Dry Cask Storage System Inspection and Robotic Delivery System Development

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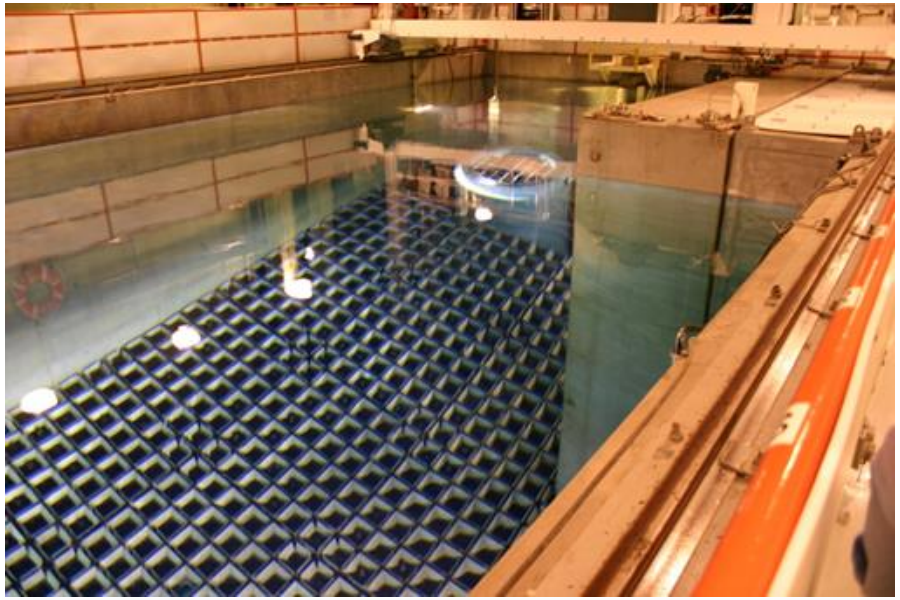
Used Fuel & High-Level Waste

2016 RegCon Meeting
Dec. 8, 2016

Background

- Dry Cask Storage System (DCSS) were originally a short term solution for expanding storage capacity of spent fuel
  - Permanent repositories not yet available
- DCSS are being used for longer than originally licensed
  - Some have been in use for >20 years
- Considerations for extending operation
  - Aging management is needed
  - A number of areas to address
  - Inspection of DCSS canisters is a key component of aging management, and hence license renewal and extended operation

