October 02, 2017

MEMORANDUM TO: John D. Monninger, Director
Division of Safety Systems, Risk Assessment,
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Office of New Reactors

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SUBJECT: SUMMARY OF APRIL 25-26, 2017, NUCLEAR REGULATORY COMMISSION AND DEPARTMENT OF ENERGY WORKSHOP ON ADVANCED REACTORS

The U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE) hosted the third workshop on advanced reactors (AR) from April 25-26, 2017. The workshop focused on modeling and testing for AR design and licensing. Workshop participants included senior officials from NRC and DOE, along with speakers, panelists, and industry represenation, the national laboratories, and other non-government organizations. DOE and NRC provided updates on recent non-light water reactor (non-LWR) licensing activities and strategies while speakers, panelists, and participants discussed review processes, highlighted progress since the last workshop, and identified both cross-cutting and technology specific AR licensing and reactor modeling and testing needs.

I. Opening Remarks and Objectives of Workshop

- Stephen G. Burns, NRC Commissioner, welcomed the attendees and expressed his appreciation for the industry and external stakeholder input gathered throughout previous workshops and public meetings. This input has served an important role in NRC's efforts to create a predictable licensing path for ARs. Commissioner Burns acknowledged the strong collaboration among NRC, DOE, and stakeholders over the past three years for development of AR design criteria (ARDCs). The NRC anticipates issuing the ARDCs as a regulatory guide (RG) by the end of 2017, after addressing public comments. Commissioner Burns emphasized the important role that industry AR working groups play in informing DOE and NRC regarding advanced research and regulatory work. While DOE and NRC are transitioning from planning to execution for near term goals, the AR community should seek to identify activities for mid– and long–term action plans now. Commissioner Burns also stressed the need for vendors and conceptual designers to engage with NRC as early as possible.

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NRC staff is ready and willing to collaborate with the vendors early on in identifying technical and/or policy issues. The NRC recognizes the need for faster, more efficient, and more risk-informed reviews for ARs and will keep challenging themselves to improve processes. To accomplish its goals, NRC will need AR stakeholder input early and often to ensure it has the right resources at the right time.

- Ray Furstenau, Acting Assistant Secretary for Nuclear Energy, DOE, also welcomed the participants and looked forward to a fruitful discussion. Secretary Furstenau reiterated the significant progress made since the first workshop, highlighting the ARDC work and development of DOE and NRC AR vision and strategy documents as key accomplishments representing successful DOE, NRC, and stakeholder collaboration and coordination. For DOE activities, the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative continues to grow and provide AR stakeholders access to DOE and national laboratory expertise and infrastructure. Through GAIN, DOE has awarded $2 million in AR technology small businesses vouchers, and plans to review applications and make further awards in 2017. DOE has also seen progress with its 2015 AR industry awards with X-energy, LLC, Southern Company, and TerraPower, LLC (TP). DOE, with input from the Nuclear Energy Advisory Committee (NEAC) and external stakeholders, continues to explore the needs and path forward for a new test reactor with potential fast neutron irradiation capabilities. Secretary Furstenau highlighted the recent increased support for nuclear energy by congress and the administration and noted that he is encouraged by the progress of NuScale and the ongoing US AP1000) pressurized-water reactpr (PWR) builds. Secretary Furstenau concluded by reiterating the need for continued stakeholder input and public–private collaboration. Stakeholder input is key to ensure that the DOE can tailor research to meet AR deployment goals and that the NRC can improve regulatory efficiency.

II. Update on Non-LWR Government Initiatives

- Trevor Cook, DOE, presented DOE AR research, development, and licensing initiatives. Mr. Cook first acknowledged the synergy between the DOE and NRC AR vision and strategy documents. Both visions have a goal of two or more AR concepts licensed and ready for commercialization by the 2030s. The DOE vision and strategy further states that ARs would have a substantial role in the US nuclear energy mix by the 2050s. To meet its vision, DOE continues to engage with NRC and industry to develop an AR regulatory framework, utilizing input through GAIN to influence AR research and development, and enhances its modeling and simulation tools for AR analysis. Mr. Cook reiterated the success of GAIN's first round of small business vouchers and stated plans for approximately 20 new vouchers in 2017 pending funding allocations. For its AR program, DOE currently pursues research and development in three main areas: fast reactors (legacy fast reactor knowledge preservation, component testing in sodium, advanced modeling and simulation), high temperature gas reactors (advanced materials and graphite qualification, scaled heat removal experiments to support design and licensing), and molten salt reactors (tritium management, sponsored university research). Mr. Cook also emphasized DOE's Nuclear Energy Advanced Modeling and Simulation (NEAMS) program as a major investments in new and improved modeling and simulation tools with the potential to accelerate AR design and licensing. Mr. Cook concluded by reiterating the need for continued AR stakeholder input to help direct DOE's future AR research and development.

- Amy Cubbage, NRC, next presented on NRC's non-LWRs vision and strategy, implementation action plans, and stakeholder engagement. The NRC vision and strategy seeks to ensure NRC readiness to effectively and efficiently review non-LWRs by 2025.

This timeline is consistent with DOE in meeting its goal of having two or more ARs licensed by 2030. To achieve its vision, NRC has developed implementation action plans focusing on near-term (0 to 5 year), mid-term (5 to 10 year), and long-term (greater than 10 year) tasks required for NRC to achieve non-LWR licensing review readiness. The near-term plan has six strategies: develop knowledge, skill, and capacity to perform non-LWR reviews; develop computer codes for the reviews; develop guidance for flexible, staged licensing review processes; identify applicable industry codes and standards for fuels and materials; resolve technology inclusive policy issues; and develop structured strategy to communicate with internal and external stakeholders. Mid-term and long-term plans will build off the near-term plans and may require further congressional support. Ms. Cubbage discussed ongoing NRC activities including finalization of the ARDCs, AR security design considerations, and development of draft prototype guidance. Ms. Cubbage stressed the importance of early stakeholder engagement in the pre-application process, recognized current ongoing pre-application work with AR designers such as Oklo and Terrestrial Energy, and anticipates additional pre-application review requests in the near-term.

