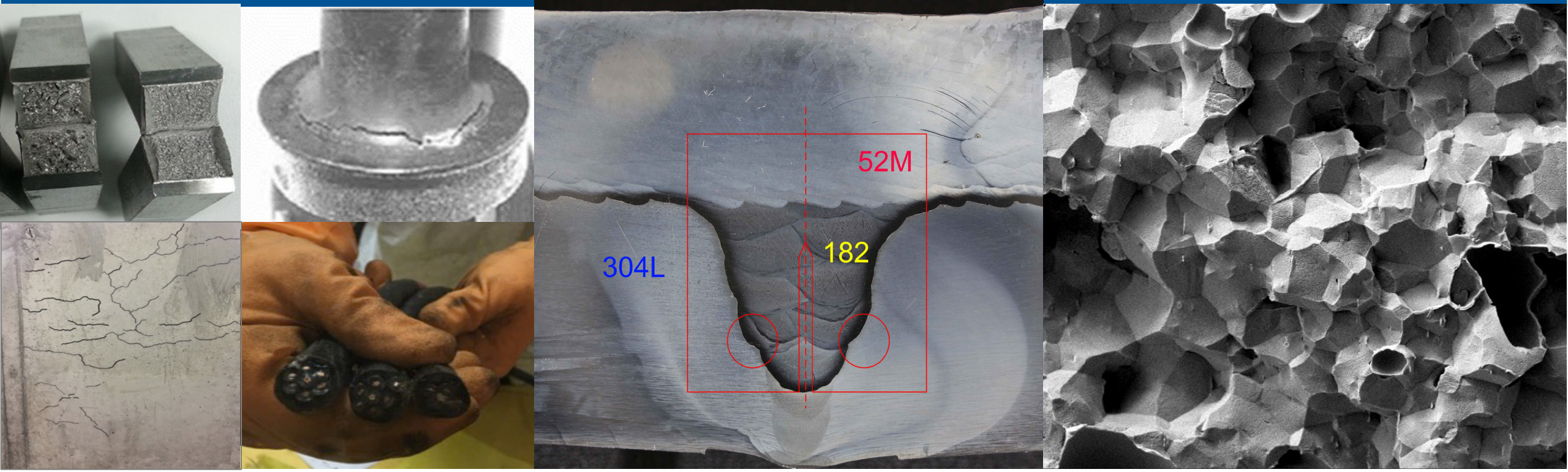


Overview of NRC Materials Research Supporting Long-Term Operation

Jeff Poehler
Nuclear Regulatory Commission

LWRS Spring Program Review Meeting
May 1, 2024

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Materials and Aging Research

- Research objectives
  - Improve timeliness of regulatory decision-making on the use of new materials, manufacturing technologies, and inservice inspection techniques through independent and confirmatory research.
  - Address materials degradation during long-term plant operation.
  - Inform and enhance the use of risk information in regulatory decision making.
- Strategic Focus Areas
  - Support resolution of safety-significant technical issues
  - Maintain core capabilities to support emerging technical needs related to corrosion, metallurgy, component integrity assessment, and non-destructive examination
  - Enhance modeling/analytical tools to support efficient regulatory decision-making
  - Foster collaborations with domestic and international counterparts to stimulate information sharing and cooperative research approaches
- More information contained in U.S.NRC's Research Prospectus for Fiscal Years 2022 – 2024 (ML22235A651)

Long-Term Operation (LTO) & Aging Management

- **What are we doing?** Supporting guidance development, coordinating related research activities, developing a systematic approach for harvesting materials and components from reactors.
- **Motivation:** Provide assurance that aging effects will be adequately managed during LTO.
- **Regulatory Application:** Refine, as appropriate, existing aging management programs and guidance
- **Collaboration:** DOE and EPRI
  - Significant activities:
  - Draft report on knowledge gaps in online monitoring and structural health management for NPP LTO in FY24
  - Collaborating with EPRI on cables aging management workshop (June 13-14, 2024.)
  - Workshops on structural materials (metals and concrete) aging management for LTO (October 1-4, 2024)

Materials Harvesting

- **What are we doing?** Extracting materials (metallic, structural and electrical) from decommissioning or operating plants for laboratory testing.
- **Objective:** Improve understanding of material degradation associated with LTO, reduce uncertainty and unnecessary conservatism.
- **Motivation:** Harvested materials can confirm information on aging mechanisms generated through other research programs and operating experience.
- **Regulatory Application:** Inform aging management approaches for extended operation to ensure they are appropriate and adequate.
- **Collaboration:** DOE, EPRI, OECD/NEA, other international partners
- Significant activities:
  - OECD/NEA SMILE project (2021-2025), potential SMILE 2 project (2026-)
  - Updating NRC's harvesting priorities

