



## EPRI Long Term Operations Program

**Sherry Bernhoft**

EPRI Program Manager, Long Term Operations

**R&D Coordination Meeting**

June 7, 2012

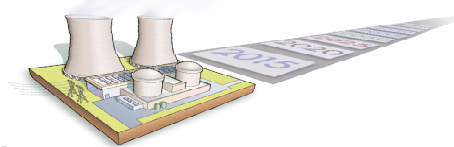
### Objectives



- ✓ Technical basis for **decisions** to operate through an extended lifetime
  - Supports **business case** for life extension and/or refurbishment
  - Supports **License Renewal** for “*Life beyond 60*” in U.S.
  - Results by 2014-2019
- ✓ Technology to **manage** plant assets throughout lifetime
  - Includes aging management, asset management, and risk management
  - Addresses safety, performance, and cost

## Criteria for Selecting LTO Activities

- ✓ **Technical basis for license renewal or life extension**
  - Investigates a potential “life limiting” issue
  - Enhances aging management
  - Improves life-cycle management
  - Identifies modernization and up-rate opportunity
  - Develops enabling technology (e.g., analysis methods)
- ✓ **Not addressed by another EPRI program**
- ✓ **Produces results by 2014 - 2019**
- ✓ **Collaborates with DOE, NRC-RES, member utilities**



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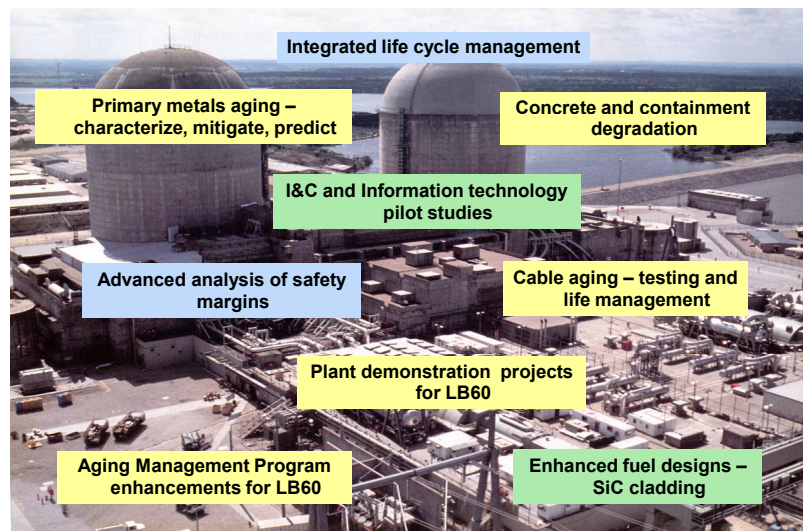
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## Technical Areas for LTO R&D

Aging Management

Modernization

Enabling Technology



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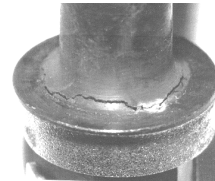
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## Aging Management

- **Aging Management R&D for SLR**

- Primary system materials
  - Issue management (MDM and IMTs)
  - EAC, IASCC
    - Crack rate growth assessments
    - Mitigation strategies
- Reactor pressure vessel embrittlement
  - Coordinated Reactor Vessel Surveillance Program
- Reactor vessel internals
  - MRP-227
  - Baffle bolt testing
  - Advance welding techniques



## Aging Management (Cont.)

- Concrete and containment structures
  - Concrete Structures Aging Management Manual
  - Literature Survey – Effects of Radiation on Concrete
  - Developing collaborative program with DOE LWRS to study irradiated concrete
- Cable systems
  - Aging Management GLs have been published for MV cables
  - Developing strategy for improved technical basis for aging management
- Ginna and NMP-1 Demonstrations for SLR decisions
  - Inspections and NDE methods for containment and reactor internals, reactor vessel data/analysis plan

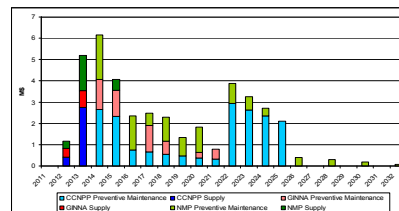
**Significant results 2013 – 2016.**

## Support Technical Basis for SLR

- Proactive review to indentify Aging Management Program needs for 60 to 80 years
  - Comprehensive review of AMPs
    - AMPs, MDM, IMT, OE, Expert panel input
  - Identify enhancements and revisions to current AMPs
  - Identify areas where new AMPs may be required
- Interface with NEI working groups on License Renewal
- Working draft end of 2012

## Life Cycle Management (LCM) Data and Methods

- **What Life Cycle Management data and methods can enhance high-performance long term operation?**
  - Integrated Life Cycle Management Project
    - Asset Management process for key SSCs – failure models, assessment process, modeling and optimization tools, and pilot studies

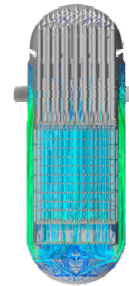


**Data, methods, and software in 2013.  
Living ILCM program to continue thereafter.**



## Plant Modernization Opportunities

- **What new plant modernization opportunities affect the decision to seek operations beyond 60 years?**
- Advanced Fuel Design for Existing Plants
  - Development and deployment of SiC fuel cladding
- I&C and Information Technology
  - Pilot studies and requirements for advance control rooms, technology for process improvement, integrated operations, outage control, on-line monitoring, etc.



**Advanced fuel rod/assembly tested in commercial reactor by 2021  
I&C pilot studies and guidelines 2013 and beyond**

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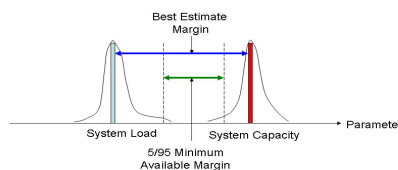
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## Enabling Technologies

- **What enabling technologies can be available for decisions to operate beyond 60 years?**
- Safety Analysis
  - Safety margins methods and analysis/simulation
  - Advanced PRA for configuration management, SDP, design improvements, operational and regulatory changes.

**Analysis methods available 2015.  
Advanced methods in common usage 2020.**



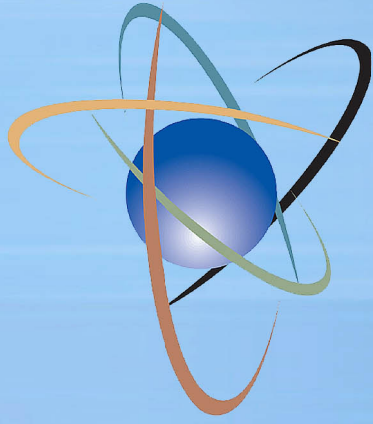
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**Together...Shaping the Future of Electricity**

# Lessons Learned from Aging Management Effectiveness Audits Applicable to Subsequent License Renewal



**U.S. NRC**  
UNITED STATES NUCLEAR REGULATORY COMMISSION  
*Protecting People and the Environment*

Sandra Lindo-Talin,<sup>1</sup> Amy Hull<sup>1</sup>, Bennett Brady<sup>2</sup>,  
Makuteswara Srinivasan<sup>1</sup>, and Albert Wong<sup>2</sup>

**U.S. Nuclear Regulatory Commission**

<sup>1</sup>Office of Nuclear Regulatory Research, Division of Engineering

<sup>2</sup>Office of Nuclear Reactor Regulation, Division of License Renewal

# Outline

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- Overview of License Renewal Guidance Update Process
- Overview of Materials Degradation Technical Issues
- Subsequent License Renewal (SLR) Research
  - Aging Management Program (AMP) effectiveness audits
  - Pilot study of international Periodic Safety Reviews (PSR)
  - Incorporate Extended Material Degradation Assessment (EMDA) findings
  - Incorporate all updates to license renewal guidance documents
- Summary

# Acronyms/Definitions

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AMR: Aging Management Reviews

AMP: Aging Management Programs

EPMDA: Expanded Proactive Materials Degradation Assessment  
(also known as EMDA)

GALL: Generic Aging Lessons Learned

ISG: Interim Staff Guidance

LRA: License Renewal Application

LRGD: License Renewal Guidance Documents

LTO: Long Term Operations (beyond 40 yrs)

PEO: Period of Extended Operation (40+ yrs)