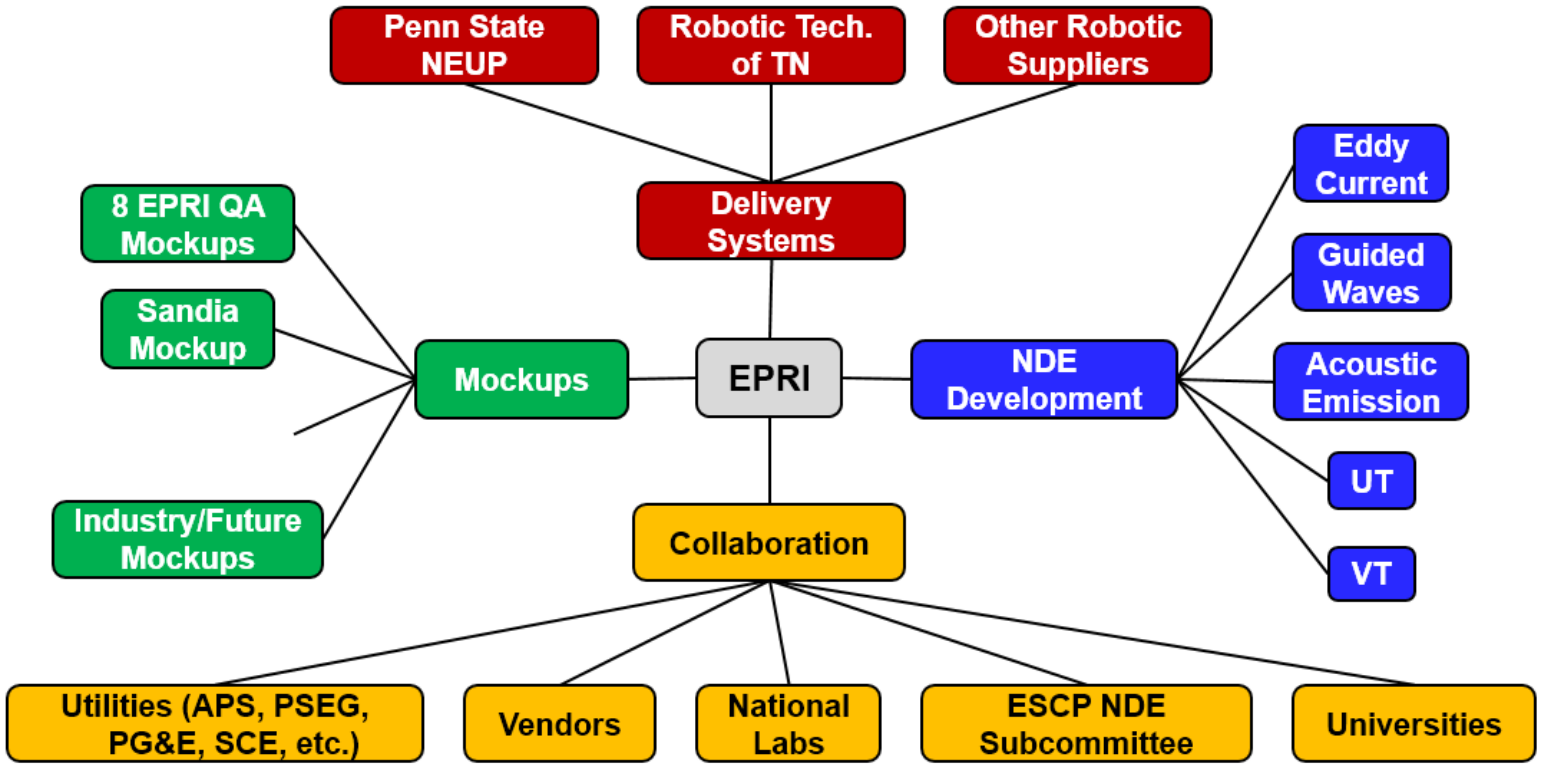


DCSS Inspection Background

- DCSSs were not designed with inspection in mind
  - High temperature
  - High radiation
  - Difficult to access & confined space
- Components of interest:
  - Stainless steel canisters used in canister-based systems
- Aging degradation mechanism of primary concern:
  - Chloride-induced stress corrosion cracking in stainless steel storage canisters

EPRI Project Overview

- EPRI is working to provide inspection options for DCSSs
  - 4 Key Focus Areas
    - Collaboration
    - Mockups
    - NDE Development
    - Delivery Systems



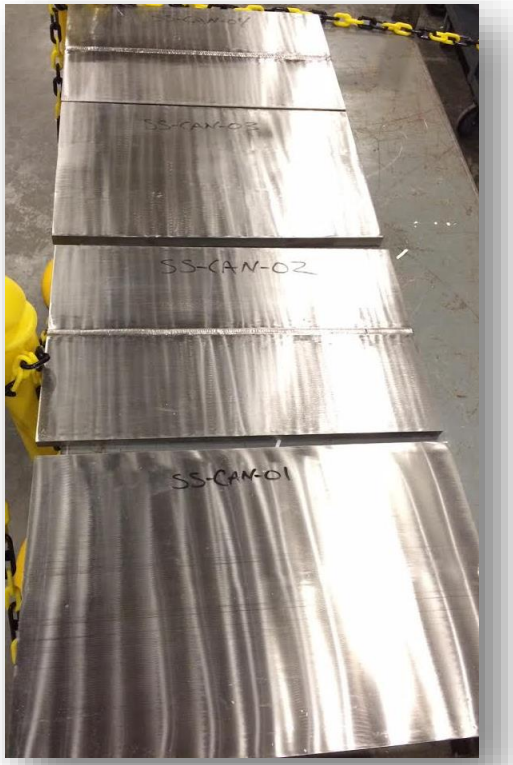
Goal: Develop Capability to Detect a Part-Wall Crack with ASME-accepted methods

Collaboration

- EPRI currently working with
  - Robotic Technologies of Tennessee (RTT) and GE on robotic delivery and visual inspection
  - University of South Carolina on acoustic emission
  - PNNL on VT inspection and canister flaw mockup development
  - Structural Integrity for guided wave inspection
  - AREVA for ultrasonic and eddy current inspection
  - EDF Energy on inspection ring concept
- NRC petitioned ASME to develop inspection and evaluation criteria for DCSS
  - ASME Task Group formed (Initial meeting April 2015)
  - Task Group Charter was approved by Section XI Executive Committee
  - Goal is to complete code action within 5 years
  - The ASME code case will then be available for NRC use in licensing
  - Collaboration with NDE development for useable outcome
- EPRI also engaged with DOE funded university programs
  - Penn State-led consortium developing electromagnetic acoustic transducer (EMAT) technique
  - University of Mississippi-led consortium investigating emissions tomography, physical and structural acoustics, acoustic emissions interrogation and muon imaging
  - Colorado School of Mines-led consortium evaluating various NDE techniques for canister inspections

