Review of DOE/NE's Activities to Support the U.S. Commercial Nuclear Fleet

Initial Report to the Nuclear Energy Advisory Committee (NEAC)

and the Assistant Secretary for Nuclear Energy

Prepared by the NEAC Existing Fleet Subcommittee

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Summary of Recommendations

Key Finding - Policy changes are necessary to ensure survival of the existing fleet of U.S. commercial nuclear plants. Continued early shutdowns of operating plants are jeopardizing the ENTIRE domestic commercial nuclear industry and threaten to have extremely severe repercussions on national security and the integrity of the national electricity grid. Without policy changes, reductions in operating costs and improved efficiencies utilizing advances in technology will not be sufficient to address the crisis in short-term economic sustainability.

Based on this key finding, recommendations for Policy are listed first, followed by those for Technology.[1]

Also provided are recommendations for increased DOE-NRC research collaboration. These are motivated by a Subcommittee discussion with the NRC's Director of the Office of Nuclear Regulatory Research and deemed important for the livelihood of the existing fleet.

Acronyms are discussed in the body of the report and listed in Appendix B.

Policy Recommendations

P-1. In recognition of the national security value of the interrelationships among the nation's commercial nuclear plants, our economic security, and the naval reactor program, as well as a range of international considerations related to nuclear energy, a Senior Director position in the White House should be created, responsible for all nuclear energy domestic and international programs, reporting to both the National Security Advisor and the Chairman of the National Economic Council. This Senior Director should also facilitate appropriate sharing of physical security-related information and/or best practices with the commercial nuclear fleet from U.S.

[1] Regarding the Policy recommendations, if the full NEAC accepts this Subcommittee's recommendations, they may then inform DOE/NE, which may in turn choose to forward them to other decision-makers in the Department and Administration.

experts in this field (in the military, DOE, national laboratories, and NRC), with a focus on reducing security costs of the fleet.

P-2. In recognition of the national security value of the synergisms between LWR commercial and naval reactor technology, the fragility of the commercial LWR enterprise, the high probability that new near-term LWR domestic construction will involve SMRs, and opportunities for advanced reactors to enter the future U.S. market, a new Production Tax Credit (PTC) should be proposed. We suggest that this PTC should be set at a level (adjusted for inflation) comparable to the past levels for solar and wind sources of $23/MWh – for all Light Water SMRs and other advanced reactors coming online before 2040. This PTC would replace the current one, which has a very limited capacity, of $18/MWh for advanced nuclear deployments. This tax credit would serve to stimulate the nuclear industry, in direct analogy to approaches previously employed to stimulate the solar and wind industries.

P-3. The Administration should develop a program to create several pilot programs, either with existing LWRs or with planned SMRs in the 2020s, to demonstrate utilization of nuclear energy in several sectors beyond traditional electricity production. Regional differences will be important in choosing these projects, since different regions may benefit from applications of nuclear energy in very different sectors of the economy (for example, some regions may have a great need for desalinated water, while others might benefit from hydrogen production).

P-4. As states consider policies that impact the future economics of nuclear power plants, the Secretary and other senior Administration officials should provide their expert witness to the importance and benefits of maintaining a strong nuclear industry and interact with leadership of the fossil and renewables industries to discourage their opposition to nuclear energy. Their expert witness should extend to comments on proposals to power the national grid with any single source, such as proposals espousing 100% renewables, to highlight both the impracticality of such proposals and their neglect of the importance of fuel diversity, which bolsters national security and grid resilience.

P-5. The Administration should recognize the separate attributes of coal and nuclear energy and, for programs designed to preserve these options, ensure that programs recognize those separate attributes and be tailored to the needs of each energy source.

P-6. The Administration should support creation of a revenue-neutral legislative vehicle to recognize financially the zero-carbon attributes of nuclear power and its substantial contribution to clean air.

P-7. The Administration should develop a legislative proposal or propose a rule to FERC to assure that any state or federal mandate for specific energy sources does not discriminate against any energy source with comparable emission attributes.

P-8. In recognition of the national security and environmental importance of the LWR existing fleet, the Administration should work with FERC on market structure issues that currently do not recognize, or that frustrate the effectiveness of state and federal financial incentives designed to recognize, the attributes of nuclear power. The Administration should also encourage FERC to adopt market structures that permit units needed to serve demand, such

as nuclear plants, the opportunity to set price and earn their competitive returns in the markets.

P-9. The Administration should consider recommending, in regulated states, review by the public utility commission whenever closure of any operating nuclear plant is considered.

P-10. DOE/NE should expand existing programs to assure that the university community is more involved in issues relevant to the sustainability of the existing fleet.

P-11. In recognition that failure to develop credible, funded, used fuel management policies is inhibiting acceptance of nuclear energy, the Administration should work with Congressional leaders to craft such a policy that can be enacted into law with adequate funding.

P-12. Under provisions of Public Law 115-246, the Department is encouraged to assure with high priority that re-start of the Low Dose Radiation Research Program is dedicated to resolving the uncertainties in health effects of low doses of radiation.

The following policy recommendation was discussed at the EF Subcommittee meeting and at the recent meeting of the International Subcommittee. We agreed that both Subcommittees would advance this important policy issue.

P-13. In order to avoid ceding international leadership of nuclear power to Russia and China, charge the NSC with development of a comprehensive suite of programs to re-invigorate U.S. global competitiveness in nuclear energy.

And finally, the policy recommendation below arose from the January 24-25, 2019 meeting of the Fuel Cycle Subcommittee, where that Subcommittee was informed that the NEUP portion of the Nuclear Fuel Cycle and Supply Chain budget was being reduced by $23M (or about 70%) for FY19.

P-14. DOE/NE's support for universities through the NEUP program remains vital to the health and sustainability of the entire national nuclear enterprise, including defense needs. The FY19 reductions in the NEUP program should be restored immediately.

Technology Recommendations

Our recommendations for technology considerations are primarily derived from our review of the LWRS program and presentations from the Nuclear Energy Institute (NEI) and the Boiling Water and Pressurized Water Owners' Groups (BWROG and PWROG).

The Subcommittee compliments the leadership of the LWRS program, both in the DOE and at INL, for programmatic re-direction that has already taken place to emphasize support for economics of the existing fleet.

The Subcommittee's overarching suggestions on the three LWRS pathways are:

Materials Research: This pathway has performed vital work that has enabled successful license renewals, but this area has less near-term relevance to the current economic crisis of the operating plants and could be partially redirected in the near-term. This redirection is already in progress in the LWRS program and could be subject to further redirection.

Plant Modernization and **Risk-Informed Safety Analysis**: These two pathways have many projects with the potential for significant impact on the near-term economic crisis. The Subcommittee's suggestion is to prioritize projects in these areas, in consultation with industry, based on analysis of their potential for such impacts. These two pathways would benefit from increased resources in the LWRS program. Increased work on the first and second bullets, in **bold** below are the strongest priorities for expanded work.

Specific suggestions include:

T-1. The Subcommittee applauds the shift in focus of LWRS to include, and recommends expansion of efforts for:

- **a. Optimization of plant physical security with emphasis on technology-driven solutions that reduce security costs,**
- **b. Research supporting utilization of ATFs in the near-term, and**
- **c. Integration of smart instrumentation into the existing plants.**

Additional suggestions on these three areas are included in recommendations for support of NRC issues.

