fixed this year but please let's fix it for the figure.

Karen Kirkland: Our technology recommendations are given in Slides 6 and 7. The first several are meant to address economic issues facing plants. We started out looking at what DOE is already doing. We invited DOE to give us a presentation on our light water reactor sustainability program and gave us supported recommendations. Our recommendations say "Here's what your doing and here's what you should do ..."

We need to address near-term economic issues. We have several recommendations that would be included in plant modernization and risk-informed plans. We need optimization of plant security. This would emphasis technology-driven solutions over labor-driven solutions. Finally, we recommend more ATF research in near-term and integration of smart integration into the existing plants.

We also have a second group of technology recommendations to address the economic plants and assist the plants in becoming more flexible. We needed to bring in the BWR and PWR groups, and so we had a lineup of speakers. Both said we would like becoming more flexibility to better handle loss of coolant accidents [LOCAs].

We also recommend providing additional assistance for more insight on plant decision-making, help make them cheaper to run, and the replacement of existing battery systems (BWRs), plus labor optimization including training methodologies. For improving performance measurements and task performance measurements, they would like to change equipment and procedures to make more automated.

Our committee suggested increasing support to university systems. Our first sub-bullet point is how to integrate our efforts with universities with industry's efforts. DOE could help us interface to make the curriculum more industry-relevant. Areas for university improvement would include development of ATF, data analytics, sensors, safety and severe accidents. We'd like to have more integration with industry.

We also have recommendations on detecting fraudulent components and additional support on low-dose radiation health effects.

Finally, on recommendations for increased cooperative research with NRC, these could include areas of strategic areas of intersection such as ATF, security, and digital instrumentation.

Lastly, on the acknowledgements slide, we didn't think we were going to get all these people speak to us. It was a challenge to get discussion time. But this illustrates how we went about trying to make recommendations to DOE. We were charged with addressing long-term sustainability. We invited speakers and our approach was to hear what is being done at DOE and come up with additional recommendations.

Our next meeting priorities will include ATF and Modeling and Simulation. We've had a lot of interaction with other committees, but we are being careful not to duplicate efforts.

Post-Presentation Discussion / Q&A

David Blee: We are talking about licensing renewal, and you need plants to extend. Is it going to 25%, 50%, 75%, or 100% of them? Regardless, when you say we need to save the existing fleet, it is a glass half empty approach. Maybe instead say, "extend the fleet as long as we can."

Pete Lyons (Response): One of our policy recommendations was look to a Production Tax Credit. The existing PTC is limited to what's left over after Vogtle is gone. To your point, to extending, we would look toward an expanded PTC and using same number, adjusted for inflation, used for renewables rate of 2.3 cents. We also recognized that in the U.S., the expansion will probably be SMRs with few opportunities for gigawatt-level expansions. But our suggestion was that all LWRs and advanced reactors be covered for the PTC.

David Blee: Last figures I saw, nuclear energy was the least subsidized energy source, larger due to the investment tax credit (ITC) and other credits. (\$1.6B versus \$16B). The PTC is very important.

Regis Matzie: How do we overturn the issue of "adding more science" to it – it is a political question.

Peter Lyons: The previous low-dose radiation program at DoD was starting with a genomic approach instead of an epidemiology approach. The genomic approach had gotten to the point of saying that LND cannot work. The program was then cancelled. Wisely, it is being considered restarted. My view is that the genomic approach is the only way to approach it. There needs to be real data to convince the standards making bodies.

Joy Rempe: In your recommendation for increased cooperative research with NRC, I think that's a great way to leverage our tax dollars. There are few other topics that Maria brought up such as additive manufacturing and big data. I realize in big data, the datasets might be different and you can't share, but a framework where that data can be put and shared would be a great addition. The taxpayer could benefit.

Pete Lyons: Even though we revised LWRS, much of the advanced manufacturing work had been done outside of it and other programs had done outside of it. NRC doesn't care how you manufacture it but rather just the properties. There are strong programs out there.

Joy Rempe: But there could be collaboration with regulators.

