U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Energy University Programs (NEUP) Fiscal Year (FY) 2016 Annual Planning Webinar

Light Water Reactor Sustainability (LWRS) Program

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Light Water Reactor Sustainability (LWRS) Program

Program Goal

- Develop fundamental scientific basis to allow continued long-term safe operation of existing LWRs (beyond 60 years) and their long-term economic viability

Developing technologies and other solutions to

- Enable long term operation of the existing nuclear power plants
- Improve reliability
- Sustain safety

Focus areas

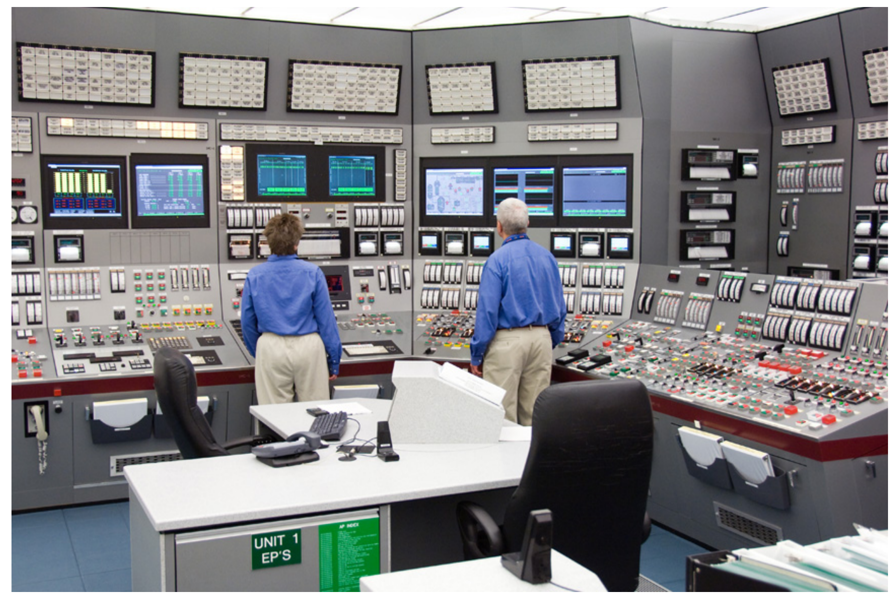
- Materials Aging and Degradation
- Advanced Instrumentation, Information and Controls Technologies
- Risk-Informed Safety Margin Characterization
- Reactor Safety Technologies

Materials Aging and Degradation

- **Metals: including Reactor Pressure Vessels, core internals, steam generators, piping and balance of plant components**
  - Irradiation-Assisted Stress Corrosion Cracking
  - High-fluence phase transformations and swelling of core internals
  - High-fluence effects on RPV steel
  - Crack initiation in Nickel based alloys
  - Thermal Aging of Cast Austenitic Stainless Steels
  - Environmentally Assisted Fatigue
- **Concrete: Joint research plan with EPRI focused on radiation effects (supports and biological shield) and monitoring tools**
- **Cables: Joint research plan with EPRI and NRC to better predict and monitor cable aging**
- **Mitigation, repair, and replacement technologies: Weld repair techniques; Post irradiation annealing; Advanced replacement alloys; and Advanced Non-Destructive Examination techniques**

Advanced Instrumentation, Information, and Control (II&C) Systems Technologies

- **Address long-term aging and reliability concerns of existing II&C technologies and develop and test new technologies**
- **Establish a strategy to implement long-term modernization of II&C systems.**
- **Develop the scientific and technical bases to support safe and efficient plant II&C modernization.**



Risk-Informed Safety Margin Characterization (RISMC)

- **Margins Analysis Techniques**
  - Develop techniques to conduct margins analysis, including methodology for carrying out simulation-based studies of safety margin
- **Simulation components of the RISMC Toolkit**
  - RELAP-7
    - Systems code that will simulate thermal-hydraulics behavior at the plant level
    - Advanced computational tools and techniques to allow faster and more accurate analysis
  - Simulation Controller (RAVEN – Risk Analysis Virtual ENvironment)
    - Provides input on plant state to RELAP-7 (including operator actions, component states, etc.)
    - Integrates output from RELAP-7 with other considerations (e.g., probabilistic and procedures information) to determine component states
  - Aging Simulation (Grizzly)
    - Component aging and damage evolution will be modeled in separate modules that will couple to RELAP-7 and RAVEN

Reactor Safety Technologies

- **Fukushima Daiichi Lessons Learned**
  - Address the impacts of the Fukushima Daiichi accident on current plants with a focus on enhancing the accident tolerant characteristics of the reactors
- **Technical focus areas**
  - Address long-term core cooling concerns during potential station blackout scenarios
  - Help inform revisions to Severe Accident Management guidelines (SAMGs) by understanding severe accident modeling uncertainties
  - Collaborate with the Japanese in planning for the forensic activities at Fukushima

NEET NSUF 1.1: Materials Irradiations in support of LWRS

1.1a: Targeted irradiations of LWR core internals

- Support research on irradiation induced phase transformations of materials used in core internal, such as 316 stainless steel.
- Under irradiation, large concentrations of radiation-induced defects will diffuse to defect sinks such as grain boundaries and free surfaces.
- This can lead to coupled-diffusion with particular atoms.
- This results in Radiation-Induced Segregation (RIS) of elements within the steel.
- Proposals are sought for irradiation and post-irradiation examination of LWRS core internal materials to provide validation data for phase transformation models under development in the LWRS program.

