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Light Water Reactor RD&D: Sustaining the Existing Fleet and Enabling Nuclear Power

August 2021

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Changing the World's Energy Future

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Light Water Reactor RD&D: Sustaining the Existing Fleet and Enabling Nuclear Power

LWRS LIGHT WATER REACTOR SUSTAINABILITY

Alison Hahn

August 1-2, 2021

Needs and Approach

- Need:
  - Enhance the economic competitiveness and performance of the existing fleet of operating light water reactors and enable long term operations.
  - Through existing programs, develop and demonstrate technologies, methods, and approaches to ensure nuclear energy is competitive for electricity generation and non-electrical markets.
  - Establish the basis for future reactor designs and concepts.
- LWRS Program: Research and Development Focus
  - Plant modernization
  - Flexible Plant Operations and Generation
  - Risk-informed systems analysis
  - Materials research
  - Physical Security

Nine Mile Point (Courtesy of Exelon)

LWRS LIGHT WATER REACTOR SUSTAINABILITY

Research Areas

Plant Modernization	Enable plant efficiency improvements through a strategy for long-term modernization
Flexible Plant Operation & Generation	Enable diversification and increase revenue of light water reactors by extracting electrical and thermal energy to produce non-electrical products
Risk Informed System Analysis	Develop safety analysis methods and tools to optimize the safety, reliability, and economics of plants
Materials Research	Understand and predict long-term behavior of materials in nuclear power plants
Physical Security	Develop technologies and the technical bases to optimize physical security postures

Approach: Industry engagement

Industry Engagement

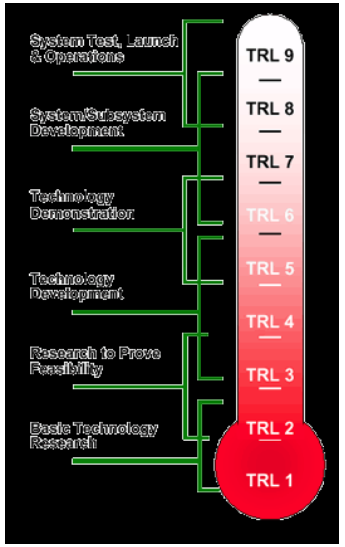
Develop private-public partnerships to define and sponsor research projects that will collectively enable significant plant performance gains and minimize operating costs as part of the larger national effort to ensure long-term sustainability of the LWR fleet.

Engage – Collaborate with stakeholders to identify critical challenges faced by the nuclear industry and develop targeted research plans to address those challenges

Develop – Create high impact technology modernization solutions that support optimized long-term operational performance. (Low TRL)

Demonstrate – Demonstrate effectiveness of research solutions by conducting collaborative research with LWR stakeholders. (Medium TRL)

