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Light Water Reactor Sustainability (LWRS)
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Office of Nuclear Energy
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Light Water Reactor Sustainability (LWRS) Program

LWRS 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

LWRS program is developing technologies and other solutions to

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

LWRS focus areas

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

Nine Mile Point ~ Courtesy Constellation Energy

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Technical Focus Areas Summary

- **Nuclear Materials Aging and Degradation**
  - Understand and predict long-term environmental degradation behavior of materials in nuclear power plants, including detecting and characterizing aging degradation
- **Advanced Instrumentation, Information, and Control Systems Technologies**
  - Address long-term aging and obsolescence of existing instrumentation and control technologies through a strategy for long-term modernization
- **Risk-Informed Safety Margin Characterization**
  - Develop significantly improved safety analysis tools (computer codes called RELAP-7 and Grizzly) and apply these tools to analyze the safety margin of aging plants
- **Systems Analysis and Emerging Issues**
  - Address high impact emerging issues such as flexible operations and water usage issues (the potential backfit of cooling towers)
- **Reactor Safety Technology**
  - Address emerging safety concerns in response to the Fukushima accident
  - Develop technologies to enhance the accident tolerance of current and future reactors

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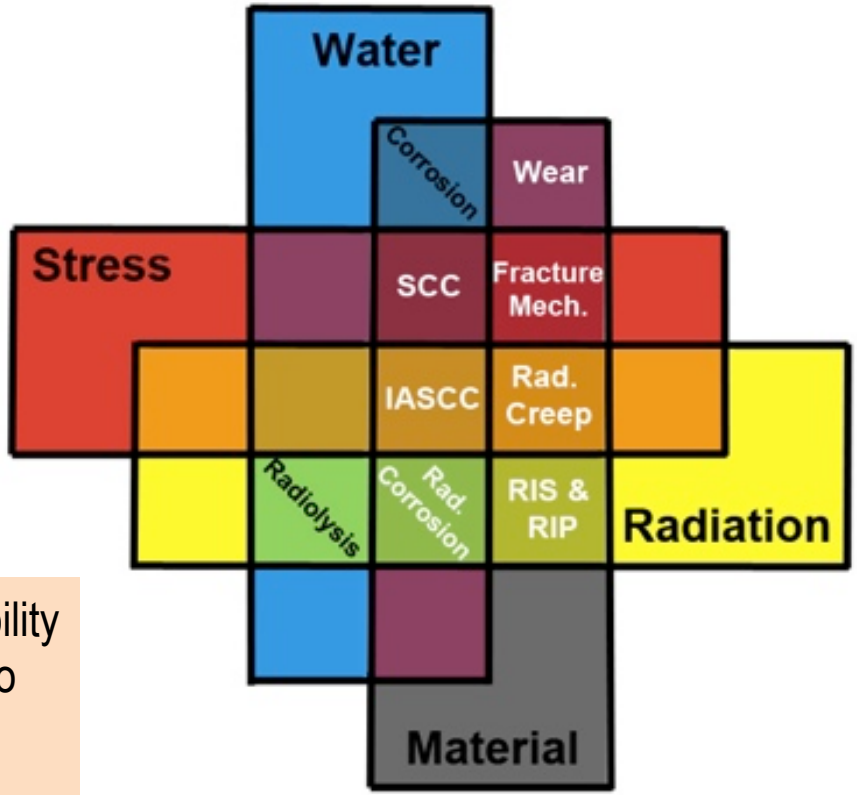
Materials Aging and Degradation

- **Metals: including Reactor Pressure Vessels, core internals, steam generators, and balance of plant**
  - 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**

