SCHEDULING NOTE

Title: **BRIEFING ON ADVANCED REACTORS (Public Meeting)**

Purpose: To provide the Commission with an update on the staff's activities to prepare for effective and efficient reviews of advanced reactor applications and to provide stakeholder perspectives on advanced reactor development activities, including projected policy and program issues that need to be resolved.

Scheduled: **April 24, 2018**
9:00 am

Duration: Approx. 3 hours

Location: Commissioners' Conference Room, 1st Fl. OWFN

Participants: **Presentation**

<u>**Panel 1**</u> **36 mins.***

Dr. John Herczeg, Deputy Assistant Secretary, for Nuclear Technology Research and Development, Department of Energy (DOE) — 6 mins.*

Topic:

- DOE perspectives on advanced reactors, including DOE's vision/strategy for deployment

Dr. Rita Baranwal, Idaho National Laboratory, Director of the Gateway for Accelerated Innovation in Nuclear — 6 mins.*

Topic:

- Advanced nuclear technologies developmental efforts

Dr. Farshid Shahrokhi, Framatome Inc., Chair of the NEI High Temperature Gas-Cooled Reactor Technology Working Group — 6 mins.*

Topic:

- Activities of the NEI High Temperature Gas-Cooled Reactor Technology Working Group

Dr. Jacob DeWitte, Oklo Inc., Chair of the NEI Fast Reactor Working Group — 6 mins.*

Topics:

- Activities of the NEI Fast Reactor Working Group

Nick Irvin, Southern Company Services, NEI Molten Salt Reactor Technology Working Group — 6 mins.*

Topic:

- Activities of the NEI Molten Salt Reactor Technology Working Group

Dr. Edwin Lyman, Union of Concerned Scientists 6 mins.*

Topic:

- Perspectives on advanced reactor regulatory and policy issues

Commission Q & A **30 mins.**

Break **5 mins.**

Panel 2 **40 mins.***

Victor McCree, Executive Director for Operations

Fred Brown, Acting Director, Office of New Reactors (NRO)

Topic:

- Overview of staff accomplishments and challenges to prepare for efficient and effective review of advanced reactor applications

John Monninger, Director, Division of Safety Systems, Risk Assessment, and Advanced Reactors, NRO

Topic:

An update on ongoing and planned activities to ensure readiness to efficiently and effectively review advanced reactor applications

Stephen Bajorek, Senior Level Advisor for Thermal Hydraulic Code Development and Analysis, Division of Systems Analysis, Office of Nuclear Regulatory Research

Topic:

- Identification, assessment, and enhancement of analytical computer codes, tools, and industry codes and standards for confirming advanced reactor safety

Brian Smith, Deputy Director, Division of Fuel Cycle Safety, Safeguards And Environmental Review, Office of Nuclear Material Safety and Safeguards

Topic:

- Fuel cycle considerations for advanced reactor applications, including fuel development

Commission Q & A **30 mins.**

Discussion – Wrap-Up **5 mins.**

*For presentation only and does not include time for Commission Q & As

U.S. Department of Energy Advanced Reactor Research and Development Program for Fast Reactors

John W. Herczeg

Deputy Assistant Secretary

for Nuclear Technology Research and Development

Office of Nuclear Energy

April 24, 2018

U.S. DEPARTMENT OF
ENERGY

Presidential and Departmental Nuclear Energy Priorities

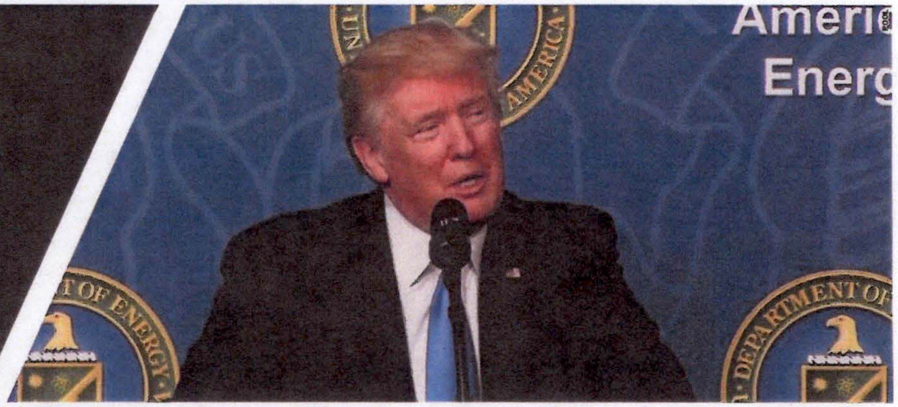
- President Trump ordered review of nuclear energy policy:

  "[W]e will begin to revive and expand our nuclear energy sector…which produces clean, renewable and emissions-free energy. A complete review of U.S. nuclear energy policy will help us find new ways to revitalize this crucial energy resource."

- Nuclear energy role as clean baseload power is key to environmental challenges:

  "If you really care about this environment that we live in…then you need to be a supporter of this amazingly clean, resilient, safe, reliable source of energy."
  Secretary Rick Perry at Press conference, May 10th

- Executive Order Promoting Energy Independence and Economic Growth
- Commercialization of advanced SMRs crucial to future of US nuclear sector



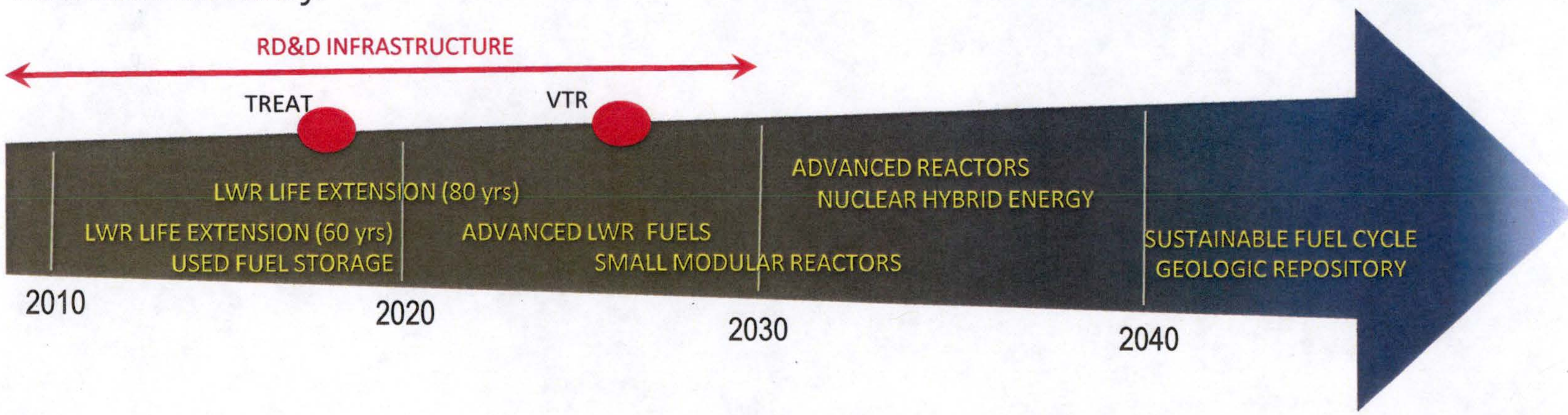
DOE-NE MISSION AND PRIORITIES

DOE-NE MISSION

- Advance nuclear power as a resource capable of making major contributions in meeting our Nation's energy supply, environmental and energy security needs
- Seek to resolve technical, cost, safety security, and regulatory issues through RD&D
- By focusing on the development of advanced nuclear technologies, support the goals of providing domestic sources of secure energy, reducing greenhouse gases, and enhancing national security.

