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# Dry Cask Storage Inspection and Delivery System Development

**NRC RegCon**


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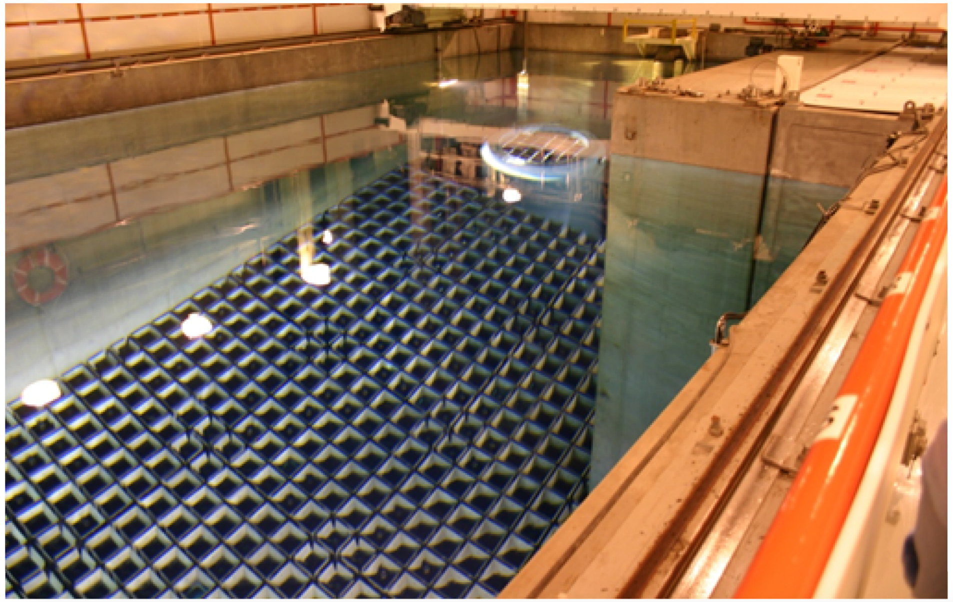
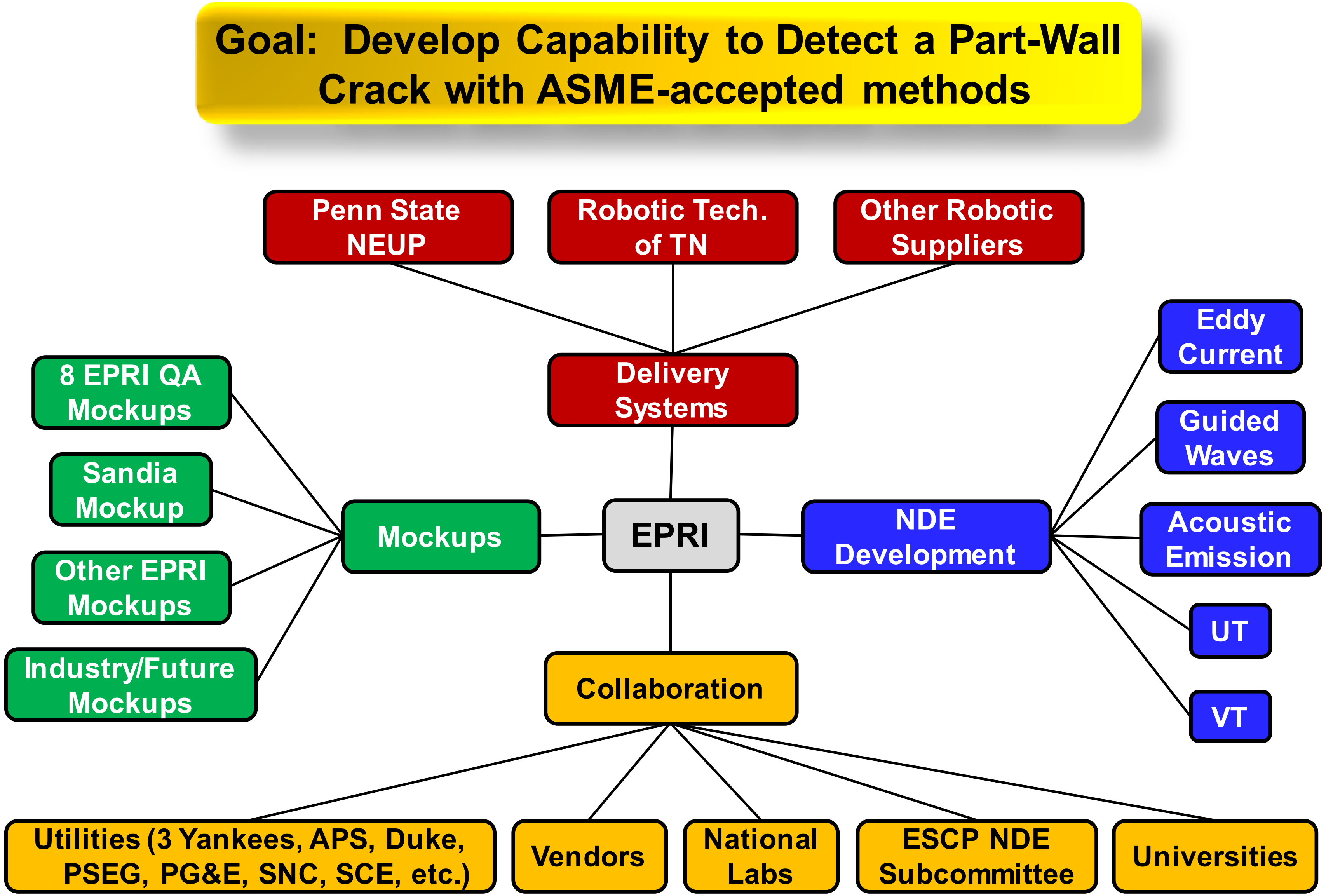
Tuesday, October 31, 2017