Mockup Development

- Existing mockups were identified
  - None had flaws, most could not have flaws
- EPRI worked with flaw mockup manufacturers to build 8 mockups with flaws for industry use.
  - Flaws of interest primarily in and around the weld
  - Mockups are complete and being used for NDE technique development
- Sandia mockup has been provided to EPRI
  - Full diameter, 2’ long section
  - PNNL funded flaw implantation for a realistic flaw in the weld



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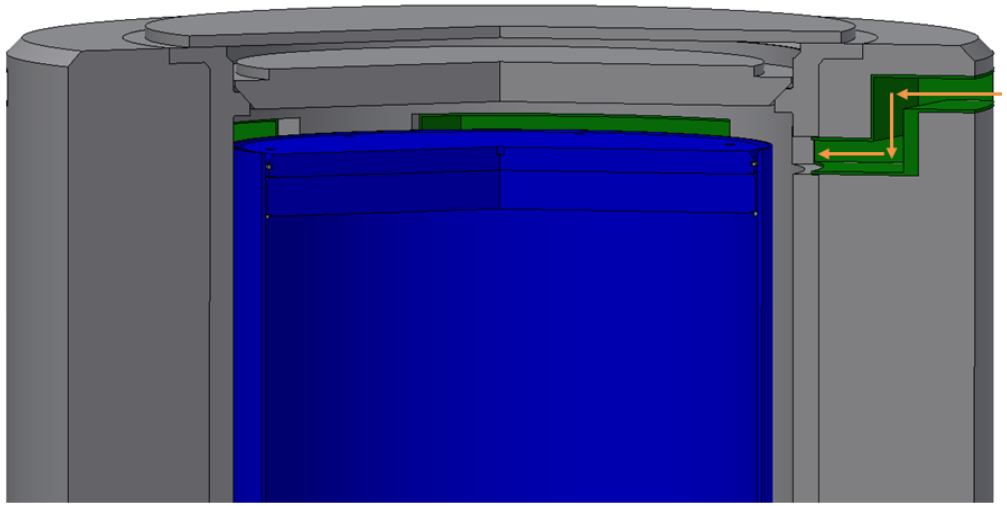
NDE for DCSSs

- DCSS present challenging conditions for NDE
  - Estimated radiation dose was 1-10,000 R/hr
    - Max. measured dose to date is ~100 R/hr
  - Temperatures from ~70-250+°F
    - Location and heat load dependent
  - Challenging access
    - Small vent ports for access
    - Complex entry pathway and obstructions
    - Narrow annulus between canisters and concrete overpack