Extension of service life may cause new challenges for materials……

Various mechanisms have impact on plant economics, reliability and safety

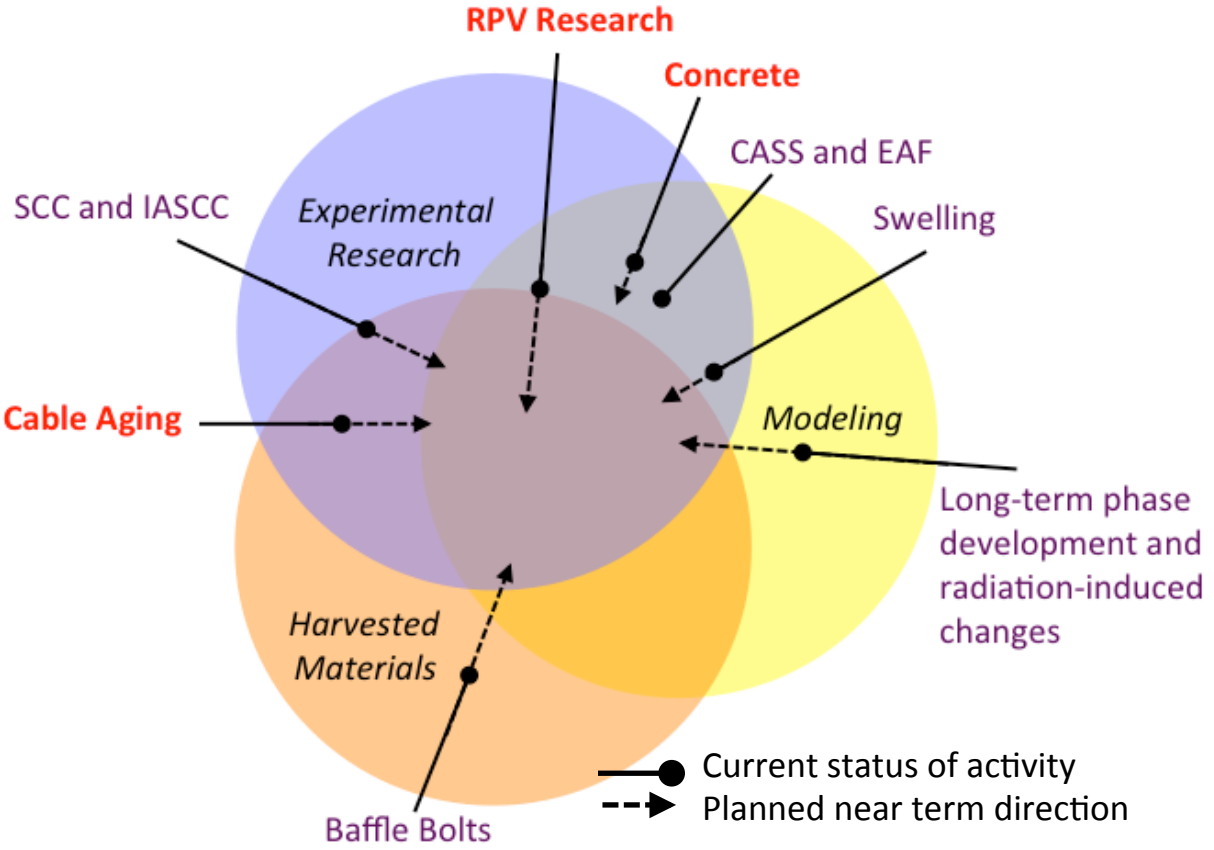


The vision of the DOE Light Water Reactor Sustainability (LWRS) Program is to enable existing power plants to safely provide clean and affordable electricity beyond current license periods (beyond 60 years)

The goal of materials research in the LWRS program is to develop the fundamental scientific basis to understand, predict and measure changes in materials as they age in reactor environments.

And to apply that knowledge in developing new methods for monitoring, new materials and new technologies that enhance plant performance and safety.

Methodology



Addressing scientific gaps in knowledge of extended life predictions, requires a multidirectional approach.

- Individual tasks within the pathway provide contributions to the overall pathway goal through high quality scientific measurement of materials performance to understand the active modes and mechanism of degradation.

