Advanced technologies are critical for assessing condition, estimating remaining lifetime, and avoiding failure of power plant components and for ensuring safe, reliable, long-term operation of nuclear and fossil generating assets.

STRATEGIC DRIVERS
Long-Term Operations

INNOVATION TARGETS
• Expand coverage
• Improve accuracy in detection and sizing
• Reduce costs
• Enhance management of major damage and aging mechanisms

EPRI is leading the development of advanced nondestructive evaluation (NDE) techniques for inspection of cast stainless steel components, early detection of creep and stress corrosion cracking (SCC), and real-time examination of weldments during the solidification process. In addition, modeling and simulation methods are being created to support ultrasonic testing of buried piping and address other industry priorities. Based in part on previous work under this program, EPRI has launched a Strategic Concrete Program (see EPRI fact sheet 1023473), and the acoustic mouse for handheld, 3-D ultrasonic imaging of components is undergoing accelerated development as a Breakthrough Technology (1021510).

Strategic Value
If successful, this program will transfer innovative NDE technologies and advanced inspection capabilities to EPRI’s Nuclear and Generation Sectors, power producers, commercial suppliers, and service providers for application-oriented development and full-scale demonstration and deployment. Early detection of damage and improved condition and remaining life assessment are critical to address emerging regulatory issues and safety concerns and support long-term operation of nuclear power plants, as well as to inform run/repair/replace decision-making for fossil capacity. By helping optimize maintenance interventions and reduce failure rates, this program will provide millions of dollars in annual benefits across the existing generation fleet and for new assets.

Technology Gaps
Strategic work addresses the following critical capability gaps:
• Reliable NDE techniques for materials, components, and failure mechanisms resistant to examination using existing technologies
• Lower-cost inspection methods for underground piping
• Modeling and simulation tools supporting NDE application and data analysis

NDE innovations—including fiber-optic strain gages for early detection of incipient cracking damage—reduce O&M costs, improve safety and reliability, and support long-term operation of nuclear and fossil plants.
**R&D Highlights**

*Cast Austenitic Stainless Steel (CASS).* Regulatory requirements mandate volumetric examination of CASS piping in nuclear plant primary coolant systems, but no reliable NDE methods exist due to the material’s complex and coarse-grain microstructure. Existing and emerging NDE technologies with potential for CASS applications have been tested on materials coupons. Low-frequency ultrasonic transducers and flexible phased arrays show promise, with results from mockup components being correlated with those from continuing grain-structure mapping experiments. A large-footprint, 2-D, low-frequency, flexible phased-array transducer is being developed to help alleviate stringent surface finish requirements associated with existing technologies. Further evaluation of thermography, vibrothermography, and computer tomography methods also is planned.

**2011-12 Milestones**

- Continue assessment and refinement of low-frequency ultrasonic NDE technologies using mockups made of various CASS materials
- Initiate laboratory evaluation of vibrothermography, computer tomography, and other methods

*Early SCC & Creep Detection.* Mechanical damage generally cannot be detected until it has progressed for several years and entered the final, rapid phase of crack growth. To support detection, monitoring, and management of incipient damage, EPRI has completed a state-of-knowledge assessment and developed a laboratory setup for monitoring damage processes and evaluating NDE capabilities. For piping mockups exposed to conditions associated with creep and intergranular SCC, data collected using acoustic emission, x-ray tomography, fiber-optic strain monitoring, and other techniques are being compared to identify detectable indicators of damage progression. To date, an outside-diameter surface strain effect associated with early SCC has been identified. Field demonstration of promising techniques is anticipated to begin in 2013. Applying NDE results to achieve crack arrest in a single 14-inch-diameter dissimilar metal weld at a nuclear plant would yield savings on the order of $1 million, giving a sense of the scale of potential economic benefits.

**2011-12 Milestones**

- Complete experimental evaluation and refinement of acoustic emission techniques for detecting creep in carbon steel seam welds
- Complete testing of fiber-optic strain gages for early SCC indication in stainless steel piping mockups and initiate testing for dissimilar metal welds

*Real-Time Welding NDE.* The ability to perform inspections as new welds are constructed and existing welds repaired would improve productivity by eliminating wait-time for traditional NDE while avoiding the need for excavation and repair of defects detected after welding is completed. It also could help avoid residual stresses created during defect repair, extending weld lifetime. To support technology development, techniques for reliably creating flaws during welding were devised in 2010. These techniques have been applied to demonstrate the feasibility of using ultrasonic guided waves produced by an electromagnetic acoustic transducer (EMAT) to detect fabrication flaws during the root pass. Continuing experimental study of EMAT capabilities focuses on identifying correlations between welding process parameters with the creation of flaws, while infrared imaging equipment and smart cameras are being evaluated. Field trials of a prototype inspection for real-time welding NDE are expected in 2013.

**2011-12 Milestones**

- Complete experimental evaluation and refinement of acoustic emission techniques for detecting creep in carbon steel seam welds
- Complete testing of fiber-optic strain gages for early SCC indication in stainless steel piping mockups and initiate testing for dissimilar metal welds

*NDE Modeling & Simulation.* In 2011, EPRI is launching efforts to create a fully integrated, global NDE Modeling & Simulation Center providing a one-stop source of technical expertise and tools addressing power plant components, materials, and damage and aging mechanisms. A worldwide survey of existing NDE modeling and simulation tools and research activities is under way in light of industry needs. This will

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**PROGRAM LEVERAGE**

**10%**

**INNOVATION NETWORK**

**University**
- Clemson University
- Georgia Institute of Technology
- Iowa State University
- Lehigh University
- Pennsylvania State University

**Public & Private Sector**
- EDF
- Materials Aging Institute
- Oak Ridge National Laboratory
- Los Alamos National Laboratory
help identify the state of the art, critical capability gaps, and opportunities for future collaboration to advance NDE capabilities.

Ongoing research demonstrates EPRI's planned approach: Field tests on underground piping mockups identified guided-wave (GW) ultrasonic testing as a potential approach for “minimal dig” NDE at nuclear plants. As mockup development is costly and time-consuming, EPRI is applying finite element modeling (FEM) to build 3-D representations of piping systems and create the required analytics for practical GW applications. FEM simulation of GW interactions with piping, elbows, and welds is enabling refinement of signal processing and analysis methods for improved flaw detection and sizing in underground environments. Successful demonstration and commercialization of GW technology will help minimize the need for costly excavation while preventing failures and lowering the risk of tritium leaks.

For more information
For more information, contact the EPRI Customer Assistance Center at 800.313.3774 [askepri@epri.com].

Contact
John Lindberg, Program Manager, Nuclear jlindberg@epri.com, 704.595.2127.

EPRI employs technology readiness level (TRL) metrics to monitor the status of individual technologies as they advance through its innovation process and transition into its sector programs toward commercial application. (NUC = Nuclear Sector; GEN = Generation Sector)

### Startup Conditions, End-of-Year 2011 Status and Sector Transitions

<table>
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<th>Project Area</th>
<th>Research and Discovery</th>
<th>Innovation and Development</th>
<th>Demonstration</th>
<th>Commercialization and Diffusion</th>
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<td>TRL1</td>
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<td>Early SCC and Creep Detection</td>
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<td>Real-Time NDE for Welding</td>
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<td>NDE Modeling and Simulation</td>
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= Anticipated Progress Through EOY11
= Anticipated Progress at Transition Point

2011-12 Milestones
- Benchmark existing NDE modeling and simulation tools and complete initial gap analysis of industry-wide capabilities
- Develop signal processing techniques in support of GW ultrasonic testing for NDE of underground piping elbows and continue modeling in other areas

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