# Introduction

- Dry Cask Storage System (DCSS) are intended for temporary storage of spent fuel
- Permanent repositories not yet available
- DCSS are now being used for longer than anticipated (or licensed) for storage of spent fuel
  - Some have been in use for >20 years
  - Currently, >2500 casks/canisters in operation
- Concern for long term operations, especially at coastal sites
  - Inspection of DCSS canisters is one of the key issues for continued licensing and operation

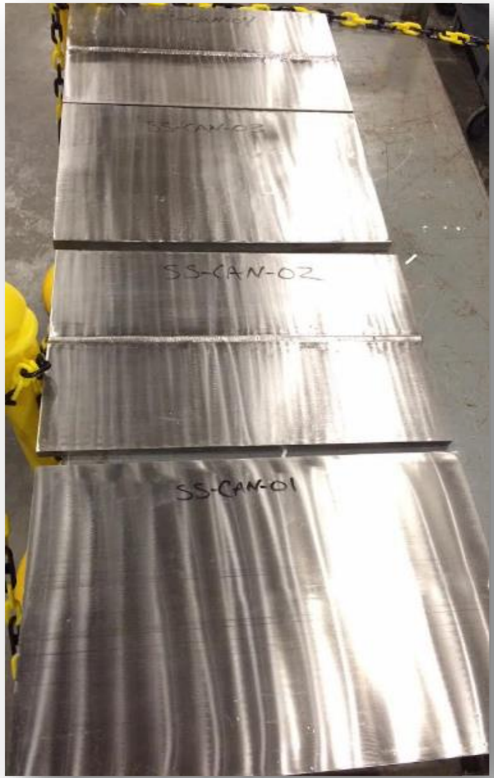


# Project Overview – Significant Industry Collaboration



# Mockup Development

- EPRI worked with flaw manufacturers to build flaw mockups for industry use
  - **8 QA flaw mockups**
  - 3 non-QA mockups
  - Flaws of interest primarily in the weld and heat-affected zone
  - All are complete & available for open technique development
- 4 additional mockups were provided to EPRI by Sandia National Labs
  - One full diameter, 2’ long section
    - PNNL funded flaw implantation
  - Two welded mockups
  - One base metal sample





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# DCSSs Present Challenges for NDE

**Temperature**

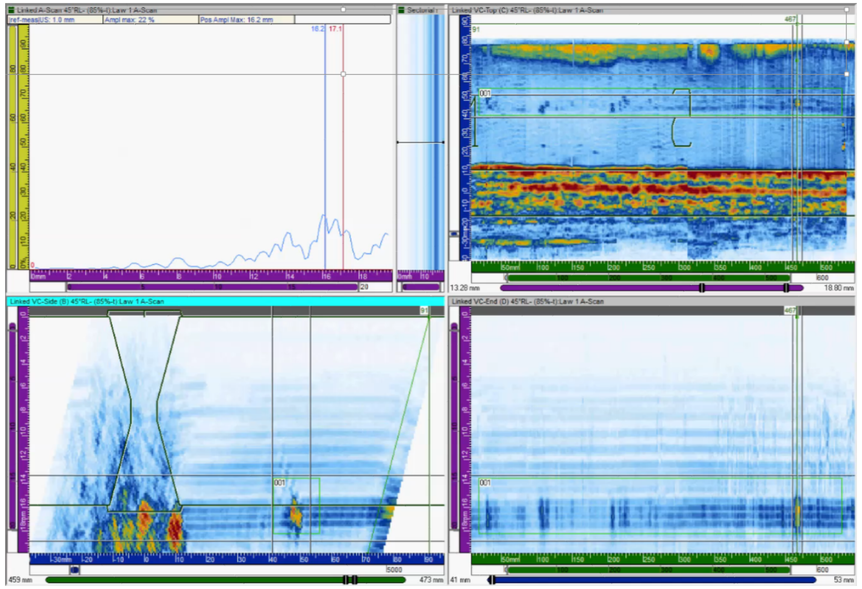
- Originally estimated to be up to ~180°C
- Measured temperatures have ranged from 21-118°C (70-245°F)