T-2. Help plants become more flexible.

- **a. Committee members noted that plants which are not flexible to respond to changing economics are more at risk.**
- **b. Extension of some plants' products outside the traditional electricity sector may enhance their economic situations.**
- **c. The subcommittee notes that both Owners' Groups included load-following as a top priority. We support the BWROG chair's suggestion that research to better understand factors that may limit increased load following be enhanced.**

T-3. Focus LWRS projects on improving the economic competitiveness of the existing fleet on a near-term time scale.

T-4. Provide additional assistance with the following technologies

- a. Data analytics on large data sets to provide insights for decision-making as well as better prediction of equipment performance and maintenance requirements,
- b. Replacement of existing battery systems with a fast charge system,
- c. Labor Optimization
  - i. Training methods for operations, maintenance, and others,
  - ii. Advancement of nuclear training to the latest technologies and techniques to eliminate dated methods (Classroom, JPM, TPE, etc.), and
  - iii. Change of equipment and procedures to reduce manpower needed at plants

T-5. Increase support to the nation's university research reactors and better utilize our university nuclear engineering programs in mission support of DOE/NE programs to assure that the nation's nuclear engineering university sector remains the gold standard for global excellence.

- a. Advise and assist nuclear engineering programs in evaluating which technical topics related to the existing fleet should be included in course offerings and research efforts. The DOE can provide this national perspective, in coordination with industry, at venues such as the NEDHO (Nuclear Engineering Department Head Organization) meetings, which are held at every ANS Winter Meeting, and Annual Meeting. [Suggestions for educational offerings that would benefit the existing fleet usually now come to the

university programs through interactions of individual faculty/staff with industry acquaintances and sometimes through the programs' Advisory Councils. These inputs are therefore individual snapshots of needs without prioritization. Consistent input from the DOE on behalf of the entire industry to the nuclear engineering educational community would promote better coverage of needed topics and increase the programs' relevancy to the needs of the existing fleet.]

b. Topics relevant to the existing fleet, on which university programs could provide greater focus and support to DOE/NE programs, include several areas with relevance to near-term economic issues:
    i. ATF
    ii. Data analytics coupled with artificial intelligence
    iii. Smart sensors
    iv. Advanced Manufacturing
    v. Fire PRA
    vi. Reactor safety and severe accidents
c. Some university reactors could be used to address some of the research programs that are being lost with shutdown of the Norwegian Halden reactor. The DOE should facilitate discussions with the NRC and selected industries, led by EPRI, who are being severely affected by the Halden shutdown with a goal to explore how some university research reactors could address vital capabilities lost as the Halden programs cease.

T-6. Develop technologies to detect fraudulent components.

T-7. Support additional research on health effects of low doses of radiation, as in recommendation P-12. (This would not be an LWRS mission; the current law places this responsibility within the Office of Science. Nevertheless, NE can add its voice within DOE to encourage priority for this work.)

Recommendations for Increased Cooperative Research with the Nuclear Regulatory Commission

The Committee recommends increased cooperative research between the DOE and the NRC in key strategic areas. There are many current examples of coordination between NRC needs and DOE research programs, but increased coordination and focus of some DOE research on challenges faced by the NRC would benefit the commercial nuclear industry. Some of these suggestions could be incorporated within the LWRS program, others may be more appropriate to include in other DOE/NE programs. (The first three bullets expand on Recommendation T-1 of the preceding section.) As examples:

- ATF
  ATFs may represent one of the strongest near-term potentials for reduction in operating costs to impact the existing fleet. The NRC has approved insertion in operating plants of a few in-core ATF lead test rods or lead test assemblies, but the situation will be vastly different if the initial tests encourage utilities to propose full core loads of ATF. Only in this latter case will possible efficiencies be gained, yet NRC approval of a full core load of ATF will require more detailed understanding of the source term characteristics of ATF (for normal operation and the range of accident conditions) to justify any revisions, proposed by the industry to the NRC. Furthermore, while NRC may be interested in utilizing some of the DOE M&S code capabilities relevant to ATF, that can only happen if these codes are well validated throughout the range of potential

operating and accident conditions and can assist in calculation of source terms. While all these areas may be beyond the scope of an expanded LWRS, DOE/NE might consider these needs as they evaluate all their ongoing programs on ATF.

- Security
  Security requirements are a very significant cost for current commercial plants. DOE, especially NNSA in protecting key weapons facilities, has immense expertise in evaluating risk-informed approaches to security. The Office of Electricity has also focused in this area recently. This may be a fruitful area for cooperation to assist the operating plants, although those plants are constrained by their pre-existing configurations, and could be extremely useful in both new LW (light water) SMRs as well as other non-LW-cooled concepts.
- Digital Instrumentation
  The existing plants are challenged by the increasing difficulty of obtaining replacements for their analog instrumentation, but a transition to digital instrumentation has historically been very challenging. Cooperative industry-DOE programs should focus on accelerating implementation at existing reactors and could include research to better define methodologies to identify potential common cause failures of digital systems and to enable commercial grade dedication (potentially a large cost saving). Such work could reduce the need for redundancies in some aspects of digital controls. One avenue for program expansion might be additional interactions with the nuclear navy, which has effectively used digital instrumentation for many years.
- Cyber-security
  The transition to digital instrumentation introduces concerns for cyber-security, an area where DOE has very strong expertise.
- Fire PRA
  PRAs for fire and/or high-energy, arc fault scenarios are currently supported by bounding case analyses. Analyses that are more realistic would benefit the existing fleet.

Introduction and Discussion of Subcommittee work to date

The Existing Fleet (EF) Subcommittee received its Charter in September 2018, in which responsibility was given "to provide expert advice and guidance to the Assistant Secretary for Nuclear Energy (NE) in the U.S. Department of Energy (DOE), through the NEAC, on topics related to the long-term sustainability of the current fleet of nuclear power plants." Shortly thereafter, a telephone conference was organized to discuss the next steps. The urgency of our Charter was highlighted in the Charter Statement, which noted that "since 2013, 6 reactors have retired prematurely (i.e., prior to license expiration) and 13 more are currently scheduled to retire prematurely." The Subcommittee concurs in the urgency of this topic. Furthermore, as the number of operating reactors in the United States decreases, our Subcommittee is concerned that the number of operating reactors will decrease to a number below which the rate of closures will rapidly accelerate - such that the nation may lose, over a short period, its domestic nuclear power industry. Such a "cliff" could occur when many plants perceive that the number of remaining plants is insufficient to maintain the supply chain on which they all depend.

We discussed the Charter of the Subcommittee and agreed it was well formulated to address the sustainability, economic viability and longevity of the existing fleet through consideration of a blend of both technology development and policy issues.

We agreed to work towards a one or two-day meeting as soon as possible with the goal of developing our initial report for the full NEAC. Subcommittee member schedules dictated only a one-day meeting on November 2 in Washington, DC. Based on discussion in our initial teleconference and as noted in our initial meeting agenda, the focus of that first meeting was two-fold: a review of the Light Water Reactor Sustainability (LWRS) Program and discussion of policy options important to sustainability of the existing fleet. Those two areas form the basis for this report. In addition, NRC agreed to provide a briefing on their interests related to the EF charter.

