U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

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Light Water Reactor Sustainability (LWRS) FY 2019 CINR Webinar: RC-8,9,10

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Alison Hahn

Program Manager
Light Water Reactor Sustainability

Light Water Reactor Sustainability

- **Goal**
  - Enhance the safe, efficient, and economical performance of our nation's nuclear fleet and extend the operating lifetimes of this reliable source of electricity

- **Objectives**
  - Enable long term operation of the existing nuclear power plants
  - Deploy innovative approaches to improve economics and economic competitiveness of LWRs in the near term and in future energy markets.
  - Sustain safety, improve reliability, enhance economics

- **Focus Areas**
  - Materials Research
  - Plant Modernization Research and Development
  - Risk-Informed Systems Analysis

Nine Mile Point ~ Courtesy Exelon

Technical Focus Areas

- **Nuclear Materials** – Understand and predict long-term environmental degradation behavior of materials in nuclear power plants, including detecting, characterizing, and mitigating aging degradation

- **Plant Modernization** – Address long-term aging of legacy instrumentation and control technologies through their modernization and replacement and develop advanced condition monitoring technologies for more automated and reliable plant operation

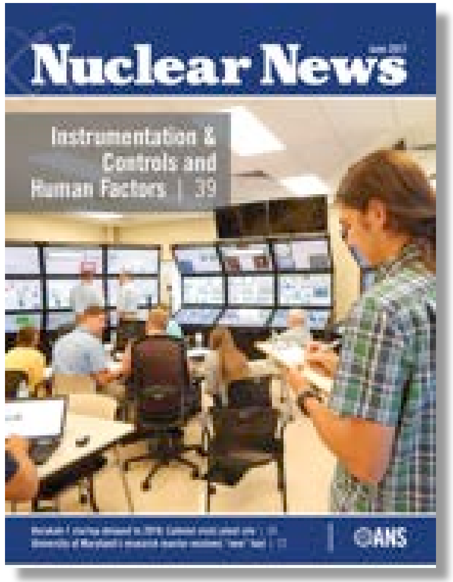
- **Risk-Informed Systems Analysis** – Couple risk-assessment methods and safety margin quantification to provide a more accurate representation and recover margins for the long-term benefit of nuclear assets

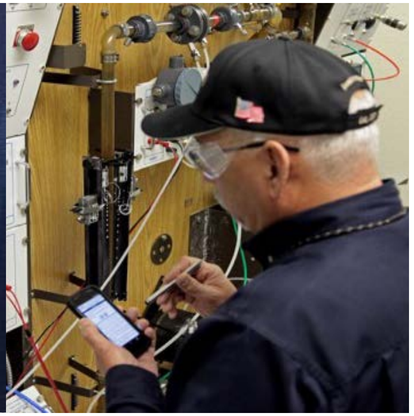
- **Systems Analysis and Emerging Issues** – Address high impact emerging issues such as flexible operations and chemistry control

Plant Modernization Research & Development

Addressing long-term aging and reliability concerns of existing II&C technologies and enabling plant efficiency improvements

- Establish a strategy to implement long-term modernization of II&C systems
- Develop, test, and deploy advanced technologies
- Promulgate technologies, lessons learned, and foster industry standardization
- Reduce technical, financial, and regulatory risks
- Develop advanced condition monitoring technologies to monitor, detect, and characterize aging and degradation processes