Following the session, the presenters received several questions.

- Ms. Cubbage was asked how ARs can be risk-informed if traditional containment is required. She responded that NRC is open to different approaches.

- Mr. Cook was asked if there should be concern about advanced gas-cooled reactor tests being completed. Mr. Cook responded that if Congress funds the tests, they will be completed and stated that there is likely enough data to start a topical report.

III. Regulatory Review Process Options

- Jeffrey Merrifield, U.S. Nuclear Infrastructure Council (NIC), expressed his appreciation for the significant amount of progress since the last workshop, discussed his views on the state of the nuclear industry, and presented results from a recent NIC-led survey of 18 AR companies. Mr. Merrifield emphasized more overt bipartisan and bicameral support for advanced nuclear, citing recent advanced nuclear technology bills submitted this year and encouraging words supporting advanced nuclear development from Secretary of Energy Rick Perry. NuScale's progress, proactive NRC engagement with stakeholders, GAIN vouchers, active AR technology groups, and current estimates of more than $1 billion in US industry advanced nuclear investment all point to a promising future for AR development. While support is growing, DOE and NRC budgetary concerns, the recent Westinghouse bankruptcy, NRC commission vacancies, high assay low-enriched uranium (LEU) access issues, and international competition still serve as challenges. NIC's recent survey of 18 AR companies yielded several key results: 84% state inadequate funding to DOE for US AR development, majority believes the DOE and NRC vision and strategy deployment timeframe should be closer to 2020-2025, DOE needs to improve access to its expertise and increase public–private funding collaborations, assured supply of high assay LEU is a high priority, and a new test reactor is highly relevant to the AR community. Mr. Merrifield concluded with his view of the road ahead for NRC, DOE, Congress and the White House and by stating that the AR community should not narrow its options too quickly and should explore AR uses beyond just electricity production.

- Bill Reckley, NRC, provided an overview on possible interactions between AR designers and the NRC. Designers should develop licensing project plans on how and when they are going to interact with NRC throughout the design process and what outcomes are needed

from interactions. Early interactions include discussions of schedule and cost as well as identifying issues and possible approaches to achieve a desired level of resolution. Research and test plans (e.g., historical programs, qualification, validation, and testing needs) should be discussed up front to establish expectations. Mr. Reckley then discussed potential flexible licensing options that provide pathways to both Part 50–Domestic Licensing of Production And Utilization Facilities and Part 52–Licenses, Certification, And Approval For Nuclear Power Plants licenses and processes available to support subsequent applications. The topics addressed and timeframes for applications and decisions will vary for different reactor technologies, so early sharing of design details is important to developing plans for the design, licensing, and deployment of an AR.

- Chantal Morin, Canadian Nuclear Safety Commission (CNSC), provided an update on the Canadian advanced and small modular reactor (SMR) programs and efforts. Recent Canadian national and provincial government reports have shown a potential need for ARs and SMRs in remote areas throughout the nation. To assist AR vendors during the design phase, the CNSC uses a vendor design review process. The vendor design review serves as a feedback mechanism to identify early conceptual barriers to licensing. To request a review, a vendor must have a nearly complete conceptual design and be on the verge of basic engineering research. The high level review covers 19 topic areas, and gives a transparent look at projected schedule and costs for licensing. Terrestrial Energy, UltraSafe, StarCore, and ARC 100 have recently engaged CNSC for a vendor design review. Canada has issued recent reports and is developing a readiness approach on SMR and AR licensing.

- Kati Austgen, Nuclear Energy Institute (NEI), presented on NEI and industry AR regulatory needs. There has been widespread growth of startup AR companies in recent year. NEI recognizes this growth and maintains a long–term vision of new advanced nuclear plants by the 2030s. To meet this vision, the community seeks a demonstration of one or two non-LWR technologies by 2025, while NRC needs to be ready to review an AR license application. Ms. Austgen said that an AR licensing framework should be technology-inclusive, risk-informed, performance-based, and consist of staged approvals. Recent NEI activities include the licensing technology requirements modernization project in coordination with Southern Company, codes and standards development, identifying updates to the NRC's standard review plan for research and test reactors (Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors [NUREG--1537]), and exploring methods to obtain high assay LEU. NEI has also organized an AR working group to address generic issues, with technical working groups addressing technology-specific topics.

- Ashley Finan, Ph.D., Nuclear Innovation Alliance (NIA), provided NIA's insights on AR licensing needs. Dr. Finan also identified the need for a technology-inclusive licensing process with optional stages, an AR test bed and demonstration platform, potential international commercial testing, and financial support for early stage testing and deployment. Challenges include the need to modify heavily LWR based licensing documents for non-LWRs, prohibitive upfront investments are needed unless a staged licensing approach can be implemented, and vague guidance on prototype licensing. NIA has issued its publicly available report on "Strategies for Advanced Reactor Licensing" and has engaged NEI and other stakeholders in efforts to modernize licensing strategies for ARs.

Following the session, the presenters received several questions.

- Mr. Reckley was asked about NRC's interactions concerning NEI's licensing modernization project. Mr. Reckley stated that NRC has been providing feedback on white papers submitted by NEI and would likely review a consolidated document written by NEI and subsequently publish a RG to endorse the NEI document with limitations and conditions, as necessary. Mr. Reckley was also asked if there were NRC regulations for a prototype license. Mr. Reckley stated that there exists no "prototype license," the appropriate mindset would be to use a first-of-a-kind reactor for future reference.

- Ms. Morin was asked how CNSC trains specialists in advanced designs. Ms. Morin responded that the vendor design review typically identifies challenges and gaps.

- Ms. Austgen was asked what the basis was for NEI not proposing the development of a new risk informed, performance based, and technology neutral rule for ARs. Ms. Austgen stated that before considering the development of a new rule, issues associated with SMR's must be addressed, ARDC's must be clearly articulated, and more experience needs to be gained.

- Dr. Finan was asked whether using a standard design approval (SDA) could reduce cost durations for a designer. Dr. Finan responded that the SDA process is an option but that it is also not free. Dr. Finan elaborated that the fastest path might not be the practical one.