Irradiation Assisted Degradation (IAD)

- **What are we doing?** Testing highly irradiated materials to characterize irradiation effects on fracture toughness and stress-corrosion cracking.
- **Motivation:** Confirm adequacy of reactor internals aging management programs.
- **Regulatory Application:** Support reviews of internals inspection/ evaluation guidance, ASME Code changes and associated rulemaking.
- **Collaboration:** EPRI, OECD/NEA, DOE
- Significant activities – Testing of Zorita RVI materials, participation in OECD/NEA SMILE and FIDES projects.

Primary Water Stress Corrosion Cracking (PWSCC)

- **What are we doing?** Mainly testing Alloy 690/52/152 crack growth rate (CGR) and initiation, and related evaluations.
- **Motivation:** Provide assurance of reactor coolant pressure boundary integrity
- **Regulatory Application:** Support reviews of proposed changes to the inspection requirements in the ASME Code and associated rulemaking
- **Collaboration:** EPRI, DOE
- **Significant activities:** CGR and initiation testing, participate in expert panels reviewing CGRs.

Steam Generator Tube Integrity Program (SG-TIP)

- **What are we doing?** Evaluating effectiveness of SG tube NDE.
- **Motivation:** Confirm adequacy of industry practices and new inspection approaches used for SG tube in-service inspections.
- **Regulatory Application:** Review acceptability of current and new approaches to inspection techniques plus changes to SG guidelines as proposed by industry
- **Collaboration:** EPRI, CNSC, KINS, KAERI, GRS, MPA, and IRSN
- **Significant activities:**
  - Report evaluating eddy current sizing capabilities for PWSCC at expansion transition regions of SG tubing.
  - Independent assessments of industry ET approach and probe-probe equivalency.

Probabilistic Integrity Assessment

- **What are we doing?** Developing probabilistic methods to assess structural integrity of RPV and piping components.
- **Motivation:** Confirm continued integrity of safety-critical components subject to degradation mechanisms
- **Regulatory Application:** Risk-inform regulatory decision-making on component integrity
- **Collaboration:** EPRI and CSNI (xLPR)
- **Significant activities:**
  - Development of the FAVPRO PFM code for RPV integrity (replace existing FAVOR code)
    - Issue FAVPRO v1.0.x and associated manuals and QA documentation (2024Q2)
  - Continued development and modernization of the xLPR code for probabilistic piping integrity.
    - Prob. Risk assessment of French SCC OE impact on US PWRs ML23236A080
    - Confirm LOCA frequency estimates from NUREG-1829

Piping Integrity

- **What are we doing?** Leak-before-break (LBB) and high energy line break (HELB) studies. Assess thermal aging embrittlement (TE) of cast austenitic stainless steel (CASS) and austenitic stainless steel welds (ASSW)
- **Motivation:** Confirm integrity of safety-critical piping systems during LTO
- **Regulatory Application:** Enhance guidance for piping structural integrity calculations
- **Collaboration:** EPRI and CSNI
- **Significant Activities:**
  - Developing alternative HELB framework for existing and new reactors and assessing risk-informed HELB.
  - Updating Flaw Evaluation Software (FES) for evaluating PWSCC in piping and CRDM nozzles
  - Reports on TE of CASS and ASSW.

Nondestructive Evaluation (NDE)

- **What are we doing?** Evaluating effectiveness and reliability of NDE techniques. Looking at application of machine learning (ML) to NDE.
- **Motivation:** Confirm adequacy of industry procedures and practices
- **Regulatory Application:** Support reviews of ASME Code modifications and proposed revisions of current requirements
- **Collaboration:** EPRI, IRSN, and PIONIC
- **Significant activities:**
  - Report on assessment of ML applied to UT NDE ML24046A150
  - Assess NDE capabilities for carbon fiber reinforced composite repairs (2025)
  - Assess the capabilities of machine learning and automated data analysis in NDE (2026)