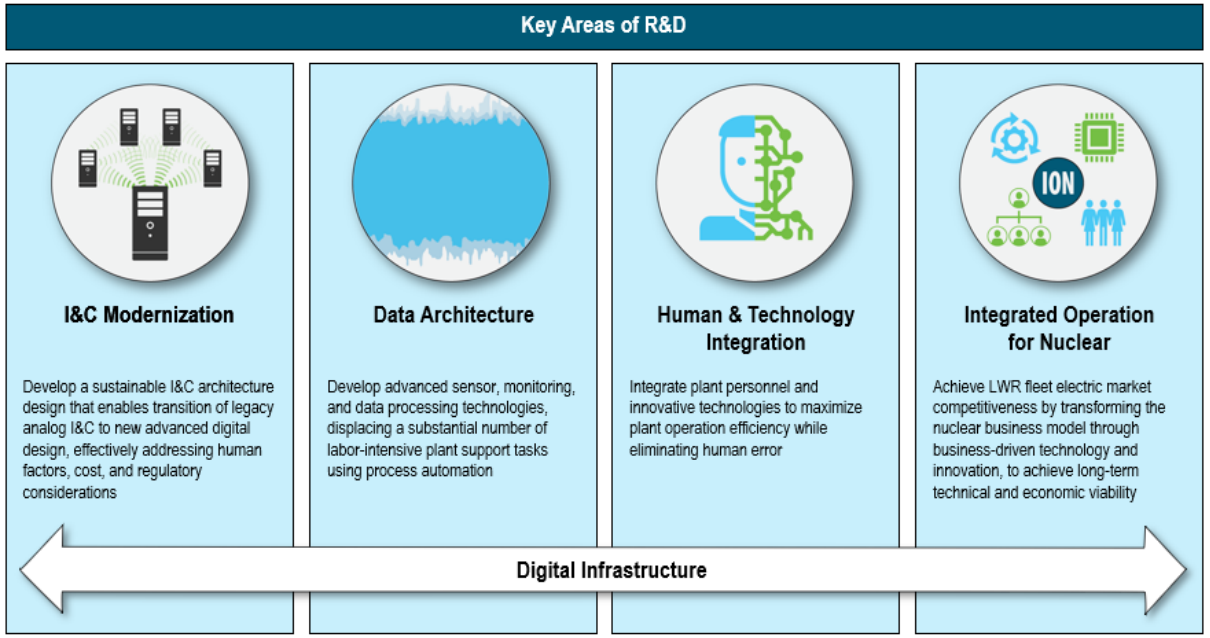
Deploy - Enable broad deployment and use of technical capabilities by stakeholders (High TRL)



Xcel Energy · Exelon · Energy Northwest · USA Utilities Service Alliance · aps · NextEra · Dominion Energy · Southern Company · Duke Energy · TVA · STP Nuclear Operating Company · energy harbor · EPRI Electric Power Research Institute · PG&E · SCANA · INPO · HRP · Entergy · NEI Nuclear Energy Institute · Luminant · KAERI Korea Atomic Energy Research Institute

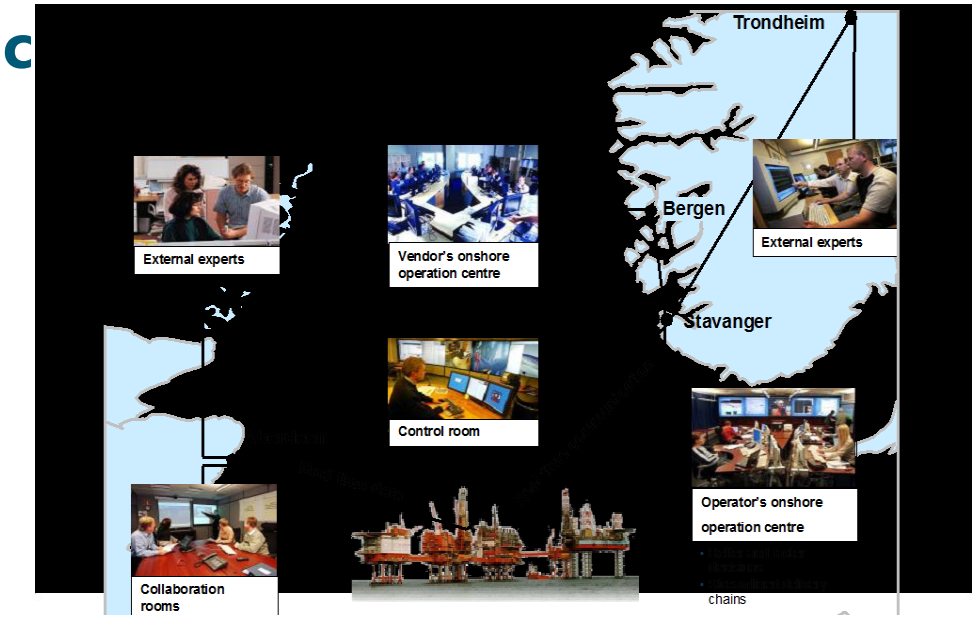
Plant Modernization to Enhance Economic Performance

