NRIC National Reactor Innovation Center

Overview of DOE Regulatory Development

Advanced Non-Water Technologies

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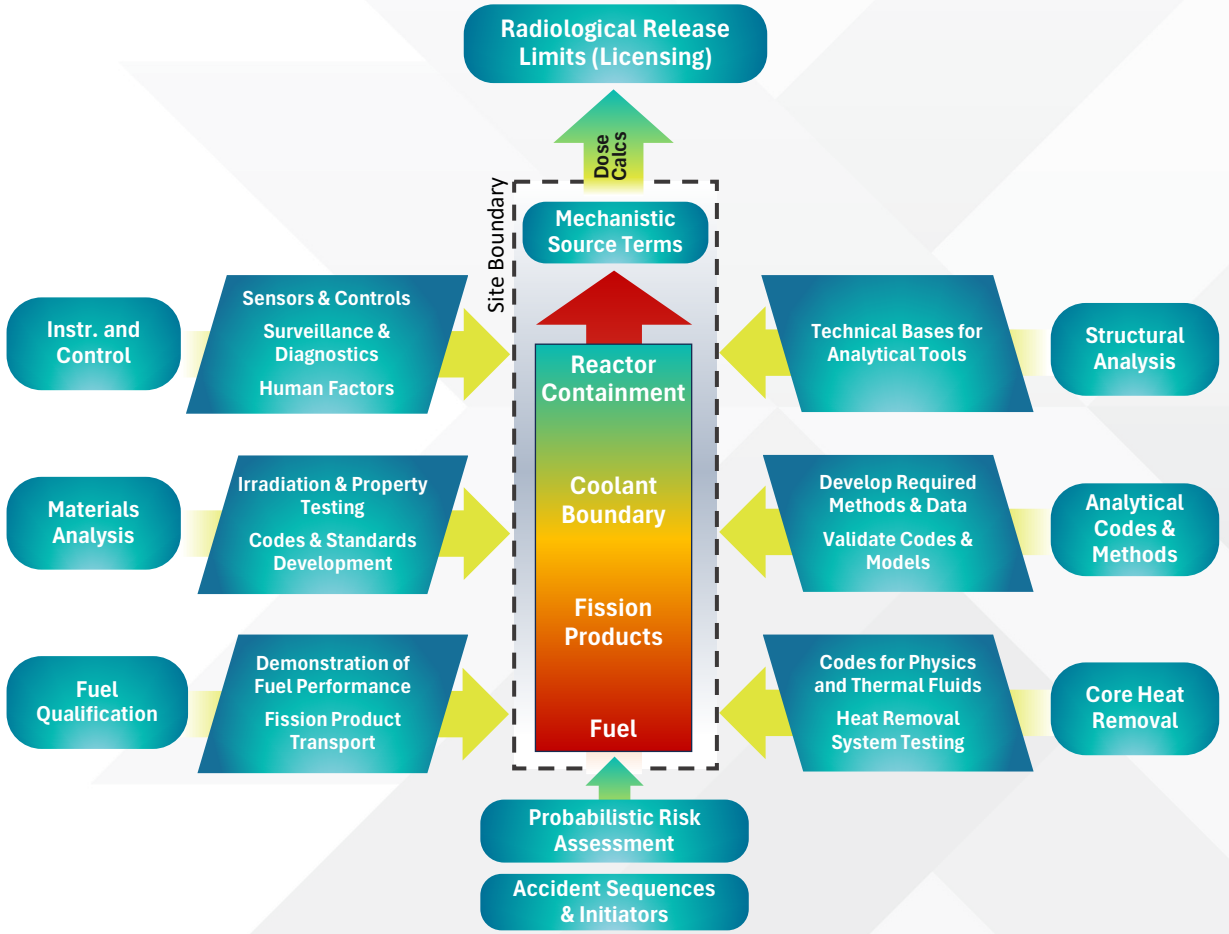
Overview of Licensing Inputs

All advanced reactor deployments will need to develop a design and associated safety case that satisfy regulatory requirements regarding protection of the public.

Multiple and integrated technical inputs are needed (advanced materials, cybersecurity, radionuclide transport analysis, etc.), and rely heavily on Department of Energy (DOE) programs.

Multiple DOE program efforts, including the National Reactor Innovation Center (NRIC) and the Advanced Reactor Regulatory Development Program, seek to help close technical and regulatory gaps that are inherent in the licensing tree depicted above for new advanced technologies.