MISSION PRIORITIES

- Existing Fleet
- Advanced Reactor Pipeline
- Fuel Cycle Infrastructure



DOE-NE ADVANCED REACTORS PIPELINE

REACTOR TYPES

Light-Water Based SMRs
e.g. NuScale

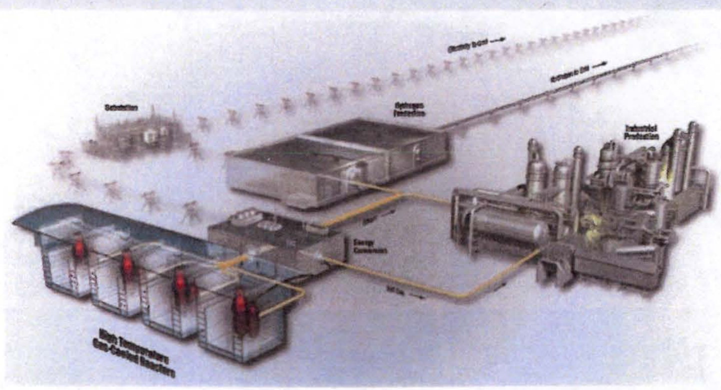
High-Temperature Reactors
- Prismatic & pebble bed designs
  - Helium Cooled
  - Molten Salt Cooled

Emphasis: TRISO fuel and Graphite qualification

Liquid Fueled Reactor (Molten Salt)
- Fast-, thermal- and hybrid-spectrum designs

Metal-cooled Fast Spectrum Reactors

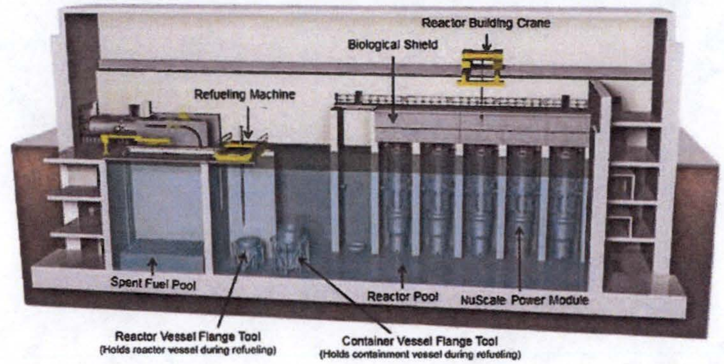
Micro Reactors



AREVA - HTGR

12 X 50 MWe

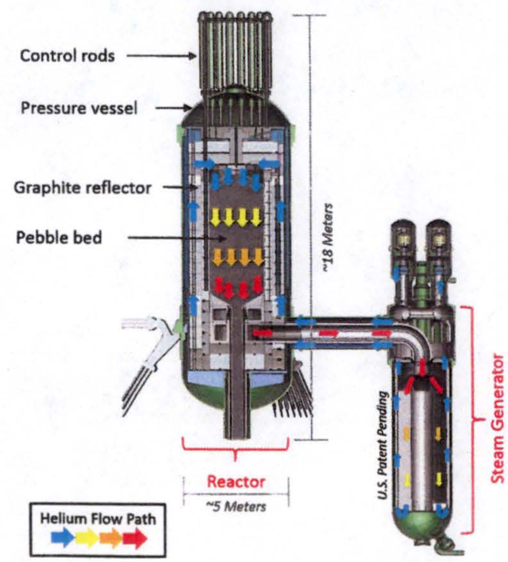
Inside a NuScale Small Modular Reactor Building



Source: NuScale Power LLC

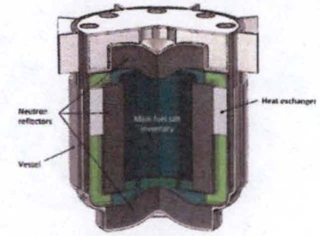
A BNA Graphic/reac13g1

Xe-100 Pebble-Bed Reactor (200 MWth)

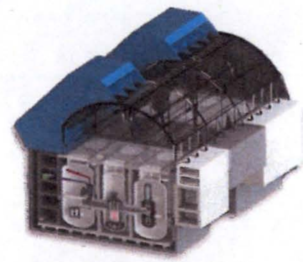


ADVANCED REACTOR TECHNOLOGIES FOCUS AREAS

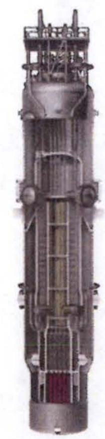
- Advanced Light Water Reactors
- Fast Reactor Technologies
  - Demonstrate feasibility of advanced systems and component technologies
  - Methods and code validation to support design and licensing
  - Advanced alloy materials qualification for metal-cooled systems
- Gas Reactor Technologies
  - Advanced alloy and graphite materials qualification for high temperature gas-cooled systems
  - Scaled integral experiments to support design and licensing
  - TRISO-coated particle fuel development and qualification
- Molten Salt Reactor Technologies
  - Investigate fundamental salt properties
  - Materials, models, fuels and technologies for salt-cooled and salt-fueled reactors
- Cross-Cutting technologies
  - Advanced energy conversion
  - Supercritical Carbon Dioxide (sCO2) Brayton Cycle
  - Micro reactors for remote defense and commercial applications



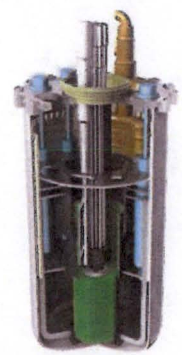
TerraPower
MCFR



GA Gas-cooled
Fast Reactor



NuScale
PWR



GE Hitachi
PRISM

VERSATILE TEST REACTOR (VTR)

IN SUPPORT OF ADVANCED REACTOR TECHNOLOGIES

NEAC Advice:

- The need for a VTR was established through a series of independent surveys of the potential U.S. user community (industry, DOE programs) and support from international partners resulting in a NEAC report ("Assessment of Missions and Requirements for a new U.S. Test Reactor" 2/2017); it states that "The Ad Hoc NEAC subcommittee recommends that DOE-NE proceed immediately with pre-conceptual planning activities to support a new test reactor (including cost and schedule estimates)."

Goals:

- 3 year R&D effort, along with appropriate reviews and planning, leading to an operational VTR by 2026
- VTR would support accelerated development of advanced fuels and materials for U.S. advanced reactor vendors, as well as to provide the capability for testing those fuels and materials to support licensing by the Nuclear Regulatory Commission.
- VTR with a high fast neutron flux would revitalize our research infrastructure and remove a critical impediment for U.S. developers of advanced nuclear energy technologies.
- Constructed and operated under DOE authority, in close collaborations with NRC.
- $35 million in 2017 Omnibus Bill for versatile fast test reactor's R&D activities to achieve CD-0 in January 2019.

SUMMARY

- The demand for domestically-generated, reliable, and clean sources of base-load electricity will continue to drive many countries toward nuclear energy as part of their "energy security" and national economic and environmental calculus.

- Profound opportunity for new nuclear growth:
  - Strong global market interest
  - Growing need for increased global access to electricity
  - Support energy security, economic and environmental goals
  - U.S. leadership to ensure safety & nonproliferation are as important as ever

- The Administration is committed to advancing nuclear energy in the United States and abroad.

"Nuclear energy is a critical component of America's energy future, and entrepreneurs are developing promising new technologies that could truly spur a renaissance in the United States and around the world."