The meeting was held as scheduled with the entire Subcommittee in attendance. The agenda for the November 2, 2018 meeting is in Appendix A. Acronyms are listed in Appendix B and in the text. Short bios for each Subcommittee member are in Appendix C. Drs. Joy Rempe and Richard A. Meserve, the co-chairs of NEAC, served as ex-officio members of this Subcommittee and participated in the preparation of this report.

With the exception of the next Section, this Report focuses primarily on discussion at our initial meeting.

Summary of interactions with other Subcommittees

Interactions with each of the other Subcommittees have begun. One or both of the co-chairs of this subcommittee participated either by phone or in person with each of the 2019 meetings of the other Subcommittees. In some cases, information gained in those meetings is reflected in this report.

With the Fuel Cycle (FC) Subcommittee: we agreed that the FC Subcommittee will focus on the technical aspects of Accident Tolerant Fuels (ATF) while our EF Subcommittee will focus on how ATF might assist the existing fleet with improved economics and thus greater sustainability. Licensing issues will be critical as the industry moves toward full core loads of ATF. In particular, we observe that the NRC will require data on any ATF candidate in order to calculate a revised source term before such deployment. Our Subcommittee will focus on these licensing and data issues.

With the International (INT) Subcommittee, we agreed that international competitiveness and its role in enabling the U.S. to lead the world on nonproliferation and safety standards was the purview of their Subcommittee. We further agreed that the EF Subcommittee will focus on national security attributes of the existing fleet from perspectives of both economic security and maintaining a strong nuclear navy. We also agreed on one joint policy recommendation that both Subcommittees will make expressing the need for a National Security Council (NSC)-level decision on policies and programs that will avoid ceding future global leadership in nuclear energy to Russia and China.

With the Advanced Reactor Pipeline Subcommittee (ARP), we discussed mutual interests in development of radiation standards for low doses of radiation that are based on modern science. Both subcommittees are concerned that the current radiation standards are not based on sound science. In fact, past DOE research suggested that the model now used in such standards is not correct. Further research to better define radiation standards is essential for both the public and for any program (from the commercial nuclear energy industry to medical applications) utilizing ionizing radiation. We agreed that both Subcommittees would encourage DOE to implement the authorities recently gained in passage of H.R.589 into Public Law 115-246. However, both the research and the processes through which improved understanding is translated into international and national standards require significant time. Thus, while it is not clear that changes in these standards could impact existing plants, they could certainly impact future plants and the work needs to start now.

Summary of the November 2, 2018 Existing Fleet Subcommittee Meeting

Opening Comments from DOE/NE leadership

The urgency and importance for the charge to this Subcommittee were emphasized by Mr. Ed McGinnis, Acting Assistant Secretary for Nuclear Energy. Mr. McGinnis opened the Subcommittee meeting with two key points:

- The DOE is now focused on nuclear energy.
- The DOE/NE wants to understand "what is going on in spaces that are vital to nuclear energy's sustainability and growth".

He emphasized that the NEAC's assistance is needed to help DOE/NE revitalize the U.S. nuclear fleet.

Mr. McGinnis cautioned that if the number of operating reactors in the U.S. fleet drops precipitously, the future of the entire nuclear power industry would be threatened. Later in the meeting, Ms. Korsnick of NEI made a similar statement: that there is some minimum number of plants that is needed to maintain the nuclear industry. That number is not known, but we absolutely need to retain the current fleet.

He continued that one reason for the early plant closures is that plants are not being compensated for their unique attributes that are valuable to society. Having replacement plants come online in the 2020s is essential to maintaining the fleet. NEAC's recommendations on what DOE/NE should be doing to help the fleet are important to the DOE/NE's assisting with the revitalization of the U.S. nuclear fleet.

Finally, Mr. McGinnis urged the Subcommittee to provide high-impact, focused options that could meet with success. The Subcommittee's comments should be formulated in accordance with the

Administration's policies, such as noting that the Administration recognizes that carbon emissions will rise if nuclear plants are shut down.

Review of the Light Water Reactor Sustainability Program

While many DOE/NE programs impact the topics of this Subcommittee, the LWRS program is the single one most focused on our assignment. Thus, review of this program was the technical focus for our first meeting.

Ms. Alison Hahn (DOE Program Manager for LWRS) and Dr. Bruce Hallbert (DOE Director for the LWRS Program Technical Integration Office) gave two presentations that are the basis of this Subcommittee's review of the DOE LWRS Program. Ms. Hahn discussed that the Existing Fleet is one of three targets of the DOE/NE's mission, the other two being Advanced Reactor Pipeline and Fuel Cycle Infrastructure. Transformative technologies are under development by the DOE for the Existing Fleet to enable: plant modernization; efficiencies in workforce; and diversity of products. Specific programs include:

ATF Program
ATFs are being pursued to improve safety, reduce operating costs, and potentially extend the life of existing LWR reactors if their use enables improved economics and avoids possible plant closures due to economic factors.
Advanced Modeling and Simulation Program
The objective of the Advanced Modeling and Simulation Program is to enable improved economics of new and existing designs, by providing leading-edge computational tools to U.S. industry.
Crosscutting Technology Development Program
Critical gaps in crosscutting technologies are being addressed that support industry needs for improved fabrication and manufacturing, such as welding technologies, additive manufacturing, concrete materials and rebar innovations, and data configuration management.
LWRS Program
The goal of the LWRS is to "enhance the safe, efficient, and economical performance of our nation's nuclear fleet and extend the operating lifetimes of this reliable source of electricity."

Technology development for LWRS is focusing on three research pathways, which were selected based on input from the U.S. industry:

- Materials Research,
- Plant Modernization, and
- Risk-Informed Safety Analysis (RISA)

The goal of the Materials Research pathway is to "understand and predict long-term behavior of materials in nuclear power plants, including detecting and characterizing aging mechanisms." This area is a current focus because the LWRS program is supporting continued operation of the plants. An earlier focus for the LWRS program was on license renewals.

The goal of Plant Modernization is to "address replacement of existing instrumentation and control technologies and enable plant efficiency improvements through a strategy for long-term modernization." In order to extend plant life and improve operations, the DOE is pursuing a move from labor-centric operations to technology-centric operations. This shift should also reduce operating costs.

In response to a question from Ms. Korsnick, Dr. Hallbert said that the next area the DOE will pursue under plant modernization is online monitoring and plant automation (or smart instrumentation).

The goal of the RISA program is to "develop significantly improved safety analysis methods and tools to optimize the safety, reliability, and economics of plants." This area came about as a result of the NRC's progress toward the use of more risk-informed analysis. Some utilities have difficulty taking advantage of risk-informed regulation because they do not have sufficient tools or expertise to perform risk analysis.

Other efforts mentioned were coordination of hybrid energy R&D with other NE and DOE programs and early-phase investigations into physical security. Plants "on the bubble" economically could be interested in hybrid energy concepts wherein a plant would produce an economically viable product in addition to electricity. The chair of the PWROG (Ken Schrader) noted that physical security costs have a significant impact on plant economics, which suggests another avenue for assistance from DOE.

Ms. Hahn said that the industry's requests are being met within the current LWRS budget, but we did hear suggestions for expanded assistance. The Materials Research pathway's budget is decreasing from past years while security and hybrid energy budgets are increasing.