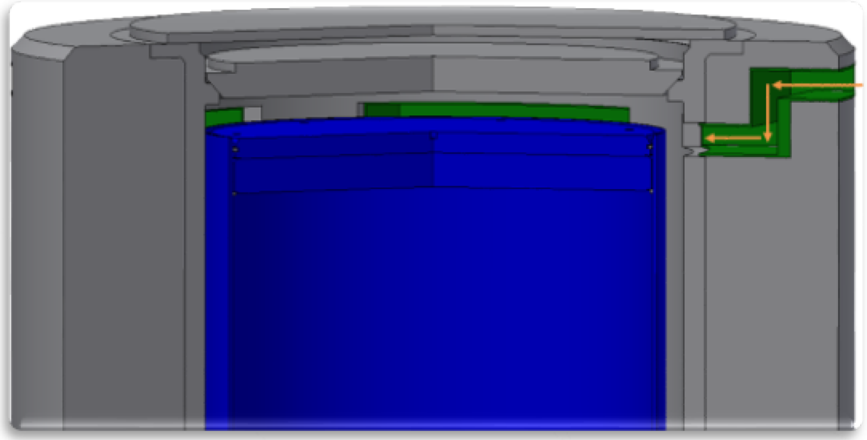
**Radiation Dose**

- Original estimate was ~1-10 kR/hr
- Max measured to date is ~0.1 kR/hr

**Challenging Access**

- Confined entry and exit pathways
- Narrow annulus between canister and overpack with obstructions



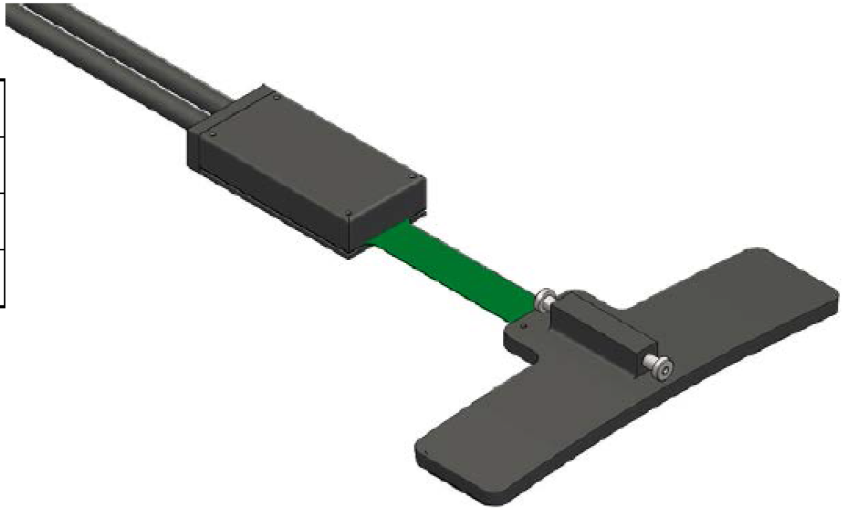


**Desire is to have qualified NDE techniques, such as visual, eddy current, and ultrasound**

# 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) | | | | | | Now |
| Eddy Current Testing (ECT) | | | | | | Now, if needed |
| Ultrasonic Testing (UT) | | | | | | |
| EMAT/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 |



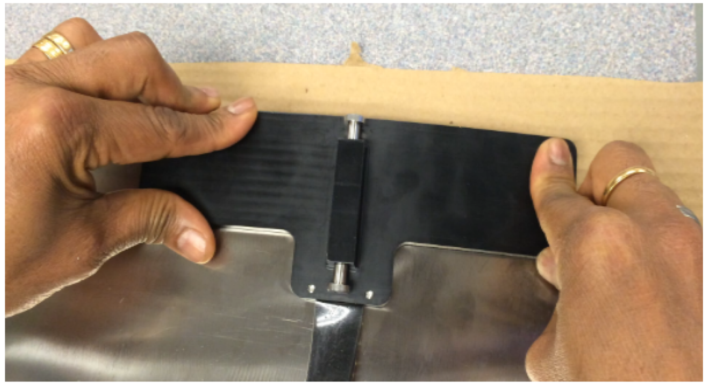
**Desire is to have qualified NDE techniques, such as UT or EC**