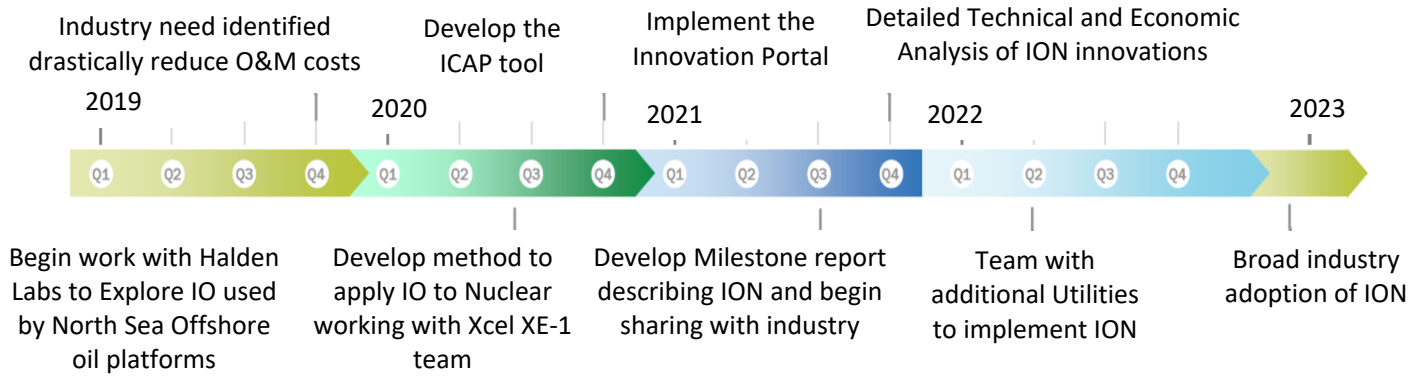
- Need: Extend life and Improve performance of existing fleet through modernized technologies and processes for plant operation and power generation
- Approach – Develop Technologies and demonstrate results to significantly reduce the technical, financial, and regulatory risk of modernization
- Research Focuses on:
  - Digital technologies that enable modernization
  - Studies to enable the transition from current to future
  - End State Requirements Studies
  - Cost Benefit Studies
  - Technical Bases Studies
  - Implementation Recommendations & Lessons Learned
- Experience & Capabilities
  - Effective engagement with nuclear power industry
  - Coordinating industry efforts to achieve greatest impact



Integrated Operations for Nuc

- **Strategy:** Integrate people, disciplines, organizations, and work processes supported by digital information
- **Approach:** LWRS research adapted the Integrated Operation concept and applied it to nuclear with a goal of reducing O&M costs by one third
- **Outcomes:** Implementing IO to fleet, and exploring opportunities with other utilities, suppliers and stakeholders

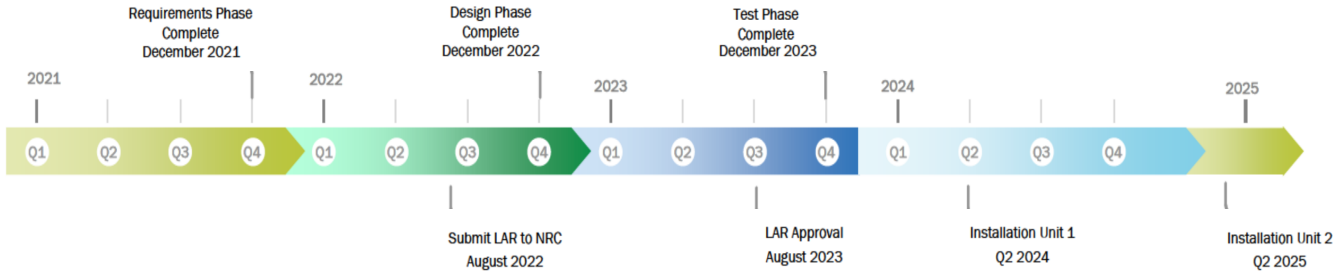




LWRS Researchers are piloting Integrated Operations concepts at Xcel Energy to evaluate how the IO concept will enable lower operating costs.