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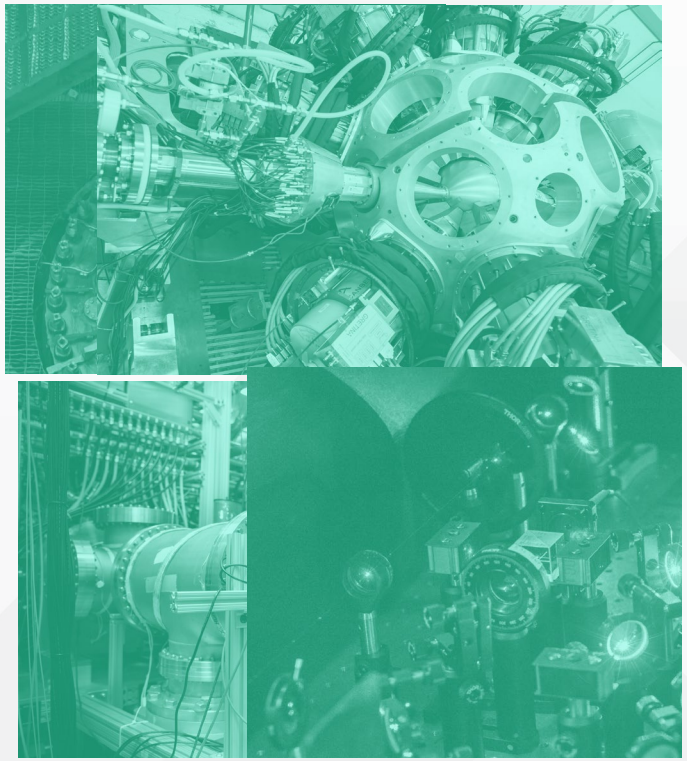
Overview of Regulatory Development Structure

Advanced Reactor Regulatory Development is one part of the DOE's Advanced Reactor Demonstration Program.

- Advanced Reactor Demonstration Projects (ARDP) (funded via DOE's Office of Clean Energy Development [OCED]).
- Risk Reduction for Future Demonstrations
- National Reactor Innovation Center
- Advanced Reactor Regulatory Development
- Advanced Reactor Safeguards

Advanced Reactor Regulatory Development then has four major components:

- Regulatory Framework Modernization
- Fast Reactor Regulatory Development R&D
- Molten Salt Reactor Regulatory Development R&D
- Gas Reactor Regulatory Development R&D



Connections to DOE-NE Mission

DOE NE Mission: Advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs.

Mission Goal # 2: Enable deployment of advanced nuclear reactors.

Objectives:

- Reduce risk and time needed to deploy advanced nuclear technology.
- Develop reactors that expand market opportunities for nuclear energy.
- Support a diversity of designs that improve resource utilization.

Note: Every commercial deployment of an advanced reactor will require regulatory engagement by the developer and the facility's owner/operator(s).

NRC's Implementation Action Plan (IAP)

The Integrated Assessment Program (IAP) is a Nuclear Regulatory Commission (NRC) initiative originated in 2015 to establish a strategy to assure NRC readiness to effectively and efficiently review non-water reactors, including consideration of their fuel cycles and waste forms.

- NRC gathered industry inputs in 2015-2017 to identify and confirm readiness needs
- The IAP was issued in 2017, with 6 major focus areas identified

Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6
Knowledge, Skills and Capability	Computer Codes & Review Tools	Flexible Review Processes	Consensus Codes and Standards	Policy and Key Technical Issues	Communication

DOE-funded programs are focused on strategy areas 2, 3, 4, & 5, and include for example:

- 2 NEAMS Program, ART Program, Microreactor Program
- 3 Non-LWR design criteria, Licensing Modernization Project, TICAP/ARCAP
- 4 ASME Section III Div. 5, Non-LWR PRA Standard, ANS 20.2
- 5 Functional Containment, "right-sized" Emergency Planning, Microreactor policy issues

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Regulatory Framework Modernization Program

Advanced Non-Water Technologies

Regulatory Framework Modernization Program

The Regulatory Framework Modernization within the Regulatory Development subprogram coordinates with the industry and the NRC to address and resolve key regulatory framework issues that directly impact the "critical path" to advanced reactor demonstration and deployment.

This area focuses on risk-informing and adapting ("modernizing") the regulatory framework for commercial reactor facilities, including:

- Resolving Commission policy issue
- Developing adaptations of light water reactor (LWR) based regulations for advanced non-LWRs
- Establishing risk-informed, performance-based NRC license application content and review criteria guidance
- Establishing risk-informed regulatory approaches for key parts of the plant operations phase

These program efforts are focused on achieving formal NRC endorsement or approval, where applicable, to ensure these areas of regulatory uncertainty are clearly resolved.