At the request of the Subcommittee co-chairs, the chairs of the BWROG and PWROG presented their perspectives on the DOE LWRS efforts.

BWROG Recommendations for LWRS Research

Mr. John Grubb spoke on behalf of the BWROG. Based on industry needs, the following topics were suggested for future LWRS research.

- Data analytics on large data sets to provide insights for decision-making,
- Data analytics on equipment performance history,
- Integration of smart instruments into the existing plant,
- Replacement of existing battery systems with a fast charge system,
- Labor optimization
    - Training methods for operations, maintenance, and others,
    - Advancement of nuclear training to the latest technologies and techniques to eliminate dated methods (Classroom, JPM (Job Performance Measure), TPE (Task Performance Evaluation), etc.),
    - Change of equipment and procedures to reduce manpower needed at plants, and
- Flexible Operation for better load-following, etc.

PWROG Recommendations for LWRS Research

Mr. Ken Schrader spoke on behalf of the PWROG and presented the following comments on current LWRS research. He reiterated that the biggest plant issue is currently economics.

Regarding the LWRS topic of "R&D to develop the scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants", 2021 program milestones include the completion of analysis of hardening and embrittlement through the Reactor Pressure Vessel (RPV) thickness for the Zion RPV sections and completion of analysis of harvested RPV sections. The PWROG notes that better understanding of the actual fracture toughness of potentially

embrittled RPVs will benefit the industry in reducing uncertainties and improving safety. Additional RPV fracture toughness data is desirable as RPVs reach higher levels of neutron fluence.

Also, under the same LWRS topic are the completion of post-irradiation thermal annealing experiments and modeling studies of RPV embrittlement. The PWROG does not believe that further research on RPV annealing is beneficial. It is highly unlikely that any U.S. utility will anneal an RPV. Furthermore, the Subcommittee is doubtful that studies of RPV embrittlement represent a near-term economic issue for the operating plants.

The PWROG sees other Zion RPV programs under this LWRS topic as beneficial:

- Mini-Compact Tension (CT) fracture toughness testing on Zion surveillance specimens to compare to the values obtained from the RPV wall samples currently being tested by ORNL and other collaborators
- Other test programs using the newly developed mini-CT technology to characterize irradiated RPV fracture toughness
- Testing on the effect of thermal aging on low alloy steels for long aging times at hot leg and pressurizer component temperatures
- Additional research on decommissioned components, especially components operated for many years at or above high hot leg temperatures, would be beneficial (This was recommended in NUREG/CR-7153.)
- Research and testing to develop standards for use of 3D-printed parts in plants (The Subcommittee understands that this work is already ongoing under DOE/NE programs separate from LWRS, but perhaps current progress in this topic could be shared within the LWRS program?)

The program investigating long-term aging and modernization of current instrumentation and control technologies is important to safe and economic operation of the U.S. nuclear industry and transition to expanded use of digital controls may represent a near-term economic opportunity, subject of course to careful study, for many plants.

The PWROG anticipates that the programs exploring water management in severe accident analyses coupled with in-vessel retention behavior; SAMG (Severe Accident Management Guidelines) actions with severe accident analysis; and incorporation of spreading and debris cool-ability models into advanced system analysis models can help remove some of the conservatisms in the new SAMGs developed in response to the Fukushima Daiichi events. The PWROG would like to be actively involved in these programs to guide the research to ensure implementable results in the SAMGs.

Another PWROG input was for R&D on approaches to support the management of uncertainty in safety margin quantification to improve decision-making for nuclear power plants. The PWROG believes that this program does not appear to be implementable at plants in the near-term due to the expected need to use super computers not readily available to utilities and the need for extended review times at the NRC to realize any improvements. They give this program low priority.

New areas for LWRS support in which the PWROG is interested include:

- Better technologies to detect fraudulent components, and
- Revision of the scientifically indefensible low dose radiation standards.

NEI Recommendations for LWRS Research

Ms. Korsnick emphasized that economic improvements alone are unlikely to be a panacea for the economic current situation impacting plant operations. She also urged the Subcommittee to keep in mind the global picture, considering that plants built overseas help to retain the current supply chain. She discussed NEI suggestions for future topics as shown below:

- Fuel security and resilience in electricity production,
- U.S. presence in the international nuclear scope (which is being discussed by the INT Subcommittee),
- Reinforced importance for states to engage in actions to protect their operating plants,
- Leveraging of big data sets (or data analytics) for improving performance and reducing costs, and
- ATF with a focus on understanding how use of such new fuels could impact the safety basis of a plant, in combination with other safety enhancements like the industry's FLEX system, and whether their use could justify lower operational expenses. Of course, these steps would require that an adequate safety case be presented to, and approved by, the NRC.

Based on the November 2, 2018 briefings and Subcommittee discussions since receiving its charter, the EF Subcommittee recommendations for DOE LWRS efforts were listed in the Opening Summary and not repeated here.

Review of Opportunities for DOE Research to Address NRC needs

The Subcommittee appreciated the briefing provided by Ray Fursteneau, Director of the NRC Office of Nuclear Regulatory Research. The title of his talk was "Safety and Security Research for Existing Nuclear Power Plants." In his talk, he emphasized the range of ongoing (very positive in the view of this Subcommittee), cooperative efforts between the NRC and DOE/NE including:

- Operations research with strong involvement of the DOE/NE LWRS program on Subsequent License Renewal,
- Spent fuel issues focused on behavior of used fuel in dry cask storage,
- ATF with emphasis on testing of new designs under various conditions and evaluation of utilization of existing codes from the CASL (Consortium for Advanced Simulation of LWRs) program,
- Modeling and simulation to seek broad leverage from the DOE/NE CASL and NEAMS (Nuclear Energy Advanced Modeling and Simulation) programs,
- Fukushima forensics research with its possible impacts on severe accident management guidelines, and
- Nuclear energy innovation focused on utilization of recent legislation (the Nuclear Energy Innovation Capabilities Act of 2017) that promotes sharing of expertise on advanced nuclear reactor technologies.

At the request of the Subcommittee, he also discussed potential new areas for cooperative research that would assist the NRC in addressing issues with the current fleet. (One of his topics was more appropriate for the ARP Subcommittee, and Mr. Fursteneau's presentation has been provided to the leadership of that Subcommittee). He listed five areas for consideration:

- Fire PRAs (Probabilistic Risk Assessment) and High Energy arc faults,
- Digital instrumentation and controls research,
- Risk-informed Security Research,
- PRA Methods and Tools, and
- Advanced (Non-LWR) Reactor Support (referred to the ARPS Subcommittee).

In discussing these areas, some seemed appropriate for near-term impact on the operating fleet, perhaps through expansion (in both funding and scope) for the LWRS program or as additional cooperative efforts within other DOE/NE programs. While there are many examples now of coordination between NRC needs and DOE research programs, increased coordination would benefit both parties. Suggestions for further support from DOE/NE to NRC interests were presented in the opening Summary of Recommendations and are not repeated here

Review of Initial Policy Options and Development of Recommendations

Our discussion focused both on broad guidelines for policy recommendations as well as on some specific recommendations. Many entities develop policies that impact the long-term sustainability of the existing fleet, including the Executive Branch, Congress, the Federal Energy Regulatory Commission (FERC), regional market organizations, and states. But since this Subcommittee is an arm of NEAC, and NEAC recommendations inform DOE/NE and the Department of Energy, we agreed that our focus should be on policy options that could be used within and/or by the DOE. The DOE might, in turn, choose to recommend these policies to other decision makers.