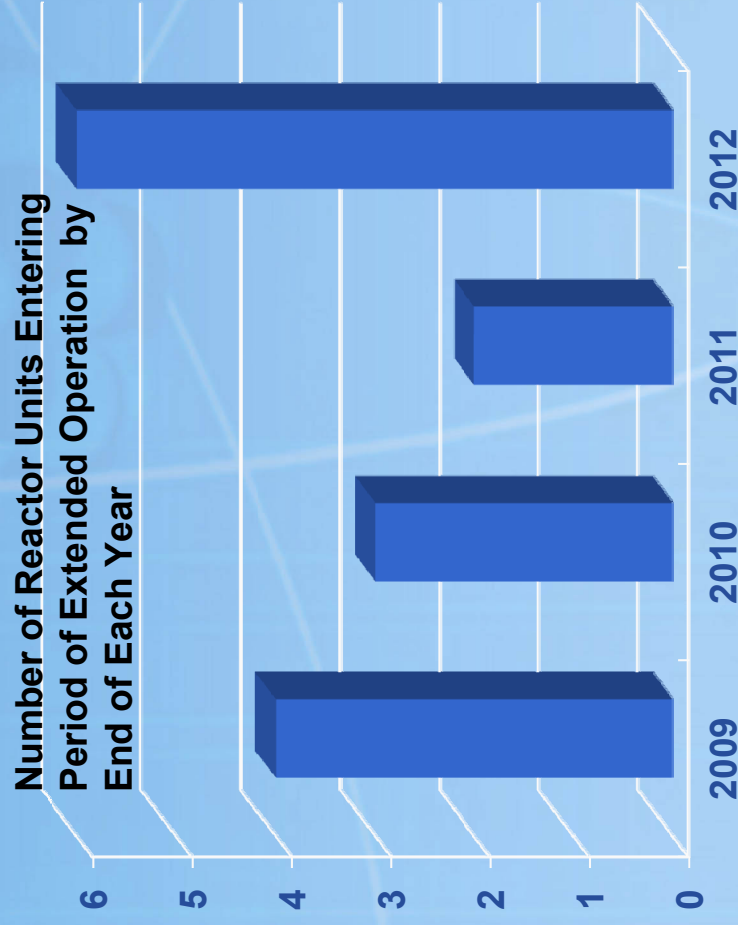
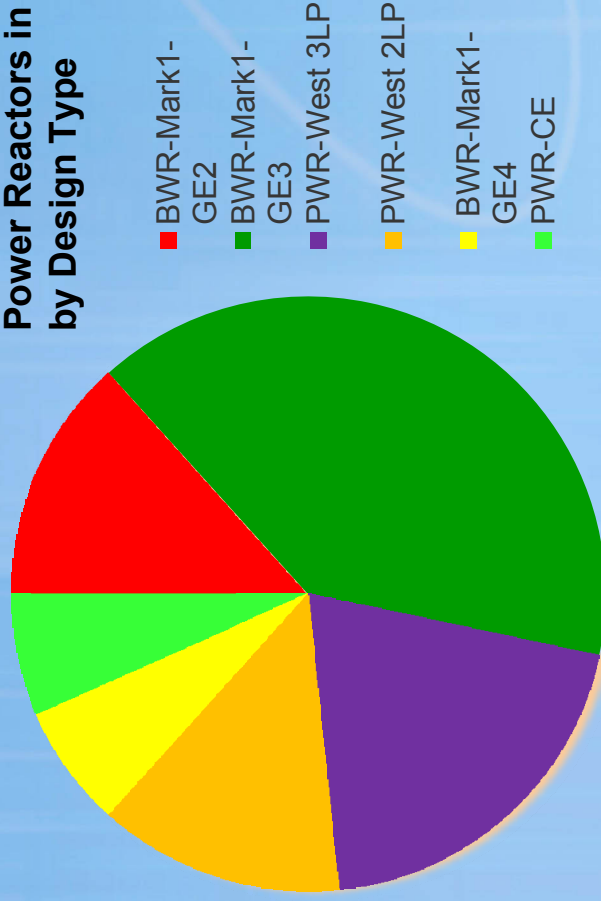
SLR: Subsequent License Renewal (after 1st renewal)

SRP: Standard Review Plan

SSC: Systems, Structures and Components

# 15 Reactor Units in Period of Extended Operation by December, 2012

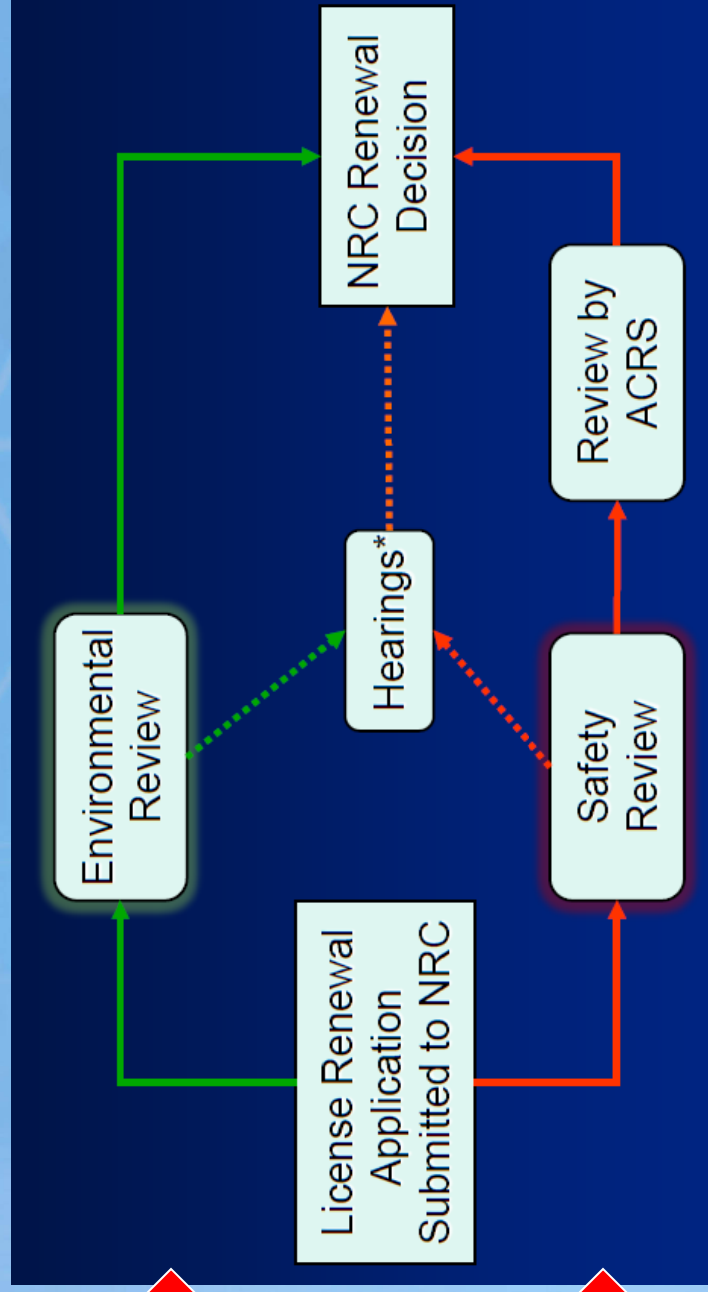
**U.S. Commercial  
Power Reactors in PEO  
by Design Type**





# NRC License Renewal Process

<p><b>PREP WORK</b> License Renewal Guidance Update for SLR:</p>	<ul style="list-style-type: none"> <li>-1<sup>st</sup> Public Meeting: 5/9/12</li> <li>-Ongoing LTO Research</li> <li>- Updates to LRGD</li> <li>- Public Input</li> </ul>
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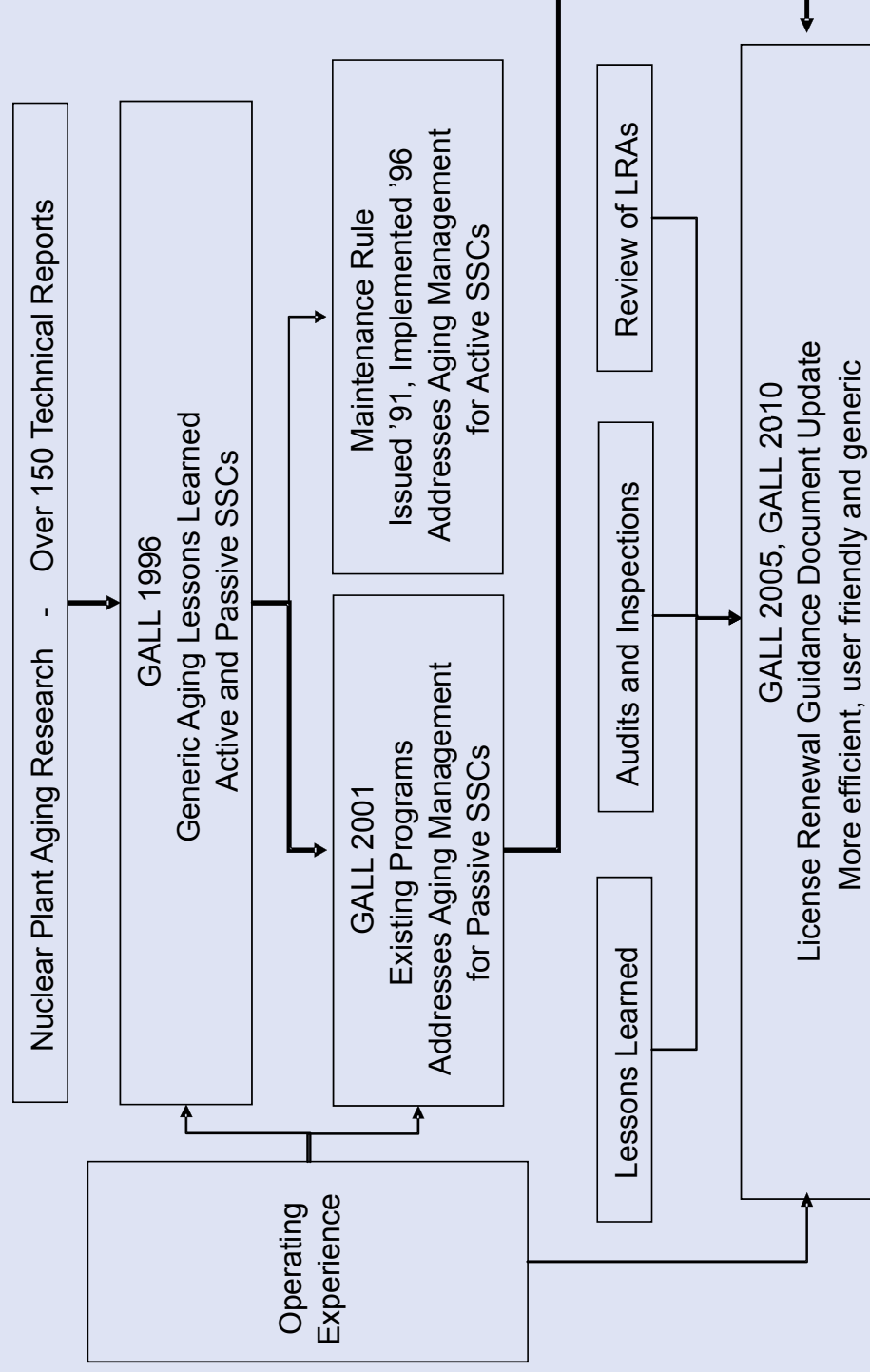
In early 2009, the staff initiated efforts to update the Standard Review Plan for License Renewal (SRP-LR) and the Generic Aging Lessons Learned (GALL)