Safety System Upgrade

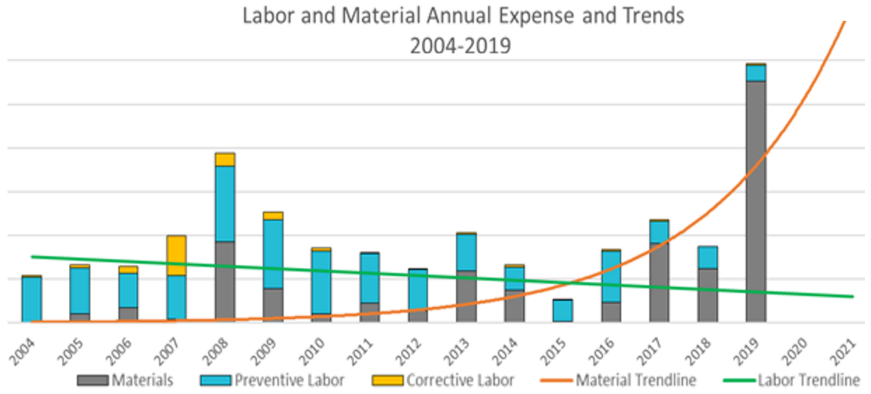
- **Scope:** First echelon safety I&C systems on two units
- **Timeline:**



Limerick Generating Station

- **Outcomes:** 2020 - Project conceptual design effort approved
  - Design Concept, LAR Framework, and Business Case Methodology made publicly available
  - Costs to sustain current systems are rising

  2021 – LAR Pre-submittal meetings with NRC



Deliver products Beyond Electricity Markets

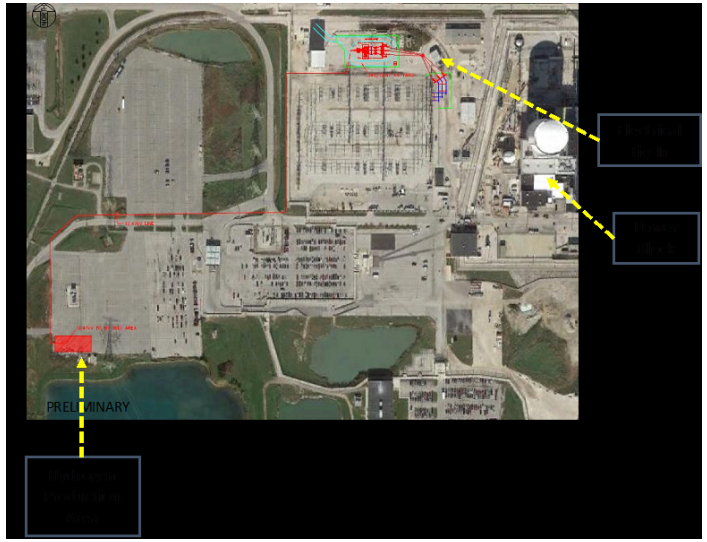
- Goal: Operation of an LWR to produce non-electrical products by 2025-2030 :
- Needs:
  1. **Technical & Economic Assessments** that evaluate FPOG market opportunities
  2. **Front-End Engineering and Design, Demonstration, and Deployment**
  3. **Probabilistic Risk Assessment and Possible License Approaches**
  4. **Stakeholder Engagement,** including nuclear power plant owners, energy conversion technology providers, energy users of energy currencies.
- FOA awards, CRADAs
  - FOA awards; **Energy Harbor, Xcel Energy, Exelon, APS**
  - Bloom Energy CRADA.
  - FuelCell Energy, Haldor-Topsoe, OxEon, Nexceris electrolysis stack testing

Increase the value of nuclear power plants by developing approaches for hybrid plant operations.