# NDE Techniques Under Development

<u>EPRI Projects</u>

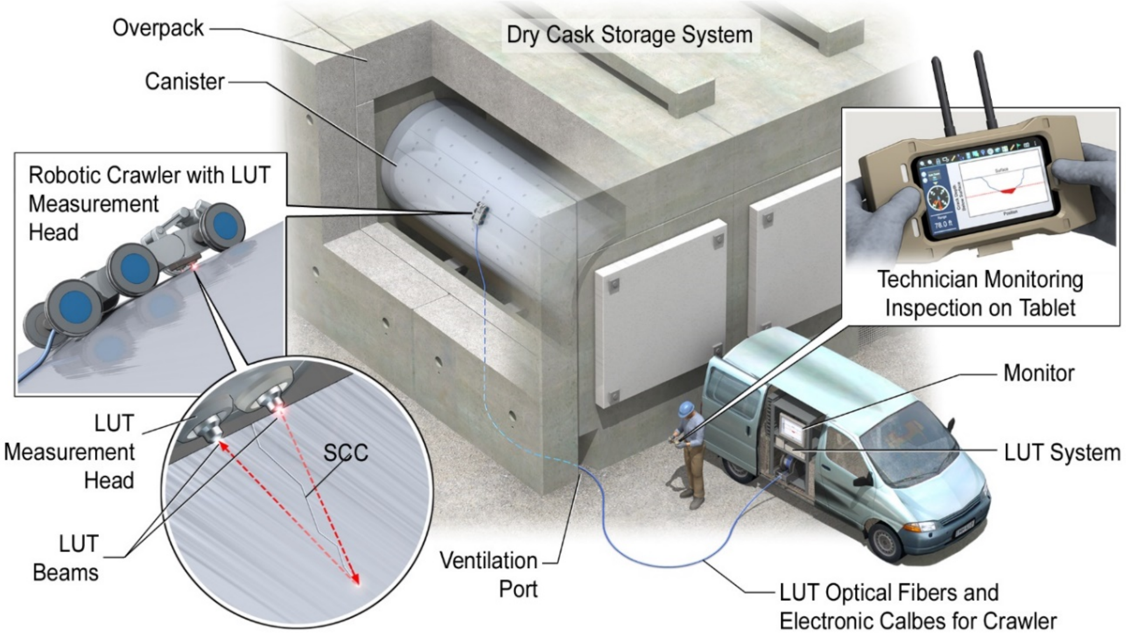
- Eddy Current Array (ECA)
  - Using ECA in a new way to help differentiate flaws of interest
  - Excellent results obtained
- Guided Waves
  - Ability to find defects in inaccessible areas (under rails, supports, etc.)
- Acoustic Emission
  - Potential to monitor from <u>outside of the cask</u>

*Supplement above inspections using visual imaging (cameras only)*



<u>Vendor Development Needs</u>

- Gaps correlate to vendor strengths
  - Visual Techniques (VT-1 & VT-3)
  - Ultrasonics for length and depth sizing
- EPRI ESCP NDE Subcommittee Report contains input from 22 organizations performing NDE R&D (30020010617)