Ed McGinnis: I just wanted to comment on the existing fleets. I want to compliment everybody. I know its not easy to find that balance and what is the most salient and where the front line is and where that nexus is for DOE beyond what we are doing. This set of recommendations are outstanding. It is the exact level that I was looking for. I'm not talking a position on every recommendation, but it really is thoughtfully including market, technology, and FERC, among others, and all focused on the viability of the full lifecycle of the fleet. It is clear that a lot of work and thought went into this. I hope these recommendations get a lot of attention. This is exactly what I was looking for.

International Subcommittee Report

Regis Matzie and Lisa Marie Cheney Presentation. See PPT slides for details.

Key Points:

Slide 2: International Subcommittee Members

Slide 3: Charter of the NEAC International Subcommittee

Remarks: Our charter given in Sept 2018. We were asked to go quickly, which we did. I think we've addressed them all in our report. We will see when you've decided how you want to move forward if we did anything useful.

Slides 4 - 5: Background, Additional Information

Overview of the history of the U.S. nuclear industry and how things changed.

Remarks: Other generation sources shutdown during severe weather episodes but only gets a passing mention in the media.

There are now new alternatives to U.S. supplying other countries, and if you read the trade press, there is a lot of success for reasons that our recommendations try to address. In short, the U.S. influence on nuclear matters is waning. The U.S. presently has a non-strategic approach.

When you sell a plant internationally, you forge a relationship between the suppliers of the reactors and the host country. That relationship lasts 50 to 100 years. So, think about the policy consequences of that. Non-proliferation is a huge area.

The Department of Commerce estimates this is a \$500 billion to \$750 billion market, and every \$1 billion spent results in 5,000 to 10,000 jobs in the U.S. There are reasons for maintaining a U.S. nuclear industry presence.

We were involved in a SWOT analysis that was useful in helping formulate our recommendations. Our subcommittee met twice in D.C. with DOE staff and the national labs, along with Xcel Energy and Southern utilities and NEI. We didn't interview NRC for this but we understand their position.

The int'l met twice in D.C. with DOE staff and national labs, Excel Energy, Southern, NEI, others ... Didn't interview NRC on this but understand their position.

Slide 6: What is Different from the Past?

- *Administration policy is favorable;*
- *Congressional support is favorable including key legislation passed or underway; and*
- *Surge in development of SMRs and Advanced Reactors/*

Remarks: This is not to say there isn't a market international market for large-scale reactors. Megacities in India, Southeast Asia, and China cannot use renewables and need concentrated power plants. Potential of new technologies such as ATF and additive manufacturing require early engagement with would-be users.

Slides 7 – 10: Recommendations

Remarks: Our subcommittee recommendations are really part of a broader U.S. Government approach. True, many of the recommendations look like "Groundhog Day" because we've made them before. Nevertheless, they are still valid and important to the U.S.

Among our recommendations, the first was "level the playing field" but in my absence it was changed to "take steps necessary to position ..." The key point is to get United States Government to use a whole-government approach. It isn't a DOE or Department of Commerce approach. It is a whole-government approach going through many departments and agencies.

We should streamline U.S. export control processes. When asking the questions of people on the commercial side, they say foreign countries get approval in exports in 1 to 3 months versus 12 to 18 months in the U.S.

Appoint special assistant to the president and envoy for nuclear energy policy to coordinate across government department sand agencies. When Joyce Connery was doing something like this, we were making great strides. We need to get back to that.

Capitalize on new authorities given to the US International Finance Corporation in the BUILD Act. This loan approval together with Ex-Im Bank would be good. But we would have to get Ex-Im Bank Board of Directors approved by Senate.

For other recommendations, advanced reactor technologies such as SMRs and non-LWRs can be disruptive in that they put the U.S. at the forefront and open up new markets because of their smaller size – especially in countries that cannot accept LWRs. These represent smaller capital investments and enhanced safety that shrinks the EPZ to enable them to be closer to population centers.

We need to expand the U.S. commercial trade presence in international nuclear market. Many countries already do this such as the French, Russians, Koreans. It is a great way to build a relationship with the people you'll be dealing with in the next 50 to 100 years.

