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Light Water Reactor Sustainability:

Nuclear Energy R&D for existing plants

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LWRS Vision and Goals

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 allow continued long-term operation of existing LWRs
- Develop technical and operational improvements that contribute to long-term economic viability of existing nuclear power plants

- Funding: FY2010 $10.0M
  - FY2011 $28.1M
  - FY2012 $21.4M

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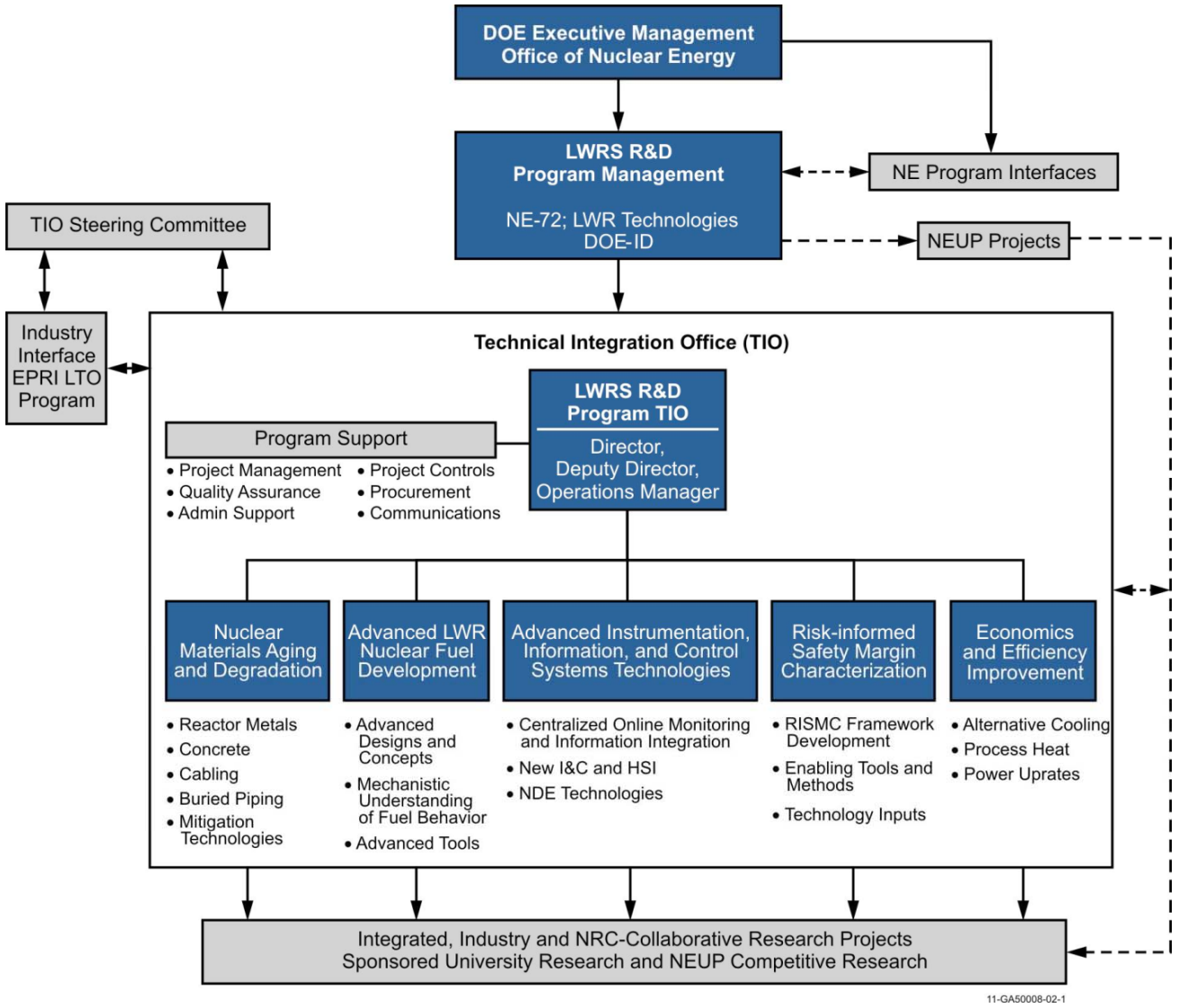
Program Coordination and Management



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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
- Industry also has an incentive, so cost-share will be employed
- Addresses fundamental scientific questions where private investment or capabilities are insufficient to make progress on broadly applicable technology issues for public benefit
- Government 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 still in development

- The Office of Nuclear Energy has signed Memorandum of Understanding with the Nuclear Regulatory Commission and the Electric Power Research Institute to cooperate on R&D related to the long-term operation of existing plants.