Materials Aging and Degradation (RC-5)

Current LWRS Activities:

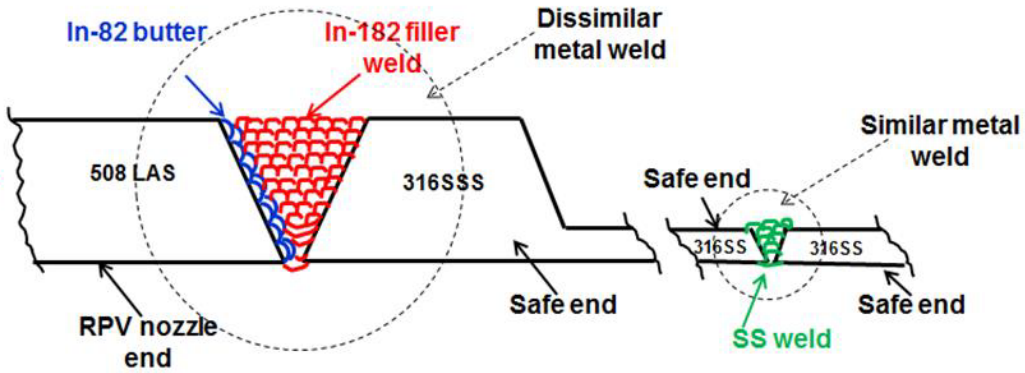
- Mechanisms of IASCC in 304 and 316 grade stainless, and modeling high fluence predictions of radiation-induced swelling, segregation and precipitation in LWR relevant conditions.
- Effectiveness of hydrogen water chemistry on crack growth rate in highly irradiated 316L.
- SCC initiation in alloy 600 and 690
- Environmentally assisted fatigue in base metal and dissimilar metal weldments (82/182) between 316SS and 508LAS

Current LWRS Interests:

- Type 308 and 309 stainless steel weldments
- Alloy 82 and 182 weldments used between dissimilar metal welds (see illustration below) or with Ni-base alloys.

Proposed Themes:

- Mechanisms responsible for the reduction in long-term thermal / irradiation effects on fracture toughness at lower temperatures in 82/182 weldments
- Swelling and other radiation-induced or enhanced effects on microstructure (segregation / precipitation) of weldments
- SCC susceptibility at very lifetimes for 308/309 weldments in BWR normal water chemistry environments
- SCC susceptibility at long lifetimes for 82/182 weldments for BWR normal and hydrogen water chemistry environment.
- Cumulative impact of corrosion and fatigue on weldments.



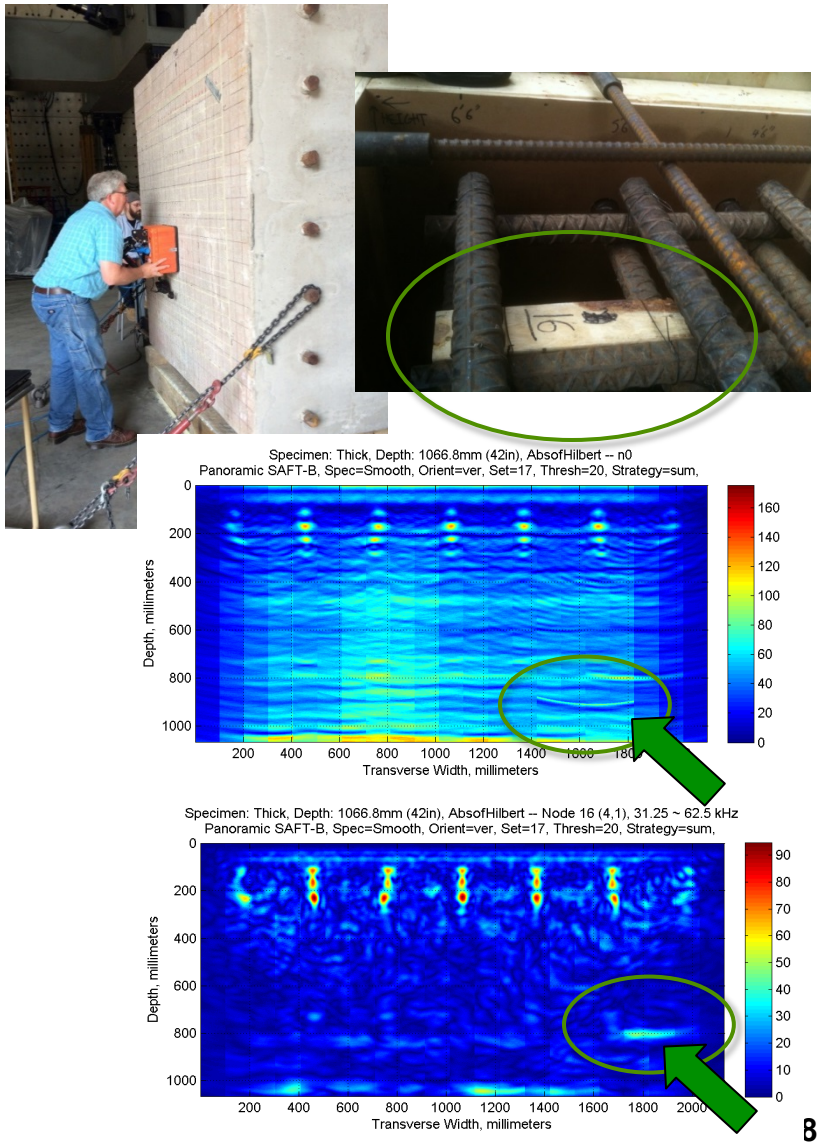
Materials Aging and Degradation (RC-5)…...continued