Revitalizing U.S. nuclear infrastructure is a recurring point and it includes building the VTR. This can also make the U.S. more of a supplier than in the traditional ways of manufacturing.

The real elephant in the room is the backend of the fuel cycle. We just need to get on with it. There is nothing technical about this – it's all just about demonstration. We also need interim storage. What's more, these can be a great example to others, a great training tool to bring in others to learn what we're doing and give them more incentive to go with the U.S. It would also help counter one of our major competitors, the Russians, who have offered fuel take-back. But we need to promote ways of solving the backend problem ourselves.

The last recommendation – and this gets to Ray Rothrock's point about the nuclear narrative. We do a lot of training. We do a lot of narrative. But it's generic. And it's not as praiseworthy as our capabilities and technological innovation. We need a forward-looking narrative, and not give the old technology in the nuclear industry that we've been giving for the past 50 years. I know some of that is already started, the idea of advanced reactors, advanced fuels, and get out there and say how they are improving our industry in terms of safety, in terms of cost, in terms of security. These are all the right kind of things we ought to be doing.

I will mention the following before I take questions: Our subcommittee currently does not have a next meeting scheduled because we are waiting for guidance from DOE on what it wants to do. I would suggest that we could do more or more of our recommendations that are helpful and fruitful. We could do a deep dive to flesh out all the details – not do the broad brush like I'm reporting but do the nitty-gritty on one or more suggested actions. That's what I propose you consider at DOE and give us a new charter to go forward.

Post-Presentation Discussion / Q&A

Ralph Disibio: One of the most cogent elements there, not just words but were factual in terms of the relationships that are built with countries when we got involved in nuclear energy. More than 30 years ago, when I used to make the trips to Taiwan, Korea, Japan, and the Philippines – think of it, over 30 years ago. What relationships do we still have with those countries? And they started with nuclear energy. And the Westinghouse nuclear energy program. That relationship issue is far more critical than just the words.

Secondly, have we thought about developing joint ventures with other countries?

Regis Matzie: One of our recommendations that I skipped over was specifically to do that. If you look at page 9 of our report on strategic collaborations. Two prime examples could be Japan and Korea. There are long term relationships and tremendous financing and construction abilities that we have lost. We could have a joint venture that could then pursue other markets.

Lisa Marie Cheney: If anything happens internationally with nuclear issues, who is the first one they will call? It will be the U.S. Maybe we can go forward by thinking about how to get back in the market by thinking about security. Maybe it wouldn't be building reactors but by providing a U.S.-level of security to these plants. Stringent safeguards are a key U.S. strength. We could maybe play a security role.

Ed McGinnis: This is an outstanding set of recommendations and analysis. You've done a good job. Many of these recommendations can withstand the test the time.

Now, what next? What can you do? You have so thoroughly looked at various aspects of US international aspects of nuclear. We are in a competitive race globally and while the technology may not hit the market as quickly as the next Smartphone, it is still a race. And I believe that the U.S. is where that technology will be developed. China is in an emulation mode and Russia not leading in the disruptive technology mode. You don't see the micros, ATFs, SMRs, or focus on market there. I just don't see others pushing the envelope the way we are. There is a huge unrealized market that is waiting to be grabbed. I think we are getting the attention of the international competitors when they hear us talking about SMRs and efforts to disrupt and see how we have done it in other industries such as telecommunications and natural gas recovery. I think the worst fear for them is that we will figure it out in the nuclear space.

Having been said, my big question is what are the opportunities globally? With the technologies we are seeking to bring into the market in the 2020s – advanced SMRs, advanced, scalable SMRs, additive manufacturing, advanced fuels – what are the market opportunities? Where are there? I see Ghana, Kenya, and Morocco, countries that could never take a gigawatt or more, now suddenly they have an open market. My fear is that China gets the jump on us. We show them and then we don't move fast enough.

Could your committee look where would the next great next-generation advanced technologies, services, and products be and what is our timeline before someone figures it out and gets it first? I would love to see you all do that.