- Capture operating experience gained since prior update in 2005
- Integrate license renewal review lessons-learned accrued since 2005
- Consider proposed changes from the industry
- Incorporate content from the license renewal interim guidance (ISG) into the review process
- Account for changes in consensus codes and standards



# License Renewal Guidance Updates (LRG)

## Historical LRG Development



- The GALL report is now a single volume, inclusive of AMR tables
- The generic GALL AMPs were updated to reflect:
  - recent operating experience
  - license renewal precedents
  - changes in NRC regulations
  - content of license renewal ISGs
  - changes in consensus codes
  - aligned with the revised AMP 10-element template

- A number of further evaluation required items in the SRP-LR were eliminated based on experience or enhancements
- New AMPs and associated AMR line items were added to address:
  - neutron absorbing materials other than Boraflex
  - PWR internals
  - buried and underground piping and tanks
- The scope of the AMP for inaccessible electrical cables updated

- RIS-2011-05<sup>[3]</sup> and RIS-2012-02<sup>[4]</sup> addressed use of the most affected AMRs, AMPs, and Time-Limited-Aging-Analysis (TLAA):
  - (X.M1) Metal Fatigue of Reactor Coolant Pressure Boundary
  - (XI.M9) BWR Vessel Internals
  - (XI.M11B) Cracking of Nickel-Alloy Components and Loss of Material due to Boric-Acid-Induced Corrosion in Reactor Coolant Pressure Boundary Components
  - (XI.M40) Monitoring of Neutron Absorbing Materials Other than Boraflex
  - (XI.S8) Protective Coating Monitoring and Maintenance Program

## Interim Staff Guidance for License Renewal Issued After Rev. 2

Number	Topic	Status as of 6/1/12
LR-ISG-2011-01	Aging Management of Stainless Steel Structures and Components in Treated Borated Water	Final
LR-ISG-2011-02	Aging Management Program for Steam Generators	Final
LR-ISG-2011-03	Generic Aging Lessons Learned (GALL) Report Revision 2 AMP XI.M41, "Buried and Underground Piping and Tanks"	Draft
LR-ISG-2011-04	Updated Aging Management Criteria for Reactor Vessel Internal Components of Pressurized Water Reactors	Draft
LR-ISG-2011-05	Ongoing Review of Operating Experience	Final

<http://www.nrc.gov/reading-rm/doc-collections/isg/license-renewal.html#previous>



## Materials Degradation With Aging

- **Technical Issues:**

- Reactor vessel and internals aging: embrittlement, volumetric changes, fatigue
- Buried/submerged structures: piping, concrete, electrical cables (insulation)
- Concrete exposed to water, high temperature, and/or radiation
- Newly identified degradation mechanisms/various environmental exposures

- **Focus Areas:**

- Information exchange with U.S. Department of Energy (LWRSP), industry researchers (EPRI), and international community (IFRAM, IAEA's PLIM, and OECD/NEA's LTO)
- Independent confirmatory research projects and scoping studies
- Plant audits of AMPs implementation and operating experience review
- Interim/generic guidance and requests for additional information
- New information from Expanded Proactive Materials Degradation Assessment
- International operating experience and practices

## Research Focus: Subsequent License Renewal

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- Evaluate the effectiveness of GALL AMPs to identify potential updates for subsequent renewal; two plant audits were completed in 2011: Ginna and Nine Mile Point 1
  - analysis reports are in progress
- Conduct NRC/DOE Expanded Materials Degradation Assessment (EMDA)
  - report due for publication this year
- Lessons learned from international experience through a Pilot Study of Periodic Safety Reviews
  - report is currently in progress

## Summary

- The staff is reviewing the adequacy of the existing regulatory framework to provide reasonable assurance of safe operation for subsequent license renewal.
- LTO research will:
  - Gather and evaluate technical safety information on aging mechanisms
  - Provide information on assessing the reliability of systems, structures and components (SSC) during long-term operation
  - Seek opportunities for improvement from international experience
- The agency will continue to conduct additional confirmatory research, as necessary
  - Industry has lead role to identify issues and propose resolutions



## References

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- [1] **SRP-LR:** NUREG-1800, rev. 2, *Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants*, Dec. 2010
- [2] **GALL:** NUREG-1801, rev. 2, *Generic Aging Lessons Learned (GALL) Report*, Dec. 2010
- [3] **RIS 2011-05:** *Information on Revision 2 to the Generic Aging Lessons Learned Report for License Renewal of Nuclear Power Plants*, July 2011
- [4] **RIS 2012-02:** *Insights into Recent License Renewal Application Consistency with Generic Aging Lessons Learned Report*, Jan. 2012



U.S. DEPARTMENT OF  
**ENERGY**

**Nuclear Energy**

# **US Department of Energy Light Water Reactor Sustainability Program**

*LTO R&D Coordination Meeting  
June 7, 2012*

*Kathryn A. McCarthy  
Director, LWRS Technical Integration Office  
Idaho National Laboratory*





# Presentation Outline

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- **Federal Role**
- **Program Vision & Goals**
- **Pathway descriptions and example activities**
- **Look ahead: RISMC Demonstration**
- **DOE LWRS/EPRI LTO Joint Plan**



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# LWRS Vision, Goals, and Scope

## ***Vision***

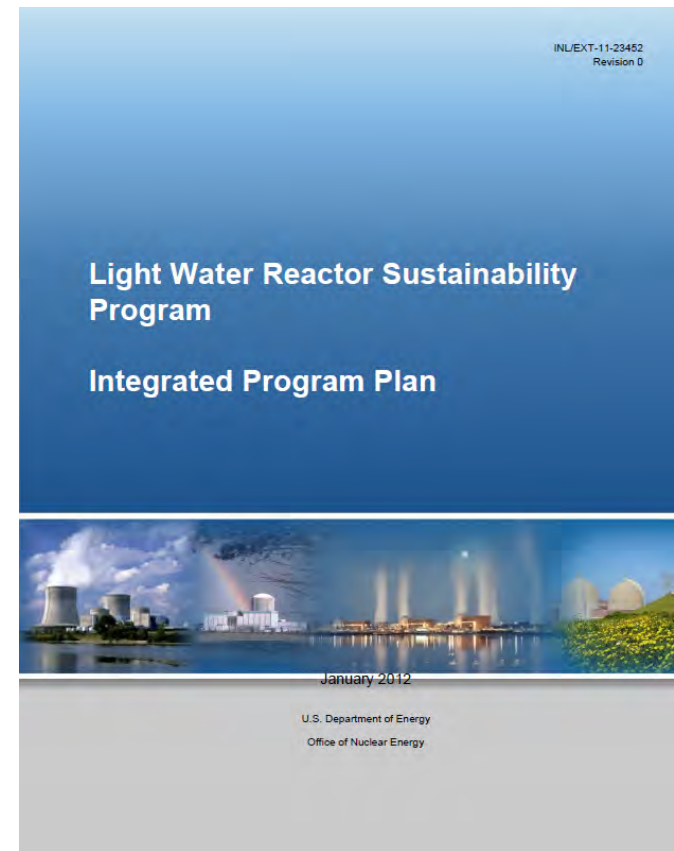
- Enable existing nuclear power plants to safely provide clean and affordable electricity beyond current license periods (beyond 60 years)

## ***Program Goals***

- Develop fundamental scientific basis to understand, predict, and measure changes in materials as they age in reactor environments
- Apply this knowledge to develop methods and technologies that support safe and economical long-term operation of existing plants
- Research new technologies that enhance plant performance, economics, and safety

## ***Scope***

- Materials Aging and Degradation
- Advanced Instrumentation and Controls
- Risk-Informed Safety Margin Characterization
- Advanced Fuels Development
- Systems Analysis and Emerging Issues



*LWRS Integrated Program Plan (INL/EXT-11-23452, Rev. 0) Available on [www.inl.gov/lwrs](http://www.inl.gov/lwrs)*



## Light Water Reactor Sustainability – Federal Role

- National strategic interest in the long-term operation of existing plants
  - Supports climate change objectives
  - Supports energy security
  - Avoids higher cost to ratepayers for new plant replacements
- Cost-sharing is being employed through cooperative research activities with industry, primarily the Electric Power Research Institute (EPRI)
- Addresses fundamental scientific questions where private investment or capabilities are insufficient to make progress on broadly applicable technology issues for public benefit
- Government (DOE and its national laboratories) holds a large theoretical, computational, and experimental expertise in nuclear R&D that is not available within the industry
- Benefits will extend to the next generation of reactor technologies being deployed and still in development
- Federal program creates an environment (by reducing uncertainty and risk) that provides incentives for industry to make the investments required for power operation periods beyond 60 years



# Materials Aging and Degradation Pathway

- **Increased lifetime leads to increased exposures**

- Time at temperature
- Stress
- Coolant
- Neutrons

- **Extending reactor life to 60, 80 years or beyond may increase susceptibility and severity of known forms of degradation**

- **New mechanisms of materials degradation are possible**



- **Develop the scientific basis for understanding and predicting long-term environmental degradation behavior of materials in nuclear power plants**
- **Provide data and methods to assess the performance of systems, structures, and components essential to safe and sustained NPP operations**
- **Develop means to detect and characterize aging degradation processes**



## Materials Aging and Degradation tasks provide results in several ways

- **Measurements of degradation:** High quality data will provide key information for mechanistic studies, and also has value to regulators and industry on its own.
- **Mechanisms of degradation:** Basic research to understand the underlying mechanisms of degradation modes will lead to better prediction and mitigation.
- **Modeling and simulation:** Improved modeling and simulation efforts have great potential in reducing the experimental burden for life extension studies. These methods can help interpolate and extrapolate data trends for extended life.
- **Monitoring:** While understanding and predicting failures are extremely valuable tools for the management of reactor components, non-destructive monitoring must also be utilized.
- **Mitigation strategies:** While some forms of degradation have been well-researched, there are few options in mitigating their effects. New technologies may overcome limits of degradation in key components and systems.