energy harbor

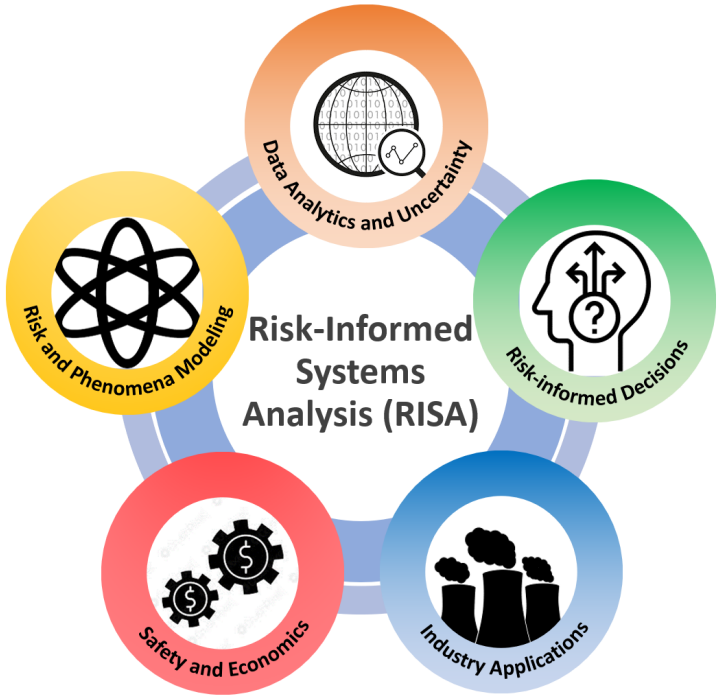
Xcel Energy

aps



Risk-Informed Systems Analysis (RISA)

- **Need:**
  - Optimize safety margins and minimize uncertainties to achieve economic efficiencies while maintaining high levels of safety
- **Approach** Provide scientific basis to better represent safety margins and factors that contribute to cost and safety
  - Develop new technologies that reduce operating costs



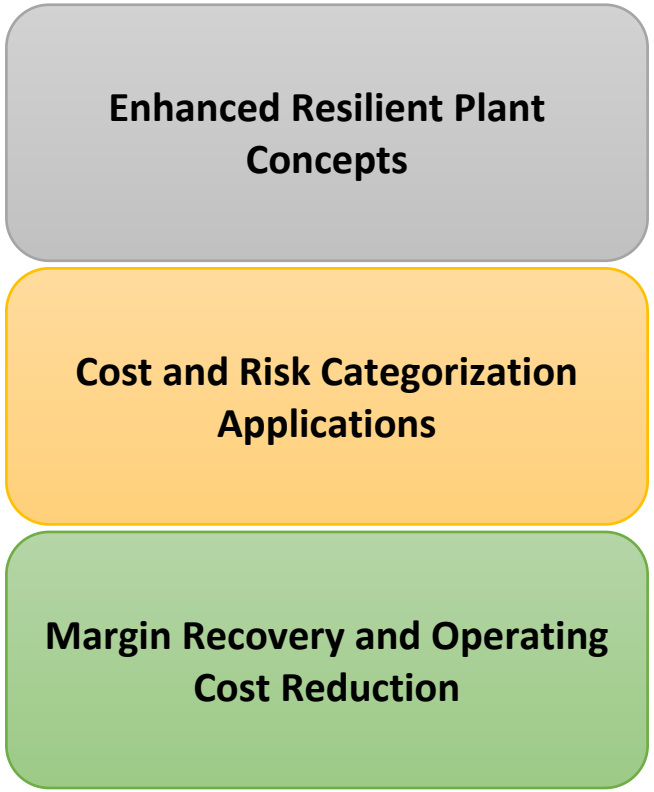
RISA Framework

Enhanced Resilient Plant Concepts	*Enhanced NPP resiliency against catastrophic events with supplemental cost savings*
Cost and Risk Categorization Applications	*Cost savings due to optimized plant health and asset management*
Margin Recovery and Operating Cost Reduction	*Cost savings due to increased safety margin, increased efficiencies, and optimized operations*