IV. Safety Focused Review for New Reactor Designs

- Lynn Mrowca, NRC, presented on enhanced safety-focused reviews for LWR SMRs and their potential applicability to non-LWRs. The safety-focused review was developed from lessons learned during recent licensing reviews such as for the AP1000. By increasing pre-application interactions with the applicant and refining the review to focus on risk-significant safety systems, structures, and components (SSCs), NRC may be able to expedite the review process. Ms. Mrowca discussed a graded approach used to identify the safety-significant SSCs using risk-informed considerations involving safety margin, defense-in-depth, operational programs, impact on safety systems, risk insights, and other considerations. The approach has led to development of a SSC safety-significance review tool to aid NRC staff in determining what SSCs would require more review and scrutiny for a novel concept. The tool may also be used to help refine pre-application focus. NRC is applying the approach to the NuScale design certification review, and plans to also use it for non-LWR designs. The NRC is committed to focus resources on safety significant aspects of non-LWR reviews and is open to feedback from the AR community and other stakeholders on the safety-focused review approach.

- Following the session, Ms. Mrowca was asked how prospective non-LWR designers could address increased uncertainty and less operating experience. Ms. Mrowca stated that this is the benefit of being in pre-application space; early interactions allows the NRC to learn more about the design from the designer. It was also noted that one would also have the benefit of employing consensus codes and standards from early interactions.

V. Use of Modeling and Testing in the Reactor Design and Licensing Process

- Steve Bajorek, Ph.D., NRC, presented on modeling and testing in the reactor design and licensing process. Modeling and simulation of accidents is critical to any reactor licensing

effort and enables developers to optimize their design as well. Dr. Bajorek summarized several NRC modeling and testing requirements including: Title 10 of the *Code of Federal Regulations* (10 CFR) 50.43e (guidance on design certification applications, demonstration of safety system performance, data sufficiency for assessment analytical tools), 10 CFR 50.46, and 10 CFR 50 Appendix K (both LWR-centric, but should be considered by non-LWR designers). While high fidelity modeling and simulation can assist in the licensing process, comparisons to applicable experimental data still must be made. The NRC has several expectations when reviewing applicant's licensing tools. Tools need to have a comprehensive description of evaluation models, assumptions, scenarios, code assessment, verification, and validation. Applicants own the models, are responsible for any errors along the way, and must report and correct errors. A tool or model is not approved generically. It is approved for a specific design and set of scenarios. Validation for a specific design is the critical component for evaluation model approval, and focuses on two elements: separate effects tests (demonstrate adequacy of models and correlations for a particular phenomenon) and integral effects tests (demonstrate adequacy of safety system performance and assesses code ability to simulate system interactions). The range of conditions must be considered for validation since extrapolation to prototypical conditions may not be accurate. Scaling and geometry are important factors in representing an actual phenomenon for validation testing as well. Dr. Bajorek concluded by recommending AR designers engage early on with NRC and Advisory Committee on Reactor Safeguards (ACRS) when developing their test and analysis plans.

- Chris Stanek, Ph.D., Los Alamos National Laboratory, discussed the capabilities of DOE's NEAMS program and its applicability to AR licensing. NEAMS aims to develop, apply, and deploy a range of predictive modeling and simulation tools for ARs that can be used on a variety of computational platforms. NEAMS has three product lines: fuels, reactor, and integration. Dr. Stanek focused primarily on the fuels simulation suite consisting of MARMOT (simulates microstructure evolution of fuels under irradiation using atomistic methods), BISON engineering scale Fuel Performance Tool (models LWR, TRISO, and metal fuels in 2D and 3D steady-state and transient scenarios), and MOOSE (simulation framework). BISON may have a role in licensing. The NRC has used BISON for limited LWR fuel work with a potential for expanded use for accident tolerant fuel (ATF). NEAMS has begun expanding BISON beyond LWR fuel to include particle and metallic fuel as well. BISON may have different uses for advanced non-LWRs and could be used by NRC for confirmatory analysis and by stakeholders as an important research and development tool. Dr. Stanek also discussed the use of NEAMS codes to study high impact problems (HIPs) pertaining to ARs. Two HIPs in FY 15 focused on ATF and NuScale steam generators. The FY18 HIP program looks to include AR topics identified through GAIN.

- Andrew Sowder, Ph.D., Electric Power Research Institute (EPRI), provided industry perspectives on modeling and testing for AR licensing. In 2016, EPRI launched a strategic program to support AR commercialization by the 2030s. Coordinating heavily with GAIN, EPRI has cohosted several technology centric workshops in 2016. For each technology, modeling and simulation was identified as a cross cutting issue. In late 2016 and early 2017, EPRI organized two workshops on AR modeling and simulation needs. The first workshop outlined the needs identified by the different technology working groups. The second workshop provided an opportunity for national laboratories to present their available AR modeling capabilities. Dr. Sowder also identified NRC's need for adequate computer models and other resources to conduct its review of non-LWRs and stated NRC independence does not preclude cooperation with DOE and stakeholders. While NRC may prefer independent confirmatory codes, it has not precluded the use of existing/common

codes. Using historical and modern examples of fuel qualification processes, Dr. Sowder emphasized that high fidelity codes may reduce but will not entirely eliminate need for experimental testing. Experimental testing does not end after new reactors are built and will be needed long into commercial operation. Dr. Sowder concluded by emphasizing the usefulness of high fidelity models to expedite qualification and licensing and stressing the need for continued coordination and collaboration among NRC, DOE, and industry.

Following the session, the presenters received several questions.

- Dr. Bajorek was asked whether modeling was as important for designs with inherently passive safety systems. Dr. Bajorek responded by saying that small driving forces increase complexity and sensitivity of calculations. Lots of safety margin should make addressing issues easier.

- Dr. Stanek was asked why NEAMS and GAIN focus on new AR tools that are “not yet ready” when there are existing tools. Dr. Stanek disagreed with the premise that there are applicable existing tools for all designs, but he did acknowledge that the new tools must demonstrate value.