## Example of MAaD Activity: Concrete Performance

***Additional data on concrete performance through extended life of a nuclear power plant are needed***

Typical Pressurized Water Reactor

*Irradiation degradation of the pedestal may decrease strength*

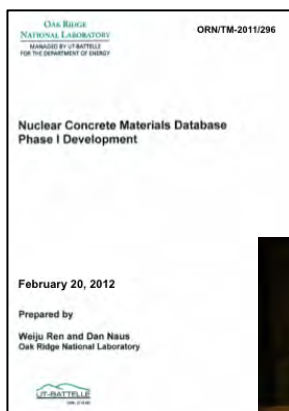
*Concrete-liner interactions are of high interest*

*Long-term exposure to elevated temperatures may reduce performance*

Source: U.S. Nuclear Regulatory Commission



# Nuclear concrete materials database



**ORNL/TM-2011/296**



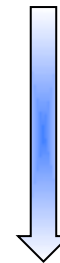
***Concrete coring to obtain samples for evaluating effects of aging and environmental stressors***

- **Phase I of NCMDB has been completed and is on internal server at ORNL**
- **Data and information for populating the NCMDB are provided from literature sources and obtaining and testing samples from aged facilities**
  - Aging
  - Elevated temperature
  - Irradiation
  - Migration of hostile species (e.g.,  $\text{Cl}^-$ ,  $\text{SO}_4$ ,  $\text{CO}_2$ )
- **Concrete irradiation damage working group formed**
  - Development of protocols related to removal and testing of irradiated concrete cores
  - Identification of potential sources of irradiated concrete cores



# Instrumentation, Information, and Control System Technologies Pathway

- **Develop, demonstrate, and deploy new digital technologies for instrumentation and control architectures**
- **Provide monitoring capabilities to enhance the continued safe, reliable, and economic operation of the nation's operating nuclear power plants**
- **Develop capabilities to support long-term NPP operations and management**
  - Improve understanding of, confidence in, and facilitate transition to advanced technologies
  - Support development of the technical basis needed to enable technology deployment
  - Create or renew infrastructure needed for research, education, and testing





# II&C Pathway Utility Working Group

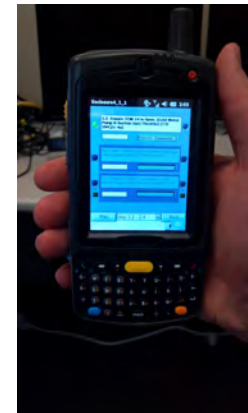
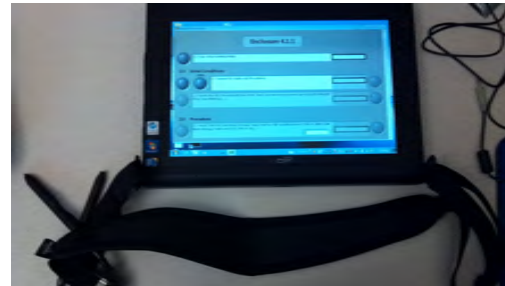


## II&C Pathway Strategy

- **Objective: To significantly reduce the technical, financial, and regulatory risk of II&C modernization by demonstrating the new technologies and operational concepts in an actual nuclear power plant setting**

- **The technologies are demonstrated in nuclear power plants under controlled circumstances to provide validation**

- A series of pilot projects is underway at host utilities
- A pilot project demonstrates a key technology or outcome and supports scaling that can be replicated and used by other plants



- **The Human Simulation Laboratory provides an advanced simulation facility to validate concepts that cannot practically be demonstrated in a nuclear power plant until they are validated (e.g., control room changes)**

- Reconfigurable simulator
- Can be linked to a virtual reality system
- Study human performance



- **Technical guidance will be developed for implementation of the new technologies**
- **II&C Vision document (INL/EXT-11-24154, R1) is available on the the LWRS website ([www.inl.gov/lwrs](http://www.inl.gov/lwrs))**

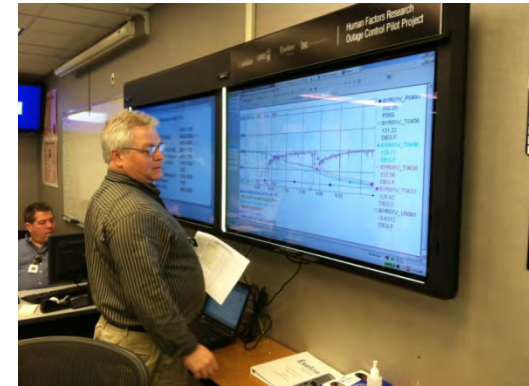




## Example of II&C Activity: Advanced II&C Systems Technologies Pilot Project

### NPP Outage Safety and Efficiency

- Technology deployed during two successive outages at Exelon's Byron Nuclear Station
- Information exchange between the Outage Control Center and the Work Execution Center
- Continuous archival of issue resolution information
- Saves outage managers two hours per day in reduced time to coordinate outage issues



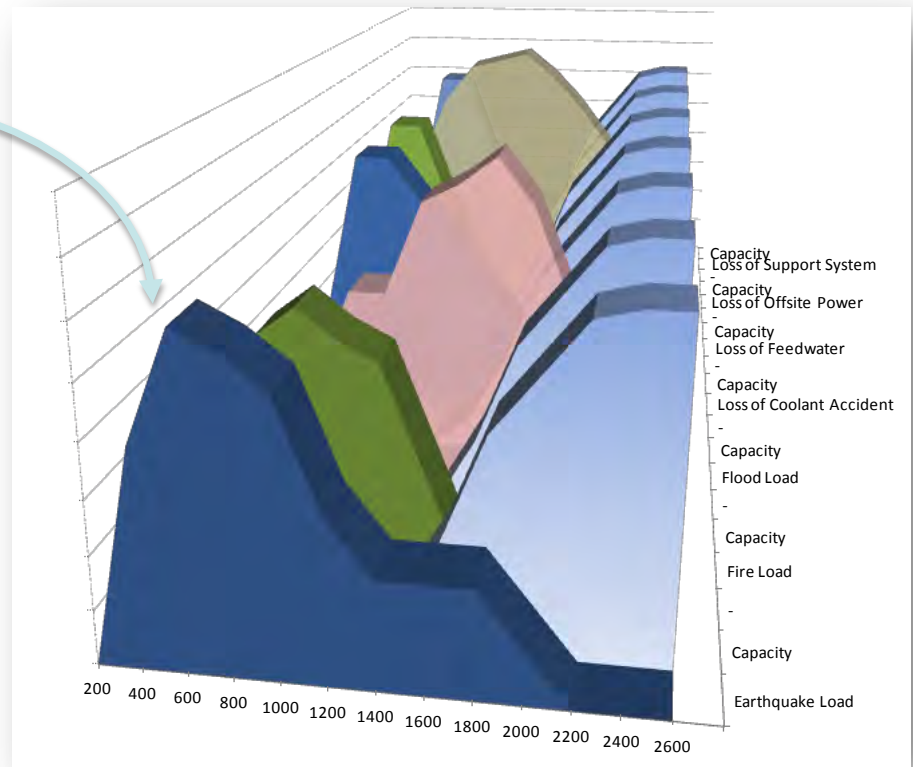
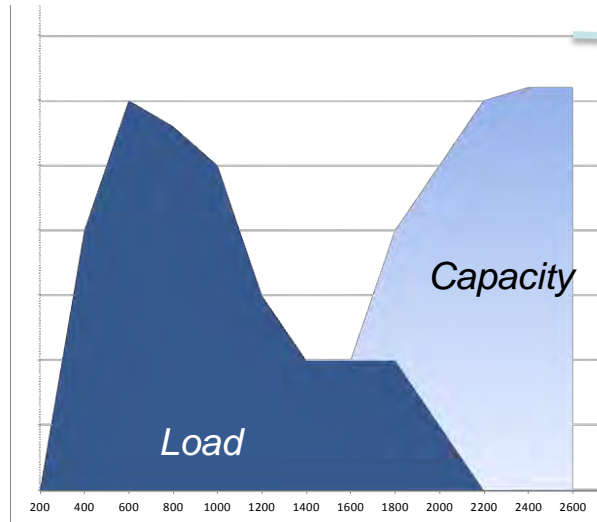
### Human Performance Improvement for NPP Field Workers

- Mobile Technology demonstrated at Duke's Catawba Nuclear Station for component identification, placement of safety tags, direct access to reference documents, and direct video streaming of emergent problems to operations managers
- 25 Catawba operators participated in the pilot project
- Reduces human error, improves efficiency, creates "collective situational awareness"
- Current work will provide electronic work packages for several field worker tasks