Note: The identification and prioritization of topics address specific regulatory challenges faced by ARDP Demonstration Project awardees and benefit the broader advanced reactor stakeholder community.

Examples and Outcomes of Completed Program Efforts

Regulatory Framework Modernization Program efforts eliminated regulatory uncertainties in key areas supporting advanced reactor deployments. Key achievements include:

Licensing Modernization Project (LMP) – NRC endorsed in Regulatory Guide 1.233

- Established a risk-informed and performance-based approach to advanced reactor design and licensing

Technology Inclusive Content of Application Project (TICAP) – NRC endorsed in Regulatory Guide 1.253

- Provides guidance to both industry and NRC staff on LMP-based license application content expectations
- Being utilized by the two DOE-ARDP awardees (TerraPower & X-energy) for commercial licensing

Historical DOE experimental databases to used support NRC licensing

- NRC Safety Evaluation approving Argonne National Laboratory QA program to qualify certain EBR-II historical data

DOE R&D program results to used support industry fuel qualification efforts

- NRC Safety Evaluation of EPRI topical report that establishes an accepted foundation for TRISO particle fuel qualification

Examples of Current Framework Modernization Work

Further Development of Risk-Informed and Performance-Based (RIPB) Approach

- Technology Inclusive Risk Informed Change Evaluation (TIRICE): Guidance developed for non-LWRs to evaluate facility changes in accordance with 10 CFR 50.59 for licensees using the Licensing Modernization Project approach.
- Technology Inclusive Management of Safety Case (TIMaSC): Project focuses on integrating various activities associated with risk-informed change management for plants with an LMP-based safety case.

Risk-Informed and Performance-Based Emergency Planning

- Developing a consensus technology-inclusive RIPB approach to establishing the plume exposure EPZ and associated emergency plan.

Hazards

- Developing an approach for the assessment of low frequency external events as part of a RIPB licensing approach.

Liquid Fuel Qualification

- Investigating the MSR-specific NUREG/CR-7299 approach to assess and identify any specific challenges with achieving liquid fuel qualification by addressing the key considerations reflected in NUREG-2246, “Fuel Qualification for Advanced Reactors”.

Sodium Fast Reactor Fire Protection – Industry Standard

- Assist with industry efforts to draft an updated version of ANSI/ANS Standard 54.8 - “Liquid Metal Fire Protection …”

International Collaborations

- Continued GIF-RSWG & International Atomic Energy Agency (IAEA) participation focused primarily on development of advanced reactor safety design approaches and criteria.

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Advanced Reactor Program R&D & Regulatory Connections