Qualitative Overview of NDE Technologies

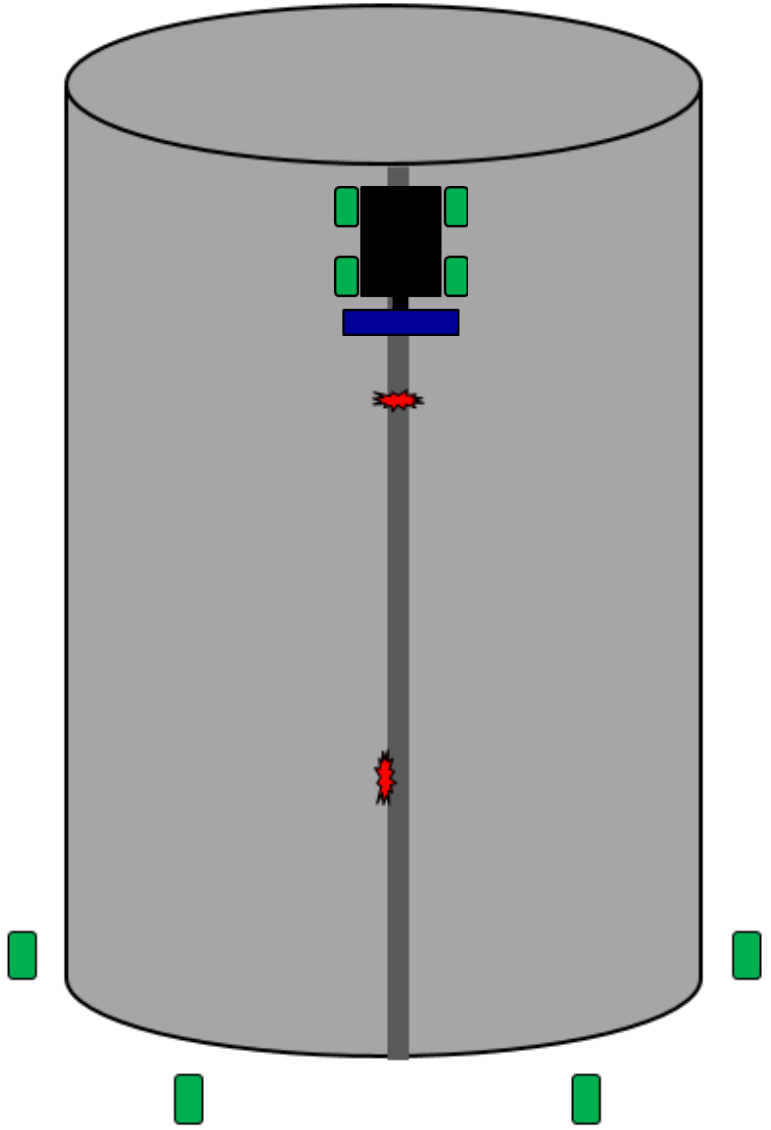
NDE Technique	Temperature Resistant	Radiation Resistant	Small Form Factor	Sensitive to ODSCC	Compatibility for DCSS Inspection	Time to Delivery
Visual (VT)						
Eddy Current Testing (ECT)						
Ultrasonic Testing (UT)						
EMATS/Guided Waves (GW)						
Acoustic Emission (AE)						
X-ray (RT)						
Penetrant Testing (PT)						N/A
Thermography						
Muon Imaging						

Now		Not Applicable
<1 year		Good Performance / Yes
<3 years		Fair Performance / Maybe
4+ years or N/A		Poor Performance / Not Well Suited

Desire is to have qualified NDE techniques such as visual, eddy current and ultrasound

Potential Inspection Sequence

- Rapid scanning for condition assessment
  - Identify suspect areas using VT-3
- Evaluation of any suspect areas
  - If needed, detailed scanning using VT-1, eddy current, ultrasonic, guided waves, etc.
- Monitoring reduce/eliminate future inspections
  - Acoustic emission or other monitoring technologies



NDE Techniques Under Development

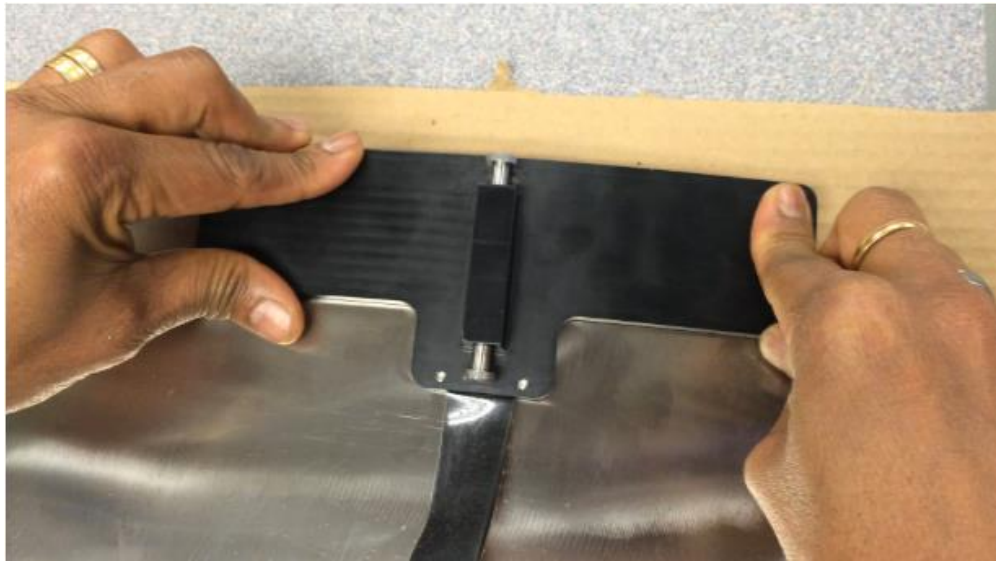
EPRI Projects

- Eddy Current Array (ECA)
  - Using ECA in a new way to help differentiate flaws of interest
  - Excellent results obtained
- Guided Waves
  - Ability to find defects in inaccessible areas (under rails, supports, etc.)
- Acoustic Emission
  - Potential to monitor from outside of the cask