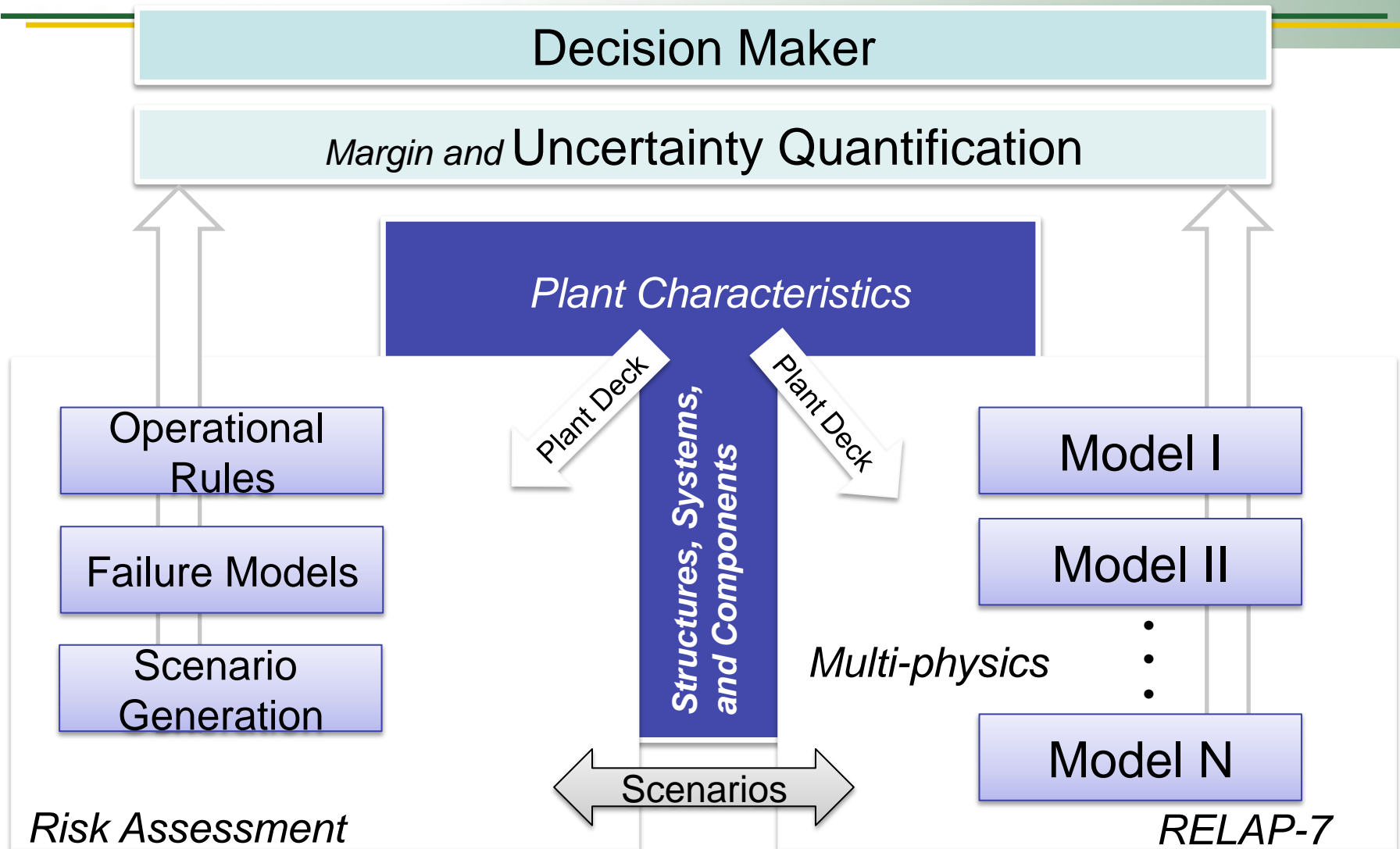


# Risk-Informed Safety Margin Characterization Pathway

- Provide more detailed information on safety margins quantification, including uncertainties, to enhance decision making for NPPs
- Goals of the RISMC Pathway
  - Develop and demonstrate a risk-assessment method for safety margins quantification
  - Create advanced tools for assessment that enable more detailed representation of NPP safety margin



## RISMC Method





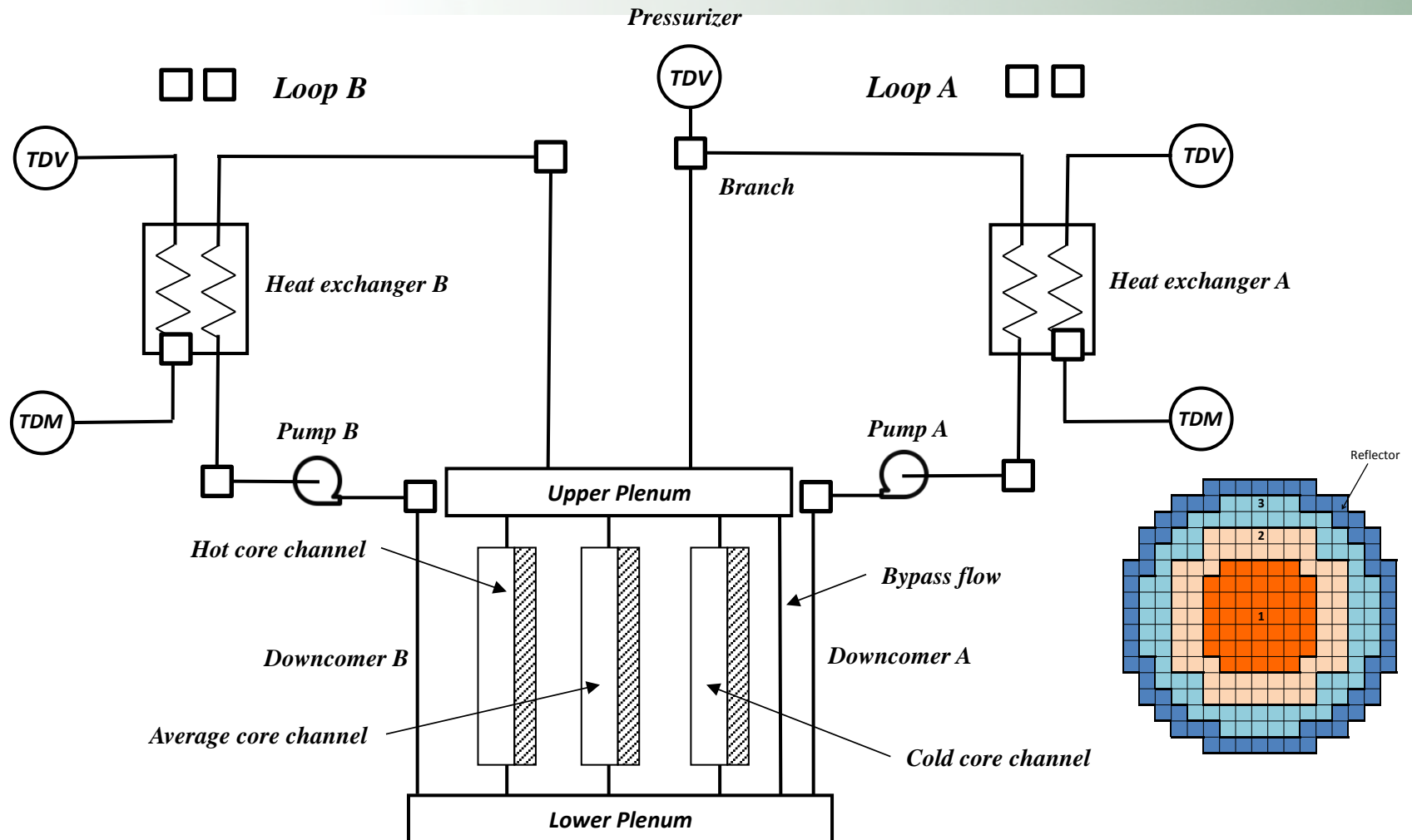
## Look Ahead: RISMC Methodology Demonstration

- **Demonstrate the RISMC methodology using the Idaho National Laboratory Advanced Test Reactor**
- **Using a margins-based approach to look at different engineering and operational issues such as**
  - Evaluate safety margin related to major capital equipment changes for emergency diesel generators (EDGs)
    - *Considering potential for replacement, substituting with commercial power backed by EDGs, or keep existing arrangement*
  - Evaluate assumptions and results from the PRA
- **RISMC methodology demonstration will be available by the next coordination meeting**