CINR Workscope: RC-8

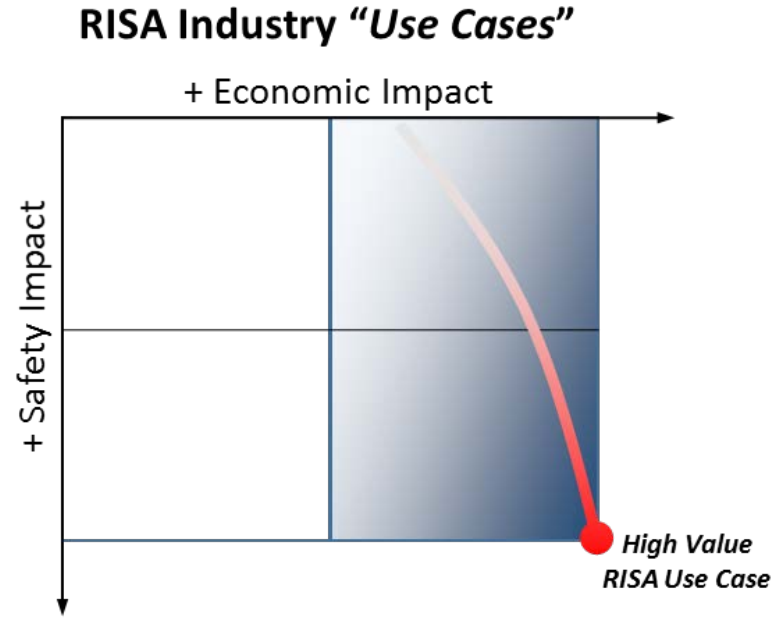
- Digital Instrumentation and Control Qualification
  - Elimination of Common Cause Failures
    - Testability – Determine and approach to perform 100% exhaustive testing to ensure no digital defects
    - Elimination of CCF Triggers - Develop an approach that would ensure latent digital defects are not concurrently triggered

- Analytics to Support Equipment Condition Monitoring
  - Automate data collection & analytic based decision making using novel:
    - Sensors
    - Automation technologies
    - Data analysis methodologies
  - Results should help to drive down costs of maintenance and enable risk informed maintenance programs

Risk-Informed Systems Analysis (RISA)

- **Mission**
  – To inform plant margin management decisions with focus on improved economics, reliability, while sustaining high levels of safety of current NPPs

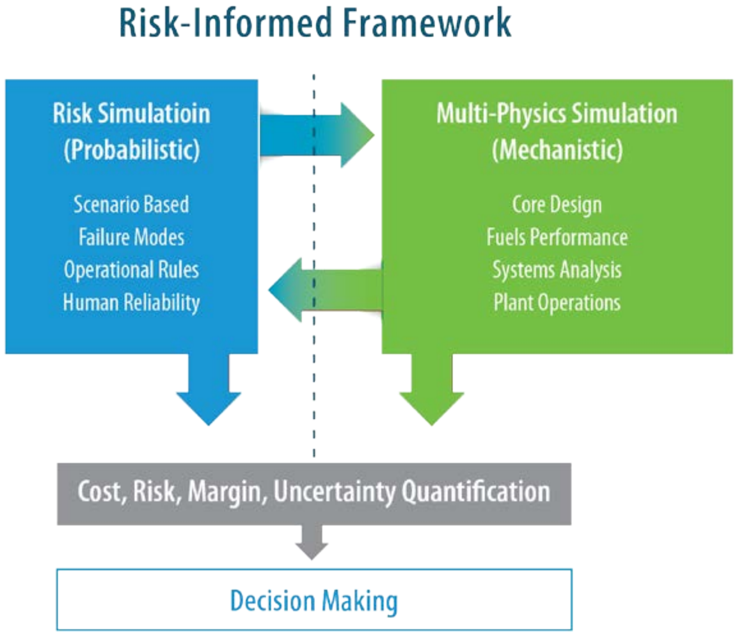
- **Goals**
  1. To demonstrate a risk-assessment method coupled to safety margin quantification that can be used by decision makers as part of their margin recovery strategies
  2. To apply the "RISA toolkit" to enable more accurate representation of margins for the long term benefit of nuclear plants (e.g., reduce conservatisms, increase realism).