We discussed broad categories for appropriate recommendations, such as:

- Encouraging the Secretary to recommend public support for specific options, which might, in turn, inform decisions made at the state level,
- Recognizing the importance of technology-neutral approaches to policy, to avoid the current situation wherein many state policies demand **renewable energy** instead of defining their end goal of **clean energy**,
- Recognizing the role of nuclear technologies in a wide range of issues impacting national security, and
- Advocating for specific legislative approaches, such as support for Investment or Production Tax Credits or for creation of specific programs.

In our discussions, we recognized that the most successful policy options utilized today to preserve existing plants have originated at the state level and that the states have very substantial impact on their own electricity markets. In some cases, state action may be appropriate because actions that may be appropriate in one geographic area may not work in other areas. (For example, the MISO (Midcontinent Independent System Operator) includes several markets with varying needs.) We also noted, unfortunately, that strong opposition to any state's debating actions to enable continuation of nuclear plants has come from the fossil energy, and to a lesser extent, renewable energy advocates.[2] It

[2] For example, the Dec 7, 2018 article in *Natural Gas Intelligence* entitled "U.S. Natural Gas Generators Urge No Subsidies for Nukes, Renewables" discusses a letter to FERC in which eight natural gas generators claim the "potential for enormous damage" in PJM (the Regional Transmission Organization coordinating wholesale electricity initially for Pennsylvania, New Jersey and Maryland and now for 13 Eastern States and the District of

is at that state level or to leadership of the fossil and renewable industries where strong suggestions from the most senior levels of the Department may be instrumental in shaping consideration of state policy initiatives. However, we also recognized that a state-by-state approach to such vital policy issues is hardly optimum and is an imperfect substitute for strong national policies that provide suitable broad guidance to all the states.

We also agreed that, while technology advancements can certainly improve the economic sustainability of the existing plants, **cost reductions and improved efficiencies alone will be insufficient to address the crisis in long-term sustainability** (even though the U.S. nuclear industry has made significant cost improvements, with the average cost of nuclear-generated electricity falling by 19% since 2012). This market challenge is greatly exacerbated by the simple fact that most U.S. electricity markets simply do not recognize the environmental, grid resilience, economic, and natural security and export attributes of nuclear power. Market challenges are exacerbated by the mandates in many states to promote use of renewable power and by production tax credits only paid to renewable sources that enable them to be profitable even at negative electricity prices. Our discussion noted that a national mandate to treat equally all electricity generation sources with similar (carbon-free) emission attributes would certainly help the situation.

Several studies, such as those done by the Idaho National Laboratory (INL) (Economic and Market Challenges Facing the U.S. Nuclear Commercial Fleet – Cost and Revenue Study, INL/EXT-17-42944, September 2017), and the Union of Concerned Scientists (The Nuclear Power Dilemma, November 2018), note that many of the nation's nuclear power units are not profitable today. However, some of those studies have noted that a relatively small revenue enhancement (around $15-20/MWh) would address the majority of profit gaps. As one response to this challenge, several domestic utilities are now exploring whether some of their less profitable GW-class LWRs could be repurposed for non-traditional applications, like desalination or hydrogen production, and encouragement of that avenue to enhance profitability of the existing fleet seems quite feasible for government policy consideration. As another consideration, some utilities are exploring expanded use of load-following to match the production of intermittent renewable sources.

Many studies also note that when an operating nuclear plant retires, its capacity is generally replaced by natural gas generation at a higher LCOE (levelized cost-of-electricity) and with greater carbon emissions. This led to discussion whether a useful national policy might require a NEPA (National Environmental Policy Act) review for shutdown of any plant, just as a NEPA review is required for the construction of any plant. This Subcommittee chose not to include a recommendation in this area.

The ties between a strong nuclear energy industry and national security were obvious in our discussions. Indeed, Secretary Perry recently stated that: "Energy security is national security," a view with which we completely agree. The role of nuclear energy in providing reliable, safe, highly resilient, clean power on demand at reasonable costs is of inestimable value to the nation and its security, but it is only one facet of national security to which the nuclear industry contributes.

Columbia) if the nuclear plants continue to operate. Additionally, proposals for a "100% renewables future" continue to surface, ignoring both the absence of feasibility and the immense benefits of fuel diversity to the security of the national grid.

The July 2018 CSIS (Center for Strategic and International Studies) report, "Back from the Brink," was useful in our initial discussion of national security implications of a strong domestic nuclear industry. In fact, the sub-title of that CSIS report is "A Threatened Nuclear Energy Industry Compromises National Security," and our Subcommittee fully endorses that view. The CSIS report notes that:

- "United States' dominance in nuclear has allowed the U.S. government to … support our naval propulsion program and nuclear weapons program,"
- "our nuclear navy depends heavily on the health of the broader U.S. nuclear energy industry for fuel, technical support, and knowhow," and
- "U.S. Naval reactors rely on a U.S. nuclear fuel cycle, a healthy U.S. nuclear support community, and staying at the cutting edge of nuclear innovation."

The report discusses how our university programs support the nuclear navy, the nuclear weapons program, and the commercial nuclear industry, and how a decline in the latter industry would undermine our universities' ability to offer the programs needed for these other elements of our national security. In addition, many retirees from the nuclear navy look forward to extending their careers in the commercial nuclear industry, and those retirees are typically in great demand by the industry. All these factors are seriously jeopardized if our commercial nuclear industry continues to wither and will seriously complicate the long-term viability of both the nation's nuclear navy and nuclear weapons programs.

Other studies reach the same conclusion. The August 2017 report of the Energy Futures Initiative stated that:

- "Meeting national security priorities requires a robust nuclear energy industry" and
- "The U.S. Nuclear Navy relies on a robust domestic nuclear energy supply chain."

In addition, William Ostendorff, now a Distinguished Visiting Professor of National Security at the U.S. Naval Academy (previously a Commissioner of the Nuclear Regulatory Commission, Principal Deputy Administrator of the National Nuclear Security Administration, and Staff Director of the House Strategic Forces Subcommittee of the House Armed Services Committee) wrote in November 2018: "There is a vital and deep nexus between the health of the U.S. nuclear industry and national security."

Similar conclusions were reached in a June 2018 letter to the Secretary from a group of 77 prominent Americans asking that he "take concrete steps to ensure the national security attributes of U.S. nuclear power plants are properly recognized."

Discussion of national security attributes of the existing fleet led to recommendations that these questions can only be fully addressed at, and certainly rise to, the level of the NSC. (Virtually the same recommendation was made by George David Banks in his January 2017 paper for the Center for Policy Research, shortly before he served for about one year as President Trump's Special Assistant for International Energy and Environment at the NEC (National Economic Council) and NSC.) These discussions also led to the observation that the nuclear navy uses only LWRs, and the existing commercial fleet is entirely composed of LWRs. While advanced coolants certainly can have a significant impact on nuclear energy applications in the future and university/lab programs on advanced coolants serve to inspire overall interest, innovation, and focus on nuclear technologies, the **national security imperative faced today centers on LWRs**. Thus, in addition to maintaining the existing fleet, some of

our recommendations encourage near-term expansion of domestic LWR technology. Furthermore, since there are very few, if any, possibilities for new construction of GW-class LWRs in this country, we recognize that the LW SMRs (Small Modular Reactors) represent the most significant possibilities for new and highly relevant construction. We strongly recommend continued government support for initial deployment as well as enough subsequent deployments to provide confidence in construction and operational costs.