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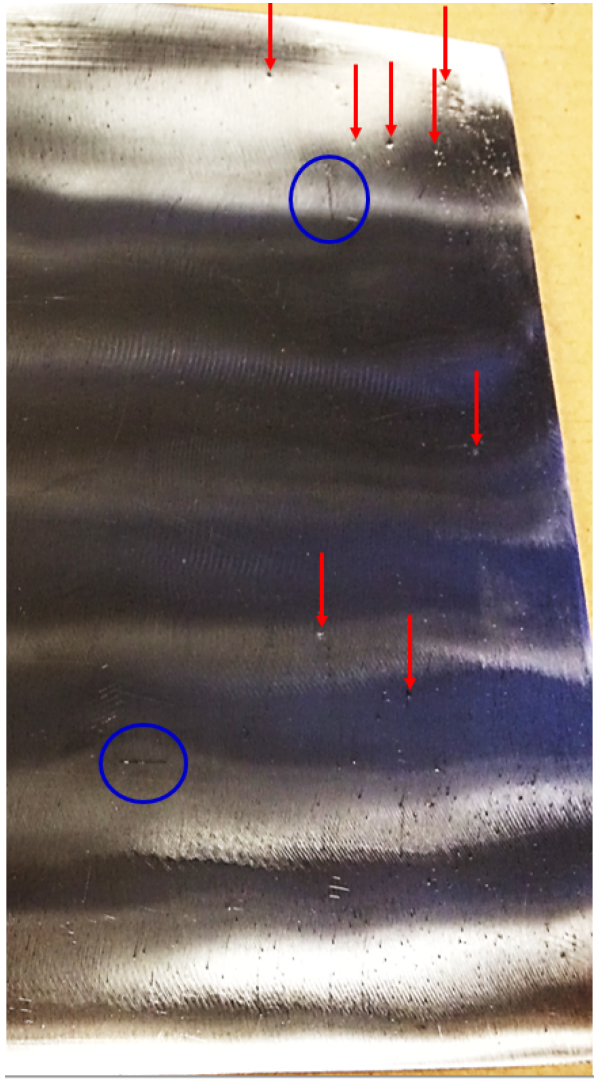
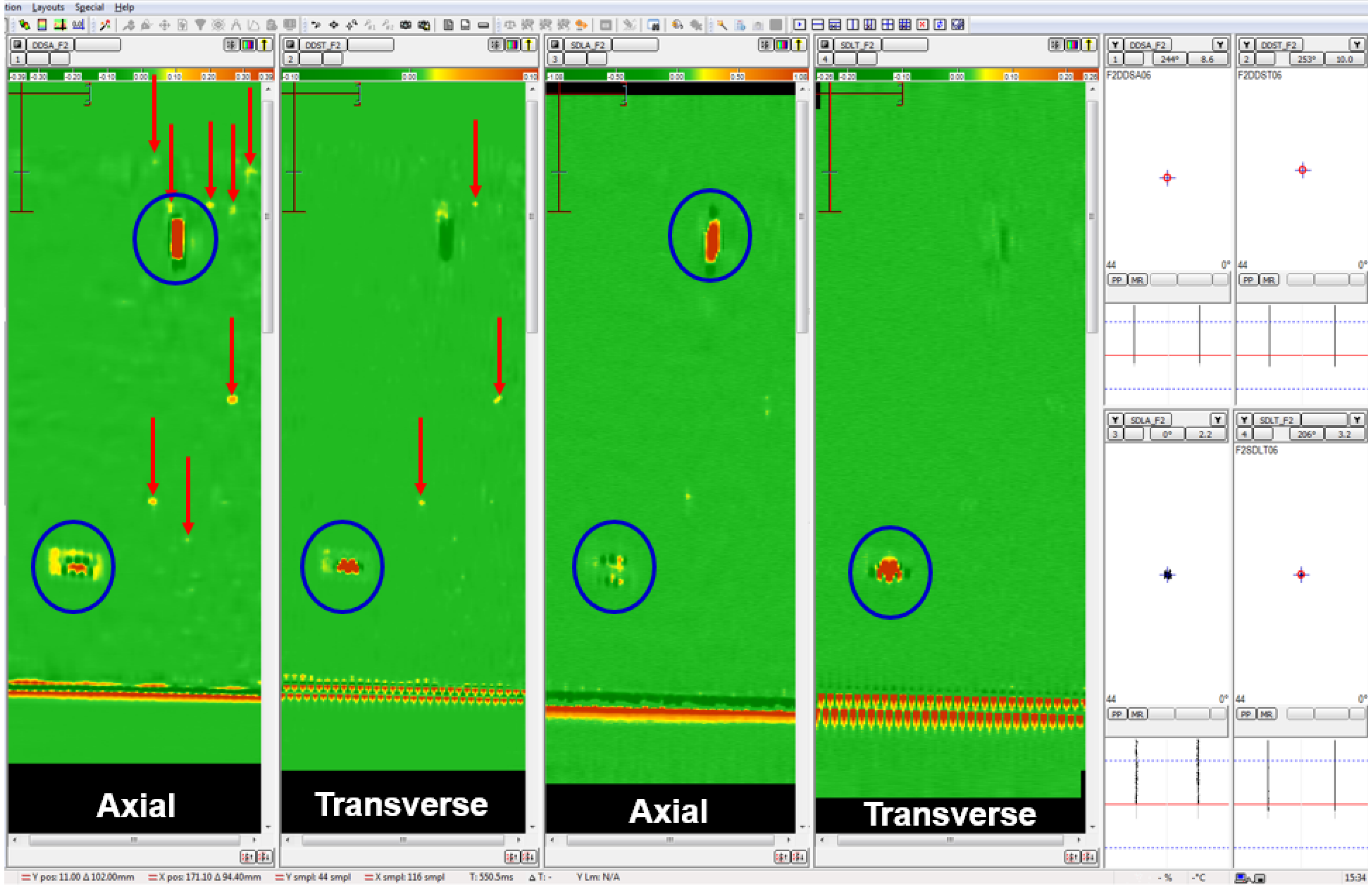
# Eddy Current Inspection – Cracks/Pitting