VI. Standard Review Plan Gap Analysis

- Jim Kinsey, Idaho National Laboratory, presented slides on the Standard Review Plan (SRP) Gap Analysis Pilot Results funded by DOE’s Office of Nuclear Energy. For the past three years, Mr. Kinsey has led a multi-laboratory team to review key NRC guidance for applicability to non-LWRs. Following the development of the draft ARDCs for stakeholder and NRC review, the team next performed a focused gap analysis on the SRP and created a pilot adaption of Chapter 4 of NUREG–0800, SRP for sodium fast reactors (SFRs) and modular high temperature gas reactors (mHTGRs). The team chose Chapter 4 as a starting point since it deals with reactor components, an area where addressing the differences between LWR and non-LWR guidance was considered most challenging. The Chapter 4 gap analysis explored five major areas: content of Chapter 4, technical reports, RGs, consensus standards, and appendices of 10 CFR 50 referenced. Gaps ranged from minor differences between standard LWR and non-LWR terminology (e.g., hot standby, cold shutdown, etc.) to major differences in fuel types and reactivity behaviors (e.g., TRISO and metallic fuels in Section 4.2). The gap analysis report final review is being finished and will be available publicly. Mr. Kinsey and his team concluded that the pilot has shown it is manageable to adapt the SRP for certain designs like SFRs though this may be more challenging for others like mHTGRs. It is probably not necessary to adapt all chapters. Risk-informed performance-based requirements need to be confirmed, and consideration should be given to expanding SRP and ARDC adaptations to molten salt reactors (MSRs).

Following the session, the presenter received several questions.

- Mr. Kinsey was asked how long it will take to complete the entire SRP gap analysis and adaption for mHTGRs. He stated that the lab effort would take about 1 to 2 years. Mr. Kinsey was also asked whether the report was publicly available and he stated that it will be soon.

VII. Security by Design

- Pete Lee, NRC, presented on security design considerations for ARs. According to 10 CFR 73, a facility should provide protection from sabotage, theft, and diversion. As such,

security needs to be considered early in the design process. The NRC has recently issued proposed considerations for AR security for public comment. The security guidelines serve as considerations and are not requirements. The considerations cover a range of SSC and response guidance to ensure an effective security system. Mr. Lee spoke about protecting from design basis threats such as vehicle bombs. The proposed considerations also discuss potential facility layouts, communication systems, and response force guidelines.

- Kim Lawson-Jenkins, NRC, presented on cyber security considerations for ARs. Guidance on cyber security requirements can be found in 10 CFR 73.54 and RG 5.71. Ms. Lawson-Jenkins emphasized the importance of cyber security measures in any nuclear facility or plant, regardless of technology. Ms. Lawson-Jenkins stressed the need for a robust defense model to protect against cyber-attack and the need to minimize potential cyber-attack access pathways.

VIII. Industry Consensus Standards Development

- Craig Welling, DOE, began Day 2 of the workshop with a summary of the following key takeaways from Day 1: NRC and DOE will continue to need external stakeholder feedback on AR licensing; the NIC-led survey provided valuable results and industry needs; several initiatives introduced in the previous workshops are now in the implementation phase; and NRC, DOE, and industry appear to be in closer alignment on AR regulatory strategy.

- Tom Boyce, NRC, presented on codes and standards requirements for reactor design. The National Technology Transfer and Advancement Act of 1995 promotes governmental regulatory use of industry standards while the 115th Cong., 1st Sess. HR 590 “Advanced Nuclear Technology Development Act of 2017” encourages incorporation of consensus based codes and standards into AR regulatory frameworks. From the NRC perspective, use of standards reduces resources and costs, provides greater predictability and wider acceptance, and allows for faster reviews. Mr. Boyce stressed that NRC relies on industry demand to determine which standards to review for endorsement. To gather industry input and provide feedback, the NRC participates in several standards development organizations (SDOs). The SDOs provide NRC, DOE, and stakeholders the opportunity to leverage experience and resources in determining whether current standards may be used for ARs if revisions or new standards are required. If new standards or revisions are needed, vendors needs to communicate this to NRC, DOE, and SDOs since standards development can take several years. To assist with standards review and development, NRC offers a standards forum as a collaborative effort among SDOs, government, academia, and industry to accelerate development of standards. Mr. Boyce highlighted several important NRC endorsements that have come out of the forum. Recently, DOE, NRC, and American Society of Mechanical Engineers (ASME) have been working closely on endorsing ASME Section III Division 5 on high temperature materials for ARs. Mr. Boyce concluded by emphasizing the need for feedback from industry and the AR technology working groups to prioritize further standards development.

- George Flanagan, Oak Ridge National Laboratory (ORNL), presented on a recent DOE scoping study to explore potential new standards for ARs in a variety of areas. The scoping study used SFRs as its starting part. The study explored multiple regulatory guides and hundreds of citations and endorsed standards to down select 59 standards relevant to the SFR Pilot. An in depth review showed that some standard categories need no changes (e.g., grades of fuel oil), limited changes (e.g., titles and definitions), substantial changes (e.g., heavily LWR based transient standards), are not applicable, or may need new design

requirements (e.g., advanced materials). The results of the scoping study are in final review and will be publicly available. Dr. Flanagan stressed that developing and approving a voluntary consensus standard is a long and involved process. Vendors need to communicate potential revisions and changes to SDOs early and be actively involved in the change process.

- William Corwin, DOE, presented on the status of DOE and NRC efforts to endorse ASME Code Section III Division 5. ASME treats metallic materials differently based on temperature. At low temperature (below 700 F for ferritic and 800 F austenitic), metals exhibit time independent behavior while at high temperatures creep has a significant impact making time an important factor. Division 5 provides instructions for high temperature materials for ARs including metallic components and graphite and ceramic composites. Since its development in 2011, Division 5 rules have undergone several updates. Recently, efforts are underway among ASME, DOE, and NRC to endorse Section III Division 5. DOE is performing research and development to include additional materials in the code such as Alloy 617 for high temperature heat exchanger and steam generator applications, Alloy 709 for improved high temperature strength, and potentially Hastelloy N for molten salt cooled reactors. DOE is also exploring design methods to reduce over conservatisms, corrosion effects in different AR coolants, and irradiation and creep effects. Updates are still needed on the following Division 5 areas: weldments, aging and environmental issues, creep and fatigue, multiaxial loading, and failure criteria analysis. DOE and NRC have put together a high priority list to expedite collaborative endorsement activities. Mr. Corwin expressed his appreciation for progress made on Division 5 endorsement since the first workshop and stressed that expanding and updating codes and standards for ARs will aid in expediting NRC reviews.