Back Up Slide

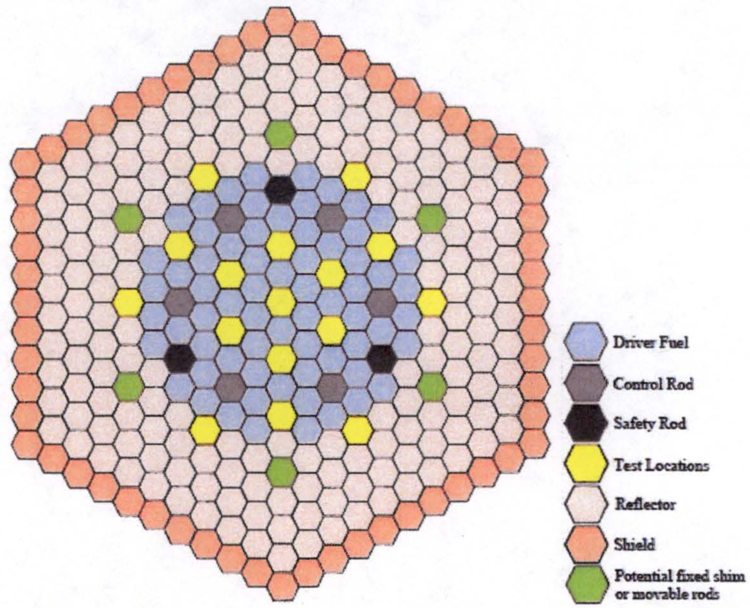
U.S. DEPARTMENT OF ENERGY

DRAFT REQUIREMENTS/ASSUMPTIONS

OF VERSATILE TEST REACTOR (VTR)

1. Approach to Design: Conducting a 3 year research & development effort on core design.
2. Reach fast flux of approximately 4.E15 n/cm^2-s, with prototypical spectrum
3. Load factor: as large as possible *(maximize dpa/year to > 30 dpa/year)*
4. Provide flexibility for novel experimental techniques
5. Be capable of running loops representative of typical fast reactors *(Candidate Coolants: Na, Lead, LBE, Gas, Molten Salt)* – May be a single location with replaceable loops.
6. Effective testing height ≤ 1 m
7. Ability to perform large number of experiments simultaneously
8. <u>Metallic driver fuel</u> (possible options: LEU, Pu, LEU+Pu)

<u>**VTR draft core map**</u>



GAIN
Gateway for Accelerated Innovation in Nuclear

Dr. Rita Baranwal
Director, GAIN

Advanced Reactor Briefing to NRC Commissioners
April 24, 2018

GAIN Gateway for Accelerated Innovation in Nuclear

INL Idaho National Laboratory

Oak Ridge National Laboratory

Argonne National Laboratory

INL-MIS-18-50139

GAIN
Gateway for Accelerated Innovation in Nuclear

What is GAIN?

Mission:
Provide the nuclear energy industry with access to technical, regulatory and financial support necessary to move innovative nuclear energy technologies toward *commercialization* in an accelerated and cost-effective fashion

GAIN is:
A private-public partnership framework aimed at rapid and cost-effective development of innovative nuclear energy technologies towards market readiness.

TRISO Fuel Particle

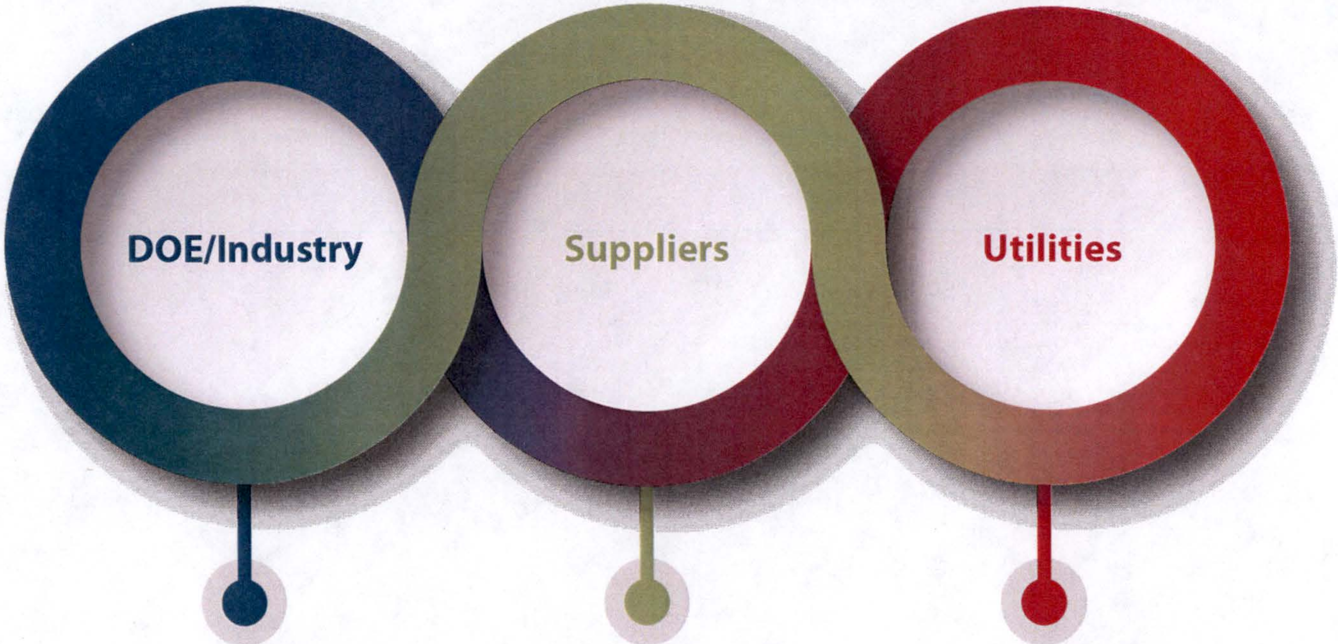
@GAINnuclear

gain.inl.gov

GAIN Initiative: Simultaneous Achievement of Three Strategic Goals

GAIN
Gateway for Accelerated Innovation in Nuclear

STRATEGIC GOALS



DOE/Industry	Suppliers	Utilities
Lead Global Technology Commercialization	Enable Global Industrial Leadership	Optimize Domestic Energy Portfolio

GAIN

Gateway for Accelerated Innovation in Nuclear

GAIN: Connecting nuclear innovators to DOE laboratory capabilities and RD&D programs

Modeling & Simulation	Crosscutting Design Support	NRC Interface	Base Reactor and Fuel Cycle R&D Programs	Experimentation
HPC Infrastructure	Nuclear Hybrid Energy	Licensing Framework	Advanced Fuel Cycles	Nuclear Fuels
Verification and Validation	Nuclear Cyber Security	Gradual Risk Reduction	Advanced Reactors	Instrumentation and Sensors
M&S Expertise	Digital I&C Human Factors	Licensing Support Expertise	LW-based Reactors	Materials Science
Reactor physics				Test Reactors