= Simulated Cracks

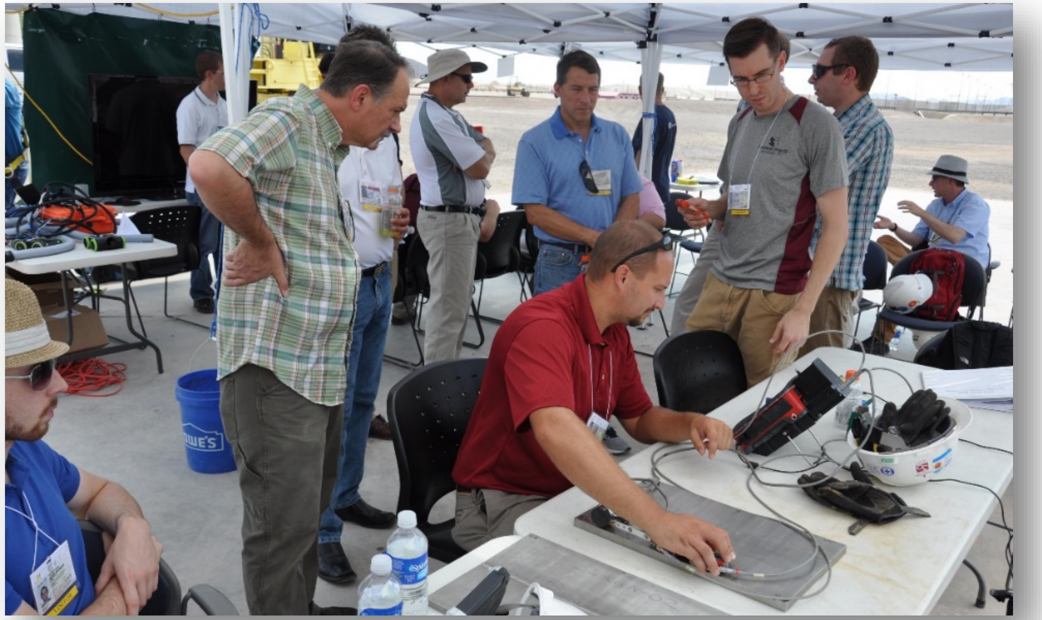
= Pitting ~1.0-2.5 mm pits

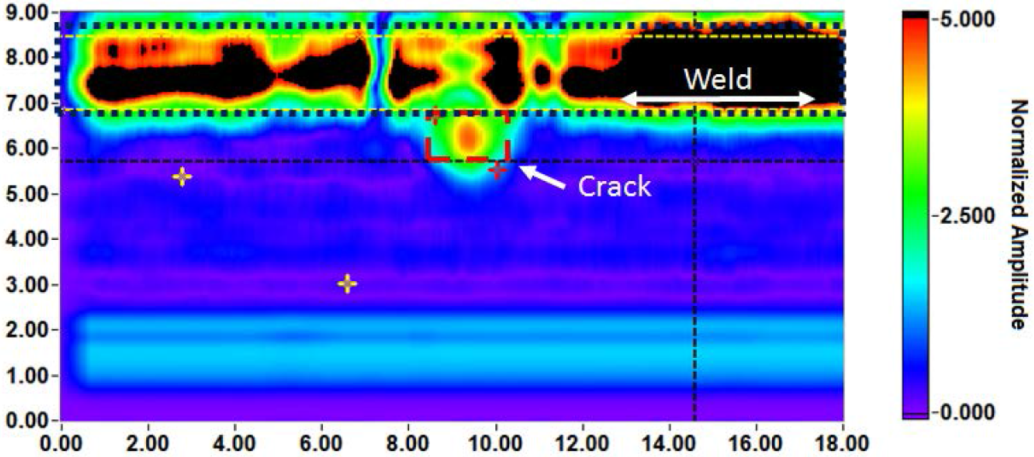




# Guided Wave Inspection

- Evaluating guided waves for DCSS inspection
- Technique has significant potential, especially for difficult-to-access or occluded areas
- Demonstration identified some areas for improvement
- Results are contained in EPRI Report 3002008234







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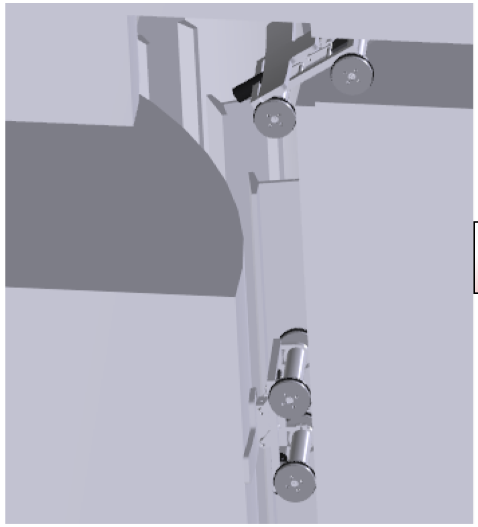
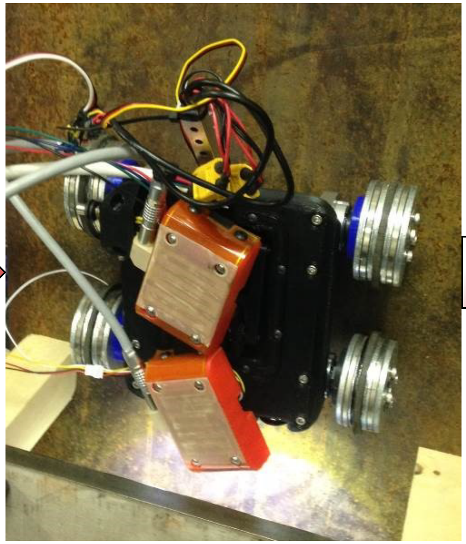
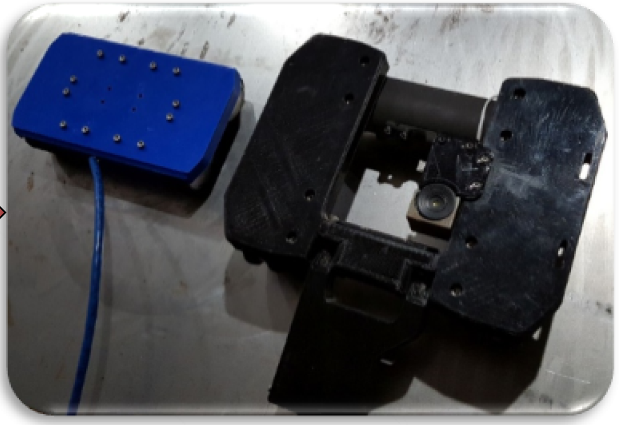
# NDE Delivery Development