Supplement above inspections using visual imaging (cameras only)

Vendor Development Needs

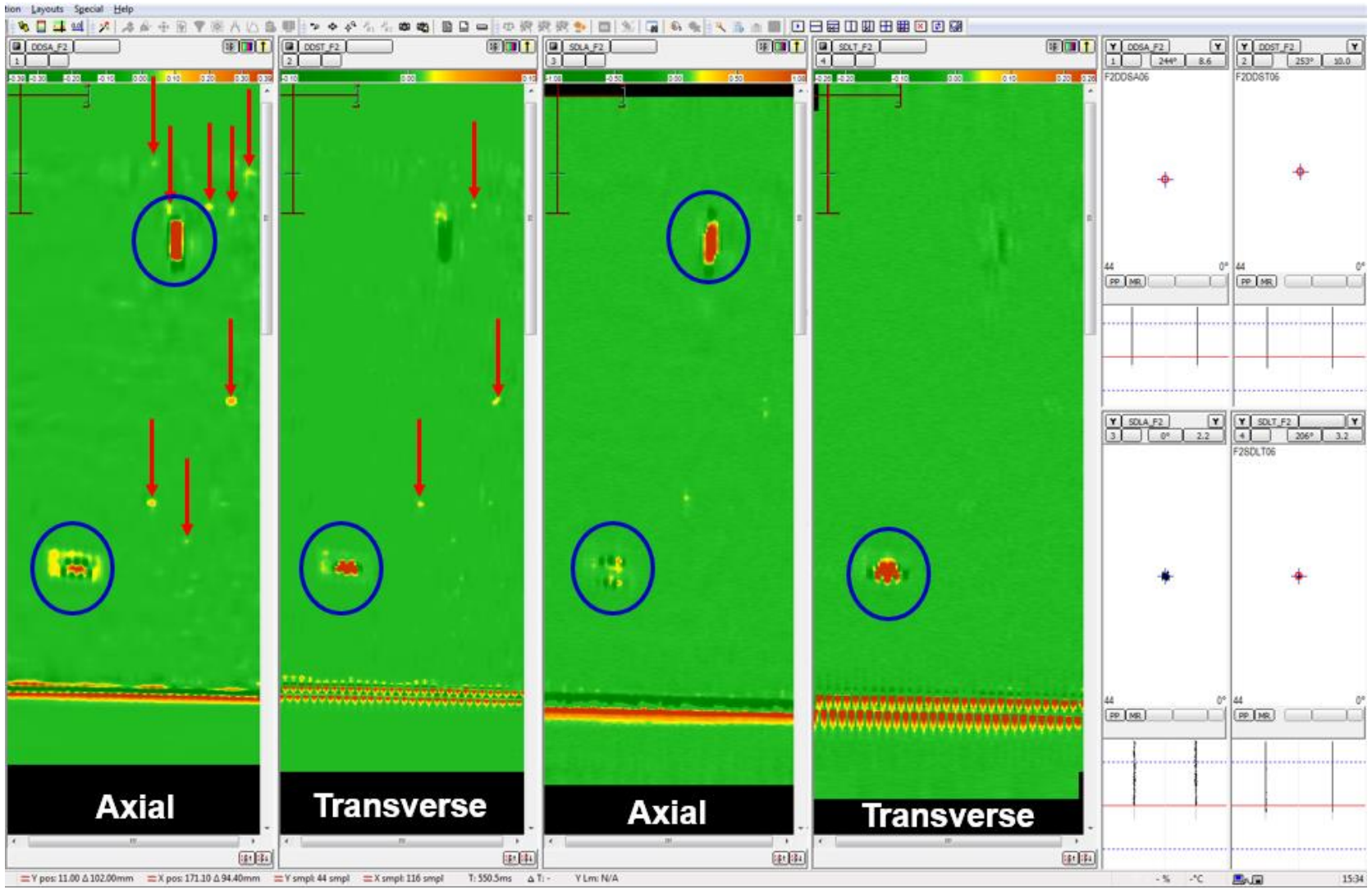
- Gaps correlate to vendor strengths
  - Visual Techniques (VT-1 & VT-3)
  - Ultrasonics for length and depth sizing