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Light Water Reactor Sustainability –
Preserving a critical national asset

- **Five LWRS research pathways**

1. **Nuclear Materials Aging and Degradation -** develop the scientific basis for understanding and predicting long-term environmental degradation behavior of materials
2. **Risk-Informed Safety Margin Characterization -** better understand and characterize safety margins and improve the reliability and efficiency of plant operations
3. **Advanced Instrumentation, Information, and Control Systems Technologies -** address long-term aging and obsolescence of existing I&C technologies and establish a strategy to modernize I&C systems
4. **Advanced Nuclear Fuel Development -** develop high-performance, higher burn-up fuels with improved safety, cladding, integrity, and economics
5. **Economic and Efficiency Improvements -** address high impact emerging issues and improve the efficiency of the current fleet

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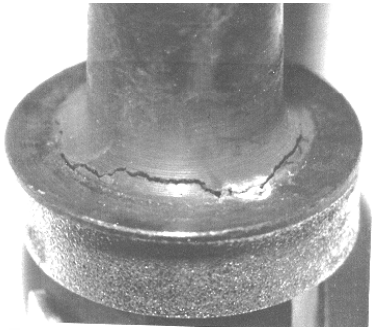
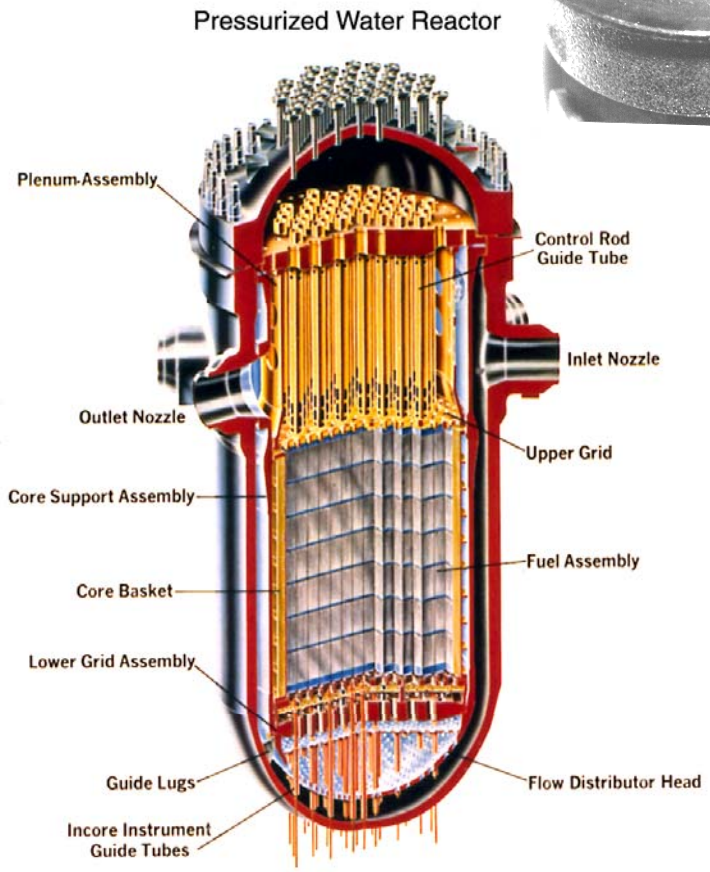
Extending service life of today's LWR fleet may create new material challenges

- **The LWRS R&D scope provides the scientific basis for understanding and predicting materials aging and degradation within components, systems, and structures**
  - Reactor metals (RPV's, internals, steam generators, balance of plant, and weldments)
    - Mechanisms of IASCC
    - High-fluence effects on RPV steel
    - Crack initiation in Nickel based alloys
  - Concrete
    - Concrete aging for long term operation
    - Monitoring tools for concrete
  - Buried piping
    - Assessment on long term piping performance
  - Cabling
    - Assessment of cable aging issues
  - Mitigation, repair, and replacement technologies
    - Weld repair techniques
    - Post irradiation annealing
    - Advanced replacement alloys





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II&C issues: significant challenges for NPPs over extended lifetimes

- **Fleet-wide benefits of modern control technologies are high but the risks executing large scale modernization are also high because of regulatory and cost uncertainties**