The need for scientifically credible radiation dose standards underpins nuclear medicine, the nuclear navy, the commercial nuclear industry, our national laboratories involved in the weapons programs, and our environmental cleanup programs. An earlier DOE Low Dose Radiation Research program was terminated in the last Administration after their work suggested that the current model for radiation effects (the Linear No Threshold or LNT model) was not valid and is not based on sound science. The LNT model has been interpreted by some groups to mean that "all radiation is harmful," which inspires unfortunate public fears of any technology based on nuclear processes. After concluding that the LNT model was probably not valid, the goal of the Low Dose Radiation Effect program was to determine what standards should replace the LNT model, but that goal was not realized due to the early termination of the program. Many economic aspects of the current domestic fleet are influenced by the existing LNT-based radiation standards and any future uses of nuclear energy and technologies will continue to be tainted by the LNT model until a credible model is in place.

The Subcommittee applauds recent (September 2018) action by Congress and the Administration to pass H.R. 589 into Public Law 115-246. Section 306 of H. R. 589 directs that "The Office [of Science] shall carry out a low-dose radiation research program to enhance the scientific knowledge of, and reduce uncertainties associated with, the effects of exposure to low-dose radiation to inform improved risk-management methods."

With these general policy considerations in mind, the EF Subcommittee developed specific policy proposals that were presented in the opening Summary of Recommendations and are not repeated here

Additional Information obtained after the Subcommittee Meeting

A major policy concern arose in the early days of 2019, well after our Subcommittee meeting, when many university programs received notifications that certain work scopes were no longer under consideration for NEUP (Nuclear Energy University Program) funding. Moreover, three significant NEUP Integrated Research Projects (IRPs) were cancelled, disrupting important university-based projects in collaborations with U.S. allies. These changes raised many questions within the university community and seem quite at odds with countless recommendations noting that the strength of the U.S. university system is one of our nation's greatest strengths for nuclear energy's sustainability and innovation, as well as the recognition that the NEUP program underpins those strengths. Uninterrupted and balanced support for university research funding is essential to sustaining our technological edge and maintaining our leadership in the global community, in addition to educating and preparing the future workforce of nuclear engineers.

Explanations for these cutbacks emerged in the January 24-25, 2019 meeting of the Fuel Cycle Subcommittee when they were informed that the NEUP portion of the Nuclear Fuel Cycle and Supply Chain budget was being reduced by $23M for FY19 (from $33.6M in F18 to $10.6M in FY19, with the explanation that these funds were needed to support a $30M increase in a new Civil Nuclear Enrichment

budget to support the first year of a new centrifuge enrichment demonstration program devoted to production of U.S. origin HALEU[3] (The Co-chair of this Subcommittee was invited to the FC Subcommittee meeting and thus heard the same briefings.) To say the least, both the FC and EF Subcommittees are extremely concerned with these cuts.

The reductions in funding to the university sector are of immense concern, but the timing of the cuts severely amplifies these concerns. The notice to the universities about the changes in funding scope came just before their proposals were due, thus the universities had already expended massive efforts to prepare the proposals. And by starting the centrifuge demonstration program long after the DOE's FY19 budget requests were sent to Congress, after the FY19 budgets were established by Congress and the Administration without any appropriations for a new centrifuge program, and after DOE/NE had completed FY19 disbursements for many programs, DOE/NE was then required to find this "new" $30M from cuts in the few remaining programs for which FY19 disbursements had not yet been made and to make cuts that did not violate specific Congressional guidance. According to DOE/NE, their only option at that point was to take most of the funds from the NEUP program. Obviously, great urgency was attached by DOE/NE for this new program since it came at the expense of undercutting the health of the U.S. university nuclear engineering programs.

Topics for Additional Subcommittee Meetings

Subcommittee members suggested topics for meetings of our group. The following list was gathered from all the members:

1) Light Water Reactor Sustainability Program,
2) Accident Tolerant Fuels - Factors impacting potential economic impact of ATF,
3) Modeling and Simulation – CASL, NEAMS, NRC interest,
4) Applications of big data sets and/or expanded use of data analytics,
5) Energy market designs, decarbonization of U.S. fleets, state regulator/shareholder attitudes toward nuclear,
6) Non-electricity applications of nuclear energy and Integration of Nuclear and Renewable energy sources,
7) National security implications of the existing commercial nuclear plants:

[3] Evaluation of any urgent need at this time for still another HALEU demonstration program falls directly under the purview of the Fuel Cycle Subcommittee of NEAC and cancellation of international collaborations are directly under the purview of the International Subcommittee of NEAC. But to briefly supplement their considerations, we offer a few observations. Certainly, availability of HALEU for initial advanced reactor work is important and, in the long-term, HEU (highly enriched uranium) will be needed for the nuclear navy. But Congress already appropriated $20M for the ZIRCEX program in FY19. If ZIRCEX (whose goal, as stated in GAO-18-126 is to "recover HEU from zirconium-clad spent naval reactor fuel") is successful and funded in future years, it could be a useful contributor to U.S. origin HALEU needs. In addition, the Department has 34 tons of weapons grade plutonium that is required by international agreement to be disposed. If that disposition involved downblending for potential use in advanced reactors, this could translate to an equivalent of at least 170 tons of U.S. origin HALEU. Thus, other very promising routes are potentially available for HALEU.

   - Synergisms between commercial and naval nuclear expertise/supply chain, and
   - Nuclear energy's contribution to resilience of the electricity grid,
8) Industry utilization of universities' expertise and facilities,
9) Health effects of low doses of radiation,
10) Public education/STEM programs to increase understanding of nuclear technologies,
11) Impact of the absence of a funded used fuel management program on acceptance of nuclear power, and
12) Transportation limitations for nuclear materials and used fuel.

The first topic, the LWRS program, was covered in the initial meeting of the EF Subcommittee.

Item #4 "Applications of big data sets and data analytics" came up several times in our first meeting, and we agreed to recommend that this area receive increased emphasis in an expansion of the LWRS program.

In discussing Item #7, "National security implications of the existing commercial nuclear plants," we agreed that the Subcommittee could propose some policy options in our first report that would begin to address this urgent topic without having received a briefing on the topic. We are relying for now, in lieu of a briefing, primarily on the excellent CSIS Report, "Back from the Brink," published July 2018 (that report was circulated to all Subcommittee members before our first meeting). We look forward to an in-depth briefing on this topic at a future meeting at which time we can refine our policy suggestions.

We also agreed that Items #8 and 9 could be addressed in our report based on limited discussion during our first meeting. The Subcommittee agreed on the importance of both topics and policy suggestions on these topics are in our first report.