Eddy Current Inspection – Cracks/Pitting

= Simulated Cracks

= Pitting ~1.0-2.5 mm pits



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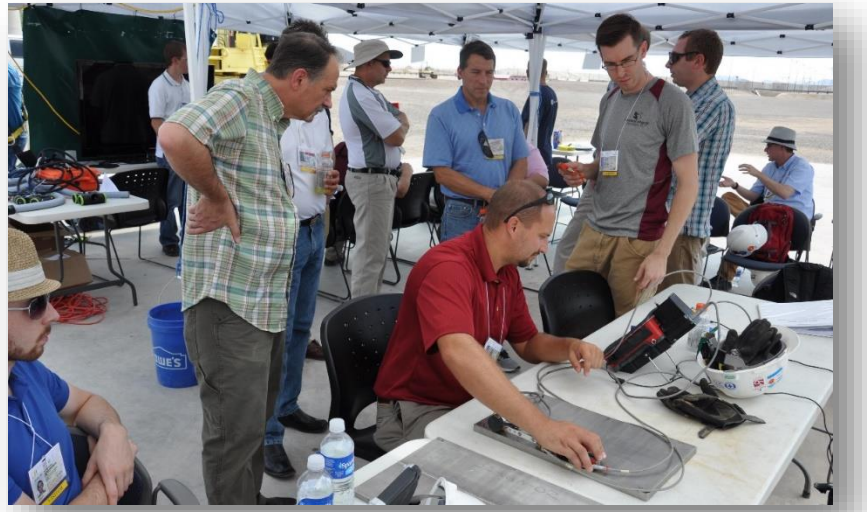
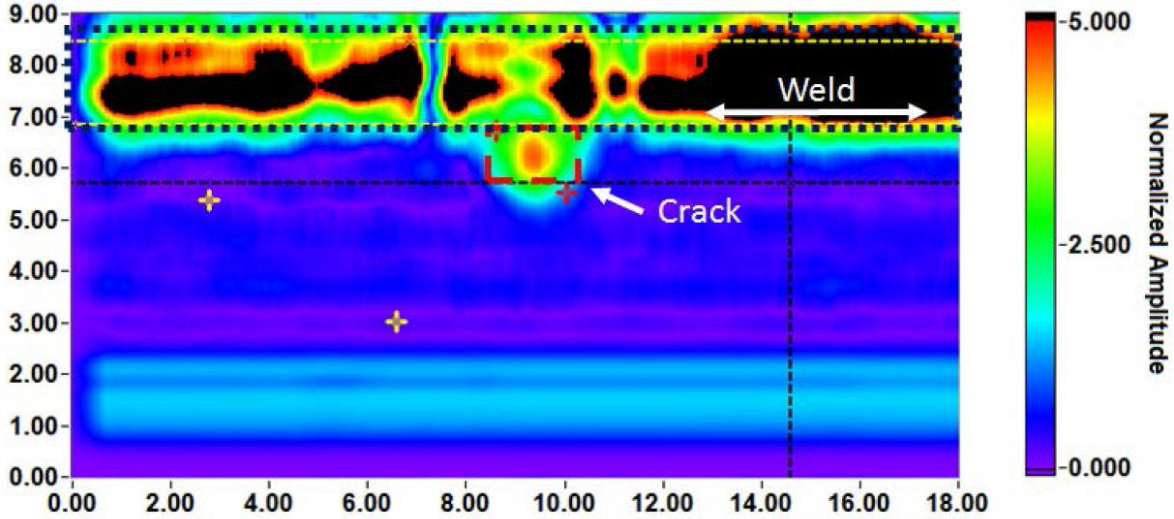
Guided Wave Inspection

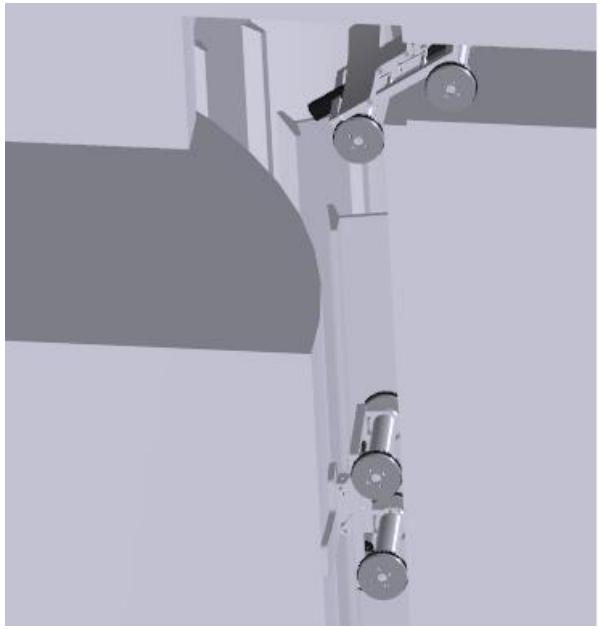
- Evaluating guided waves for DCSS inspection
- Technique has significant potential
- Demonstration identified some areas for improvement