RISA Focus Areas

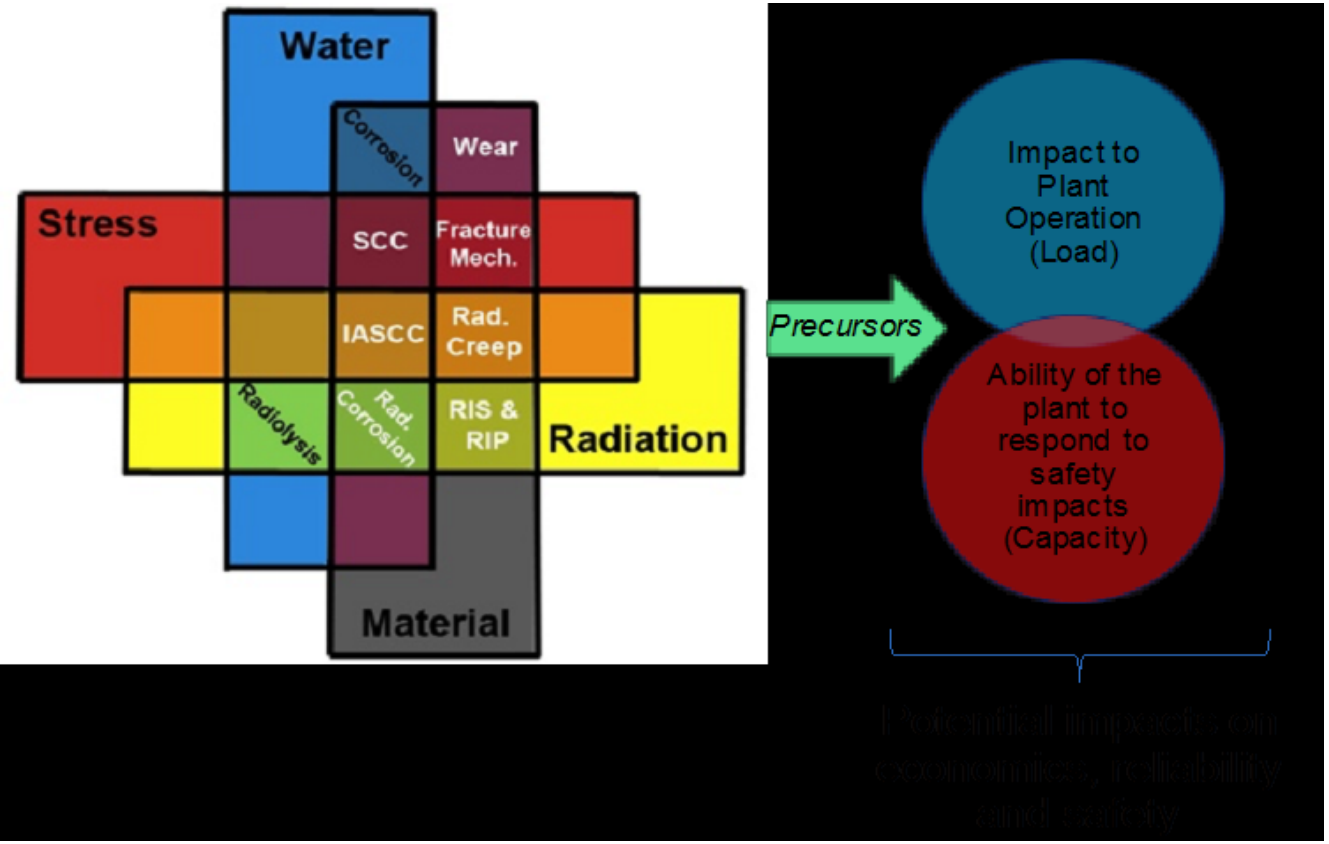
Collaborative R&D to enhance efficiency

- RISA Projects
  - Enhanced Resilient Plant Systems
  - Enhanced Operation Strategies for System Components
  - Plant Health Management
  - Risk-Informed Asset Management
  - Enhanced Fire Probabilistic Risk Assessment (PRA)
  - Digital Instrumentation and Control (I&C) Risk Assessment
  - Plant Reload Process Optimization