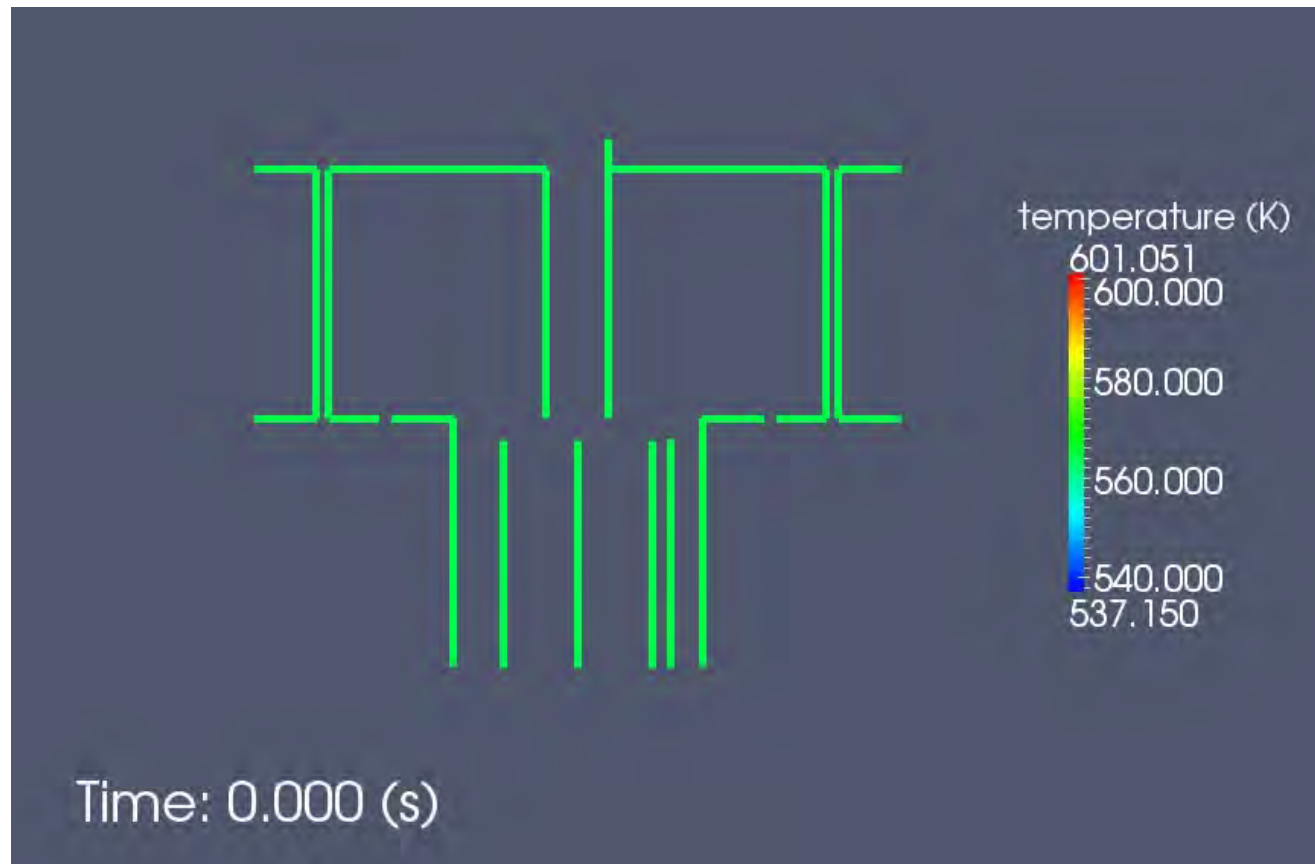




# RELAP-7 is now capable of modeling a simplified power plant (Example: OECD Test Case)

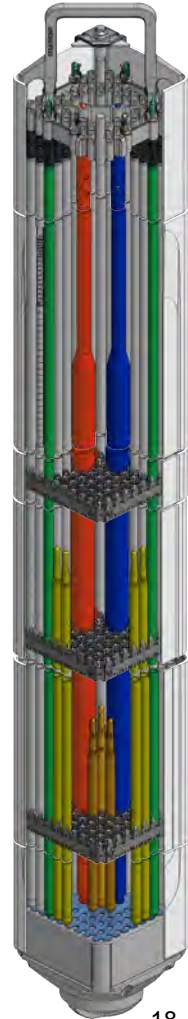


# OECD Test Case - Temperature (continued)



# Advanced LWR Nuclear Fuels Pathway

- **Improve scientific knowledge basis for understanding and predicting fundamental nuclear fuel and cladding performance in nuclear power plants**
- **Apply information to development of high-performance, high burn-up fuels with improved safety, cladding integrity, and improved nuclear fuel cycle economics**
- **Focus of this pathway is development of silicon carbide (SiC) ceramic matrix composites (CMC) nuclear fuel cladding**
  - Allows significantly improved cladding performance at very high accident temperatures and greatly reduced chemical reactivity with reactor cooling water
  - This technology has the potential to provide a very large safety margin increase and economic benefit compared to other new technologies or evolutionary advances in existing technology



## Pathway Focus is on SiC CMC Cladding

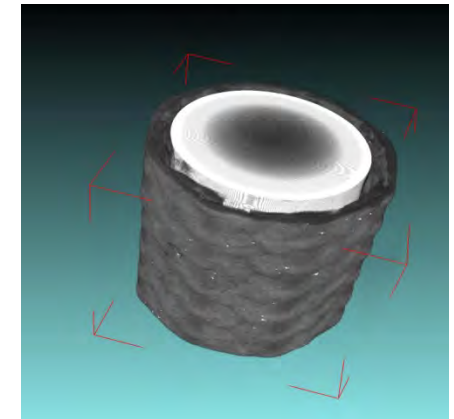
### ■ SiC CMC Characteristics

- High temperature stability with strength maintained well above 1500°C
- Low chemical reactivity
- Low neutron absorption (~20-30% less than Zr)
- Low corrosion rates
- High hardness can prevent fretting induced failures
- Reduced exothermic reaction with steam at high temperatures reduces hydrogen generation relative to zirconium-based cladding
- Improved water chemistry options for balance of plant optimization
- Database on behavior in a nuclear environment from fusion program



### ■ SiC CMC Development Issues:

- Robust end cap seal for hermeticity
- Brittle behavior (manufacturing, transport, seismic events)
- Cost and manufacturability at commercial scale
- Pellet to Clad interaction and behavior in nuclear environments, including accidents and failure modes, needs additional analysis

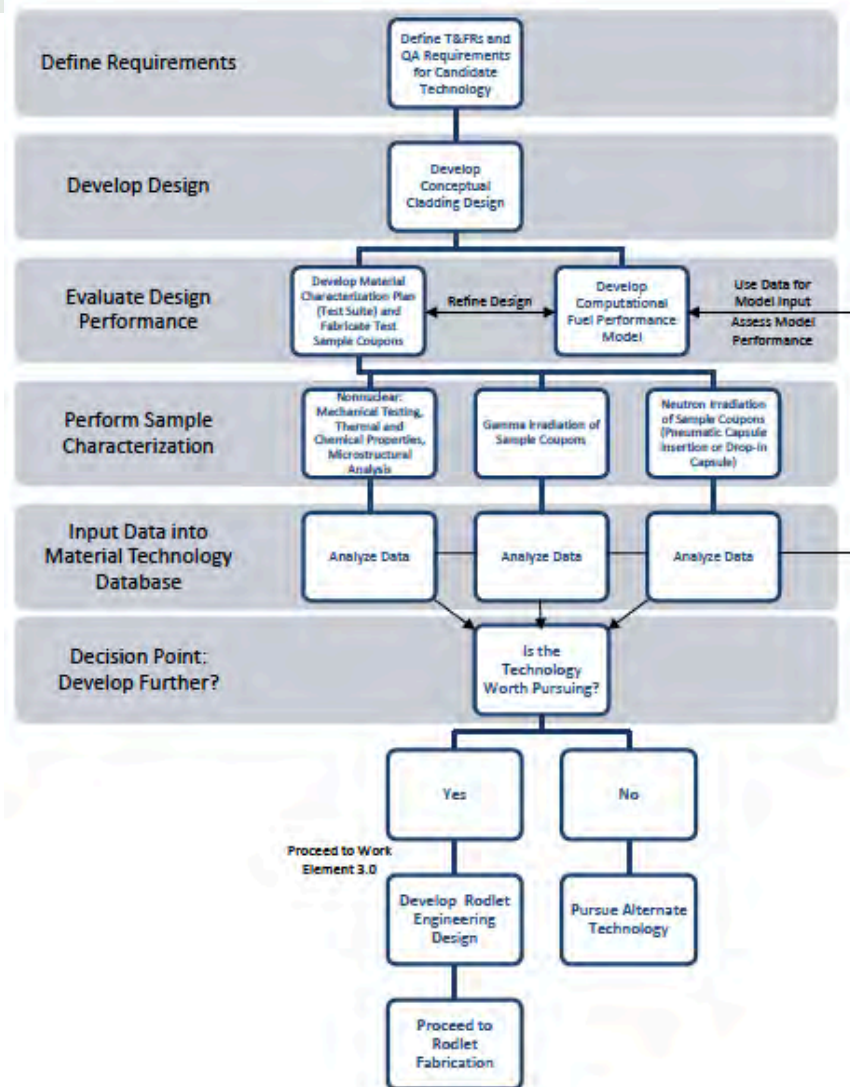




# Fuels Pathway Recent Accomplishment: Advanced LWR Nuclear Fuel Cladding System Development Technical Program Plan

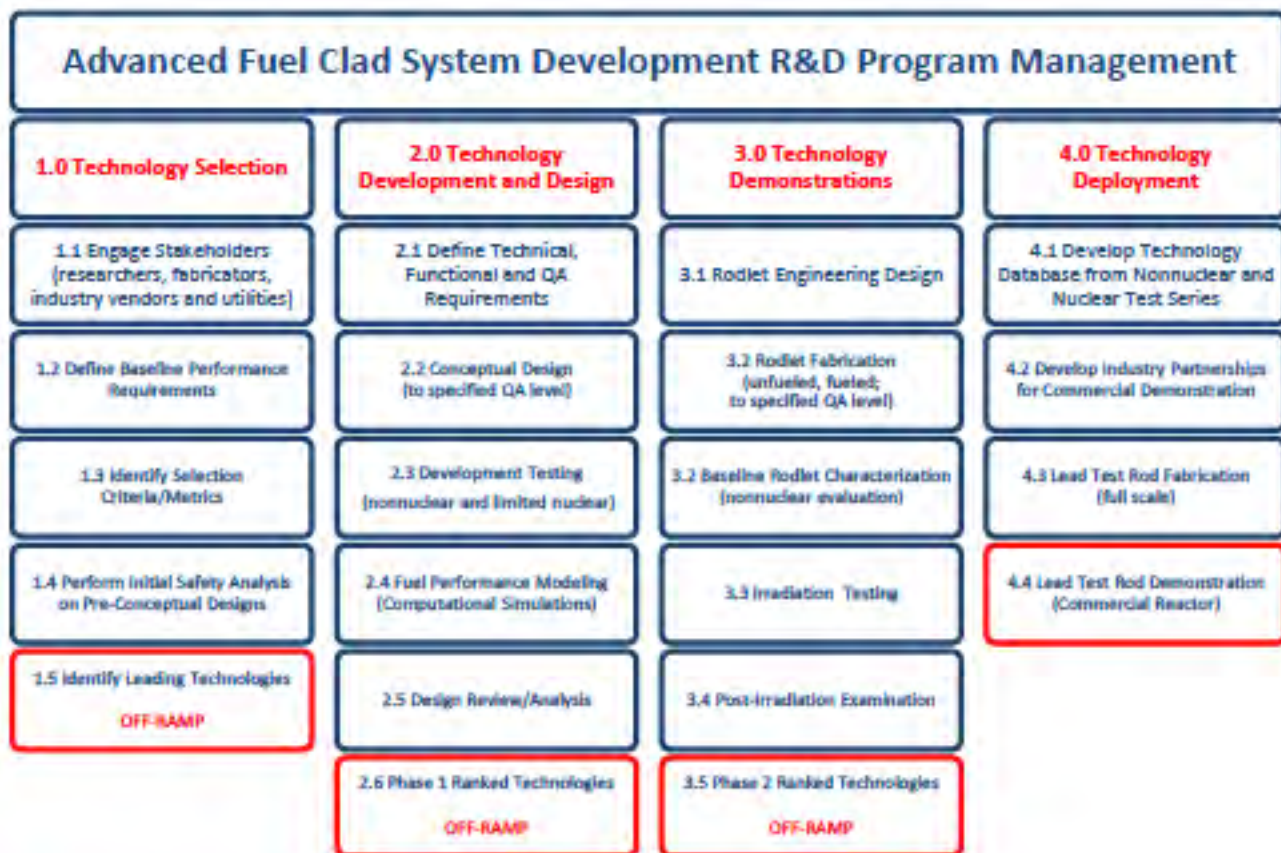
## ■ Completed the Advanced LWR Nuclear Fuel Cladding System Development Technical Program Plan