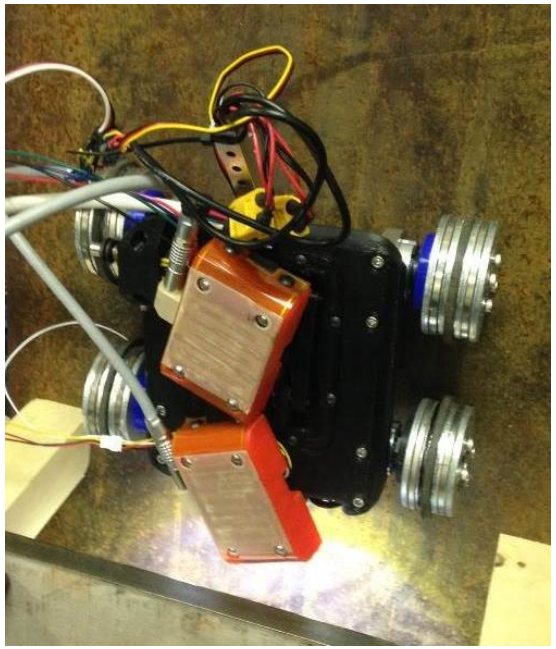




NDE Delivery Development

- EPRI initiated an RFP and signed a contract with RTT in late 2014
- Moved from design to prototyping and deployment with
  - 2 field trials in 2015
  - 2 field trials in 2016
  - 3 field trials planned for 2017





EPRI Robotic Development

- Developing two different robotic delivery systems to improve inspection capabilities
  - Magnetic wheel robot
  - Vacuum suction robot

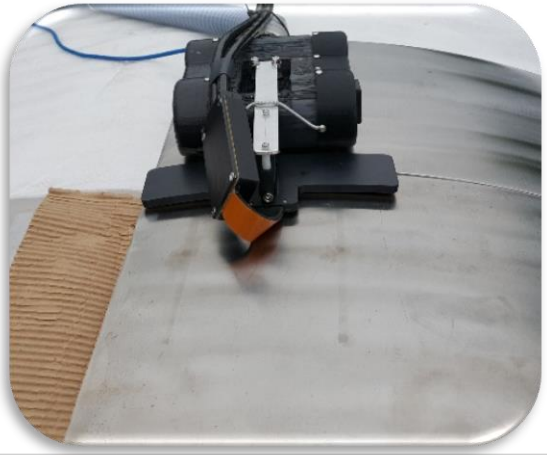
Magnetic wheel robot adheres to magnetic surfaces