- Started robotic development in late 2014
- Moved from design to prototyping and deployment with
  - 2 field trials in 2015
  - 2 field trials in 2016 (one on a GTCC canister)
  - 1+ field trials in 2017
  - Fuel-loaded canister inspection in 2018



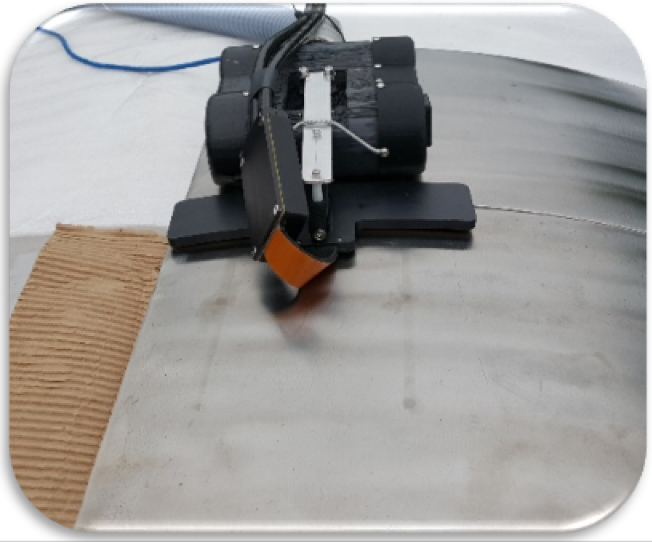




# Field Trial #1

- First robotic and NDE demonstration was completed successfully with a cask vendor
  - Field study of first operational robotic prototype carrying an NDE payload (eddy current array)
  - Field study of acoustic emission

**Key Lessons Learned**
1. Corner transitions needed improvement
2. Vacuum suction needed to be stronger



# Field Trial #2

- Second robotic and NDE demonstration was completed successfully at a nuclear plant site (Palo Verde) using two cask/canister mockups
  - 28 demonstration visitors from 15 organizations (not including Palo Verde)
  - Demonstration of a second generation robotic prototype carrying NDE payloads
    - Onboard camera
    - Eddy current array
    - EMAT-generated guided waves
  - Demonstration of acoustic emission

**Key Lessons Learned**

1. **System was able to enter an actual cask system!**
2. **Potential FME issues identified**

# Field Trial #3 – McGuire NPP

- Robotic field trial completed alongside Penn State University
  - Preparation for Maine Yankee field inspection

**Key Lessons Learned**

1. Potential issues with cables on standoffs – specific cask design
2. FME Issue – lost wheel (retrieved without issue)
3. Identified a weakness in the robot design
4. RTT made immediate (overnight) design changes to eliminate the issues and developed the next generation design



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# Field Trial #4 – Maine Yankee

- First robotic and NDE inspection completed on a live canister

**<u>Key Lessons Learned</u>**

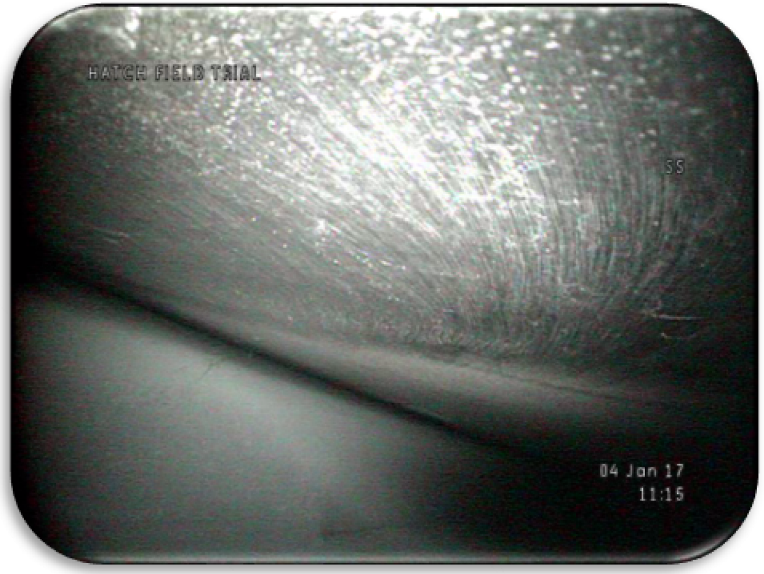
1. **Robotic system was able to take visual, thermal, and radiation data**
2. **Inspection completed without issue**
3. **Several samples taken & sent to Sandia National Labs for analysis**
4. **Identified several best practices for performing inspections**

# Field Trial #5 – Hatch NPP

- First robotic and NDE demonstration was completed successfully on a Holtec System
  - Added a thermocouple for temperature readings
  - Demonstrated the second generation cleaning pad

**Key Lessons Learned**

1. **Miniaturized robot operated well in the Holtec system – no issues**
2. **First demonstration of a thermocouple measurement**