Concrete Research

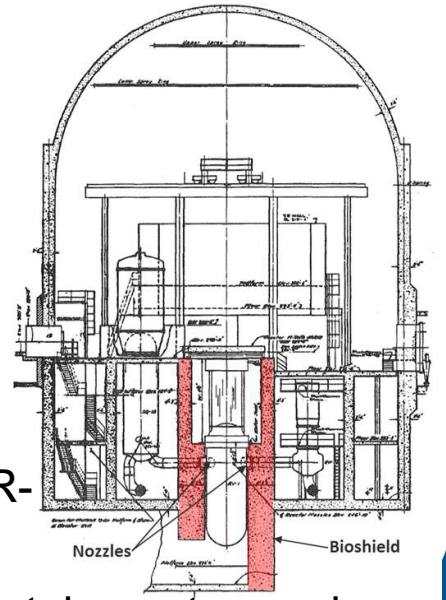
Overview

- **Objective:** Evaluate and improve concrete aging and performance for LTO
- **Motivation:** Confirmatory research for lower-knowledge aging mechanisms generated through other research programs and operating experience and potential higher significance for LTO
- **Regulatory Application:** Inform aging management approaches for renewal of plant licenses to ensure they are appropriate and adequate
- **Collaboration:** DOE, EPRI, and other international partners
- POC: Madhumita Sircar (Madhumita.Sircar@nrc.gov)

Significant Activities

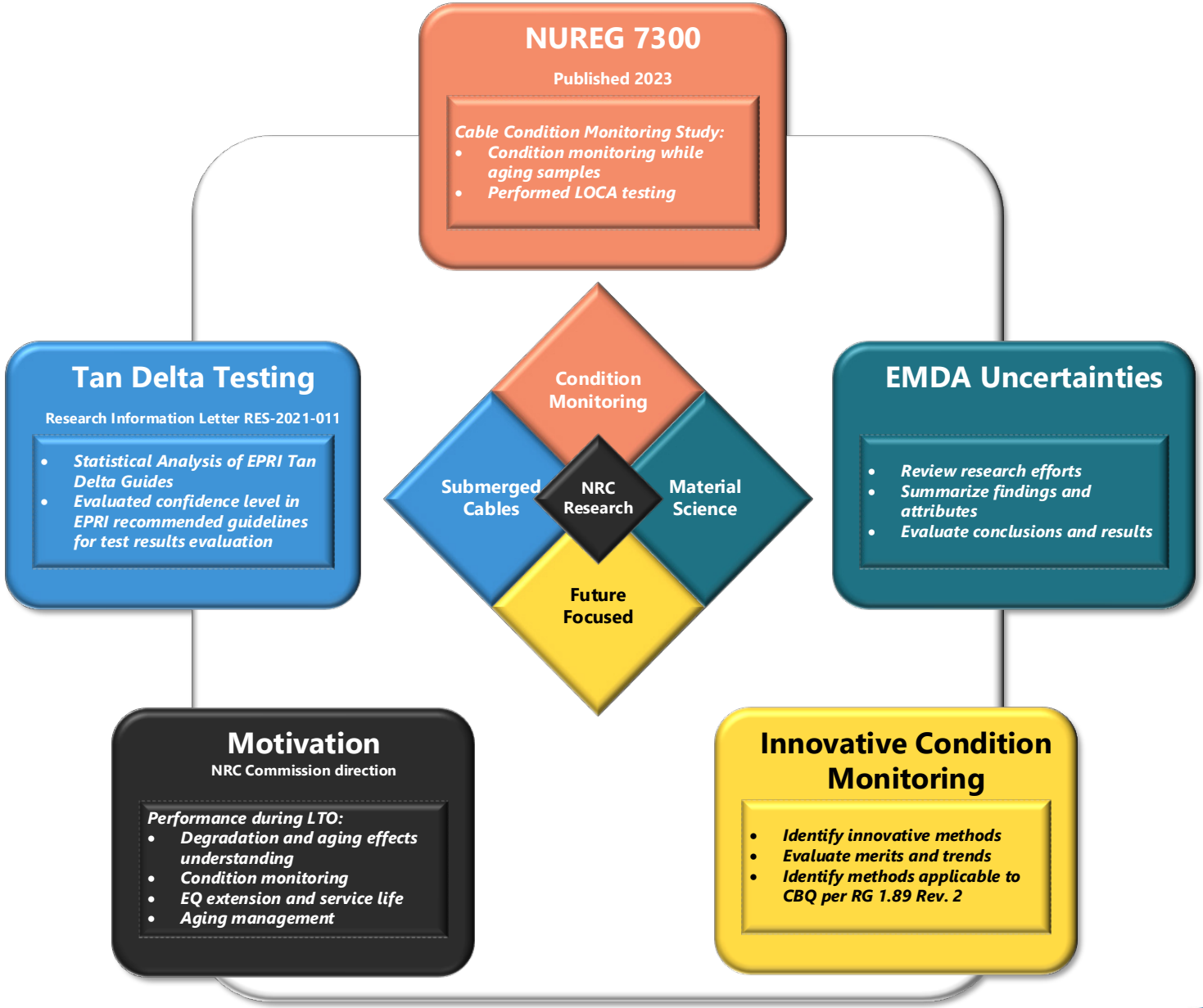
Current:

- Evaluate **effects of irradiation on concrete biological shield structures**. Experimental study to evaluate effects of irradiation on concrete-rebar bond (Using the LVR-15 reactor in the Czech Republic) and develop modeling methodology. **Report to be completed in FY2024.**
- Exploring **harvesting of irradiated concrete** materials
- Study on **creep and shrinkage** effects on PCCVs



Completed:

- Reviewed radiation-induced degradation mechanisms and potential structural implications (NUREG/CR-7280)
- Evaluated neutron fluence, gamma dose and radiation energy deposition through concrete structures (NUREG/CR-7281)
- Creep and shrinkage effects on aging of post-tensioned containment vessels (PCCVs) (RIL-2022-06)
- NRC-NIST project on Alkali-Silica Reaction (Completed)



Overview of NRC Cables Research Program

Future Work – Important Considerations

- Identify and address materials degradation during LTO.
- Develop, maintain, and implement research strategies to obtain and evaluate domestic and international operating experience on age-related degradation:
  - Harvesting aged components
  - Engage external stakeholders
  - Leverage resources
- Assess aging management approaches appropriate for extended plant operation
- Develop targeted harvesting strategies.
- Conduct workshops on topics important to safety.

Summary

- NRC Office of Nuclear Regulatory Research conducts confirmatory research to establish technical bases that support regulatory decisions and development of regulatory guidance documents.
- NRC staff exchanges information with domestic and international counterparts on materials performance and aging management of nuclear power plant structures and components, and conducts independent analyses.
  - Research results
  - Operating experience
- Research activities are prioritized to address potential safety-significant technical issues.
- Long-lead-time confirmatory research is an important consideration in proactive aging management.
- For more information contact: Jeffrey.Poehler@nrc.gov

Published Reports on Concrete Research

- NUREG/CR–7280, “Review of Radiation Induced Concrete Degradation and Potential Implications for Structures Exposed to High, Long-Term Radiation Levels in Nuclear Power Plants”, Report December 2020, published July 2021

https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7280/index.html

- RIL 2021-07, “Radiation Effects on Concrete – An Approach for Modeling Degradation of Concrete Properties”, Report December 2020, published August 2021

https://www.nrc.gov/docs/ML2123/ML21238A064.pdf

- NUREG/CR-7281, “Radiation Evaluation Methodology for Concrete Structures”, Report December 2020, published July 2021

https://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7281/index.html

- RIL 2022-06, “Aging of PCCV with Emphasis on Creep and Creep Rupture”, Report August 2021, published March 2022

https://publish.nrc.gov/docs/ML2207/ML22075A007.pdf

- RIL 2022-07, “Assessment of the San Onofre Concrete Susceptibility against Radiation Damage”, published April 2022

https://www.nrc.gov/docs/ML2211/ML22119A092.pdf

- SMiRT27 Paper, “Effects of Neutron Irradiation on the Bond Strength of Steel Embedded in Concrete

https://confit.atlas.jp/guide/event/smirt27/subject/Tu.4.H-02/detail

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Published Reports on Concrete Research

Alkali-Silica Reaction (ASR) Research at NIST: Tasks and Reports

- Task 1: Assessing In-Situ Mechanical Properties of ASR-Affected Concrete (NIST Technical Note 2121, February 2021)
  https://www.nist.gov/publications/structural-performance-nuclear-power-plant-concrete-structures-affected-alkali-silica-0
- Task 2: Assessing Bond and Anchorage of Reinforcing Bars in ASR-Affected Concrete (NIST Technical Note 2127, February 2021)
  https://www.nist.gov/publications/structural-performance-nuclear-power-plant-concrete-structures-affected-alkali-silica
- Task 3: Effects on seismic response characteristics (NIST Technical Note 2180, January 2022)
  https://www.nist.gov/publications/structural-performance-nuclear-power-plant-concrete-structures-affected-alkali-silica-1
- Tasks 4 and 5: Design of concrete mixes for all tests, and prediction of future and ultimate expansion, and degradation and methods to assess degree of reaction (current state of material degradation)
  https://doi.org/10.6028/NIST.IR.8415
  https://nvlpubs.nist.gov/nistpubs/ir/2022/NIST.IR.8415.pdf

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