Vacuum robot adheres to most surfaces

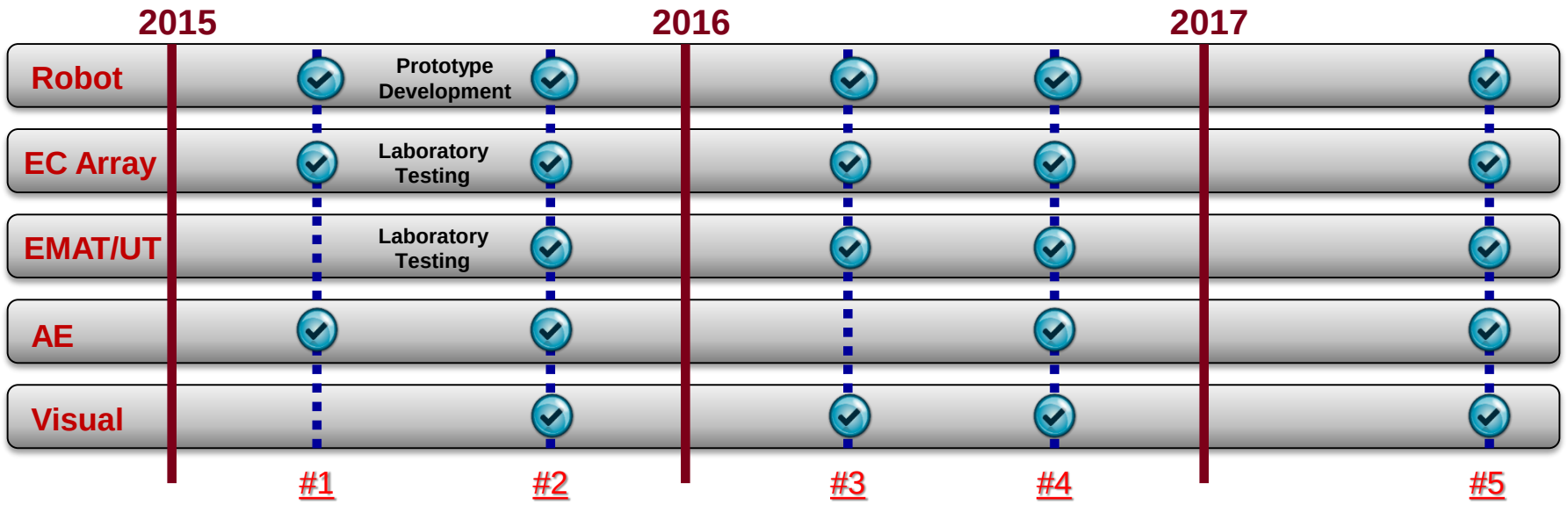
Robot in a Simulated DCSS Vent

Field Trials Summary

- To date, 4 field trials have been completed
  1. AREVA's Aiken Facility
  2. APS – Palo Verde
  3. Duke Energy – McGuire
  4. Maine Yankee
- Improvements have been made based on lessons learned from each field trial



DCSS Inspection Timeline



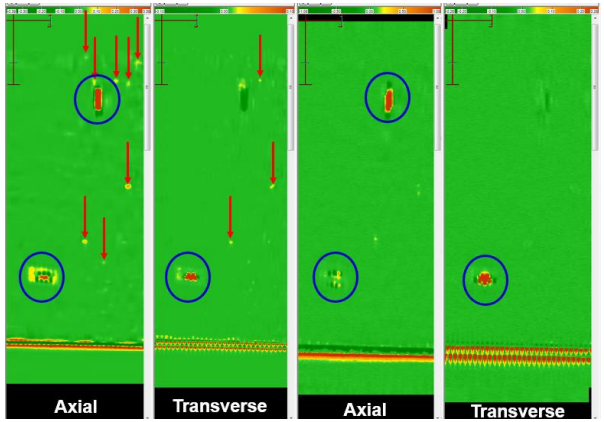
Proposed Phased Approach:

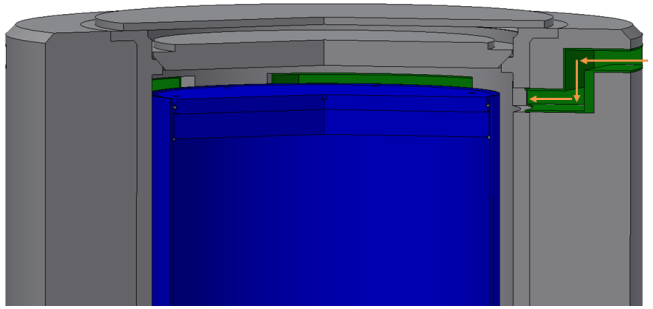
1. Testing on a TN canister mockup – Aiken, SC April 2015
2. Testing on a canister mockup (Palo Verde) – Sept. 2015
3. Test on a second unloaded canister mockup (McGuire) – early 2016
4. Temperature testing and field preparation (Maine Yankee) – mid 2016
5. EPRI Member to host pilot demos (with a vendor) - 2017-2018

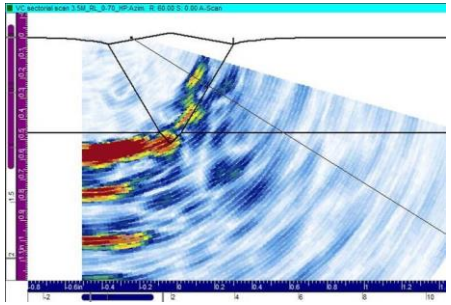
EPRI welcomes participation
Technology transfer to the industry is the goal

Summary

- EPRI is working towards solutions to the DCSS inspection issue via:
  - Collaboration – Working with many organizations and communicating via the ESCP NDE Subcommittee
  - Mockup Fabrication – 8 Mockups fabricated and open for industry use for technique development
  - NDE Development
    - Eddy current, EMAT, and Acoustic Emission work are ongoing
    - UT and VT work progressing with vendor-led collaboration
  - Robotic Delivery – Four field trials complete, additional development and demonstrations to follow
- Results contained in EPRI Report 3002008234







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