ISSUE STATEMENT

Inspection needs for certain nuclear plant applications are too complex for current nondestructive evaluation (NDE) technologies. Regulatory and industry commitments require validated solutions, but traditional approaches to validation are costly and time-consuming. Modeling and simulation technology can potentially replace and/or augment physical development and testing. Modeling can also be used to assist NDE examiners in the analysis of large quantities of data images to improve flaw detection results.

DRIVERS

Economics

Physical demonstrations of NDE techniques are expensive. Development of a new qualification program relying wholly on practical demonstration can cost several millions to tens of millions of dollars. Mockups can cost $100,000 to $1 million each and take years to build. Failed empirical trials impact cost and schedule.

Human Performance

There have been several incidents of false calls resulting from qualified examiners’ lack of experience with field situations. Additionally, an NDE workforce gap is projected. Although efforts are in place to bring new personnel into the workforce, workers will need focused training to prepare for the qualifications and for the field inspections. Modeling can be used as a training tool to bring understanding to the inspector of the complex inspection challenges associated with the component.

There have also been situations where the flaw signals in NDE data images were challenging to detect. Modeling software algorithms can be used to first identify the important characteristics of a flaw and then to highlight these areas for further review.

Reliability

An NDE probability of detection (POD) is required for condition assessment and asset management. Physical demonstration often includes personnel testing to establish inspection system capability in terms of POD; modeling can be used to predict those results in lieu of costly performance demonstration testing. Additionally, NDE reliability is critical to reduce false calls.

Regulatory

The requirements for inspection technique demonstration are increasing in virtually every nuclear nation. Theoretical justification through modeling is now a standard requirement in many countries and is recognized as an acceptable way of meeting the requirements for NDE qualification and performance demonstration (European Network for Inspection Qualification guidelines and ASME Section V/Article 14 requirements). With new qualification programs possible in several areas (welds in new plants, buried piping, PWR and BWR internals, concrete, cables, visual examinations, etc.), theoretical justification via modeling could advance implementation.

RESULTS IMPLEMENTATION

Upon completion of this work, it is expected that:

• Coordination of industry models will provide utilities with a suite of tools to address NDE issues and provide solutions
• Regulatory bodies will have increased confidence in theoretical approaches to validating NDE solutions
• Universities, research institutes, utilities, and vendors will have an integrated approach to modeling and simulation
• The nuclear industry will realize improvements in human performance through better training and understanding of NDE capability
• Other sectors such as generation and renewables will have a basis to implement modeling in lieu of physical demonstration
• The industry will have a computer-assisted data analysis software platform to increase the probability of detection
**PROJECT PLAN**

The EPRI global modeling center of excellence plan is defined in four phases:

**Scoping**

Develop a precise understanding of global needs, both present and future, on issues such as cast stainless steel, buried pipe, long term operation, and license renewal. Coordinate with regulators to understand their expectations for modeling and the criteria by which it would be accepted in lieu of physical demonstration. Explore collaborations with other institutes and universities. Perform a global survey of modeling and simulation tools available today.

**Deliverable:** Gap analysis

**Equipping**

Specify and contract development of new models as needed per the gap analysis. Acquire the necessary workstation clusters and software. Equip a modeling and simulation laboratory in the EPRI Charlotte facility and worldwide satellite laboratories. Identify and acquire resources. Develop model benchmarking and validation plan, with appropriate coordination with regulators.

**Deliverable:** Equipped Modeling and Simulation Center

**Ramping Up**

Take delivery of new models. Execute benchmarking and validation plan. Begin collaborations. Plan the integration into applications for membership needs.

**Deliverable:** Functioning Modeling and Simulation Center

**Operation**

Finalize benchmarking and validation. Finalize integration while developing NDE solutions to respond to membership needs. Continue benchmarking and collaborations.

**Deliverable:** Operational Modeling and Simulation Center

**RISKS**

Risks associated with completing this work:

- Lack of regulatory acceptance
- Legal hurdles for collaboration
- Inability to validate software for specific degradation mechanisms or component inspection conditions

Risks associated with not completing this work:

- Use of non-validated models and impact of errors/ mistakes. Inability to offer timely solutions.

**RECORD OF REVISION**

This record of revision will provide a high level summary of the major changes in the document and identify the Roadmap Owner.

<table>
<thead>
<tr>
<th>REVISION</th>
<th>DESCRIPTION OF CHANGE</th>
</tr>
</thead>
</table>
| 0        | Original Issue: August 2011  
Roadmap Owner: Mark Dennis |
| 1        | Revision Issued: August 2012  
Roadmap Owner: Mark Dennis  
Changes: Six roadmap milestones have been clarified in the flowchart. The task of collaboration with regulators in NDE modeling and simulation activities is now scheduled to start in 2012. |
| 2        | Revision Issued: August 2013  
Roadmap Owner: Mark Dennis  
Changes: Added task for computer-assisted data analysis in the roadmap description and the flowchart. The procurement of a high performance computer (HPC) was also added to the flowchart. Updated progress of existing tasks in the flowchart. |
| 3        | Revision Issued: January 2014  
Roadmap Owner: Mark Dennis  
Changes: Flowchart was updated to reflect funding for Hardware/HPC in 2012–2014 and collaboration with outside organizations interested in NDE modeling and simulation to 2014–2015. |
| 4        | Revision Issued: August 2014  
Roadmap Owner: Mark Dennis  
Changes: Update to flowchart to show status of activities. |
| 5        | Revision Issued: August 2015  
Roadmap Owner: Mark Dennis  
Changes: Updated flowchart to show status of activities. Benchmarking, validation, integration, and software configuration control/documentation activities are ongoing. Collaboration with regulators and the industry on the use of NDE modeling is progressing. |
| 6        | Revision Issued: August 2016  
Roadmap Owner: Mark Dennis  
Changes: Update to flowchart to show status of activities. |
Nondestructive Evaluation Modeling and Simulation Center

Utilities
- Buried Pipe GW Signal Processing Techniques for Inspection of Elbows
- Buried Pipe GW Sizing and Quantification Algorithms

Nondestructive Evaluation APC
- Scoping
- Gap Analysis
- Surveys
- Equipment
- Ramping Up
- Operation Begin Collaboration Finalize Validation

Material Degradation/Aging APC
- Evaluate SGMP Work on Modeling
- Leverage Existing Modeling Expertise

Government
- Regulatory Modeling
- Engagement on Industry Use of Modeling

Vendors
- Collaborate on Software Technology

Low and Research Institutes
- Begin Collaboration / Identify Application Models
  - Iowa State, Michigan State, Penn State, NC State, Saarbrucken, Kassel, Tohoku, MAI, CRIEPI, KEPRI, CEA, BAM, IrfP, etc.

Code
- Potential Need to Update Industry Codes/Standards to Address Modeling Approach to PD

Legend
- Key Milestone
- Complete Milestone
- Funded Work
- Unfunded Work

Milestones:
1. Generic Verification and Validation Process Established
2. Essential NDE Modeling
3. Arbitrary Ray Tracing
4. More Effective Inspection Procedures for CASS, Concrete, Vessels, Piping, etc.
5. Successful Functioning Modeling and Simulation Center
6. Acceptance of NDE Modeling to Supplement Performance Demonstration