David Blee: I would endorse that. There are emerging countries in Africa, South America, and Asia that are interested and that's where we can leap frog. It is from a business point of view. It's tough for businesses to send people to those countries when it isn't in the five-year wheelhouse in terms of big business development. This is where government can play an important role. It means integrating with industries, national labs, and other agencies including Department of State. The State Department is looking at an NC [Nuclear

Cooperation] MOU [NCMOU] that would be signed without having a 123 agreement which has to be approved by Congress.

Ed McGinnis: And let me just say that we met with State on this just yesterday. The idea is to have that tool. A lot of the energy ministries and utilities see as the big elephant in the room, “What do the foreign ministries think?” Then suddenly, what they think has to do with geostrategic issues. So, having a quick, nimble, State-led Nuclear Cooperation MOU that could be done promptly, and not displace the 123, could complement our efforts in these markets. I’m told Jordan is looking at two of three SMRs that they are looking at now are American. We have SMRs signed by Canada. Romania just signed an MOU with a U.S. company. It is a burgeoning market and others are getting in front of it. So, I like your word about getting in front of this.

Nuclear Energy University Programs (NEUP)

See Derick Ogg presentation

Post-Presentation Discussion / Q&A

David Blee: I was pleased to see that the line for amount of industry collaboration is ascending – that is encouraging. If we operate under the assumption that there is more engagement among government, labs, industry, and colleges, it makes everyone stronger. But what are you doing in terms of outreach with industry? How do you communicate with them? I think the general understanding of this program is low. What is the outreach mechanism?

Response: We have a huge mailing list and our announcements go out on social media. But we can always use more.

John Gilligan: Not all awards are exclusively industry and NEUP is aware of that. Faculty are regressive in talking to industry. About 50% of the awards have national labs and 25% or more have industry partners.

David Blee: It was rock bottom in 2010. But those efforts are really paying off.

John Gilligan: GAIN helps in this area.

Derick Ott: We also have an annual webinar to do outreach.

Public Comments

Richard Meserve: We have three people who have signed up to make comments. Please keep comments to under 5 minutes.

Arthur Lada, Penn State University

I am not here as a Penn State professor but as the Chair of our nuclear engineering department organization. I would like to talk about the impact that the diversion of NEUP funds. It has caused some dismay among us, but I want to emphasize that it happened in the context of a really good run of the program for a long time. And that has allowed us to do

many good things. It's not necessarily the actual financial hit, but it's the instability it fosters among people.

The programs that we have been able to grow and I give the example of the Penn State. It is now going to be a separate program and Penn State is going to hire faculty who are going to provide good innovations in all different areas such as thermal hydraulics, reactor physics, and advanced materials. We need that stable funding for this enterprise to continue. So, I would urge the Department of Energy to consider finding other ways to fund other projects, but to leave the NEUP appropriations in tact and available for our faculty that can then benefit them and our students. As you know, our universities provide the manpower for replacing the ones like me who are going to be retiring soon. And it is important that those be kept vibrant, alive, and well-funded.

Everett Redmund, NEI

First off, I would like to congratulate DOE for all its hard work in preserving the existing fleet and emphasizing the importance of moving quickly on things.

There are a couple of items that I would like to touch on and emphasize more. One is light water reactor sustainability and the potential for driving down costs in terms of the operation of the fleet is vital. And we've got a lot of good feedback from the industry on that. And then legacy data on the advanced reactor side. DOE has done a lot of good work over the years and there needs to be a good, strong, robust program to preserve that data.

High-assay LEU is quite important. We are working closely with DOE in that regard. You saw the data that John presented that we published last year. We said in that letter we would update that on regular intervals. We're going to be working to do that because the landscape has changed a bit. It's not that the numbers are invalid, but we just need to update them and include some other developers.

The last item I want to touch on is the funding opportunity announcement and the awards that were given yesterday. I'm very pleased to see DOE doing that and it was \$19 million that was awarded. There have been four awards made in this five-year program in which DOE takes quarterly applications. The quickest DOE has announced the awards is about 2-1/2 months. The last round that was announced yesterday was closer to 5 months from the time the applications were submitted. So, in terms of urgency, this is one area where I would urge DOE to try to improve and accelerate its efforts to get those awards out on a quicker timeframe.