LWRS LIGHT WATER REACTOR SUSTAINABILITY

Materials Research



Materials in Extreme Environments

- **Need:** technical basis to understand and predict long-term environmental degradation behavior of materials in nuclear power plants
- Approach: Provide data and methods to assess performance of systems, structures, and components essential to safe and economically sustainable nuclear power plant operations.

Collaborative R&D Areas

Transition Temperature Shift Model, is being developed for evaluating RPVs at extended operation

Achievement

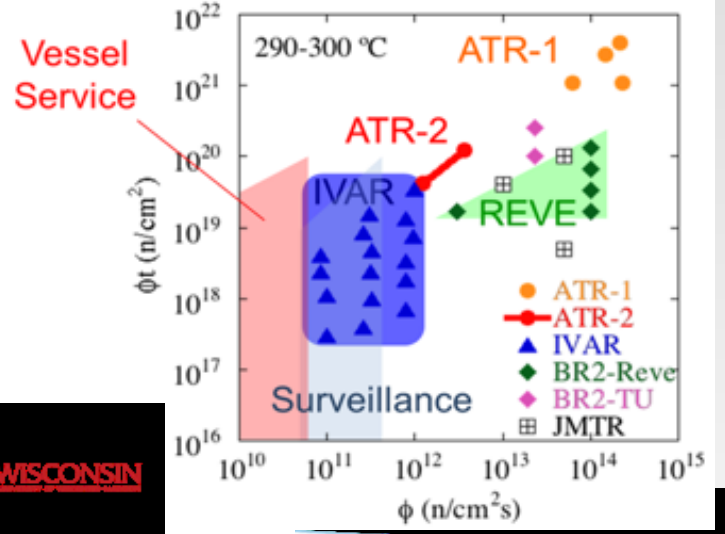
- **UCSB-led ATR-2** experiment results **bridge test reactor and surveillance capsule databases** for insight into the effects of **low flux and high fluence** on reactor pressure vessels (RPVs).
- A **new reduced order model** that includes **Ni-Mn-Si precipitate formation at high fluence** will be used to predict extended reactor pressure vessel life

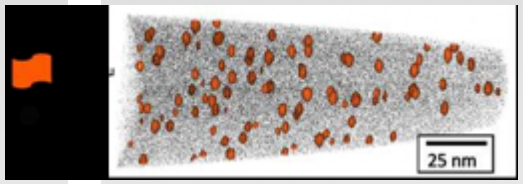
Research details

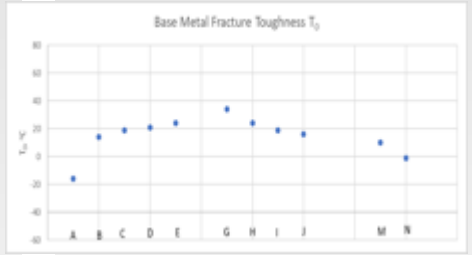
- Materials provided by **Westinghouse, EPRI, Bettis, CRIEPI**, Pressurized Water Reactor Owners Group (**PWROG), ORNL, and Rolls Royce**.
- Results of testing **decommissioned Zion RPV material** (**first in US history**) and **high-fluence surveillance capsule materials** will be used **to validate the model**.