Modeling and Simulation | **Expertise** | **Unique Facilities**

Knowledge Management & Integration

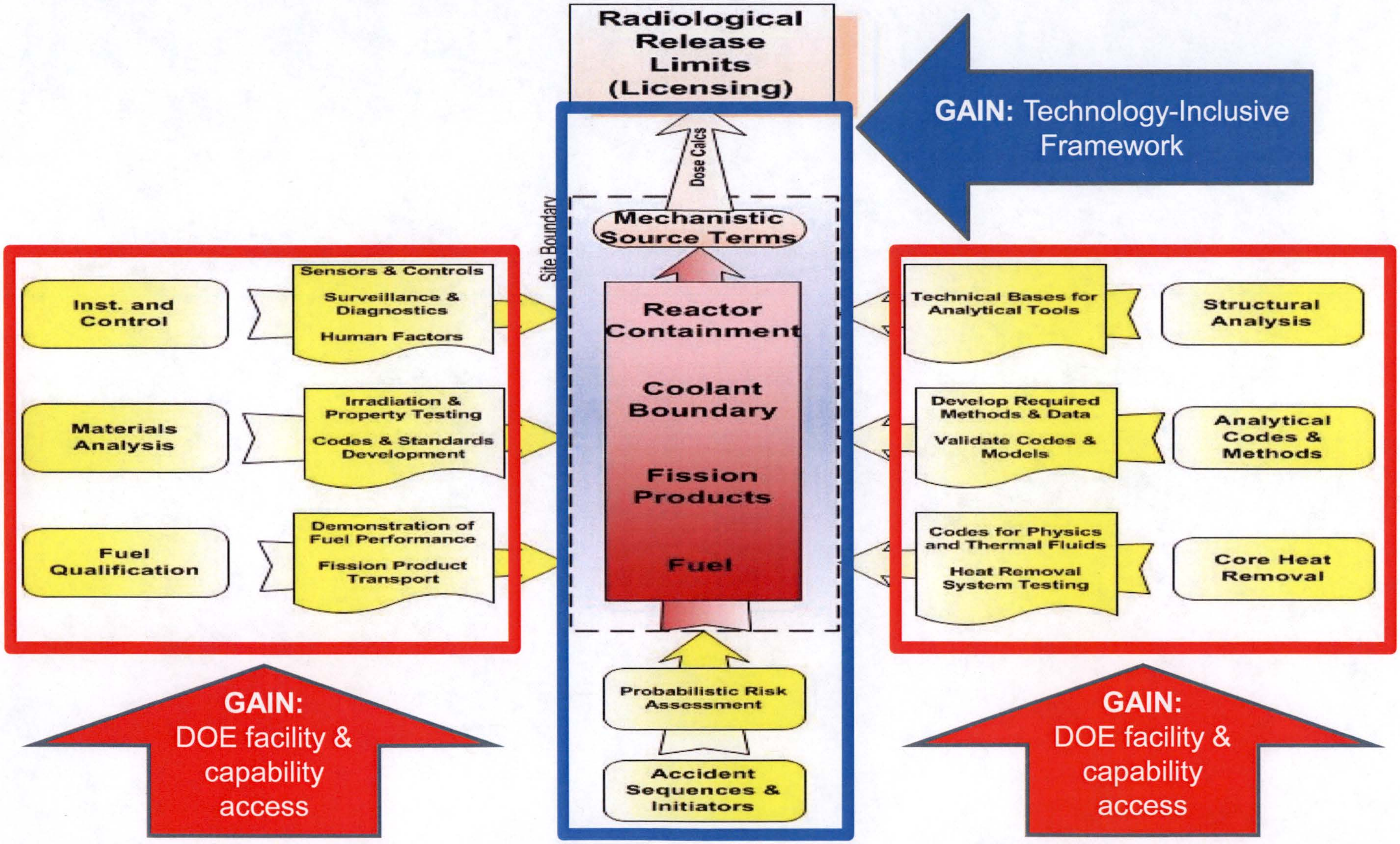
– GAIN –

Industry and investor access to DOE capabilities and expertise

@GAINnuclear

gain.inl.gov

Development & Regulatory Framework Support



GAIN NE Voucher Recipient	Title	Partner Facility
AMS Corp. **Knoxville, TN**	Radiation Aging of Nuclear Power Plant Components	ORNL
Columbia Basin Consulting Group LLC **Kennewick, WA**	Methodology for Meeting Containment System Principal Design Criteria for Heavy Metal Fast Reactor Systems	PNNL
DYNAC Systems LLC **Del Mar, CA**	Dynamic Natural Convection System	INL
Elysium Industries **Clifton Park, NY**	Synthesis of Molten Chloride Salt Fast Reactor Fuel Salt from Spent Nuclear Fuel	INL / ANL
Fauske & Associates LLC **Burr Ridge, IL**	Development of an Integrated Mechanistic Source Term Assessment Capability for Lead- and Sodium-Cooled Fast Reactors	ANL
GSE Systems Inc. **Sykesville, MD**	Human Factors Engineering for the Move to Digital Control Systems – Improved Strategies for Operations	INL
Kairos Power LLC **Oakland, CA**	NEAMS [Nuclear Energy Advanced Modeling and Simulation] Thermal-Fluids Test Stand for Fluoride-Salt-Cooled, High-Temperature Reactor Development	ANL / INL
MicroNuclear LLC **Franklin, TN**	Development of the Microscale Nuclear Battery Reactor System	INL
Muons Inc. **Batavia, IL**	Conversion of Light Water Reactor Spent Nuclear fuel to Fluoride Salt Fuel	ORNL
NuVision Engineering, Inc. **Pittsburgh, PA**	Evaluation of Power Fluidic Pumping Technology for Molten Salt Reactor Applications	ORNL
Oklo Inc. **Sunnyvale, CA**	Risk-Informed Mechanistic Source Term Calculations for a Compact Fast Reactor	SNL/ANL
SMR Inventec LLC **Camden, NJ**	Small Modular Reactor-160 Primary Flow Stability	ORNL
Terrestrial Energy USA Ltd. **New York, NY**	IMSR® [Integral Molten Salt Reactor] Fuel Salt Property Confirmation: Thermal conductivity and viscosity	ANL
Transatomic Power Corporation **Cambridge, MA**	Fuel Salt Characterization	ANL

GAIN
Gateway for Accelerated Innovation in Nuclear

FY 2017 GAIN Vouchers:

- 41 Letters of Intent
- 32 Voucher requests submitted
- 25 separate small businesses
- 9 "returnees"
- 16 new businesses compared to the 2016 pilot
- ~$4.2M awarded to 14 small businesses

GAIN
Gateway for Accelerated Innovation in Nuclear

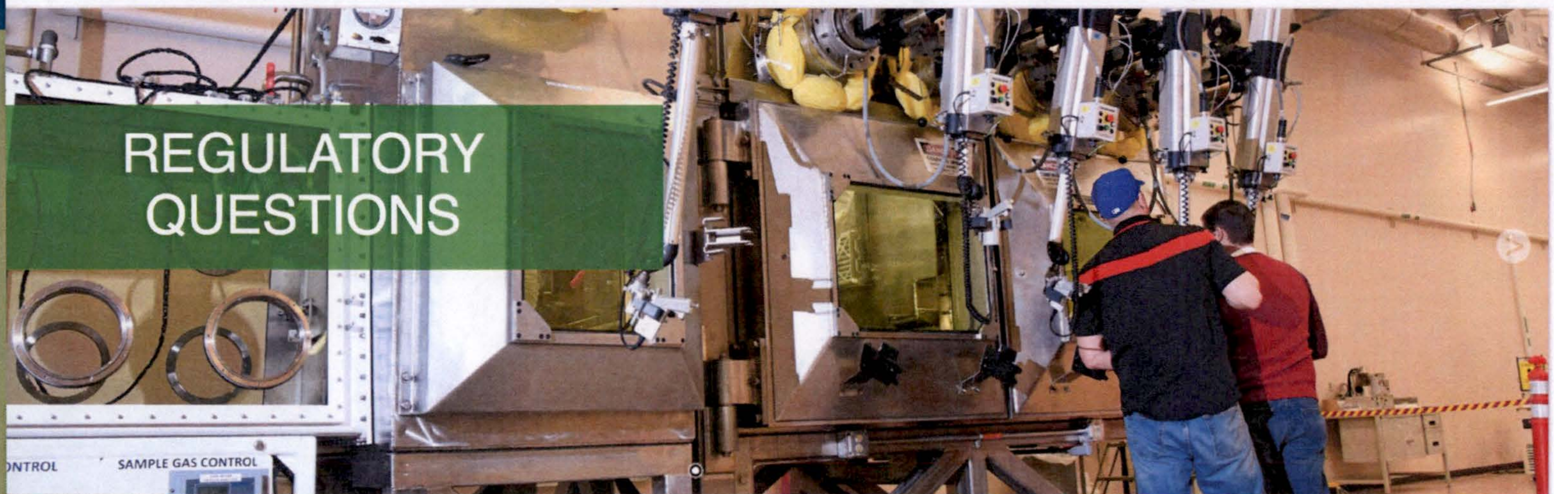
Innovator Access to DOE Facilities and Expertise

- **Accident-Tolerant Fuels** (ATF)
  - New ATF cladding conceived, developed, manufactured and tested at ORNL has been manufactured by Global Nuclear Fuels (GNF) into lead test assemblies, and shipped to Southern Nuclear Operating Company for trials in Edwin I Hatch plant.
  - FeCrAl cladding (IronClad) will be the first developed through US Department of Energy's (DOE) Enhanced Accident-tolerant Fuel program to be installed in a commercial nuclear reactor
- **Molten Salt Reactor (MSR) development**
  - Training on MSR technology and MSRE experience has been provided to NRC via series of training courses
  - Continue to support the ARC-15 FOA with TerraPower on MSR technology development, including material development, corrosion expertise, salt properties, modeling & simulation, safeguards
  - Legacy reports from MSRE and MSBR have been released for developer community
- **Database development**
  - Legacy fast reactor information, including EBR-II reactor physics and fuel performance data, and TREAT data on fuel transient testing and post-test examination. GAIN supported completion and activation of TREAT database (TREXR) for benefit of industry users.