Jeff Witt, industry representation

I find myself bridging those two comments. Thank you for letting us be here as an industry partner and an ATF partner. I kind of resonated with the NEUP comments, but then as we went through the presentations, it struck me that there might be a way we could address both of those comments.

The NEUP process is well defined and we get a list of items of interest and we go through and do a simple, brief report that gets vetted into a Go/No-Go or invite / no-invite to bid. This allows us to focus our ability on what would be a better probability for awards. I would like to suggest that you consider this type of process for your industry FOA activities since the level of effort required for submittal with no chance of award is quite a significant expenditure. A process that has an earlier vetting would be good, I would think, both for DOE and us.

Committee Formal Business

Richard Meserve: NEAC has received four subcommittee reports and we should submit them and be approved formally by the full committee.

Motion seconded and unanimous consent given with no discussion.

Closing Comments

Richard Meserve: We now walk around the table and let each member have a few minutes to say what is on their mind within the scope of this meeting.

Ralph Disibio: Thank everyone for making this come together. One thing that occurred to me, especially as it relates to ATF, and Ed's comments about international possibilities for recapturing our place in the international community, it seems that there is a sense of urgency, especially as relates to other reactors coming on line. I would add to that sense of urgency. Every 10 years something happens – TMI, Chernobyl, and Fukushima. To the degree that we can get ATFs on line, the better off we will be.

Peter Lyons: This was an excellent meeting. You heard some concerns I raised on the NEUP and I appreciated Ed's comments. But I hope DOE will take seriously that the message sent this year to the universities and especially to the students was not positive. If the cuts continue, we could see serious repercussions. Frankly, I think the reason we have such a strong advanced reactor set of programs is precisely because of strong university programs. We have students coming out with fresh new or even fresh old ideas and ready to benefit the company.

As for the Existing Fleet subcommittee, I just wanted to add that the general policy recommendations. You saw the key one that something dramatic needs to happen fast. We gave a list of things to happen fast. I don't think that is a unique list. It is the set we came up with. I'm willing to believe another group with other considerations would come up with another set. They are not unique. However, our overriding recommendation that it will take policy changes to preserve the existing fleet is correct. The situation is getting worse by the week. I hope those recommendations prove useful.

Finally, looking ahead, it would be helpful to look to the next meeting and to the extent anyone wants to provide input on ATFs and modeling simulation, I think there are plenty of issues to go around between the subcommittees.

Karen Kirkland: I would like give credit DOE for its GAIN program. They are creating a university directory to facilitate activities. As an impression, I feel very invigorated. I feel more like a stakeholder as you revamped the committee and has become more involved.

Regis Matzie: Like many of us, I have devoted my whole career to this, starting in the U.S. Navy, and I'd like to see the U.S. be perceive and project leadership in this area. I think the top three priorities are (1) protecting and prolonging the existing fleet and, if possible, growing it, since it extents a message domestically and globally; (2) our government needs to utilize a whole-government approach both domestically and internationally if we are trying to get the value of nuclear appreciated; and (3) if we want to have a product that will change the metric globally, we need to demonstrate that product domestically and do it as quickly as possible. I fully applaud VTR and Idaho's efforts, but we should have one more.

Lisa Marie Cheney: This has been an invigorating process. I was really happy to hear Ed's guidance for our next term, because I think we are right now ready. I would add a bullet point of how to make it profitable. What countries are going to be the profitable ones? This might make our assignment fun. Lastly, we talked about the NEUP cuts. I am an outside-the-box thinker. Maybe we can look to industry to do a backfill. A percentage of that coming out of your money to educating your future workforce. Maybe we can look at some ideas of how to help DOE cross that bridge.

David Blee: There is a lot of angst this time of year about budget. Fortunately, the President proposes and the Congress disposes. Nuclear energy is the most bipartisan issue in the Congress. In the last Congress, NEMA received all but 10 votes. I wanted to thank Ed and your team. It's not often you see the head of a program and every member of their team here all day – and not going in and out on the phone. That said a lot.