- **R& D Scope:**
  - **Next generation control room, IIC, and automation** – pilot projects
  - **On-line monitoring** – wireless infrastructure and life cycle prognostics
  - **Next generation NDE tools** – detection and characterization of degradation precursors

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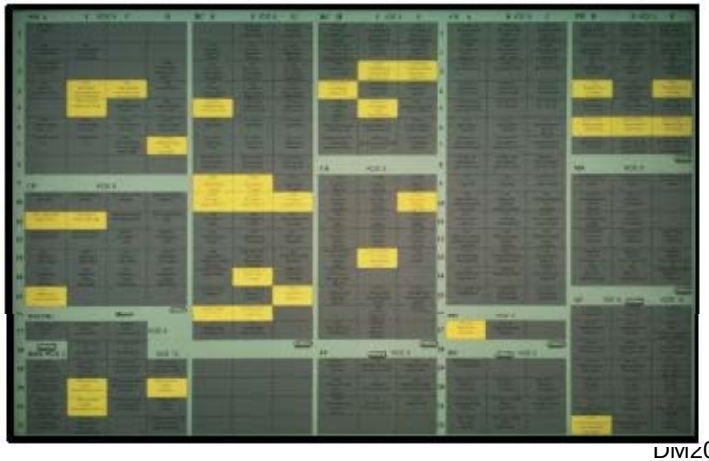
Pilot Project example: Need for Improved Alarm Systems

Current Alarm Systems in Nuclear Power Plants

- Analog systems beyond service lifetimes
  - Fundamental alarm technology developed in 60s-80s
  - Replacement parts difficult to obtain
  - Alarm systems very complex to maintain
- Overabundance of binary state alarm annunciator tiles
  - Typical plant features over 1000 individual alarm tiles
- Ineffective filtering of alarms leads to nuisance alarms that can overload operators
- Digital replacement systems have tended to be like-for-like replacements, not improved systems that intelligently filter alarms or help operator focus on most important alarms



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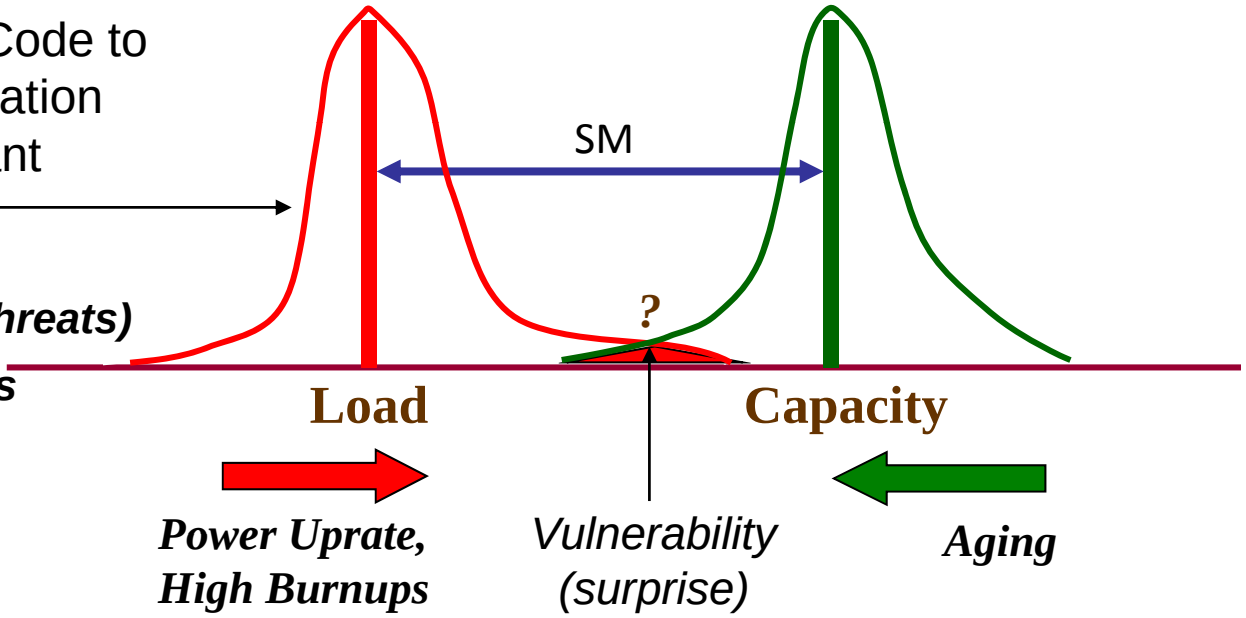
Risk-Informed Safety Margin Characterization (RISMC)