Advanced Non-Water Technologies

Fast Reactor Program

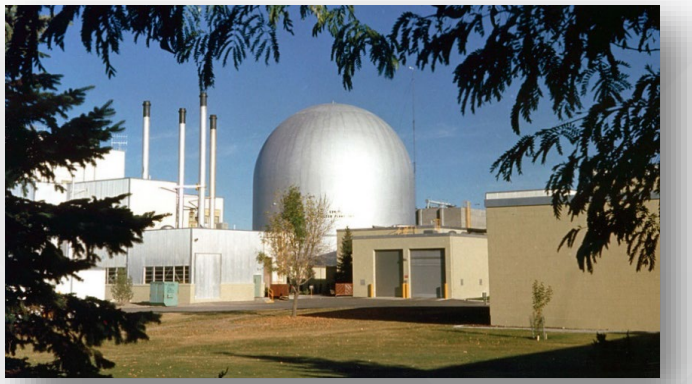
Ongoing research to support licensing

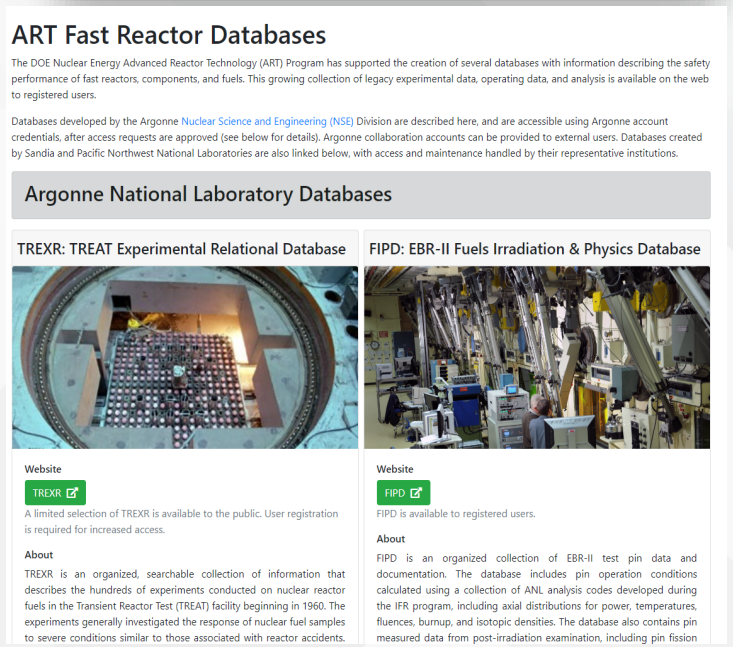
- Archival of rich U.S. fast reactor operation and testing legacy and data from other test facilities in modern web-accessible databases (frdb.ne.anl.gov):
  - EBR-II, FFTF, TREAT, and ZPR databases for fuels irradiation, safety, transients, physics, etc.
  - Out-of-pile transient fuel testing & sodium component reliability database
- Maintenance, quality assurance, continued development, and validation of fast reactor physics and systems/safety analysis software to support their use in fast reactor license applications:
  - SAS4A/SASSYS-1 (system and safety analysis), SRT (source term assessments), SPCA-ANL (sodium fire analysis), ARC suite (reactor physics, depletion, perturbation, coefficients), NUBOW (core bowing)
- Generating mechanical properties to support ASME code case for Alloy 709 for structural material use (submission on schedule for 2026) in nth-of-a-kind advanced reactors.

Current priorities in program's regulatory R&D

- Continued implementation of NRC-accepted quality assurance program plan (QAPP) to qualify legacy fuels data to enable easier commercial grade dedication of data for use in license applications.
- Modern software quality assurance (SQA) practices to support commercial grade dedication of fast reactor software by the vendors.

Experimental Breeder Reactor-II (EBR-II)





Molten Salt Reactor Program- Technical Areas of Strategic R&D

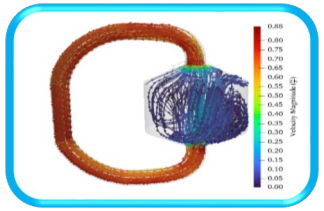
MISSION

Develop the technological foundations to enable MSRs for safe and economical operations while maintain a high level of proliferation resistance.

Technical AREAS

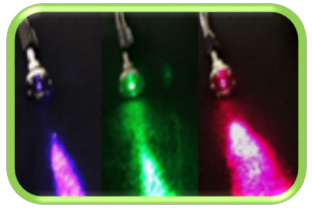
Salt Chemistry

Determination of the Thermophysical and Thermochemical Properties of Molten Salts– Experimentally and Computationally



Modeling and Simulation

Resolve technical gaps in mechanistic source term modeling and simulation tools for radionuclide transport from a molten salt to different regions of an operating MSR plant.

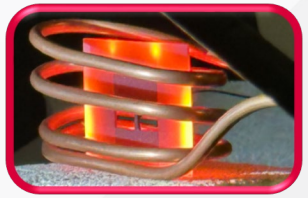


Technology Development

Off-Gas Management Radionuclide Release Monitoring, Sensors & Instrumentation LSTL & FASTR

MSR Radioisotopes

Developing new Technologies to separate Radioisotopes of Interest to the MSR Community



Advanced Materials

Development of Materials Surveillance Technology Graphite/Salt Interaction and Materials/Salt Interaction