This NEAC shows that the direction of your mission is the right direction. I would like to commend you on diversifying NEAC. As the old timers have said, they have extended diversification. Also, the efforts on communication and dialogue have been very important.

Colleen Cochran: To what Suzie was saying earlier about communication and education, and more broadly the tone and responsiveness of the organization, we have all felt it and as a new member, I've felt it. DOE's resources are spanning all the efforts – fuels, lab programs, international efforts, and other industry-critical aspects. DOE is tied so closely to the industry that it relates to it and the Nuclear Energy office is probably even more so tied to the figure of the industry. What we really need to see happen is in industry – founding a new company in the nuclear sector and show that a private company can build something. It is going to take efforts from DOE and others. If we can, it will unlock private capital and enable other resources. We feel we are an integral part. Hopefully, the goal is everyone can see the importance of success.

Seuongjim Kim: It is an honor for me to serve on the committee. Thank you. Along with Karen, I think we are one of the two representing a university center. I feel a great responsibility as we are producing future nuclear engineers and we taking great pride in our

jobs. I have been in education for over 20 years, and I've never seen such an excitement with all these new developments.

I really want to thank you for all the effort and leadership to move to the next stage. I sense that many of you lived in the 1970s. At the time, maybe you felt there was a sense of urgency in having a nuclear power plant in place. These initiatives will give a new generation this sense of urgency to put nuclear power plant in place. This urgency is critical otherwise it won't happen.

But I would also like to emphasize the existing power plants. At the end of the day, over 50% of our students will get jobs in existing nuclear power plants. You ask students, and over 50% say they chose nuclear engineering because of nuclear power. I think it is therefore critical to maintain the support for the existing LWR fleet. At the same time, I'd like to give you a head's up. We are slowly seeing a decrease in the undergraduate enrollment. Even after Fukushima, we had more enrollment and understand the science much better than 20 or 30 years ago. However, enrollment now it is going down. On the graduate side, there is a 50-50 domestic-foreign split. We have to take this seriously. Students hear on the news that plants are shutting down. Therefore, LWR support is critical in order to move forward.

Another fact is that nuclear engineering is still very small compared to other engineering departments. Remember in the 1990s, many nuclear engineering programs disappeared. While I don't think this will happen again, we must keep going forward. I hope the NEUP cuts don't happen again and was just a one-time event. One final comment, we often forget that the U.S. university structure is not found anywhere else in the world. Just by using English is a strength. The UAE power plant instructions are all in English – why is it in English? We are the leader and must maintain this.

John Bear: This was an excellent meeting. I thought the reports were good and I read them. My view before I got here was that U.S. influence internationally depends on domestic nuclear market. We must have a product who know it and sell it. It is a powerful area with a lot of energy. We want the product to be safe. Look at the foreign accidents and their impact on the U.S. Nuclear engineering has applications on both the civilian and military side.

I found very interesting the reports from the existing fleet subcommittee and international subcommittee on the impact of the nuclear program on national security. I've always believed this.

Nuclear waste, just in talking to people in the larger world, they think we don't know we know how to deal with the nuclear waste. But we do. One of the most disappointing things in my career was not being able to sign the construction permit for Yucca Mountain.

As a former council member for national council on radiological measurements, I never believed in LNT from the reports back in the 1950s.

Joy Rempe: Three items. First, I'd like to expand on the advanced reactor subcommittee. I can recall that some years ago, we had a report in which they developed some metrics with

respect to technology readiness. It might be good to look at that report and offer that to this committee as a starting point.

I would like to revisit my comment on the MIT reactor. My earlier comment was meant to focus on facilities management and the need to maintain high performance (high flux) irradiation test capabilities. Both the MITR and the Advanced Reactor have irradiation test loops. They are a bit unique. If we going to move forward, we may need the irradiation capabilities of those facilities.

Lastly, I wanted to mention my comment about collaboration between NRC and DOE. I mentioned that even with the VTR – I'm not not talking about authorization for startup – but in the design, if you are going to just consulting with design developers, that might not be enough if they aren't aware of what NRC is going to accept with respect to irradiation test data. If you don't have flowing loops in the VTR, you should talk to the regulators to see if they are going to get the data they require for deployment of advanced reactors.