Following the session, the presenters received several questions.

- Mr. Boyce was asked whether there were instances of proposed codes that NRC did not endorse. Mr. Boyce stated yes, that NRC has voted against some before and in other cases, conditions have been provided with an endorsement when needed.

IX. Quality Assurance to Support Research, Development, and Testing

- Kerri Kavanagh, NRC, presented on Quality Assurance (QA) requirements for AR design and construction. Ms. Kavanagh stated that QA is integral to nuclear power plant design and construction regardless of technology type. NUREG–1055, issued in the late 1980s, observed shortcomings in industry reactor design and construction QA methods. Lessons learned from NUREG–1055 are still relevant today. Ms. Kavanagh stressed that the applicant retains responsibility for the establishment and execution of its QA programs while NRC provides oversight of its implementation. NRC acceptance of an applicant's QA program ensures that adequate controls are in place to meet the regulatory requirements of 10 CFR 50 Appendix B. The current NRC QA licensing review process and inspection programs are effective and can readily be applied to ARs.

X. Reactor Technology Technical and Licensing Priorities

- Farshid Shahrokhi, AREVA, provided an update on the activities of the high temperature gas reactor (HTGR) technical working group (TWG). The HTGR TWG was formed in early 2017 under GAIN, though operates independently through the NEI Advanced Reactor Working Group and Technology Task Force. Current members of the HTGR TWG include AREVA,

Duke, StarCore, X-Energy, and BWXT. The group's mission is to inform DOE, NRC, and other key stakeholders on the current needs of the HTGR industry. The working group has recently submitted a short and long term needs report to GAIN and has appreciated DOE's feedback. The group has recommended specific actions for DOE including: continue support of public–private partnerships, complete the DOE-led TRISO fuel and graphite research and development program, continue work on modeling and simulation, and allow code access to commercial users. The group also has identified unique licensing challenges for HTGRs including: fuel and fuel cycle (source term, TRISO, high assay LEU, siting); HTGR safety (radionuclides retention strategy, low pressure reactor building, and no impact beyond site barrier); licensing basis event selection (use of probabilistic risk assessment [PRA], defense in depth); codes and methods (validation, use of legacy data); staffing; and off-grid regulation. Dr. Shahrokhi stressed that while members of the TWG are competitors, they will continue to discuss generic issues, provide feedback to DOE through GAIN, and engage and support NRC non-LWR licensing modernization efforts.

- Jacob DeWitte, Oklo, Inc., provided an update on the activities of the fast reactor (FR) TWG. As the largest of the TWGs, the FR TWG consists of multiple developers working on a diverse set of fast technologies including sodium, lead, salt, and gas. Dr. DeWitte discussed four major FR needs areas: modeling and simulation, prioritized research and development, versatile test reactor, and fuels. The GAIN-EPRI modeling and simulation workshops in December 2016 and January 2017 showed a high degree of maturity for fast reactor design and transient analysis codes. Enhanced use of high performance computing provides opportunities to accelerate development and design with advanced tools. While these tools are good for design and analysis, stakeholders need to identify ways to qualify tools for licensing use. The FR TWG also identified issues with accessing DOE and national laboratory codes. Different labs have different code costs and access requirements which may be prohibitive for smaller US fast reactor companies. The TWG encourages DOE to look at increasing code access to external industry. Dr. DeWitte presented a list of key research needs to support fast reactor commercialization including: access to supply of high assay LEU, determining fuel qualification requirements, access to legacy DOE metallic fuel data sets, advanced materials, and continued DOE support for a fast test reactor. The TWG fully support DOE's efforts and activities for a fast test reactor and believe it can be used to years to come to improve fuels once fast and other reactors are operating.

- Nicholas Smith, Southern Company, provided an update on the activities of the MSR TWG. The MSR TWG consists of TerraPower, Thorcon, Terrestrial, Flibe, Transatomic, Elysium, and most recently Alpha Technology. Mr. Smith emphasized that liquid fuel forms create unique phenomena with regards to delayed neutron precursor transport and reactivity. The members of the MSR TWG have concepts spanning a broad range of operating regimes, neutron spectrums, and fuel loading. Since MSRs cover such a large design space and lack the decades of research and development experience of other ARs, the TWG has many areas to consider. Recently, DOE supported a beneficial workshop to explore crosscutting MSR chemistry challenges. From a regulatory perspective, Mr. Smith thanked George Flanagan from ORNL for identifying potential pathways for MSR licensing. The TWG supports performance of a MSR based gap analysis of the SRP and general design criteria as well. Mr. Smith observed that MSR fuel qualification may be more heavily chemistry based instead of radiologically based, allowing for a potential expedited pathway towards qualification. The TWG also recognized the need to address special corrosion and chemistry challenges along with safeguards approaches for MSRs.

XI. Summary and Path Forward

- John Monninger, NRC, thanked the participants for their strong engagement during the series of workshops. Mr. Monninger summarized the following key points observed throughout the workshop: improvements in regulatory framework will enhance effectiveness and efficiency; more investment in technical and regulatory research and development is recommended; greater alignment among the AR community has been observed; continued collaboration will help guide future research and development; technical working groups have important role in identifying technology specific needs; robust QA practices and security measures will be essential for ARs; use of industry consensus based standards greatly assists NRC in its reviews; NRC is exploring flexible and safety focused reviews; and early pre-application engagement with NRC can expedite reviews. Mr. Monninger acknowledged the high level of NRC management participation at the workshop, showing the NRC's support for optimizing licensing pathways for ARs. For the path forward, while the workshops were extremely beneficial, NRC plans to now facilitate smaller, more frequent and focused interactions with stakeholders approximately every six weeks. The next focused meeting will occur on May 3-4 and involve discussion on AR security requirements, licensing basis events, PRA, functional containment, policy issues, and SDAs.