The development of effective techniques and instrumentation for condition monitoring of cables and concrete structures will reduce uncertainty in safety margins and is valuable to both industry and regulators.

Concrete

- Improvements in instrumentation and software analysis for NDE are required to advance beyond current technology to evaluate concrete structures of thicknesses and reinforcement levels that are relevant to the nuclear industry.
- Current hardware technologies were developed for thinner, less reinforced, structures related to the transportation infrastructure.
- *Proposals are encouraged that address:*
  - Changes in hardware such as linear array size, frequency or signal to improve detection of defects at deeper depths.
  - Develop signal processing methods such as forward model based image reconstruction techniques to be effective in identifying defects or level of concrete degradation.

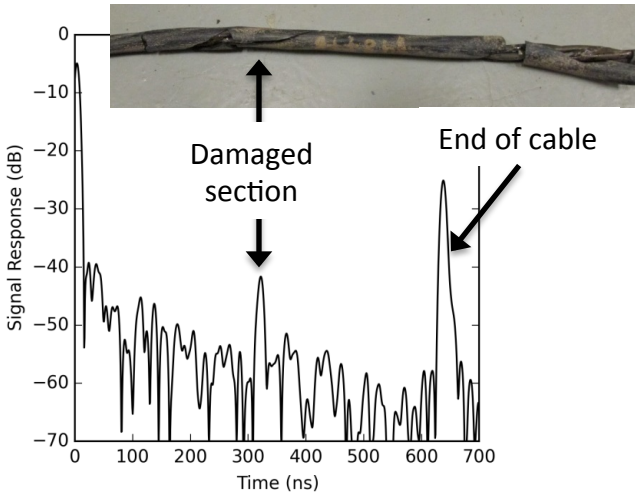
Detection of 2x4 piece in deep cover through Synthetic Aperture Focusing Technique with frequency banding



Materials Aging and Degradation (RC-5)…...continued

Cables

- A wide variety of cable NDE technologies are available. Certain methods such as frequency domain reflectometry are becoming more mature at detecting damage sections, but still rely on local measurement techniques such as indenter modulus to evaluate degree of degradation.
- NDE techniques rely on benchmarking against destructive test methods to evaluate remaining useful life.
- *Proposals are encouraged that address:*
  - Develop new active or passive methods useful in measuring cable health conditions more accurately, more economically and suitable for plant operations.
  - Refinement of signal processing based NDE techniques to provide cable health condition beyond identifying damaged region.



Frequency Domain Reflectometry (FDR) spectrum showing 18-inch thermally aged section identified along 200 ft of cable.

Indenter modulus, local measurement.