GAIN Interface with NRC

- MOU between NRC and DOE on GAIN, November 10, 2016
  - NRC provides DOE and GAIN community with current, accurate information on NRC licensing processes and regulations
- GAIN website:

HOME ABOUT OPPORTUNITIES RESOURCES REGULATORY WORKSHOPS MODELING AND SIMULATION CALENDAR NEWSROOM CONTACT



The linked memorandum of understanding (MOU) between the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Department of Energy (DOE) describes the roles, responsibilities, and the processes related to the implementation of the DOE Gateway for Accelerated Innovation in Nuclear (GAIN) initiative. GAIN is an initiative that is intended to provide the nuclear energy community with increased access to the technical, regulatory, and financial support necessary to mover new or advanced nuclear reactor designs toward commercialization while ensuring the continued safe, reliable, and economic operation of the existing nuclear

Submit your question for the NRC below. It can be regarding Licensing, Policy, Guidelines, etc. We will post questions and answers on this site.

CONTACT GAIN

Name *

Future Activities 2018

Workshops:

- Gap Analysis on Standards and Codes for Advanced Reactors at NRC Offices: May 2, 2018
- Digital Instrumentation & Controls at Argonne National Lab: June 5-6, 2018

Database/catalog:

- Develop a list of historical advanced-reactor documents to support knowledge transfer; facilitate access to key documents through OSTI
- Develop and initiate the process to appropriately remove AT designation on high priority documents requested by industry

Funding Opportunities:

- Industry-focused FOA and Vouchers awarded quarterly for 5 years

GAIN

Gateway for Accelerated Innovation in Nuclear

@GAINnuclear | gain.inl.gov

HTGR
Simple Safe Secure

HTGR Technology Working Group

<u>HTGR TWG Members</u>

BWXT
Framatome (previous AREVA)
Kairos Power
StarCore Nuclear
X-Energy

DOE, Duke Energy, EPRI and NEI

Farshid Shahrokhi (Chairman HTGR-TWG)

HTGR
Simple Safe Secure

HTGR- TWG

Developers

- Reactor Developers
  - Framatome
    - SC-HTGR - prismatic core modular high temperature gas-cooled reactor
  - Star Core Nuclear
    - StarCore - small core modular high temperature gas-cooled reactor
  - X-Energy
    - Xe-100 - pebble bed core modular high temperature gas cooled reactor
  - Kairos Power
    - KP-FHR - molten salt core high temperature reactor

- Fuel Manufacturers
  - BWXT
    - UCO based TRISO coated particle fuel
  - X-Energy
    - UCO based TRISO coated particle fuel

framatome Xenergy BWXT BWX Technologies, Inc.

STARCORE NUCLEAR Kairos Power

HTGR –TWG

Activities

- Regulatory Guide 1.232 "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors"
- Radionuclides retention - Functional Containment
- Limited Scope Topical Report (LSTR) for TRISO coated particle fuel -
  - Complete the report
  - Submit to the NRC
  - Begin NRC review/comment
- ASME Section III, Div. 5
  - Advocacy for NRC review and endorsement
  - Technical support of the NRC review and comments resolution
- Engage in efforts to reduce licensing uncertainties for advanced reactors
  - Advocacy for NRC endorsement of Licensing Modernization Project proposal and approach
  - Support for development of technology-inclusive license application content guide for advanced non-LWRs

FRWG

Fast Reactor Working Group

Fast Reactor Working Group Activities

2018 NRC Commissioner Meeting

April 24, 2018

Fast Reactor Working Group

- Multiple developers working on multiple technologies
- Spans variety of fast reactor technologies in development

ARC	Columbia Basin	Elysium Industries
General Atomics	GE	Hydromine
Oklo	TerraPower	Westinghouse
Duke	Exelon	Southern
EPRI		Studsvik Scandpower

Highlighted Efforts

- Fuels
  - Variety of fuels being considered
  - Working on infrastructure needs
  - Data
- Modeling and simulation
  - Existing and new tools
- Legacy data
  - Fuel and component databases
- Versatile test reactor
- Standards – ASME Section III, Div. 5
- RG 1.232

Good Morning – My name is Farshid Shahrokhi. I am the director of HTGR technology at Framatome.

Today I represent the High Temperature Gas-cooled Reactor Technology Working Group. We are an independent industry group formed within the NEI Advanced Reactor Working Group. Our membership includes high temperature reactor developers, coated particle fuel manufacturers, and a utility. We also have representatives from EPRI, DOE and NEI. Our mission is to express and support our members' common technical and R&D needs. We have engaged and interacted with the DOE research communities, the universities, the standards development communities, and the NRC.

Our reactor designs use Helium as the coolant or molten salt in the case of Kairos Power, graphite moderator, and Uranium Oxy-Carbide (UCO) kernel Tri-isotropic (TRISO) coated particles as our basic fuel form. Our designs produce high temperature steam (~560 °C) for either high efficiency electricity production or industrial process steam. Our reactors are modular and small - ranging in power from 10 to 275 MWe.

NEXT SLIDE

First, I would like to thank the NRC staff for working with us and the other advanced reactor communities in an effort to modernize and risk inform our regulatory infrastructure. Your work is important to us because we need guidance that applies to our reactor designs as opposed to the current guidance that has evolved over the past 50 years through licensing mainly light water reactors.

Risk-Informed and Performance-Based guidance for non-light water reactor licensing basis development will provide a systematic process for demonstrating satisfaction of existing regulations that we could use independent of any specific reactor technology. The work that the NRC is doing with support from the Licensing Modernization Project is a major step forward in the long term goal of technology inclusive regulatory structure.

For near term we support and applaud the DOE and the NRC efforts for developing and publishing earlier this month the Regulatory Guide 1.232 "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors". This guide provides acceptable ways for developing Principal Design Criteria for a range of advanced reactor designs including our modular HTGRs.

Next - within our developer community - the interim results from the DOE TRISO particle fuel qualification and characterization program (DOE AGR Program) show that reactors that use a combination of TRISO fuel, graphite core, and a single-phase chemically inert coolant could have an extraordinarily low radiological source term. This enables enhanced operational capacity and accident tolerance which is the foundation for an alternative radionuclides retention strategy and performance criteria definition.

The so called "Functional Containment" is an independent set of systems, structures and components working together to retain fission products and limit the site dose at the boundary to less than 1 REM (EPA PAG limit – which is a design goal for us) for all anticipated, design bases, and beyond design bases accident scenarios without relying on a pressure retaining reactor building.

We have worked with the NEI and the NRC staff in establishing a radionuclides retention strategy using the concept of "Functional Containment" for non-light water reactors. A draft Commission paper titled "Functional Containment Performance Criteria" is working its way through the NRC regulatory review and approval chain. Acceptance of functional containment for radionuclides retention is essential to our reactor concepts development and commercialization.

Meanwhile - Our TWG is collaborating with the DOE, Idaho National Lab, and the Electric Power Research Institute in preparation of a Limited Scope Topical Report (LSTR) to be submitted to the NRC early next year for "off-fee" review and approval. This report will be a generic Topical Report documenting the completed TRISO fuel testing results at Idaho National Lab. Once reviewed and approved, each developer that wishes to use UCO based TRISO fuel can reference this topical in its design specific fuel qualification report.

The HTGR TWG also recognizes that further advanced reactor regulatory framework development, with a goal of reduction of regulatory uncertainty, will continue to require close collaboration, coordination, and interaction with the industry. This is evident by our past and on-going engagement with the consensus standards communities such as ANS and ASME. We have proposed and encourage the NRC review and endorsement of one of our key standards - the ASME Section III, Div. 5 "High Temperature Reactors".

We will continue our engagement with the NRC staff to further develop cross-cutting improvements such as a) safety-focused regulatory reviews, b) emergency planning, c) staffing, and d) security requirements for advanced reactors to further reduce regulatory uncertainties and encourage early deployments of advanced reactors.