XII. Closing Remarks

- Vonna Ordaz, NRC, thanked the audience for their thoughtful questions and engagement in the workshop. Ms. Ordaz acknowledged the considerable progress since the last workshop and encouraged continued coordination and dialogue among the AR community.

- John Herczeg, DOE reiterated thanks for a fruitful workshop. Having attended all three workshops, Dr. Herczeg has observed and is encouraged by the evolution of NRC's positive approach to engage DOE and key stakeholders on the important topic of AR licensing. Dr. Herczeg emphasized DOE's commitment to strive for AR commercialization by 2030 and assured that DOE is committed to assisting industry and NRC with exploring AR deployment pathways.

XIII. Follow-up Actions

The table below provides a status of the follow-up actions from each meeting. The were no follow-up actions for the April 2017 workshop.

Follow-up Item	Yr. of Item	Agency	Status
DOE Vision and Strategy for ARs	2015	DOE	Completed - Vision and Strategy for the Development and Deployment of ARs (https://www.energy.gov/sites/prod/files/2017/02/f34/71160 VISION STRATEGY 2017 FINAL.pdf)
Develop technology specific working groups through GAIN	2015	DOE	Completed – See GAIN Home Page (https://gain.inl.gov/SitePages/Home.aspx) - Fast Reactor Technical Working Group - High Temperature Gas-cooled Reactor Technical Working Group - Molten Salt Reactor Technical Working Group

Complete the Advanced Test/Demonstration Reactor study and examine potential test capabilities for fuel qualification as part of the study	2016	DOE	Completed - Nuclear Energy Advisory Committee - Assessment of Missions and Requirements for a New U.S. Test Reactor
Continue developing transient testing capability	2016	DOE	Completed - Nuclear Energy Advisory Committee - Assessment of Missions and Requirements for a New U.S. Test Reactor (https://www.energy.gov/sites/prod/files/2017/01/f34/Draft Report 12-22-16.pdf)
Continue pursuing endorsement of ASME Code Section III Division 5	2015	DOE/NRC	In process
NRC vision and strategy for ARs	2016	NRC	Completed - Vision and Strategy for Safely Achieving Effective and Efficient Non-Light Water Reactor Mission Readiness, (ADAMS Accession No. ML16356A670)
Develop processes for staged licensing review and conceptual design assessments	2016	NRC	In process - A Regulatory Review Roadmap for Non-Light Water Reactors, (ADAMS Accession No. ML16291A248)
Develop prototype guidance	2016	NRC	Completed - Nuclear Power Reactor Testing Needs and Prototype Plants for AR Designs, (ADAMS Accession No. ML17025A353)
Issue a draft guide for ARDCs	2016	NRC	Completed - Draft Regulatory Guide for Non-Light Water Reactors, (ADAMS Accession No. ML16301A307)
Post draft security design considerations for public comment	2016	NRC	Completed - Preliminary Draft Guidance on Non-Light Water Reactor Security Design Considerations, (ADAMS Accession No. ML16305A328)

The meeting agenda and a list of meeting attendees are included in Enclosures 1 and 2, respectively. All of the presentations for this workshop are available on the NRC's public web site at: https://www.nrc.gov/public-involve/conference-symposia/adv-rx-non-lwr-ws/2017/presentations.html. The agenda for the workshop is similarly available on the NRC's public web site at: https://www.nrc.gov/docs/ML1709/ML17094A647.pdf.

Project No.: 0814

Enclosure:
1. Agenda
2. List of Attendees

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SUMMARY OF APRIL 25-26, 2017, NUCLEAR REGULATORY COMMISSION AND DEPARTMENT OF ENERGY WORKSHOP ON ADVANCED REACTORS October 02, 2017

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NAME	NDevaser	ARedden	JSegala
DATE	08/14/17	08/14/17	10/02/17

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Agenda
NRC-DOE Workshop on Advanced Reactors
April 25-26, 2017
Bethesda North Marriott Hotel and Conference Center

Date: April 25, 2017	**Time:** 08:30 am to 05:00 pm
Location: Bethesda North Marriott Hotel and Conference Center, Salons A-C	

Time	Topic	Speaker
08:30 - 08:35 am	Welcome and logistics	*NRC (V. Ordaz)*
08:35 – 09:00 am	Opening remarks and objectives of the workshop	*NRC (Comm. Burns)* *DOE (R. Furstenau)*
09:00 - 09:15 am 09:15 - 09:30 am 09:30 - 09:45 am	Update on non-LWR government initiatives • DOE initiatives • NRC initiatives Q&A	 *DOE (T. Cook)* *NRC (A. Cubbage)* *ALL*
09:45 - 10:05 am	***Break***	
10:05 - 10:25 am 10:25 - 10:40 am 10:40 - 10:55 am 10:55 - 11:10 am 11:10 - 11:25 am 11:25 - 11:45 am	Regulatory review process options • Conceptual design assessment, staged review, prototype, pre-application interaction • CNSC update on advanced reactors/small modular reactor activities in Canada • Industry progress, initiatives, and concerns Q&A	 *NRC (W. Reckley)* *CNSC (C. Morin)* *NEI (K. Austgen)* *NIC (J. Merrifield)* *NIA (A. Finan)* *ALL*
11:45 - 12:00 pm	Open Q&A session	*ALL*
12:00 - 01:00 pm	***Lunch***	
01:00 - 01:20 pm 01:20 - 01:40 pm	Safety-focused review for new reactor designs • Application of safety-focused review for NuScale Q&A	 *NRC (L. Mrowca)* *ALL*
01:40 - 02:00 pm 02:00 - 02:20 pm 02:20 - 02:40 pm 02:40 - 03:00 pm	Use of modeling and testing in the reactor design and licensing process • Requirements and guidance • Modeling and testing programs (NEAMS, BISON) • Regulatory gaps, challenges, and suggestions Q&A	 *NRC (S. Bajorek)* *LANL (C. Stanek)* *EPRI (A. Sowder)* *ALL*
03:00 - 03:20 pm	***Break***	
03:20 - 3:45 pm 03:45 - 4:00 pm	Standard review plan gap analysis • Standard review plan gap analysis - pilot results Q&A	 *ORNL/INL (J. Kinsey)* *ALL*
04:00 - 04:20 pm 04:20 - 04:35 pm	Security by design • Security design considerations Q&A	 *NRC (P. Lee/K. Lawson-Jenkins)* *ALL*
04:35 - 05:00 pm	Open Q&A session	*ALL*
05:00 pm	Adjourn	