Combining Probabilistic and Mechanistic Modeling to provide Integrated Quantification of Uncertainty

Area 1: Develop RELAP7 Code to Enable Plant System Simulation and Computation of the Plant Probabilistic Loads

- ✓ ***System analysis (multiple threats)***
- ✓ ***Tightly couple multi-physics***
- ✓ ***Coverage of scenarios***
- ✓ ***Computational efficiency***
- ✓ ***Appropriate model fidelity***



Area 2: Develop a risk-informed margin-based framework for construction of LWR plant life extension "safety case"

Area 3: Incorporate (aging) SSCs into a Plant Risk Model. Integrate RISMC with Materials Aging R&D

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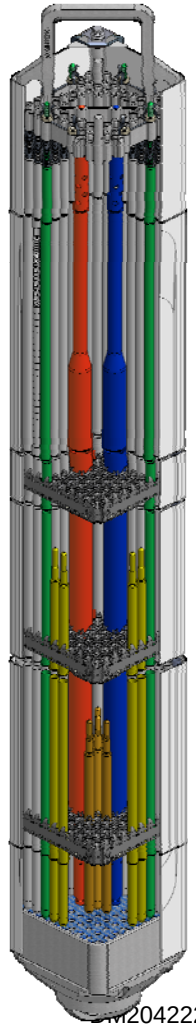
Advanced Nuclear Fuels

Goals:

- Improve the fundamental scientific understanding and prediction of the behavior of nuclear fuel pellets, cladding, and the fuel-coolant system under extended burn-ups for normal and transient conditions
- In public-private collaborations apply this information developing and demonstrating very advanced fuels with improved safety margins, and potential for higher fuel burn-ups and performance
- Develop predictive tools for advanced nuclear fuel performance
- Speed implementation of new fuel technologies to industrial application

Specific planned activities:

- Begin the development of new long-life fuel designs with advanced fuel and cladding materials
- Develop predictive tools of advanced nuclear fuel performance
- Develop a model for fuel cracking at the mesoscale level with sufficient understanding to develop a predictive model for fission gas release



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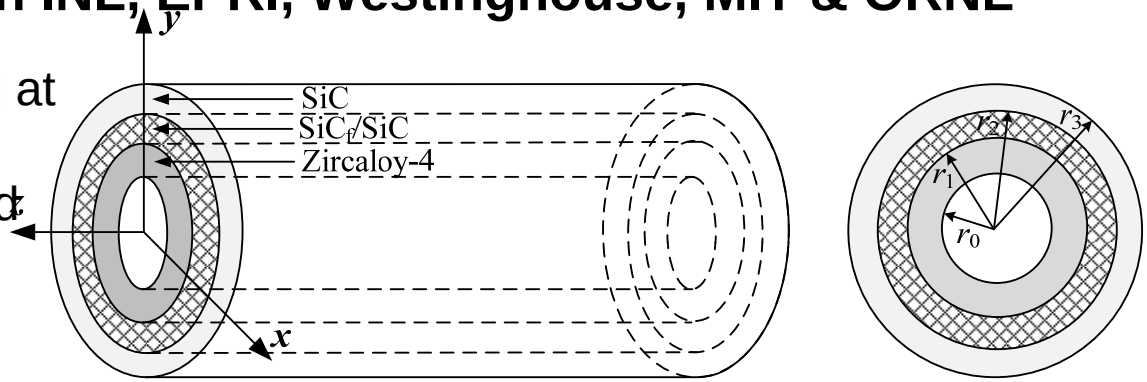
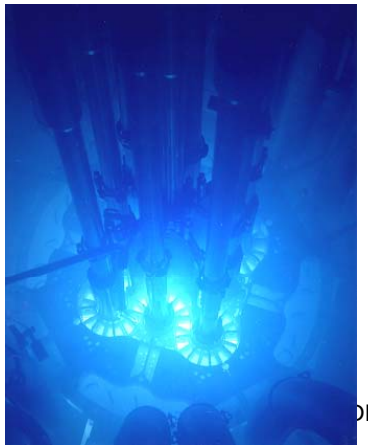
Ceramic Composite Cladding (SiC) Development

- **Collaborative efforts with INL, EPRI, Westinghouse, MIT & ORNL**
  - Fueled irradiations on-going at HFIR for ceramic matrix composite clad with UO2 and UN based on MOX testing samples
  - ATR irradiations planned for unfueled and fueled experiments in FY-11
  - Start of Halden Reactor Project irradiation planning in FY-11
  - MIT PWR coolant experiment planning in FY-11