And finally, we agreed that the next meeting of our Subcommittee would focus on Items #2, "ATF" and #3, "Modeling and Simulation." Some discussion at our first meeting noted that a major challenge of ATF will involve the potential interest of industry, in their quest for improved economics, to move rapidly from deployment of LTAs (Lead Test Assemblies) to entire cores. Thus, our meeting on this topic will focus on the challenges for such a move, including the need for validated information on potential severe accident scenarios with full core loads. Furthermore, we will explore the extent to which modeling and simulation may help address these challenges.

Appendix A

Existing Fleet Subcommittee
Nuclear Energy Advisory Committee
November 2, 2018

Idaho National Laboratory Office, Conference Room B15
955 L'Enfant Plaza, SW; North Building, Suite 6000A; Washington, D.C. 20024
Call-in: 415-527-5035 Host Access Code and PIN: 15542817 and 1342 Attendee Access Code: 15521515

8:30 – 9:00	Ed McGinnis, Acting Assistant Secretary for Nuclear Energy Overview of Committee Charter and Opening Comments
9:00-9:30	Subcommittee Co-chairs – Overview of topics proposed for Subcommittee consideration and report development
9:30-10:00	Alison Hahn, Federal Program Manager for Shane Johnson, Deputy Assistant Secretary, Overview of DOE programs targeting the existing fleet with focus on LWRS
10:00-10:15	Break
10:15-11:15	Alison Hahn, Federal Program Manager, and Bruce Hallbert, Technical Integration Office Director Light Water Reactor Sustainability program overview - impact on existing fleet
11:15-11:45	Ken Schrader,-Chair of the PWR Owners' Group Discussion of DOE Program impacts on PWRs and suggestions for greater impact
11:45-12:15	John Grubb, Chair of the BWR Owners' Group Discussion of DOE Program impacts on BWRs and suggestions for greater impact
12:15-12:30	Break and set up working lunch
12:30-1:00	Maria Korsnick, Nuclear Energy Institute President and Chief Executive Officer Delivering the Nuclear Promise and needs for DOE support
1:00 – 2:00	Ray Fursteneau, Director, Office of Regulatory Research, U.S. Nuclear Regulatory Comm. DOE program impacts on NRC evaluation of requests from existing fleet
2:00-2:15	Break
2:15-3:00	Matthew Crozat, Senior Director, Business Policy at Nuclear Energy Institute Policy considerations to assist existing plants
3:00-3:30	Gene Grecheck, former President of the American Nuclear Society Policy considerations and discussion.

Appendix B **Acronyms**

ARP	Advanced Reactor Pipeline Subcommittee of NEAC
ATF	Accident Tolerant Fuel
BWROG	Boiling Water Reactor Owners' Group
CASL	Consortium for Advanced Simulation of Light Water Reactors
CSIS	Center for Strategic and International Studies
CT	Compact Tension
DOE	Department of Energy
EF	Existing Fleet Subcommittee of NEAC
FC	Fuel Cycle Subcommittee of NEAC
FERC	Federal Energy Regulatory Commission
GW	Giga-watt
HALEU	High Assay Low Enriched Uranium
HEU	Highly Enriched Uranium
INL	Idaho National Laboratory
INT	International Subcommittee of NEAC
IRP	Integrated Research Project
JPM	Job Performance Measure
LCOE	Levelized cost of electricity
LW	Light Water
LWR	Light Water Reactor
LWRS	Light Water Reactor Sustainability
MISO	Midcontinent Independent System Operator
NE	Nuclear Energy Office of the U.S. DOE
NEAC	Nuclear Energy Advisory Committee
NEAMS	Nuclear Energy Advanced Modeling and Simulation
NEC	National Economic Council
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act
NEUP	Nuclear Energy University Program
NRC	Nuclear Regulatory Commission
NSC	National Security Council
PJM	Regional Transmission Organization coordinating wholesale electricity, initially for Pennsylvania, New Jersey and Maryland, and now for 13 Eastern States and DC
PRA	Probabilistic Risk Assessment
PTC	Production Tax Credit
PWROG	Pressurized Water Reactor Owners' Group
RISA	Risk-informed Safety Analysis
RPV	Reactor Pressure Vessel
SAMG	Severe Accident Management Guidelines
SMR	Small Modular Reactor
TPE	Task Performance Evaluation
VTR	Versatile Test Reactor, a DOE program to deploy a fast test reactor

Appendix **C**

Members of the NEAC Subcommittee on the Existing Fleet

Eric Anderson

Executive Director at J.P. Morgan

Eric Anderson is an executive director in the Mergers and Acquisitions group of J.P. Morgan in the greater Chicago area. He is focused on M&A advisory services to global clients across the energy sector, including power and utilities, generation and renewables.

Anderson also has experience with diversified industrials businesses that have connectivity with the energy sector. His extensive experience across transactions with total value in excess of $250 billion includes buy-side, sell-side, and separation transactions involving both public and private companies, as well as subsidiaries. He has also advised clients related to shareholder activism and corporate defense.

Prior to J.P. Morgan, Anderson worked in private equity at Unigestion and Kingsman Capital in Chicago. He has also served as senior manager, enterprise risk services, at Deloitte and Touche.

Anderson holds a degree in finance, management Information Systems from Boston College, and a Master of Business Administration degree from The University of Chicago Booth School of Business. He also studied at the University of California, Los Angeles, in management information systems.

John Bear

Chief Executive Officer, Midcontinent Independent System Operator (MISO)

John Bear joined MISO in 2004 and has more than 25 years of executive leadership in the utility industry. As chief executive officer of MISO since January 2009, he leads MISO's continuous efforts to work collaboratively and transparently with its members to reliably deliver low-cost energy through efficient, innovative, operations and planning.

Prior to his current position, Bear was MISO's president and chief operating officer, overseeing the initial design, implementation and daily operation of MISO's energy markets and transmission system planning.

Previously, Bear was president of Houston-based Reliant Resources, where he directed all operations and commercial activity for 14,000 megawatts of generation as well as serving as managing director of Reliant's European operations.

Bear also served as president of the GO15, the world's largest power grid operators. The GO15 shares knowledge on key issues representing more than 75 percent of the world's electricity demand and 3.4 billion customers on six continents.

He is a former board member of NERC regional entity ReliabilityFirst, and a founding board member of the Amsterdam Power Exchange (APX).

Bear is currently an advisory board member of the Energy Systems Network (ESN), an initiative focused on bringing clean technology solutions to market. He is also a member of the governance board of the Ohio, Kentucky and the Indiana Chapter of the Make-A-Wish Foundation and served as vice-chair of the Indiana Regional Board.

Bear graduated from Southern Methodist University with a Master of Business Administration degree and a Bachelor of Business Administration degree. He also attended the INSEAD Advanced Management Program for Senior Executives.

Matthew P. Crozat

Senior Director, Policy Development, Nuclear Energy Institute

Matt Crozat is Senior Director for Policy Development aat the the Nuclear Energy Institute. He is responsible for directing NEI efforts to identify policy initiatives that will improve economic viability of operating plants and enhance prospects for new plant construction. Mr. Crozat examines market operations and proposed policies to assess their impact on nuclear energy. He also oversees analyses of nuclear industry cost performance and trends.

Before joining NEI in 2015, Mr. Crozat was a Senior Policy Advisor in the Office of Nuclear Energy at the U.S. Department of Energy.