Thank you

FRWG
Fast Reactor Working Group

Fast Reactor Working Group Activities

2018 NRC Commissioner Meeting

April 24, 2018

Fast Reactor Working Group

FRWG
Fast Reactor Working Group

- Multiple developers working on multiple technologies
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Highlighted Efforts

- Fuels
  - Variety of fuels being considered
  - Working on infrastructure needs
  - Data
- Modeling and simulation
  - Existing and new tools
- Legacy data
  - Fuel and component databases
- Versatile test reactor
- Standards – ASME Section III, Div. 5
- RG 1.232

Molten Salt Reactor Technology Working Group (MSR TWG)

↗

Nick Irvin
Director - Advanced Energy Systems,
Southern Company Services

4.24.18

Molten Salt Reactor TWG →

ONE

Terra Power

Fast
Breeder
Liquid Fuel
Salt Cooled
Uranium
(Could use Th)

TWO

Thorcon

Thermal
Burner
Liquid Fuel
Salt Cooled
Thorium

THREE

Terrestrial Energy

Thermal
Burner
Liquid Fuel
Salt Cooled
Uranium
(Could use Th)

FOUR

Flibe Energy

Thermal
Breeder
Liquid Fuel
Salt Cooled
Thorium

FIVE

Transatomic Power

Hybrid
Burner
Liquid Fuel
Salt Cooled
Uranium

SIX

Elysium Industries

Fast
Breeder
Liquid Fuel
Salt Cooled
Uranium

SEVEN

Alpha Tech Research Corp

Thermal
Breeder
Liquid Fuel
Salt Cooled
Thorium

EIGHT

Muons Inc.

Thermal
Burner
Liquid Fuel
Salt Cooled
Uranium

Exelon. NEI NUCLEAR ENERGY INSTITUTE DUKE ENERGY. EPRI

Highlighted Topics→

- NUREG 1537 update for use with MSR Test Reactor licensing

- Supportive of the development of risk informed, performance based regulatory structure
  - Utility led Licensing Modernization Project results are promising
  - Regulatory guidance on functional containment is supported

- Fuel qualification approaches for MSR need to be developed

- Modeling and simulation tools – working with NEAMS on Multiphysics tools to support MSR analysis

- Participating in the development of ANS 20.2 Standard for MSRs

- Need for HALEU is consistent across designs

UCS Perspectives on Advanced Reactor Regulatory and Policy Issues

April 24, 2018
Dr. Edwin Lyman
Senior Scientist
Union of Concerned Scientists

Advanced reactors

- All non-light water reactor (LWR) reactor concepts have both advantages and disadvantages compared to LWRs
- All non-LWRs have novel features whose behavior will require significant testing and analysis to quantify margins and uncertainties for licensing purposes
- At this stage of development, there is **no technical basis** to support the assertion that non-LWRs will be inherently safer or more secure than LWRs
- In fact, there is reason to believe that characteristics of non-LWRs could render them less safe and secure overall than LWRs, requiring compensatory measures

Advanced reactor licensing

- The NRC's regulatory processes are being unfairly maligned as significant obstacles to advanced reactor deployment
- In fact, the main barriers are the huge investments in cost and time required for non-LWR vendors to develop their concepts to the level of maturity needed to support high-quality applications
- Weakening NRC licensing standards to expedite advanced reactor licensing is unnecessary and potentially dangerous
- Congress should ensure that the NRC has licensing authority over any advanced reactor built in the U.S., even when the Atomic Energy Act does not require it

Expectation versus reality

- ***"The new designs typically have lower probabilities of severe accidents because of their smaller size or innovative safety features, which would also likely lower impacts to public health and safety from any radiological emergency."*** – NRC, Final Regulatory Basis, Rulemaking for Emergency Preparedness for Small Modular Reactors and Other New Technologies," Sept. 2017
- For non-LWRs of any size, this is an unverified and likely false assertion
- The Advanced Reactor Policy Statement "expects," but does not require, that advanced reactors "will provide enhanced margins of safety and/or use simplified, inherent, passive, or other innovative means to accomplish their safety and security functions."
  - This non-mandatory expectation must be extensively validated before it can be used as a basis for regulatory decisions

A self-defeating prophecy

- Even for designs that can be shown to have additional inherent safety, overall safety will depend on NRC policy decisions on
  - siting
  - functional containment and other changes to the General Design Criteria
  - emergency preparedness
  - security
  - use of probabilistic risk assessment (PRA)
  - testing requirements/acceptance of advanced modeling and simulations
  - special treatment requirements
- Excessive reductions in safety margin and defense-in-depth could undermine, rather than enhance, safety
- Rather than reduce margin, the NRC should treat any first-of-a-kind (FOAK) demonstration reactor as a "prototype" and require additional safety features to compensate for uncertainties

Non-LWR safety and security vulnerabilities

- Gas-cooled reactors can be seriously damaged by air or water ingress
- Liquid sodium-cooled fast reactors have reactivity instabilities and flammable coolant
- Molten-salt reactors must be kept within a narrow temperature range to prevent freezing of the coolant or rapid destruction of the reactor (within ten minutes)
- Must consider implications for the entire fuel cycle
  - Any reactor with co-located reprocessing facilities will raise many novel safety and security issues

"Risk-informing" advanced reactor licensing

- PRAs for non-LWR designs are largely academic exercises and lack data for validation
  - Uncertainties in defining design-basis accident spectrum
  - Uncertainties in evaluating severe accident progression and consequences
- Thus the risk information from such models has little utility for FOAK reactor licensing
- Over time, use of PRA may be increased as operating reactor information becomes available

Non-LWR security rulemaking

- The Nuclear Energy Institute (NEI) has proposed that the NRC weaken its security requirements for advanced reactors that meet certain conditions:
  - No need to protect against the design basis threat (DBT)
  - No need for security performance evaluations
- The NRC's position is that the current regulatory framework for security is already flexible enough to accommodate different design features that may impact security
- However, the staff is scheduled to submit a paper to the Commission later this year that may include a rulemaking option
- In our view, this would be an unnecessary effort
  - there is no conceivable circumstance under which the fundamental requirements for protection against radiological sabotage could be safely waived for advanced reactors

Excessive secrecy

- It appears that vendors are withholding far more basic information about their designs during pre-application reviews than in the past
  - Toshiba 4S fast reactor: detailed design and safety basis information were presented in several public meetings (e.g. ML072950026)
- There is virtually no comparable information about the Oklo or Terrestrial Energy design or safety basis on ADAMS
- It is unclear why the standard for proprietary information protection would be different today
  - UCS may need to test the standard by challenging the NRC's proprietary information determinations
- Much more information will have to be eventually released if vendors pursue design certifications or construction/operating licenses
  - Why shouldn't early engagement with the public be as important to the vendors as early engagement with the regulator?

Acronyms

- **DBT: Design Basis Threat**
- **EP: Emergency Preparedness**
- **FOAK: First of a Kind**
- **NEI: Nuclear Energy Institute**
- **PRA: Probabilistic Risk Assessment**
- **UCS: Union of Concerned Scientists**

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Protecting People and the Environment

NRC's Advanced Reactors Program "Enabling the Safe and Secure Use of Nuclear Materials"

- Commission Meeting
- April 24, 2018

Agenda

- NRC's Advanced Reactors Program – Fred Brown
- Licensing Readiness and Potential Policy Issues – John Monninger
- Analytical Codes, Tools, and Industrial Standards – Stephen Bajorek
- Fuel Cycle Considerations – Brian Smith