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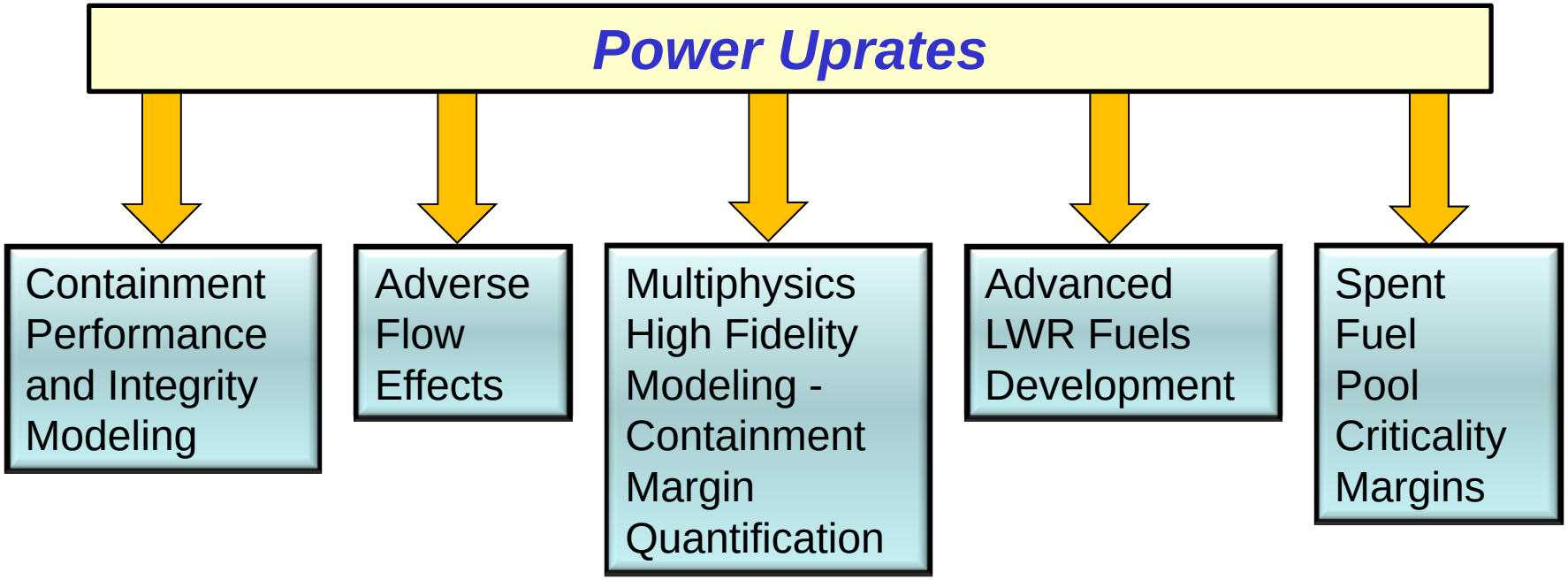
Economics and Efficiency Improvement



Goal: Facilitate power uprates for operating LWRs – identify, investigate obstacles and resolve issues that inhibit potential power uprates in aging fleet

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Pilot Plant Projects

- **Ginna**
  - Containment assessment
    - *Fiber optic strain gage measurement of tendon relaxation*
    - *Coring and subsequent spectroscopy and strength testing*
    - *Rebar condition assessment*
    - *NDE (test various methods)*
    - *Digital Image Correlation trial*
  - Augmented Reactor Internals Aging Assessment (baffle bolts)
  - RPV embrittlement
    - *Reconstitute specimens*
    - *Irradiate further*
    - *Re-test to expand vessel embrittlement database*
- **Nine Mile Point Unit 1**
  - Investigate top guide cracking
  - Other activities TBD
- **Zion D&D**
  - Concrete Specimens
  - RPV Specimens
  - Other Specimens TBD

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Conclusion

- The existing fleet of nuclear power plants provide the majority of the Nation's non-carbon emitting electrical generation
- The continued operation of the existing fleet is in the National interest as a key strategy for meeting climate change and energy supply goals
- Federal efforts are essential to stimulate and encourage industry efforts as well as to address the longer-term, high risk research that industry can not address
- Sustained R&D on long-term LWR operations is needed to identify issues and develop the technical basis that supports industry efforts to relicense plants for long-term operation