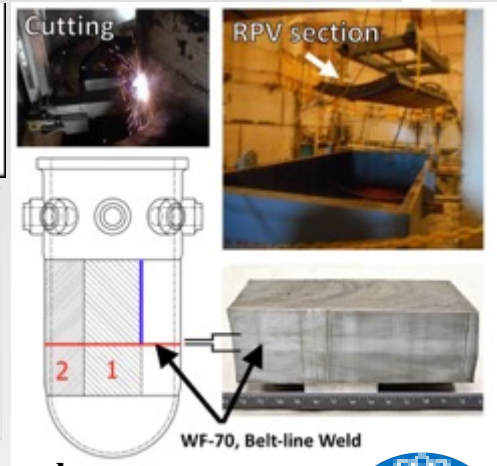
Significance and impact

- **Addressing issues with existing regulatory models that under predict the RPV embrittlement** at high fluence
- Expected outcome: a **critical aging management tool for extended operating life of existing US LWR fleet when implemented into codes (E-900) and regulatory gu**

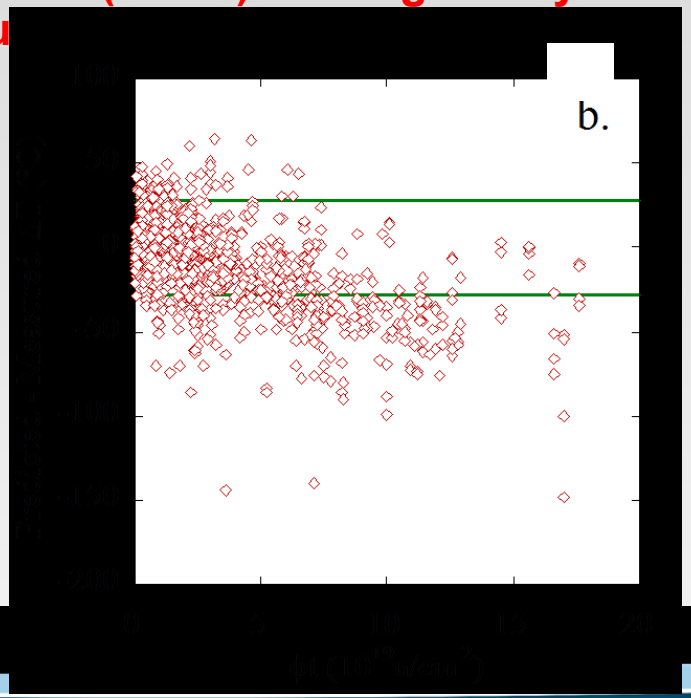








Distribution of the fracture toughness



Enhance Approaches to Ensure Physical Security

Need: tools, technologies, and risk-informed approaches to physical security to enhance approaches to ensure physical security at nuclear power plants

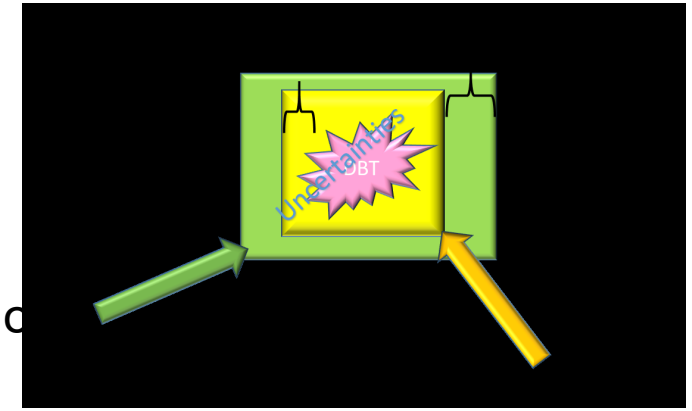
Approach:

- Developing mitigation strategies and the technical basis necessary for industry stakeholders to enhance approaches to achieve physical security, meeting all regulatory requirements.
- Create new technologies, methods, and tools to optimize physical security at U.S. nuclear power plants that address design basis threat and regulatory requirements.

Main research areas:

- Advanced Security Technologies
- Risk-Inform Methods for Physical Security
- Advanced Security Sensors

Near-term goal is to enable industry to operate ne ents c



Sustaining National Nuclear Assets

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