- **Strategy:**
  - Develop and demonstrate industry applications (RISA pilot projects) in collaboration with the nuclear industry;
  - Align demonstrations with existing RISA methods and tools capabilities;
  - Use demonstrations to resolve gaps, increase confidence in use through validation and maturing RISA methodology

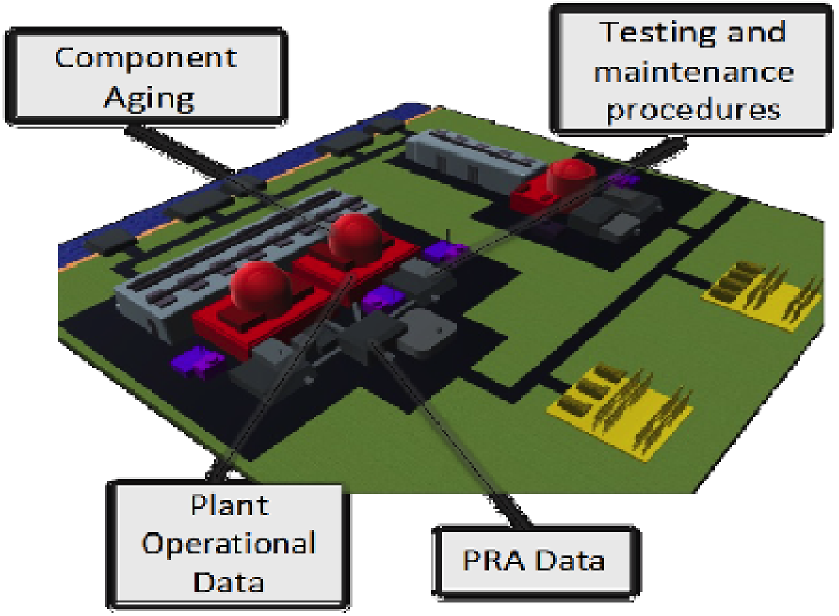
CINR Workscope: RC-9.1

- Use of Integrated PRA and Mechanistic Tools to Accelerate Deployment of Advanced Technologies to LWRs
  - Objective:
    - Use of advanced computational tools to optimize economic performance of the existing nuclear fleet
    - Advanced modeling and simulation tools can play an important role to accelerate the deployment of enhanced operational strategies
  - Strategy:
    - Use of a risk-informed framework, integrating risk simulation (PRA tools and methods) and multi-physics, multi-scale simulation (deterministic analysis)
    - Combining enhanced operational strategies
  - Examples of enhanced operational strategies / new technologies:
    - accident tolerant fuel
    - increased enrichment and fuel discharge burnup
    - fuel cycle length extension
    - FLEX equipment
    - flexible operations
    - passive cooling
    - digital instrumentation and control upgrades
    - applications other than electricity generation



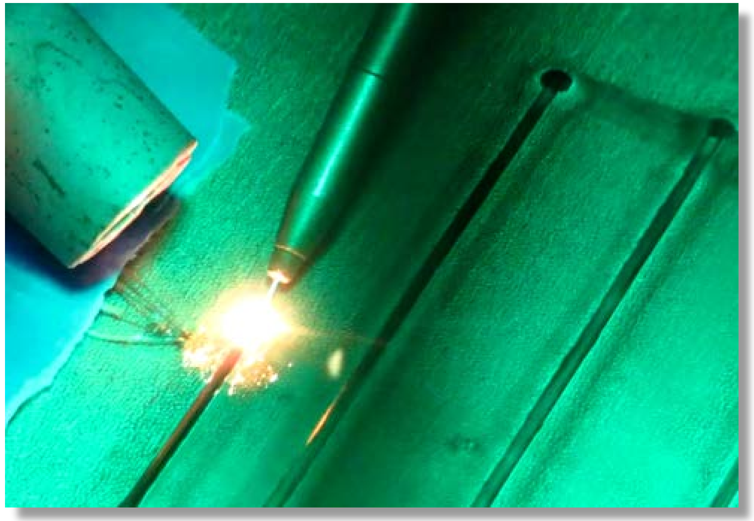
CINR Workscope: RC-9.2

- Risk-Informed Asset Life Cycle Management And Maintenance Optimization
  - Objective:
    - Use of risk assessment methods to reduce costs and manage plant financial risk
  - Strategy:
    - Risk-Informed Systems Analysis uses a variety of tools, methods and data to inform equipment performance management
  - Asset and maintenance management categories:
    - System Structure and Components (SSCs) aging
    - Test and maintenance data
    - Long term capital asset management