Richard Meserve: You've heard a lot of enthusiasm today about nuclear. I am one of those people who believes we have to have a bright future for nuclear. Maybe we haven't stressed that vigorously enough today. Having aggressive programs in government and private sector is going to be essential. I finally just read the IPCC from late 2018. What happens if we overshoot 1.5°C and go to 2.0°C, and of course, as you know, we are on a trajectory where we shoot over 2°C?

Of course, this is an effort involving top scientists from around the world. The impacts get more threatening as you go from 1.5°C to 2.0°C – the effects are not linear but the severity of storms, depths of droughts, increases in flooding, reduction of food production, health effects of extended heat waves go up. They also do modeling of what to do to go to 1.5°C. We need to get this underway.

What I believe is that we have a public that accepts climate change and that it is anthropogenic in cause. But the urgency isn't there. The "cost" of it hasn't impacted people.

The political pressure is going to grow more intense including that to decarbonize our economy. It is going to be forced on this. The electrical sector is probably the easiest sector. There is a huge benefit from renewables but they are intermittent. The need is going to be for baseload.

Carbon capture and sequestration is risky and adds to plant cost. Truly decarbonizing is impossible and you end up with opportunity costs.

You look at batteries and if you want to have a grid that is as reliable as today, you need battery capacity to carry you through the night, but also extended periods – cloudy or no wind. That is hugely expensive.

There is an MIT report in technology review that looks at the consequences of California going to 100% renewable with batteries it would increase the cost from \$50/MWh to over \$1,000/MWh.

That leaves nuclear – which still has to be shut down occasionally. Then using power for high temperature process heat, hydrogen heat, and all kinds of things that we should be thinking about. There is a big opportunity for advanced reactors which react at higher temps with more process heat. Looking ahead, I see a path where renewables are complementary to nuclear. I see a special roll for everything to increase even with the economics.

There is also electrification of cars, which gets you back to the electricity sector.

I am someone who sees us engaged in something very important and if we can eliminate or deal with the problems, this will be the path that is absolutely critical. Nuclear is going to be an essential part of the answer for addressing climate change internationally in the future. We need response capabilities that can meet this.

This has been a huge effort and the production of the new people has been very, very valuable.

Ed McGinnis: I want to give an incredibly huge thanks. I had high expectations and this day exceeded them. I see fantastic leadership. I appreciated Karen's point that this should be a strongly egalitarian, participatory forum. We have too much on the line for this not to be participatory. We can't afford to fail.

It seems like a few years ago, we would have until the 2030s when nuclear energy would be at a crossroads, a tipping point, if we weren't building by then. At that time, the thought was, relax, don't be chicken little. We've a long way. But now – from Capitol Hill, the environmentalists, resiliency community, the military including many other generals – I've never seen a time when so many people see this growing consensus that we are at this point that we could start losing our nuclear sector if we don't start doing things now.

The time for talking is over. And if we just talk, things will happen, and what will happen is not pretty. And we will start losing major portions of our sector. There is only so far you can go in squeezing electricity out of these plants. We need all brains on deck, and I believe the next two years is going to be highly determinative – whether it is Sen. Alexander and a new Manhattan Project on energy and the administration saying we've got to do this. The community is saying the consequences for the global climate – we are being thrust on stage and it is going to be on our watch. Will we respond and innovate our way to the next generation of nuclear or be part of the twilight. I don't want to be part of the twilight of nuclear.

All four working groups – there is so much to do. Whether it is the pipeline or the value proposition about safety and waste. There's the fuel cycle with so much to do on the frontend, the backend, additive manufacturing, the current fleet. What can we do? I feel support the administration. We can't let others put out a narrative that is incorrect. Domestic and international is an integrated calculus. So, all four subcommittees have tremendous amount of work to do and I look forward to working with you and defining the missions.

It pained to have to do anything to NEUP as it is the heart and soul of our program, and I'll do everything to avoid having that happen in the future.