- Timeline supports demonstration of a lead test rod in a commercial reactor within 10 years
- Assumes standard UO<sub>2</sub> fuel pellets for deployment in currently operating LWR power plants
- Outlines the work breakdown structure and path forward for the development and test of advanced cladding for LWR nuclear fuel under the LWRS Program
- Allows for alteration of the existing zirconium-based clad system through coatings, addition of ceramic sleeves, or complete replacement (e.g. fully ceramic cladding)
- A variety of cladding designs will be explored (e.g., fully SiC CMC, fully ceramic cladding that incorporates layered monolithic and CMC SiC, or coated zirconium alloys to enhance corrosion resistance as a nearer-term, back-up technology option, as well as hybrid designs)
- Early development work will focus on non-nuclear testing and characterization of candidate cladding materials and designs prior to commencing in pile tests
- Modeling and simulation is an important component of exploration of clad options
  - Fuel Performance
  - Safety Analysis





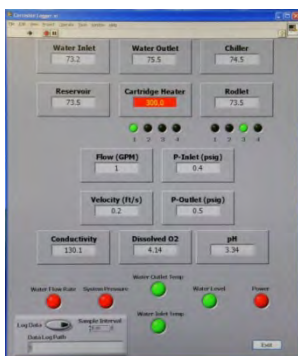
# Work process for the Advanced LWR Nuclear Fuel Development Pathway





# Advanced Fuels Corrosion Flow System

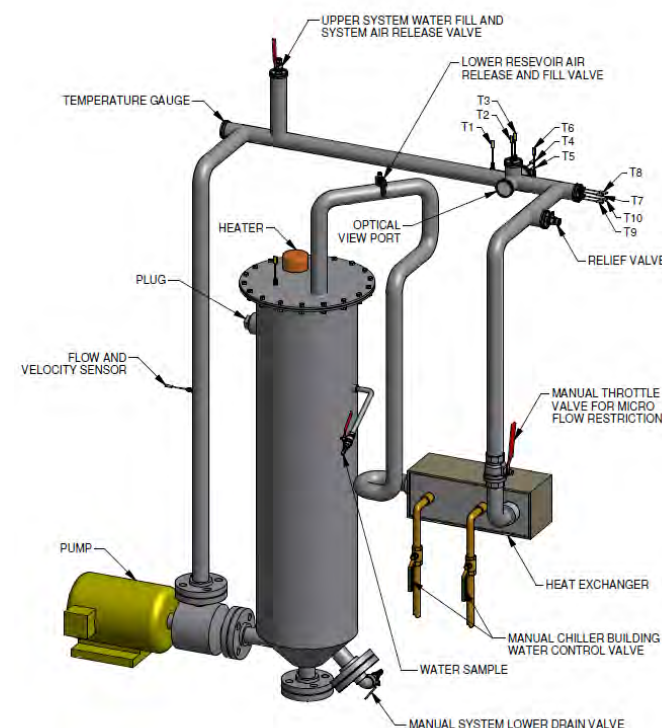
- Simulate water flow rate, chemistry, temperature, and pressure in an LWR
- Insert CMC rodlets with internal heaters
- Evaluate:
  - Corrosion resistance
  - Abrasion resistance
  - Heat transfer behavior
  - Water chemistry
    - pH
    - Dissolved oxygen
    - Conductivity



Control Panel and Data  
Logger Screen



Cladding Sample Holder. Unit  
fits behind view port



Corrosion Flow System Schematic



## DOE-NE LWRS Program and EPRI LTO Program – Joint R&D Plan

- **The DOE LWRS and EPRI LTO Programs are separate but complementary**
- **Provides for the integration of the separate LWRS and LTO Program Plans at the project level**
  - Schedule, budgets, and key interrelationships between the LWRS and LTO programs
- **Two categories of work are described**
  - Coordinated Activities:
    - *Managed by either DOE or EPRI, using standard, approved processes for R&D management.*
    - *Coordination will be limited to joint planning and communications to limit possible overlaps and gaps that may exist in the planned activities*
  - Collaborative Activities:
    - *Planned and executed on a collaborative basis*
    - *Efforts may involve, to a significant degree, joint funding as permitted by law and available appropriations*
    - *DOE and EPRI will determine which organization will lead each effort based on which party is positioned to most efficiently and effectively execute the work*
- **Report includes a brief summary of the R&D activities**
- **Available on the LWRS web site ([www.inl.gov/lwrs](http://www.inl.gov/lwrs)): INL/EXT-12-24562 Rev.1**

*Helping to Sustain National Assets*

**LWRS**

Light Water Reactor Sustainability



# Identification of Research Issues for Reactor Ageing Management

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# Integration of Domestic Nuclear Research Programs

INDUSTRY

- Profit motive / shareholder perspective
- Short term research addressing known problems and managing costs / downtime
- Ex: IASCC – Better, faster weld repairs needed for reliability and reduce field repair times

[Long Term Operability Program](#)

NRC

- Public health and safety protection perspective
- Confirmatory research addressing known safety issues
- Ex: Better testing and repair integrity assurance methods needed

[Life Beyond 60 Program](#)

DOE

- Long term national interest perspectives
- Long term research addressing predictive and improvement opportunities
- Ex: Crack precursors and irradiation damage need to be understood for better predictions and future material selection

[LWR Sustainability Program](#)

Individually, each program addresses a specific perspective; collectively, they address the majority of issues that need to be answered for safe extended operations.



# NRC Aging Management Research



- Identify Degradation Scenarios Not Addressed in NUREG-1801, “Current Generic Aging Lessons Learned (GALL) Report”
  - Identify Inspection and Monitoring Programs and Associated Requirements for Highly Likely Degradation Scenarios
- Assess Results from Implementation of License Renewal Aging Management Programs and Recommend Improvements for Subsequent License Renewal Periods
- Develop Domestic and International Partnerships to Share Expertise, Capabilities and Resources Related To Aging Management Research

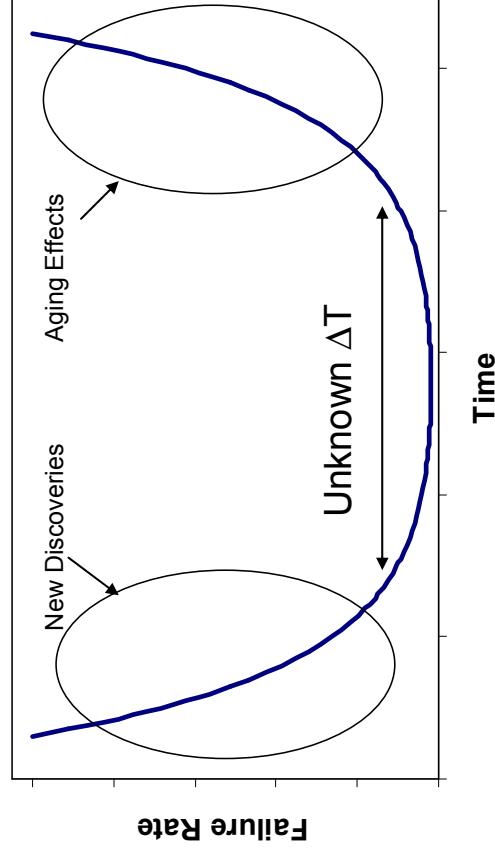


# Materials Degradation Issues Key

- Extending safe operating life of NPPs will require comparing known modes of materials degradation, and identifying emerging degradation mechanisms, with expected service life to identify potential issues
  - Materials degradation can lead to increased maintenance, increased downtime, and increased risk

- 1958 - Vibration Fatigue
- 1966 - IGSCC in 304 SS
- 1970 - Corrosion Fatigue
- 1984 - Erosion Corrosion
- 1987 - Microbial-Induced Corrosion
- 1993 - IGSCC in TP347 Stainless Steel
- 2001 - PWSCC
- ????