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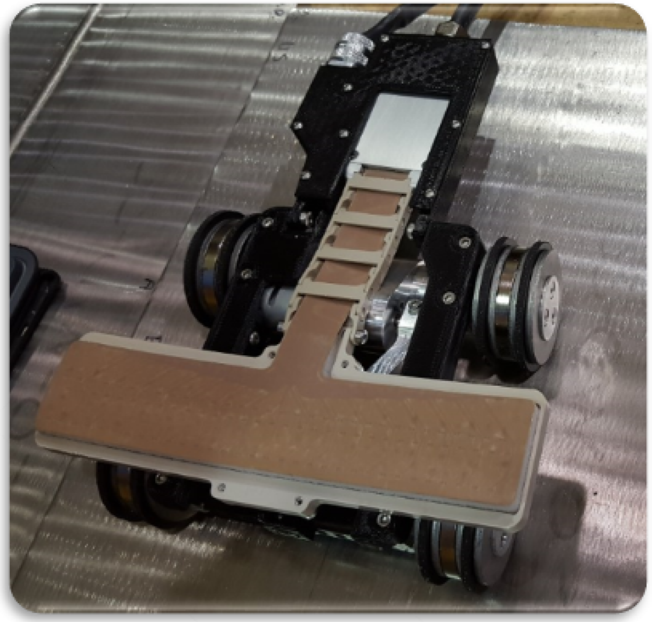
# Field Trial Compilation

# Field Trial Summary

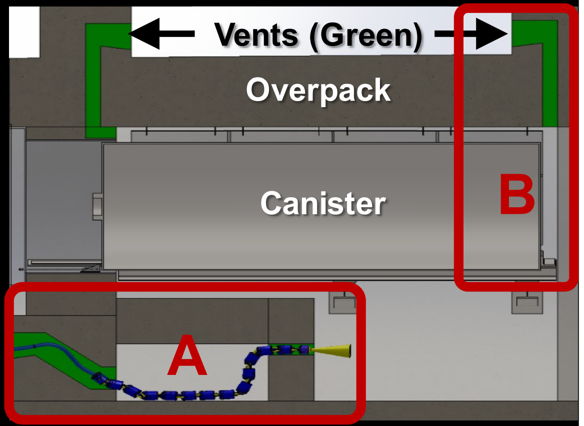
- To date, 5 field trials have been completed
  1. AREVA's Aiken Facility
  2. APS – Palo Verde
  3. Duke Energy – McGuire
  4. 3 Yankees – Maine Yankee (loaded GTCC canister)
  5. Southern Company – Hatch
- Improvements have been made based on lessons learned from each field trial
- Field deployment on a canister loaded with fuel is scheduled for 2017-8, 1-2 years ahead of schedule



**EPRI welcomes participation**

**Technology transfer to the industry is the goal**

# “Hot Off the Presses” – Horizontal Cask Developments





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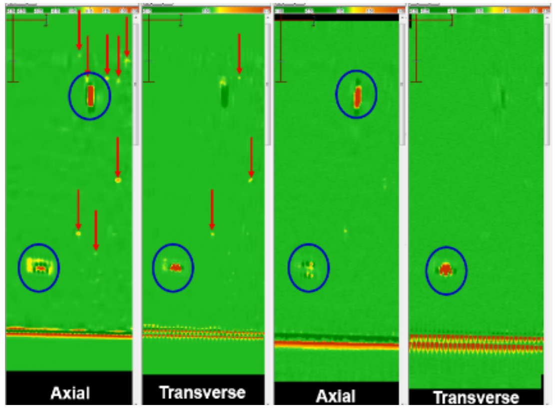
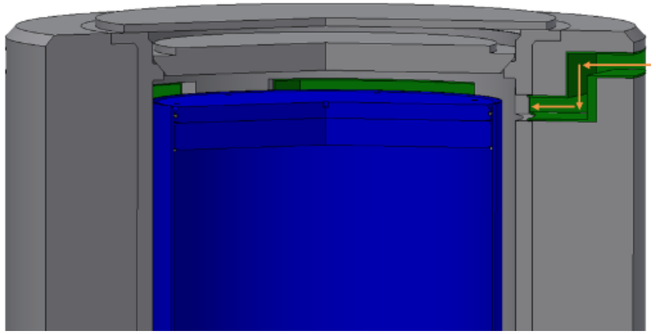
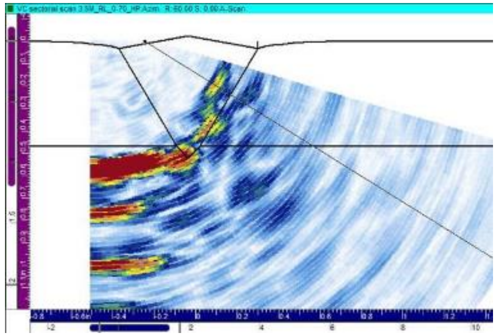
# Summary

- 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 QA plus 8 non-QA 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 – Five field trials complete, additional development and demonstrations to follow
- Results contained in EPRI Reports 3002008234 & 3002010617
  - Upcoming report: 3002010621 (latest developments)









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