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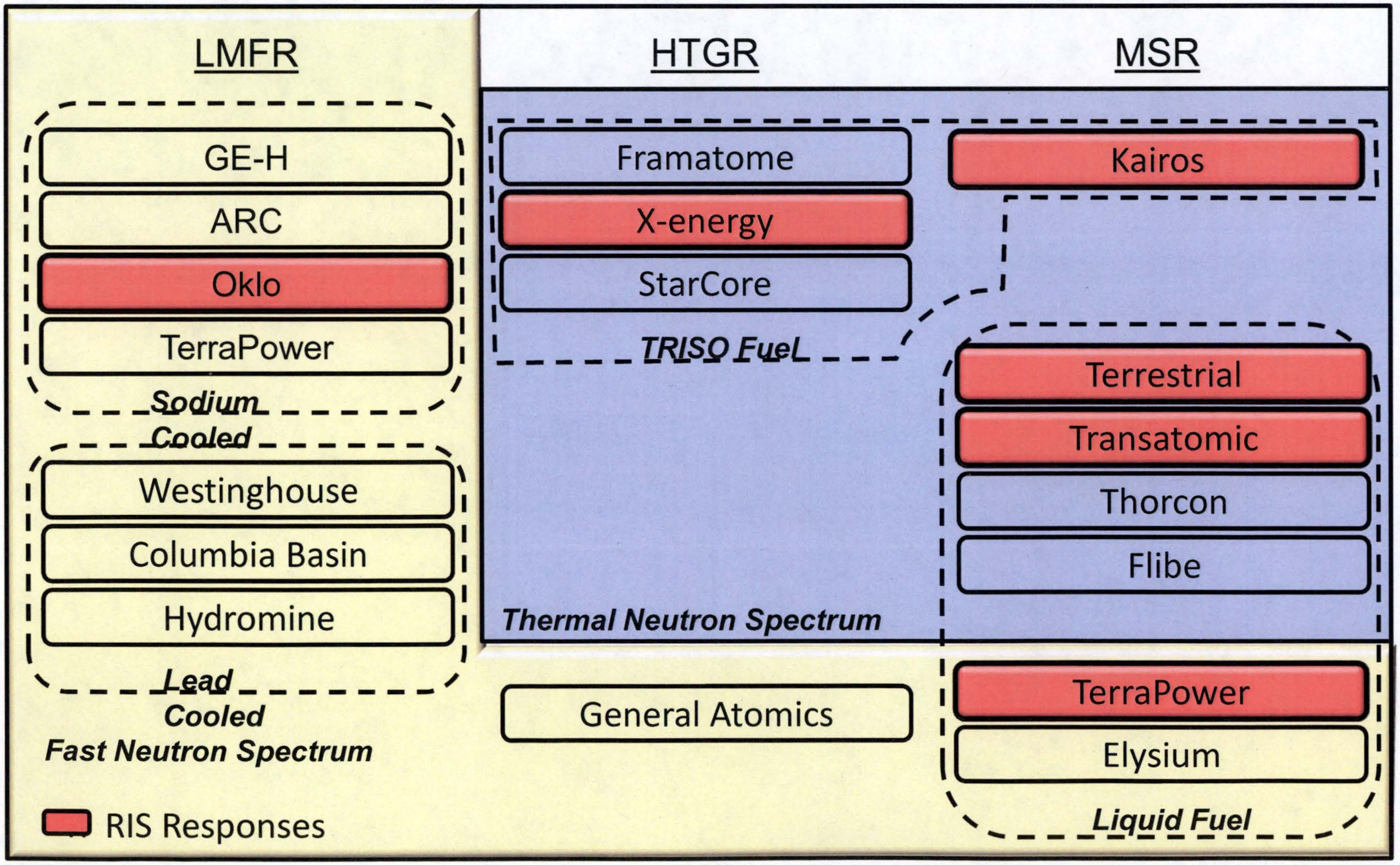
NRC's Advanced Reactors Program

Fred Brown, Acting Director

Office of New Reactors

Dynamic and Evolving Landscape



Assuring Readiness

- Developed the Vision and Strategy
- Executing the Implementation Action Plans
- Building capabilities
  - Incremental progress
  - Identifying key policy issues
  - Focused "Core" team concept

Potential Early Applications

- Individual developer's timelines
- Recognizing relative maturity
- Further transformation
  - Leveraging advancements from recent light water reactors licensing
  - Optimizing the regulatory structure

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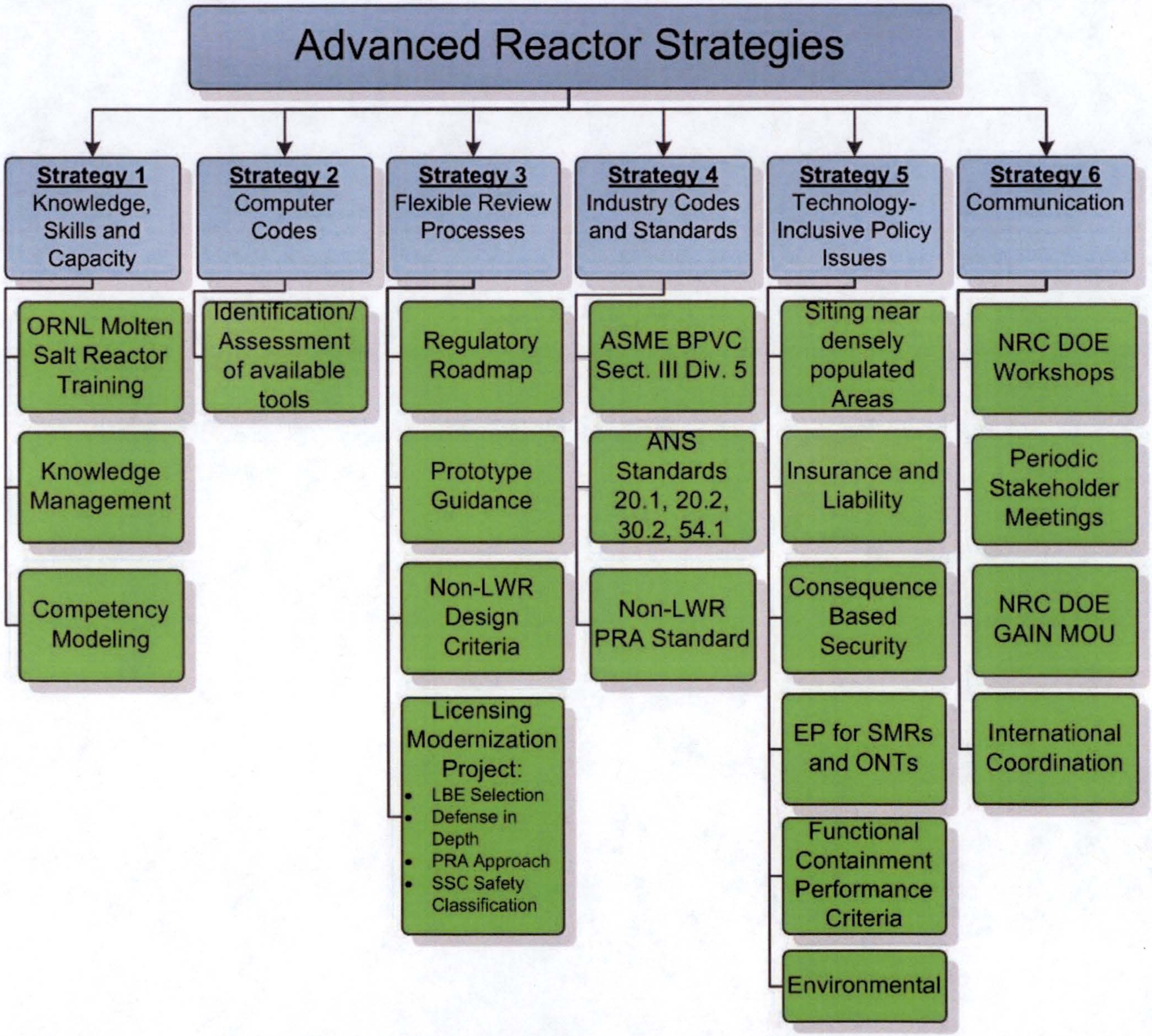
Licensing Readiness and Potential Policy Issues

John Monninger, Director
Division of Safety Systems, Risk Assessment, and Advanced Reactors
Office of New Reactors

Making Progress in the Near-Term



Modernizing the Licensing Approach

- Flexible, staged, and predictable processes
- Advanced Reactors Design Criteria
- Developing a risk-informed, and performance-based approach
  - Identification of licensing-basis events
  - Probabilistic risk assessment approach
  - Classification of structures, systems, and components
  - Defense-in-depth