Date: April 26, 2017	**Time:** 08:30 am to 03:30 pm
Location: Bethesda North Marriott Hotel and Conference Center, Salons A-C	

Time	Topic	Speaker
08:30 - 08:35 am	Opening remarks and summary of day 1 activities	*DOE (C. Welling)*
08:35 - 08:50 am 08:50 - 09:05 am 09:05 - 09:20 am 09:20 - 09:40 am	Industry consensus standards development • NRC strategy and priorities • DOE R&D scoping and support • Industry priorities and gaps/needs Q&A	*NRC (T. Boyce)* *ORNL (G. Flanagan)* *DOE (W. Corwin)* *ALL*
09:40 - 10:00 am	***Break***	
10:00 - 10:30 am 10:30 - 10:50 am	Quality assurance to support research, development, and testing • QA oversight of NuScale pre-application activities Q&A	*NRC (K. Kavanagh)* *ALL*
	Reactor technology technical and licensing priorities	
11:00 - 11:30 am 11:30 - 11:50 am	High temperature gas reactor technology working group Q&A	*TWG (F. Shahrokhi)* *ALL*
11:50 - 01:00 pm	***Lunch***	
01:00 - 01:30 pm 01:30 - 01:50 pm	Fast reactor technology working group Q&A	*TWG (J. DeWitte)* *ALL*
01:50 - 02:20 pm 02:20 - 02:40 pm	Molten salt reactor technology working group Q&A	*TWG (N. Smith)* *ALL*
02:40 - 03:00 pm	Open Q&A session	*ALL*
03:00 - 03:15 pm	Summary and path forward • Specific actions, desired outcomes, timetable Potential framework for future discussion	*NRC (J. Monninger)*
03:15 - 03:30 pm	Closing remarks	*NRC (V. Ordaz)* *DOE (J. Herczeg)*
03:30 pm	Adjourn	

Attendence List
NRC-DOE Workshop on Advanced Reactors
April 25-26, 2017

Last Name	First Name	Affiliation
Yaw	Adu Poku	Ghana Atomic Energy Commission
Amir	Afzali	Southern Company
Alan	Ahn	Global American Business Institute
Don	Algama	USNRC
Irfan	Ali	Energy Innovation Reform Project (EIRP)
Jason	Andrus	Idaho National Laboratory
Michael	Appiah	Ghana Atomic Energy Commission
Kati	Austgen	Nuclear Energy Institute
Odunayo	Ayegbusi	USNRC
Daisuke	Baba	Embassy of Japan
Stephen	Bajorek	USNRC
Suzanne	Baker	Third Way
Michelle	Bales	USNRC
Gautam	Banberjee	Exelon
Rita	Baranwal	Idaho National Laboratory
Sudhamay	Basu	Self
Russell	Bell	Nuclear Energy Institute
Randy	Belles	Oak Ridge National Laboratory
Thomas	Bergman	NuScale Power, LLC
Jana	Bergman	Curtiss Wright
David	Blee	U.S. Nuclear Infrastructure Council
John	Bolin	General Atomics
Stephen	Booker	Norfolk Naval Shipyard
Alexander	Both	SGL Carbon, LLC
Tom	Boyce	USNRC
Lori	Braase	Idaho National Laboratory
Robert	Braun	ARC Nuclear, LLC
Gilbert	Brown	UMass Lowell
Acacia	Brunett	Argonne National Laboratory
Matthew	Bucknor	Argonne National Laboratory
Alexandra	Burja	USNRC
Edward	Burns	X Energy, LLC
Allyson	Byk	ASME
Francis	Cameron	CameronGray LLC
Shawn	Campbell	USNRC
Alice	Caponiti	USDOE
Daniel	Carleton	Terrestrial Energy USA
Marcia	Carpentier	USNRC
Michael	Case	USNRC
Mike	Cassidy	Apollo Fusion, Inc.

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Ethan	Chaleff	Kairos Power LLC
Desmond	Chan	Bechtel
Wei-Wu	Chao	Atomic Energy Council
Doug	Chapin	MPR Associates
Bryan	Cheong	Global American Business Institute
Phyllis	Clark	USNRC
Caroline	Cochran	Oklo, Inc.
Keith	Consani	NIST
Trevor	Cook	USDOE
William	Corwin	USDOE
Arlon	Costa	USNRC
Anne	Cottingham	Nuclear Energy Institute
Mark	Cox	Idaho National Laboratory
Amy	Cubbage	USNRC
John	Cushing	USNRC
Kirsten	Cutler	U.S. Department of State
Russell	Daniel	Bechtel
Billy	DeMaic	IDA
Jared	DeMeritt	Bechtel
Kyle	Deming	International Technology and Trade Associates, Inc.
Sachin	Desai	Hogan Lovells US LLP
Nishka	Devaser	USNRC
David	Diamond	Brookhaven National Laboratory
Steven	Dolley	S&P Global Platts
Zach	Dubel	Federation of Electric Power Companies of Japan
Andrew	Ebert	PwC
Janelle	Eddins	USDOE
Hossein	Esmaili	USNRC
Thomas	Fanning	Argonne National Laboratory
Madeline	Feltus	USDOE, NE-42
Ashley	Finan	Nuclear Innovation Alliance
George	Flanagan	Oak Ridge National Laboratory
Michael	Franovich	USNRC
Steve	Frantz	Morgan Lewis
William	Freebairn	S&P Global Platts
Steven	Freel	Studsvik Scandpower
Daniel	Frumkin	USNRC
Edward	Fuller	USNRC
Peter	Gaillard	TerraPower
Randall	Gauntt	Sandia National Laboratories
Vince	Gilbert	U.S. Nuclear Infrastructure Council
Mark	Giles	Dominion Resources, Inc.
Frank	Gillespie	Mitsubishi Nuclear Energy Systems
Sal	Golub	USDOE