NEET NSUF 1.1: Materials Irradiations in support of LWRS

1.1b: Gamma irradiation of LWR cables

- **Support research on aging related cable degradation in nuclear power plant environments.**
- **The insulation of Low and Medium voltage electric cables undergo aging due to a combination of factors such as temperature, radiation, moisture, vibration, chemical exposure, mechanical stress and the presents of oxygen.**
- **Proposals are sought to expose cables in the HFIR gamma irradiation facility followed by examinations to support the determinations of remaining useful life of cables.**

NEET NSUF 1.1: Materials Irradiations in support of LWRS

<u>1.1c: Irradiation of LWR weld meterial</u>

- Support the development of weld repair technologies for highly irradiated materials such as core internals.
- In a collaborative program with EPRI, advanced welding technologies are under development for highly irradiated materials that avoid helium-induced cracking.
- These weld repairs must be resistant to long-term degradation mechanisms.
- Demonstration of the long-term performance of these weld repairs is required before they can be used by industry.
- Proposals are sought for the examination of materials both pre- and post- irradiation as well as both pre- and post- welding.

Materials Aging and Degradation research (RC-4)

- **Materials and components under extended service conditions may see very long lifetimes under stress, temperature, corrosive coolant, and/or neutron or gamma radiation fields.**
- **The Expanded Materials Degradation Assessment (EMDA), NUREG-CR-7153, identified potential knowledge gaps.**
- **The LWRS program addresses a number of knowledge gaps, but some important issues are not being addressed. Therefore, research proposals are desired to address these gaps, specifically in the following areas:**
  - Effect of irradiation on fracture toughness, irradiation creep, swelling, and stress corrosion cracking (SCC) for Type 308/309 Stainless Steel (SS) weldments;
  - SCC susceptibility at very long lifetimes for 304, 316, and 308/309 weldments, particularly in Boiling Water Reactor (BWR) normal water chemistry (NWC) environments;
  - Potential impact of poor water chemistry control in service water on crevice corrosion, pitting, and microbial-induced corrosion for 304, 317, and 308/309 SS weldments;
  - Potential impact of thermal embrittlement on low-alloy steel reactor pressure vessel components and dissimilar metal weldments;
  - Creep-crack interaction in concrete structures due to structure modification or changes in loading; and
  - Mechanistic understanding of the effects of long-term wetting on low and medium voltage cable insulation.

II&C: Signal processing to detect component degradation (RC-5)

- **Improved methods to detect and character the degradation of passive components operating in nuclear power plant environments is desired.**
- **Proposals are sought to develop advanced signal processing capabilities related to active or passive sensors.**
- **In particular, capabilities related to alkali-silica reactions in concrete as well as flow assisted corrosion are desired.**
- **A flow assisted corrosion test rig and sensor network is under development at INL.**
- **Desired outcomes include the development of:**
  - Structural modeling framework
  - Diagnostic indicators, and
  - Prognostic parameters

Reactor Safety Technologies: Modeling of an extended loss of coolant accident (RC-6)

- **Observations from the Fukushima accident indicate there may be alternative strategies to better address extended station blackout scenarios.**
- **Additionally, the recent industry initiative to implement FLEX equipment and research on the potential use of accident tolerant fuels will also impact potential plant response to stations blackouts.**
- **Plant simulation studies, using advanced modeling codes and techniques are desired for station blackout scenarios, that can address code uncertainties and help evaluate the effectiveness of:**
  - FLEX equipment
  - Alternative operation strategies for passive heat removal systems
  - Alternative fuel designs

RISMC: Validation of RELAP-7 (RC-7)

- **The LWRS program is developing the RELAP-7 code, a next generation thermal-hydraulics plant simulation tool based on the Multiphysics Object Oriented Simulation Environment (MOOSE) capabilities.**
- **The complexity of these new models and associated computation methods present significant challenges for code validation.**
- **However, some level of code validation is required before these codes can be provided to industry where additional code validation work is expected.**
- **Proposals are sought in the following areas:**
  - a survey of available data and data gaps (building on reports generated by the LWRS Program and the LWRS Program partner, EPRI),
  - acquisition of new validation data from existing facilities,
  - synthesis of the data into a form that can be used in RELAP-7, and validation of RELAP-7 models against existing data,
  - acquisition of new validation data from new facilities and experiments, and
  - identification of additional experiments needed if any.

IRP-RC-1: Validation of Advanced Computer Models

- **The complexity of advanced simulation codes presents a challenge for traditional code verification and validation (V&V) methods.**
- **Multiple simulation codes may be coupled together and address different "scales" ranging from whole facilities down to atomistic scale physics.**
- **However, extensive V&V is required for use by the nuclear industry.**
- **This Integrated Research Project (IRP) seeks the development of novel methodologies for V&V suitable for advanced computer models and the application of this methodology to the codes in the RISMC toolkit, which include:**
  - NEUTRINO (plant flooding model)
  - MASTODON (seismic model)
  - GRIZZLY (component aging model)
  - RELAP-7 (thermal-hydraulics), and
  - RAVIN (simulation controller and probabilistic analysis tool).