Pursuing Resolution of Policy Issues

- Emergency preparedness for small modular reactors and other nuclear technologies
- Consequence based physical security
- Functional containment performance criteria

Evaluating Other Potential Issues

- Engaging with stakeholders to identify and prioritize potential policy issues
  - Siting
  - Insurance
- Technology-specific policy issues

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Analytical Codes, Tools, and Industrial Standards

Stephen M. Bajorek, Ph.D.
Senior Level Advisor for Thermal Hydraulics
Division of Systems Analysis
Office of Nuclear Regulatory Research

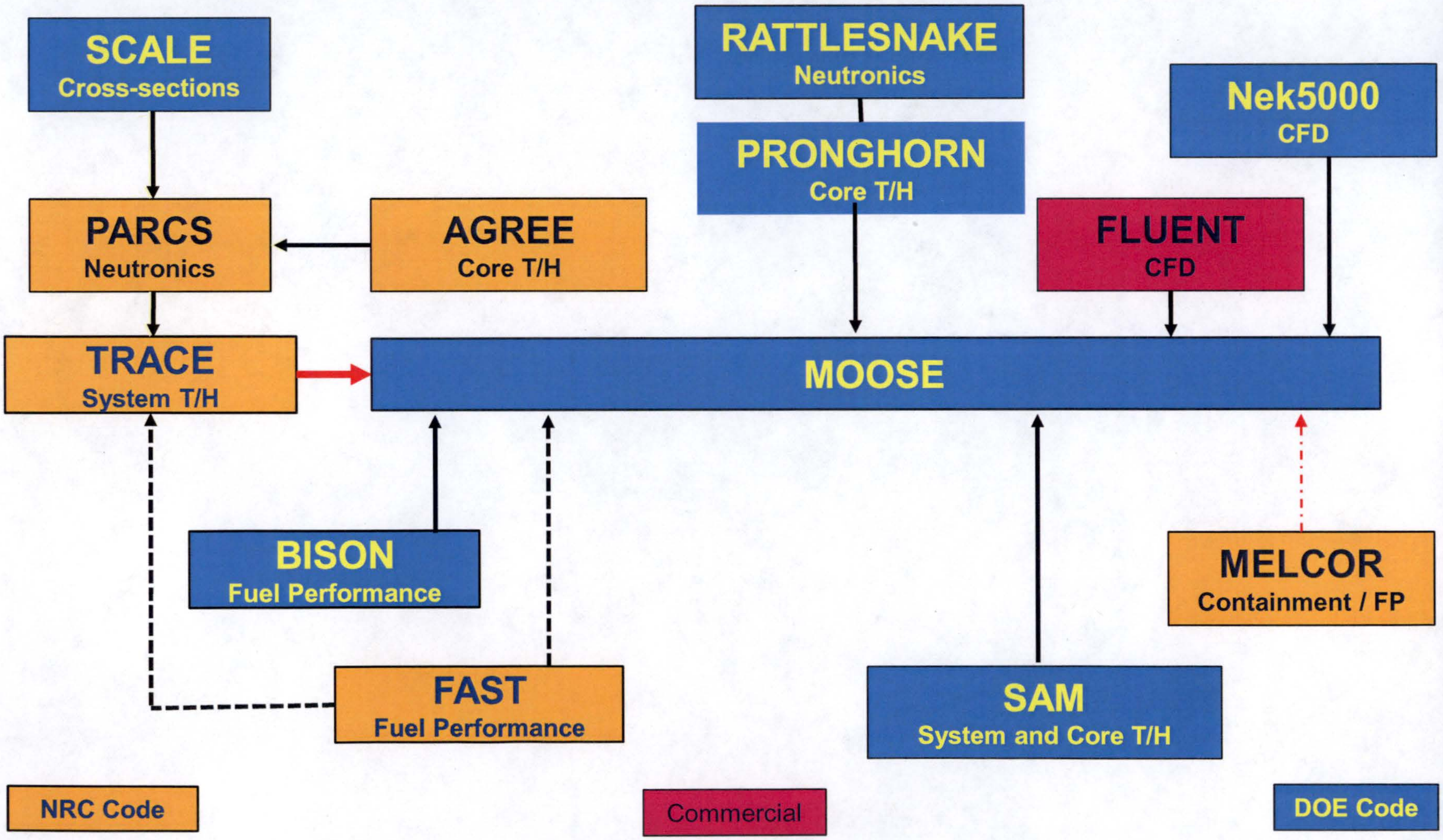
Progress in Technical Readiness

- Familiarization with advanced reactor technologies and technical issues
- Access and training with DOE analysis codes and evaluation of existing NRC code capabilities
- Identification of technical "gaps"
  - Code capabilities and limitations
  - Experimental data and code verification and validation
  - Industrial standards for materials

Methodical Approach to Selection of Codes

- Does a code contain the correct physics and modeling features?
- Is it more economical to develop an NRC code, or adopt use of a code developed elsewhere?
- If a non-NRC code is used, how does the NRC maintain its independence?
- Can a code be developed for application to more than one reactor design type?
- What applicable verification and validation exists for a particular code?

Comprehensive Reactor Analysis Bundle (CRAB)



Resolving Technical Challenges

- Numerous advanced reactor designs
- Some (vital) data is non-existent
  - Molten salt thermophysical properties
  - High temperature material behavior
- DOE and NRC codes have been developed for different purposes
  - DOE: Normal operation, very high detail
  - NRC: Accident scenarios, peak power regions
- DOE codes designed for high performance computing systems

Leveraging Industrial Standards

- NRC Objectives
  - Obtain performance needs and identify issues for structural materials and component integrity
  - Support consensus standards
- Staff participation on Industrial Standards activities
  - ASME Section III, Division 5 – High Temperature Materials
  - ANS Committees and Working Groups
  - ASME/ANS Joint Committee on Nuclear Risk Management

Path Forward

- Efforts in 2018 will be primarily generic and focus on identification of gaps in knowledge, data, and code modeling requirements
- DOE codes will continue to be tested and cooperative efforts expanded
- Support for Industrial Standards activities will continue with emphasis on high temperature materials

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Fuel Cycle Considerations

Brian Smith, Deputy Director
Division of Fuel Cycle Safety, Safeguards, and Environmental Review
Office of Nuclear Material Safety and Safeguards

Engagement on Fuel Cycle Considerations

- Participant in meetings with developers, industry, and DOE
- Participant in advanced reactors training
- Reviewed draft NEI white paper on challenges for front end fuel cycle

Evaluation of Fuel Cycle Regulatory Framework

- Existing framework has sufficient flexibility for solid-fueled reactors using once through fuel cycle
  - May require new regulatory guidance for new design characteristics
- Potential for regulatory challenges for fluid-fueled reactors or reactors with closed fuel cycles

Engaging on Issues that Need to be Addressed by Industry

- Obtaining uranium enriched greater than 5% and subsequent fuel fabrication
- New transportation packages
- Criticality benchmark experiments

Proactively Identifying Regulatory Issues

- Material control and accounting requirements for Category II facilities
- Physical security requirements for Category II facilities
- Material control and accounting requirements for fluid-fueled reactors

Continue Active Participation

- Maintain involvement in advanced reactors activities
- Encourage industry development of fuel cycle technology and designs in parallel with reactors design
- Encourage industry development and implementation of regulatory engagement plan

Acronyms

- ANS – American Nuclear Society
- ASME – American Society of Mechanical Engineers
- BPVC – Boiler and pressure vessel code
- DOE – Department of Energy
- EP – Emergency preparedness
- GAIN – Gateway for Accelerated Innovation in Nuclear
- HTGR – High temperature gas reactor
- LBE – Licensing basis events
- LMFR – Liquid metal fast reactor
- MOU – Memorandum of Understanding
- MSR – Molten salt reactor
- NEI – Nuclear Energy Institute
- Non-LWR – Non light-water-reactor
- ONT – Other nuclear technologies
- ORNL – Oak Ridge National Laboratory
- PRA – Probabilistic Risk Assessment
- RIS – NRC Regulatory Information Summary
- SMR – Small modular reactor
- SSC – Structures, systems, and components