**"Bathtub" Curve**



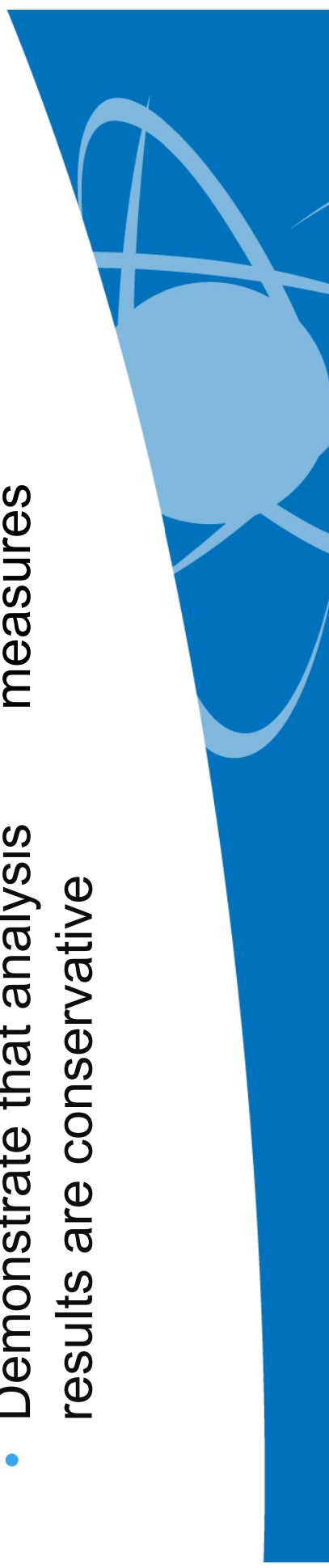
# Materials Issues

## Metal Fatigue

- Analysis methodology could yield non-conservative results
- Potential delay in implementation of planned corrective actions to address aging
- Demonstrate that analysis results are conservative

## Buried Piping

- Corrosion on soil side of piping
- Potential effects on key systems
- Enhanced guidance to increase inspections and focus on preventive measures



# Materials Issues

## Electric Cable Insulation

- Cable failures worldwide increasing with plant age
- Cables provide power needed to operate equipment and transmit signals to and from the various controllers
- Research to confirm whether requirements for electrical equipment are being met through an extended period

## Submerged Electric Cables

- Cables not designed for continuous submerged service in electrical manholes
- Cable failure can disable safety systems
- Revised inspection procedures and program guidance to increase and expand inspection and test frequencies

# Materials Issues

## Steel Containment and Liner Plate Degradation

- Corrosion because of contact with foreign objects
- Potential impact leak tightness
- Impacted scope of inspections; advisory to other licensees

## Refueling Cavity/Spent Fuel Pool Leakage

- Concerns regarding the impacts of historical water leakage from concrete walls and floors
- Potential effect on structural integrity and leak tightness
- Engaged industry





# Materials Issues

## Neutron Absorber Degradation

- Some spent fuel pool neutron absorber materials are degrading
  - Reduces safety margins and could violate sub-criticality requirement
- Developed new aging management program for neutron absorbing materials degradation

## Concrete Civil Structures

- Prolonged exposure to elevated temperatures and radiation facilitates chemical interactions and induces strains
  - Compromise concrete performance
- Research on sufficiency of current methods to evaluate effects and the effects themselves



# Moving Forward

- Take concrete steps in ensuring that needed research will provide necessary technical verification of ability of NPPs to safely operate in subsequent renewal term(s)
  - DOE & EPRI have integrated their research programs (DOE-NE Light Water Reactor Sustainability Program and EPRI Long-Term Operations Program – Joint Research and Development Plan, Revision 1, INL-EXT-12-24562, April 2012)
  - Next step is to more fully integrate NRC's LTO research activities with DOE & EPRI's
- Look at Codes & Standards updates
- Obsolescence of existing SSCs



# Conclusions

- Research is necessary to establish the technical bases for potential subsequent license renewals, and this research will:
  - Answer safety questions on aging, reliability, and long-term operability of systems, structures and components
- NRC ensures that safety-significant issues are identified and resolved in a timely manner
  - It is **not** NRC's responsibility to resolve any potential aging issues that may impact continued safe operation of existing fleet
  - NRC seeking to cooperate, as appropriate, with domestic and international stakeholders in an integrated, holistic program to ensure long-term safety



# **Westinghouse Long Term Operations (LTO) Program and Activities**

June 7, 2012

Barbara Baron, PE, Principal Engineer, Engineering Services

Michael Semmler, PE, Program Manager,  
Aging Management, Radiation, and Nuclear Operations Services

# Westinghouse Long Term Operations Program

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The purpose of the Westinghouse Long Term Operations (LTO) Program is to identify and develop products and services to resolve technical issues that would preclude operation of nuclear plants beyond 60 years of service and coordinate business segment entity efforts internally and externally with the DOE, EPRI, NEI, NRC, National Labs, utilities, Owners' Groups, and vendors.



# Westinghouse LTO Program Objectives

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- Identify and develop the applicable products and services that support, long term operation and license renewals of the LWR fleet for 60 years and beyond;
- Provide the critical skills to satisfy safety, technical, economic, and regulatory needs for nuclear power plant long term operation;
- Collaborate with the DOE, PWROG, utility customers, EPRI, NEI, and the National Labs to develop and implement technologies required to support plant long term operation; and
- Formulate ideas to enhance the LWR fleet to ensure superior safety, high reliability, and optimal economic performance throughout plant lifetimes.

# NRC Aging Issues Currently Being Addressed for LTO

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- Buried Equipment
- Cables
- Concrete
- Reactor Vessel and Internals
- Primary Piping



- Westinghouse is currently working in several of these areas to resolve these issues

# Westinghouse LTO Activities

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- Buried Equipment
  - Working with the PWR Owners Group (PWROG) on a workshop for the utilization of an Underground Piping & Tank Degradation Evaluation Handbook (DEH).
  - Developing alternate inspection technologies that will allow inline inspections, minimizing the need for excavation to complete the inspection phase of NEI 09-14 directive.
  - Developing varied methods of repair and/or remediation of underground piping that shows degradation only in localized areas or in areas inconvenient for excavation.

# Westinghouse LTO Activities

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- Cable Aging

- Westinghouse has developed a comprehensive cable program called Cable Health & Aging Management Program (CHAMP). It is comprised of the following elements:
  - Cable Prioritization – allows a focus on the smallest population of cables, while ensuring the safety and peak performance of your plant
  - Dynamic Cable Database – provides “living” documentation to illustrate a healthy program
  - Site Walk downs – expertise in identifying adverse environments and avoid burdening your internal resources during critical outage times
  - Testing – expertise in the use of testing methods to determine the health of your medium voltage cables
- Repair/Replace/Supply – providing installation & EQ services for splices or new cable replacement



# Westinghouse LTO Activities

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- Cable Aging (cont.)

- Westinghouse Sweden participates in the ADVANCE cable aging initiative in Europe. We would like to expand our cable aging research, and we have the capabilities to do so.
- Partial list of lab capabilities (Chicago/Vasteras, Sweden)
  - Forensic Analysis
  - Condition Monitoring
  - Artificial aging and environment simulation
    - Thermal Chambers
    - DBE and LOCA Chambers
    - Submergence
    - Mechanical and vibration aging
    - Post LOCA simulation
    - Partnering with others for irradiation aging, fire resistance and seismic



Westinghouse

# Westinghouse LTO Activities

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- Concrete
  - Assisted DOE/EPRI on concrete samples from Zion for further analysis
  - Under the EPRI Advanced Nuclear Technology (ANT) Program, Westinghouse, EPRI, Federal Institute for Materials Research and Testing (BAM), and Construction Testing Labs (CTL) Group used the AP1000 shield building design mockups to inspect through steel and from the exposed concrete.
    - The results are still pending.
    - The results appear to not be favorable for going through the steel face when concrete shrinkage occurred.
    - The results show success for going through the exposed concrete using a specialized ultrasonic technique.
  - On-going discussions with utilities and regulators (domestic and international)



# Westinghouse LTO Activities

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- Reactor Vessel, Internals, and Piping
  - Reviewing and identifying those analyses associated with the reactor vessel, internals, and piping that will preclude operation to 80 years and beyond
  - Including operation beyond 60 years in reactor vessel action plans and program plans
  - Provided assistance to DOE/EPRI on RV samples from Zion for further analysis

# Westinghouse LTO Activities

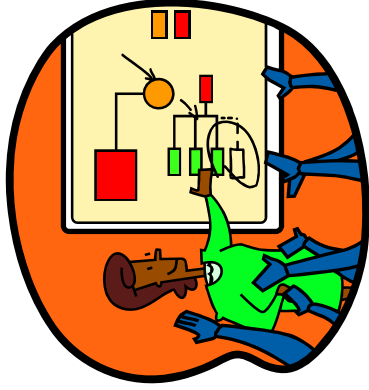
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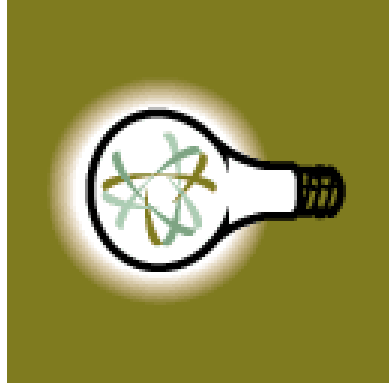
- PWR Owners Group (PWROG) Proposal
  - Developing an overall PWROG Long Term Operation program that spans multiple PWROG Subcommittees
  - Establishing a collaborative relationship with the DOE Light Water Reactor Sustainability (LWRS) Program
    - DOE LWRS Program R&D leads are invited to participate in the next PWROG meeting
  - Leveraging experience and deliverables from first license renewals to support second license renewals
    - Developing component roadmaps of potential LTO/LB60 technical issues
    - Identifying first license renewal documents that support the identified components
  - Establishing PWROG representation at the NEI License Renewal Task Force meetings and industry LTO Coordination meetings

# Westinghouse LTO Activities

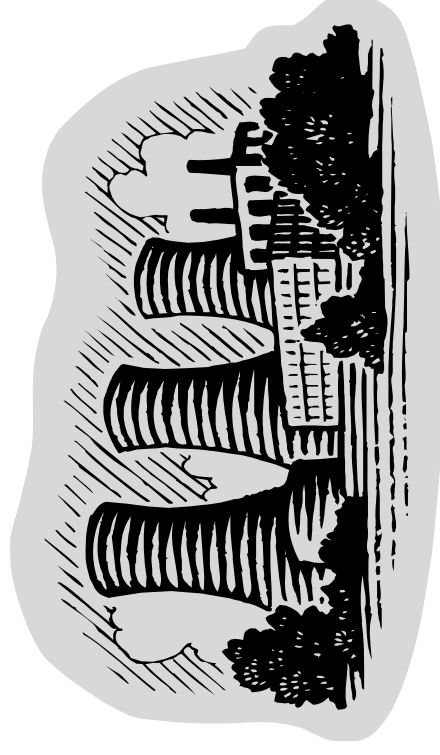
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- Industry LTO Involvement
  - Involved in NEI Groups working on LTO
  - Accepted lead to develop supplement for NEI 95-10 to address required changes for subsequent submittals
  - Attending industry/NRC meetings on long term operation to stay abreast of issues





# Thank You!





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