Materials Research

- Develop predictive model for RPV embrittlement validated through experimental, surveillance and ex-service materials
- Understanding mechanisms of IASCC failure and SCC initiation of SS and Ni-base alloys – predict and develop mitigation strategies
- Produce a fully coupled thermo-hydro-mechanical-chemical model for reliably predicting the performance of concrete structures
- Understand cable degradation modes, predict performance and evaluate rejuvenation strategies
- Establish condition monitoring techniques for cables and concrete structures
- Development of advanced alloys
- Development of procedures, techniques and computational modeling for advance weld repair

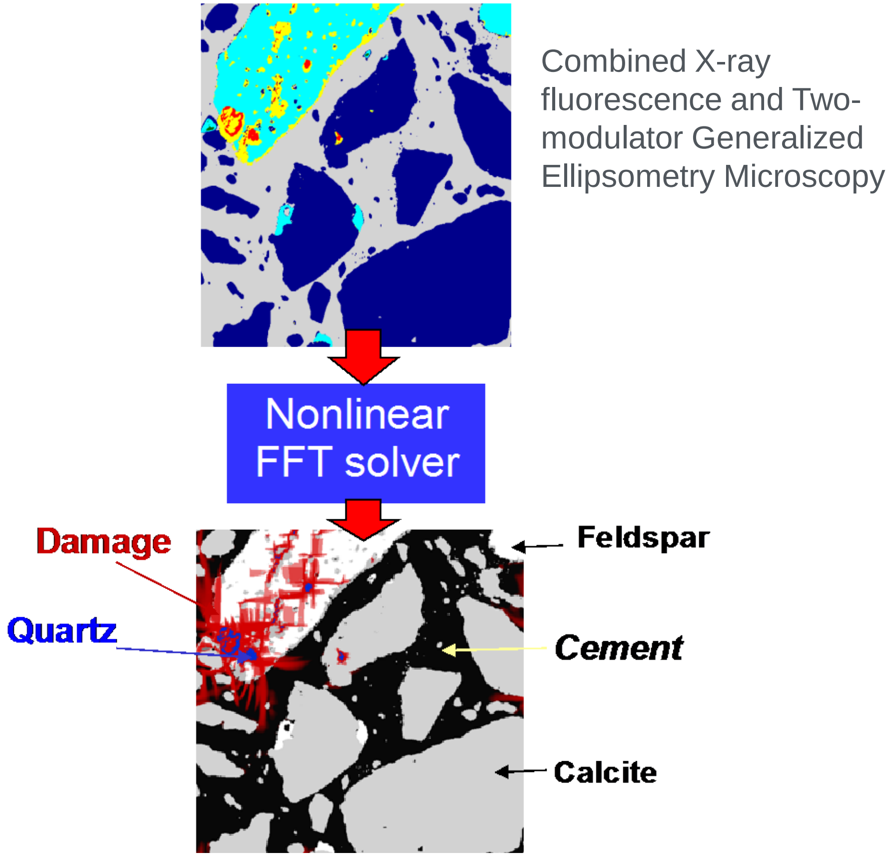


Laser welding/ cladding technology development

CINR Workscope: RC-10.1

- Rapid, multi-modal characterization of concrete's degradation tolerance in support of second license renewals of nuclear power plants
  - Concrete's tolerance to environmental degradation is dependent on the degradation of its aggregate constituents.
  - This proposal looks to develop new science-based, rapid characterization methods that exploit multi-modal imaging, compositional analysis and related methods to assess tolerance of concrete towards degradation.
  - Degradation modes of relevance include (but not limited to): irradiation damage resistance and chemical inertness at super-ambient temperatures in the presence of moisture.
  - Researchers are encouraged to integrate their pioneering experimental analysis with the integrated computational materials engineering software, MOSAIC (Microstructure-Orientated Scientific Analysis of Irradiated Concrete) tool being developed by the DOE – LWRS Program.