Mr. Crozat is recognized as an international expert on nuclear energy economic issues. He served as co-chair of the Working Party on Nuclear Energy Economics at the Nuclear Energy Agency of the OECD for over ten years. He holds an M.A. from Cornell University and a B.A. from Tulane University.

Eugene S. Grecheck

Principal, Grecheck Consulting LLC

Past President, American Nuclear Society

Eugene S. Grecheck is Principal of Grecheck Consulting LLC. He provides management and technical consulting to the nuclear industry, with emphasis on performance improvement, regulatory issues, and developing and integrating emerging technologies. He is also Past President of the American Nuclear Society.

He retired from Dominion Nuclear in late 2013, following more than 38 years with the company. His career there included a wide variety of leadership positions at the company's nuclear stations as well as the corporate offices. He served as Plant Manager at North Anna, Site Vice President at Surry and Vice President of Nuclear Operations at Millstone. He led Dominion's new plant development activities for over a decade, including the submittals of the Early Site Permit and Combined Operating License applications for the proposed North Anna 3 project.

Grecheck received a bachelor's degree in physics and a master's degree in nuclear engineering from Rensselaer Polytechnic Institute, as well as an MBA from Virginia Commonwealth University. He also completed The Executive Program at the Darden Graduate School of Business at the University of Virginia

Grecheck is an affiliate faculty member of the Virginia Commonwealth University Department of Mechanical and Nuclear Engineering and Chair of the Strategic Advisory Council for the Department of Mechanical, Aerospace and Nuclear Engineering at Rensselaer Polytechnic Institute. He has previously served as Chairman of the Nuclear Energy Institute New Plant Working Group and member of the NEI New Plant Oversight Committee. He has participated on numerous advisory and oversight boards for the US Department of Energy, national laboratories, academic institutions, and nuclear technology suppliers. He recently served as the Founding Board Chair of Generation Atomic, a leader in grassroots nuclear policy advocacy, and is currently serving as Treasurer of the Virginia Nuclear Energy Consortium Authority, a gubernatorial appointment.

Dr. Karen Kirkland

Associate Department Head and Associate Professor, Texas A&M University

Dr. Karen Kirkland is Associate Department Head and Professor at Texas A&M University. Prior to joining Texas A&M, she was an Assistant Professor at Purdue University. Dr. Kirkland has also served as assistant chief engineer at Nuclear Power Engineering Corp., engineer at GE Nuclear Energy, and as visiting researcher at Hitachi Energy Research Laboratory.

Dr. Kirkland has served as a consultant or team lead on a number of nuclear energy research projects including the following: MELCOR Severe Accident Code Assessment and Application, 2001-2007; consultant, SOARCA Peer Review Committee, 2009-2012; Testing of RCIC Performance for Mark I BWRs under Prolonged Station Blackout Conditions, 2012-2014; Multi-Phase Model Development to Assess RCIC System Capabilities under Severe Accident Conditions, 2014-2017; and, Terry Turbopump Expanded Operating Band Full-Scale Component and Basic Science Testing at Texas A&M University, 2017-2019. She is also the co-author of 10 research articles or papers that appeared in multiple technical publications.

Dr. Kirkland earned her Bachelor of Science degree in nuclear engineering from Purdue University, her Master of Science degree in nuclear engineering / thermal-hydraulics from the University of California at Berkeley, and her Ph.D. in quantum engineering and system sciences / thermal-hydraulics from the University of Tokyo.

Dr. Seungjin Kim

Professor, Purdue University School of Nuclear Engineering

Dr. Seungjin Kim is a Professor and Head of the School of Nuclear Engineering at Purdue University. He is also the co-director of the Thermal-hydraulics and Reactor Safety Laboratory.

Dr. Kim has more than 30 years of experience in the area of reactor thermal-hydraulics and two-phase flow experiments. More specifically, he has done research in reactor thermal-hydraulics, reactor safety analysis, two-phase flow experiments, interfacial area transport, and instrumentation and diagnostics of two-phase transport.

To date, Dr. Kim has published more than 150 technical papers, among which more than 60 were peer-reviewed journal papers. Dr. Kim's research has led to the development of the interfacial area transport equation that has been implemented in a commercial computational fluid dynamics code FLUENT for two-phase flow simulation as well as into system analysis code. His work on advanced two-phase flow instrumentation has made significant impact on two-phase flow experimental capabilities and is now being employed widely by many international research groups.

Dr. Kim has actively taken leadership positions in his field of technical expertise and has served as chair of the American Nuclear Society (ANS) Thermal Hydraulics Division. In 2017, he was awarded ANS Fellow for his contributions toward "advancing reactor thermal-hydraulic analysis methods by developing dynamic two-phase flow models, developing advanced instrumentation that expanded capability of two-phase flow experiments, educating nuclear engineers in academics, and providing services to ANS through various leadership positions in the Thermal-Hydraulic Division and in professional meetings."

Maria Korsnick

President and CEO, Nuclear Energy Institute (NEI)

Maria Korsnick is president and chief executive officer of the Nuclear Energy Institute, the nuclear industry's policy organization in Washington, D.C.

Drawing on her engineering background, hands-on experience in reactor operations, and a deep knowledge of energy policy and regulatory issues, Korsnick aims to increase understanding of nuclear energy's economic and environmental benefits among policymakers and the public.

Before joining NEI, she was senior vice-president of Northeast operations for Exelon, responsible for overseeing operation of the Calvert Cliffs 1 and 2, R.E. Ginna, and Nine Mile Point 1 and 2 nuclear power plants

Before Exelon, Korsnick served as chief nuclear officer (CNO) and acting chief executive officer at Constellation Energy Nuclear Group. She began her career at Constellation in 1986 and held positions of increasing responsibility, including engineer, operator, manager, site vice-president, corporate vice-president, and CNO.

Korsnick holds a Bachelor's degree in nuclear engineering from the University of Maryland and has held a senior reactor operator license.

Peter Lyons

Former Assistant Secretary for Nuclear Energy, U.S. Department of Energy

Dr. Peter Lyons consults on several corporate and laboratory boards, after retiring in 2015.

At DOE/NE, he focused on incorporating modeling and simulation into all programs, on management of used fuel, and establishment of the Small Modular Reactor Licensing Technical Support. He also championed the Nuclear Energy University Program.

Prior to joining DOE, Dr. Lyons served as a Commissioner of the U.S. NRC. Before becoming a Commissioner, he served as science advisor on the staff of U.S. Senator Pete Domenici and the Senate Committee on Energy and Natural Resources. Prior to that, he worked at the Los Alamos National Laboratory starting in 1969.

Dr. Lyons is a Fellow of both the ANS and APS; received the Henry DeWolf Smyth Award from the ANS and NEI, the Alvin M. Weinberg Medal from the ANS, and the James Landis Medal from the ASME. He was recognized by the NIC for a Lifetime Achievement Award. He was elected to 16 years on the Los Alamos School Board.

Dr. Lyons has presented more than 400 papers or talks on a wide range of technical and policy topics in addition to testifying before the U.S. Congress on many occasions. He holds four patents related to fiber optics and plasma diagnostics.

Dr. Lyons received his doctorate in nuclear astrophysics from the California Institute of Technology and earned his undergraduate degree in physics and mathematics from the University of Arizona.