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Ravi	Grover	USNRC
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James	Hammelman	USNRC
Shyrli	Harmon	X Energy, LLC
Michelle	Hart	USNRC
Alexander	Hashemian	AMS Corporation
Hashemian	Hashemian	AMS Corporation
Peter	Hastings	The Hastings Group, LLC
Alfred	Hathaway	USNRC
Jerry	Hawkins	AAG, LLC
Michelle	Hayes	USNRC
Adam	Hemmeter	USDOE
Laura	Hermann	PCG
Jim	Hobbs	Nuclear Fuel Services
Mark	Holbrook	Idaho National Laboratory
Laura	Holgate	United Nations/IAEA
Wendolyn	Holland	Transatomic Power Corporation
John	Holt	NRECA
Michael	Houts	NASA MSFC
Lane	Howard	Southwest Research Institute/CNWRA
Nathanael	Hudson	USNRC
Lauren	Hughes	Washington Policy and Analysis
Amy	Hull	USNRC
Sapna	Hurd	USNRC
Kathryn	Hutcheson	USDOE
Shintaro	Ito	Embassy of Japan
Debbie	Jackson	USNRC
Jon	Johnson	Lightbridge Corporation
Steven	Jones	USNRC
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N Prasad	Kadambi	Kadambi Engineering Consultants
Rebecca	Karas	USNRC
Kerri	Kavanagh	USNRC
Joseph	Kelly	USNRC
Rebecca	Kern	Bloomberg BNA
Richard	Kerr	GenScript
Hussein	Khalil	Argonne National Laboratory
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Elizabeth	Kleinsorg	Jensen Hughes
James	Komosinski	Swiss Mountain Energy Consulting

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Robert	Lanza	ICF
Richard	Lee	USNRC
Pete	Lee	USNRC
Christina	Leggett	USNRC
Diana	Li	USDOE
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Shanlai	Lu	USNRC
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Dimitri	Lutchenkov	MPR Associates
Edwin	Lyman	Union of Concerned Scientists
Steve	Lynch	USNRC
Imtiaz	Madni	USNRC
Shah	Malik	USNRC
Don	Marksberry	USNRC
Roy	Mathew	USNRC
David	Matthews	Nuclear Energy Consultants, Inc (NEC)
Patrick	Mattie	Sandia National Laboratories
Gary	Mays	Oak Ridge National Laboratory
Kevin	McClellan	AFI
Victor	McCree	USNRC
Fredrick	McCrory	Sandia National Laboratories
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Nicholas	McMurray	USNRC
Shivani	Mehta	USNRC
Jeffrey	Merrifield	Pillsbury Winthrop Shaw Pittman
Aaron	Miles	USDOD
Steven	Mirsky	NuScale Power, LLC
Wayne	Moe	Idaho National Laboratory
Jill	Monahan	Westinghouse
John	Monninger	USNRC
Chantal	Morin	Canadian Nuclear Safety Commission
Carol	Moyer	USNRC
Lynn	Mrowca	USNRC
Eben	Mulder	X Energy, LLC
Akinori	Naito	Japan Atomic Energy Agency
Ty	Naquin	USNRC
Spencer	Nelson	ClearPath
Steve	Nesbit	Duke Energy
James	Nestell	MPR Associates

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Richard	Perkins	USNRC
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Ian	Porter	USNRC
Iouri	Prokofiev	USNRC
Sheila	Ray	USNRC
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Jason	Redd	Southern Nuclear
Everett	Redmond	Nuclear Energy Institute
Wendy	Reed	USNRC
Adam	Reichenbach	Duke Energy
Benjamin	Reinke	Senate Committee on Energy and Natural Resources
Jason	Reynolds	Southern Company
Robin	Rickman	Terrestrial Energy USA
Alison	Rivera	USNRC
Chris	Robinson	Y-12 National Security Complex
Jordi	Roglans-Ribas	Argonne National Laboratory
Stacey	Rosenberg	USNRC
Stuart	Rubin	Numark Associates
George C.	Rudy	Integrated Systems Technology
Marek	Ruščák	Centrum Vyzkumu Rez (Research Centre Rez)
Fanto	Saeko	USNRC
Michael	Salay	USNRC
James	Saldarini	ARC Nuclear, LLC
John	Segala	USNRC
Farshid	Shahrokhi	AREVA
Martha	Shields	USDOE
Girija	Shukla	USNRC
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Sandra	Sloan	BWXT
James	Smit	Jensen Hughes
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James	Strnisha	USNRC
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Casper	Sun	USNRC
Tarico	Sweat	USNRC
Robert	Sweeney	IBEX
Chew Charn	Tan	De Leng Construction Pte Ltd
Takeshi	Tanaka	The Federation of Electric Power companies Japan
George	Tartal	USNRC
Getachew	Tesfaye	USNRC
Matt	Thomas	USNRC
Caroline	Tilton	USNRC
Kenneth	Tobin	Oak Ridge National Laboratory
Pamela	Tomski	SAS
Michael	Tschiltz	Nuclear Energy Institute
Haileyesus	Tsige-Tamirat	European Commission
Nobuyuki	Tsukabe	Japan Atomic Energy Agency
Kyler	Turner	US Department of State
Stephen	Unwin	Pacific Northwest National Laboratory
Rodolfo	Vaghetto	Texas A&M University
Marcus	Voth	Self
Stephen	Ward	VH Strategies, LLC
Tammy	Way	AdSTM
Kevan	Weaver	TerraPower
Michael	Weber	USNRC
Craig	Welling	USDOE
Steven	Wessels	USNRC
Staci	Wheeler	Alpha Tech Research Corp
Patrick	White	Massachusetts Institute of Technology
Sean	White	AECOM
Jennifer	Whitman	USNRC
Bradley	Williams	USDOE
Don	Williams	Oak Ridge National Laboratory
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Tom	Williamson	Enercon Services, Inc
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Jonathan	Witter	Elysium Industries USA
Carolyn	Wolf	USNRC

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Jack	Zhao	USNRC
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