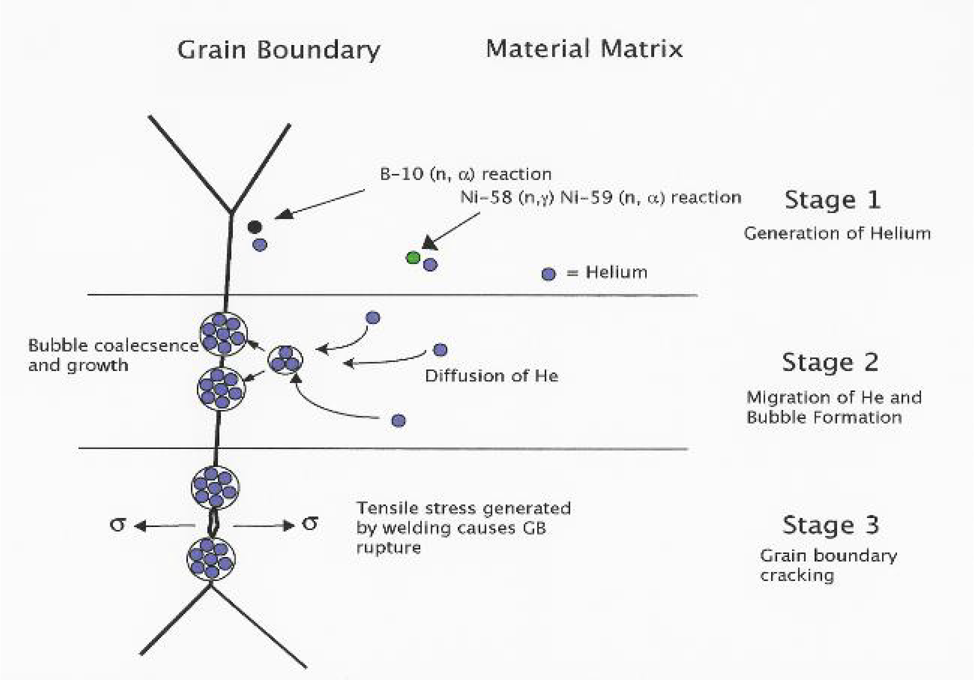
MOSAIC

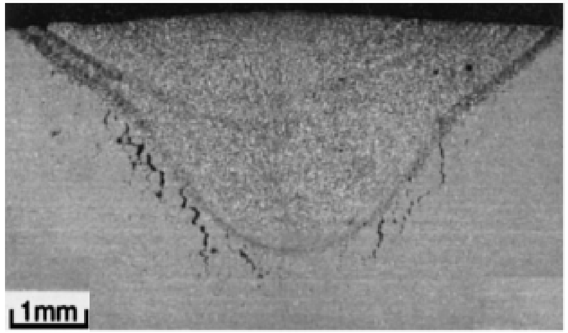


Simulated irradiation damage

CINR Workscope: RC-10.2

- Modeling of helium bubble development during welding of irradiated metal alloys
  - Welding is commonly used during repair and upgrades of nuclear components.
  - Helium induced cracking in the heat affected zone of welds can be a problem with irradiated materials and may become a more severe issue as reactors components further age.
  - Proposals are sought for a comprehensive model of helium bubble growth on grain boundaries for a given material condition (type, microstructure, reactor aging condition) and heat input (welding technique).
  - Model should account for transient high temperature stresses generated during welding and grain boundary cohesivity, to provide industry with a clear evaluation of what weld techniques and parameters should be considered in the repair of reactor components.
  - Supports activities in the DOE-LWRS program on weld development techniques for highly irradiated materials.





Helium-induced cracks in the HAZ after welding stainless steel containing 8.3 appm He.

From: K. Asano, et al. Journal of Nuclear Materials, 264, 1 – 9 (1999)

Questions?

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