Our Participating LABORATORIES

INL Idaho National Laboratory

OAK RIDGE National Laboratory

Argonne NATIONAL LABORATORY

Los Alamos NATIONAL LABORATORY

Pacific Northwest NATIONAL LABORATORY

Sandia National Laboratories

Molten Salt Reactor PROGRAM

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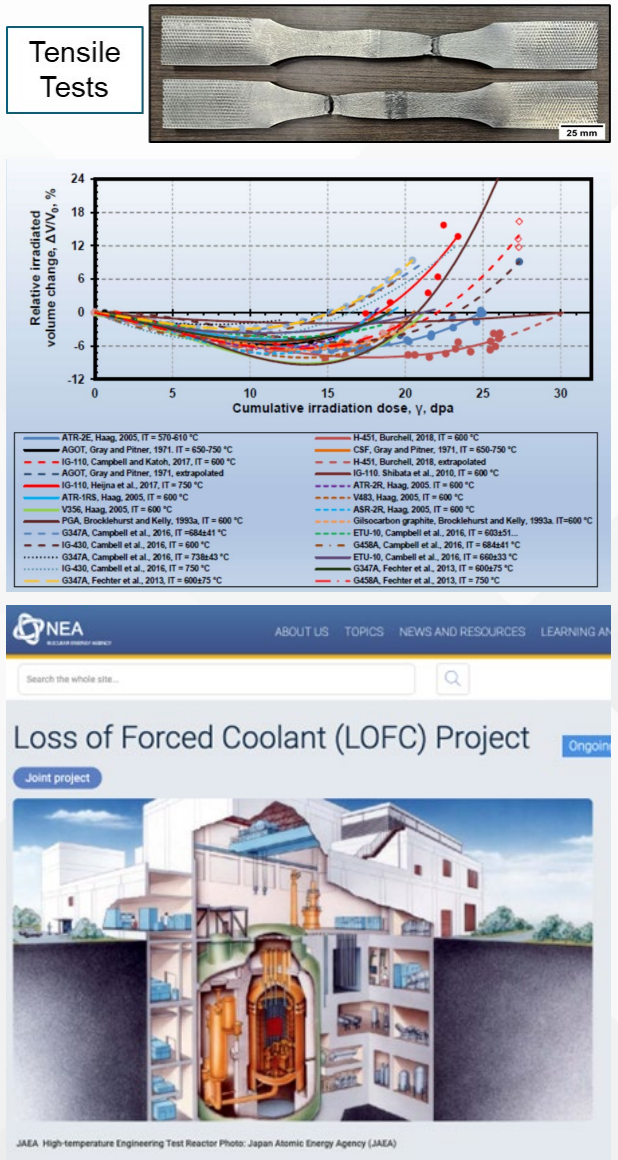
Gas-Cooled Reactor (GCR) Program

Current R&D activities that support industry regulatory engagements

- High-Temperature Metallics and Graphite Qualification
  - Continue the qualification of Alloy 709 for incorporation into the American Society of Mechanical Engineers (ASME) Code.
  - Continue the high-dose graphite (HDG) experiments at INL to provide baseline vs. irradiation performance data for various commercial graphite grades.
  - Develop and implement the design methodology needed for graphite and metals used in Gas-Cooled Reactor (GCR) designs into the ASME Code.
- HTGR Core Simulation and Methods Development & Validation
  - New code capabilities developed in the DOE-NE NEAMS program will be used by the NRC as part of the “BlueCRAB” code suite to assess GCR license submissions.
  - The ART-GCR program validates these codes utilizing several valuable experimental and reactor data sets and international benchmarks, for example:
    - NSTF (ANL): Water- and air-cooled reactor cavity cooling system experiments
    - HTTR (Japan): Loss of Forced Cooling tests demonstrated inherent safety
    - HTR-PM (China): First-criticality physics benchmark
    - HTTR (Japan): Assessment of Tritium release in primary system during operation.
    - ATR (INL): Depletion of AGR TRISO fuel in the Advanced Test Reactor



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Stakeholder Engagement & Coordination

Regulatory Engagement Considerations

DOE program outputs have several connections to industry regulatory engagements – close coordination is critical:

- Currently ongoing NRC licensing reviews (Kairos-Hermes 2, Abilene Christian-NEXT, Terra Power construction permit)
- Design and commercial license application development is underway (incl. DOE ARDP awardees)
- NRC pre-application interactions by various industry advanced reactor technology stakeholders is underway

General types of regulatory engagement directly supported by DOE NE-5 programs:

- Completion of R&D that provides experimental results, data, and validated methods that are reflected in DOE national laboratory reports (OSTI) that can be directly referenced by industry stakeholders in support of their license applications and associated regulatory interactions.
- Completion of R&D and development of associated industry proposals that are submitted to NRC for formal endorsement and can then be utilized by multiple industry stakeholders without additional “up-front” regulatory approach evaluation.

Regulatory Development Support for NRIC and Industry Needs

Regulatory Development obtains inputs from key stakeholders and reports (DOE, NEI/NEA, Developers, NRC, etc.) to prioritize and propose regulatory projects. Examples:

- Participation in NEI New Reactor Regulatory Working Group
- Regulatory topics within EPRI/NEI Advanced Reactor Roadmap – North America
- Participation in DOE advanced reactor technology program reviews

Regulatory development leadership desires additional information to meet the needs of NRIC and NRIC customers

Avenues for stakeholder engagement and input:

- Scott Ferrara, Technical Area Lead, Regulatory Framework Modernization Program
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- Brad Tomer, National Technical Director, NRIC Programs
  Bradley.Tomer@inl.gov / (208) 526-2679

Questions?

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