

NRC REG CON MEETING

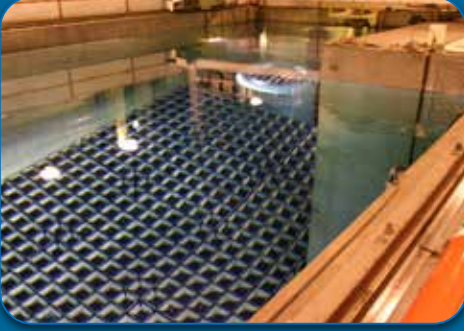
Dry Storage Canister Inspection, Mitigation, and Repair R&D Efforts

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Introduction



Permanent repositories are not available to accept used fuel

- Spent Fuel Pools are approaching capacity at many sites around the world
- Increased need for dry storage systems



>3000 dry storage systems are in operation in the US alone

- ~200 systems are added per year
- Dry storage systems will operate for longer than their original licensed period



Aging management is required to extend licenses

- NDE inspections will be required to support aging management
- Mitigation and repair tools and technologies may be needed

Project Overview – Industry Collaboration & Progress



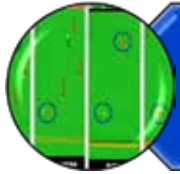
Significant Industry Collaboration



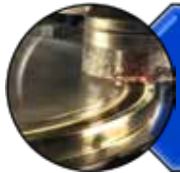
Robust robotic delivery systems developed



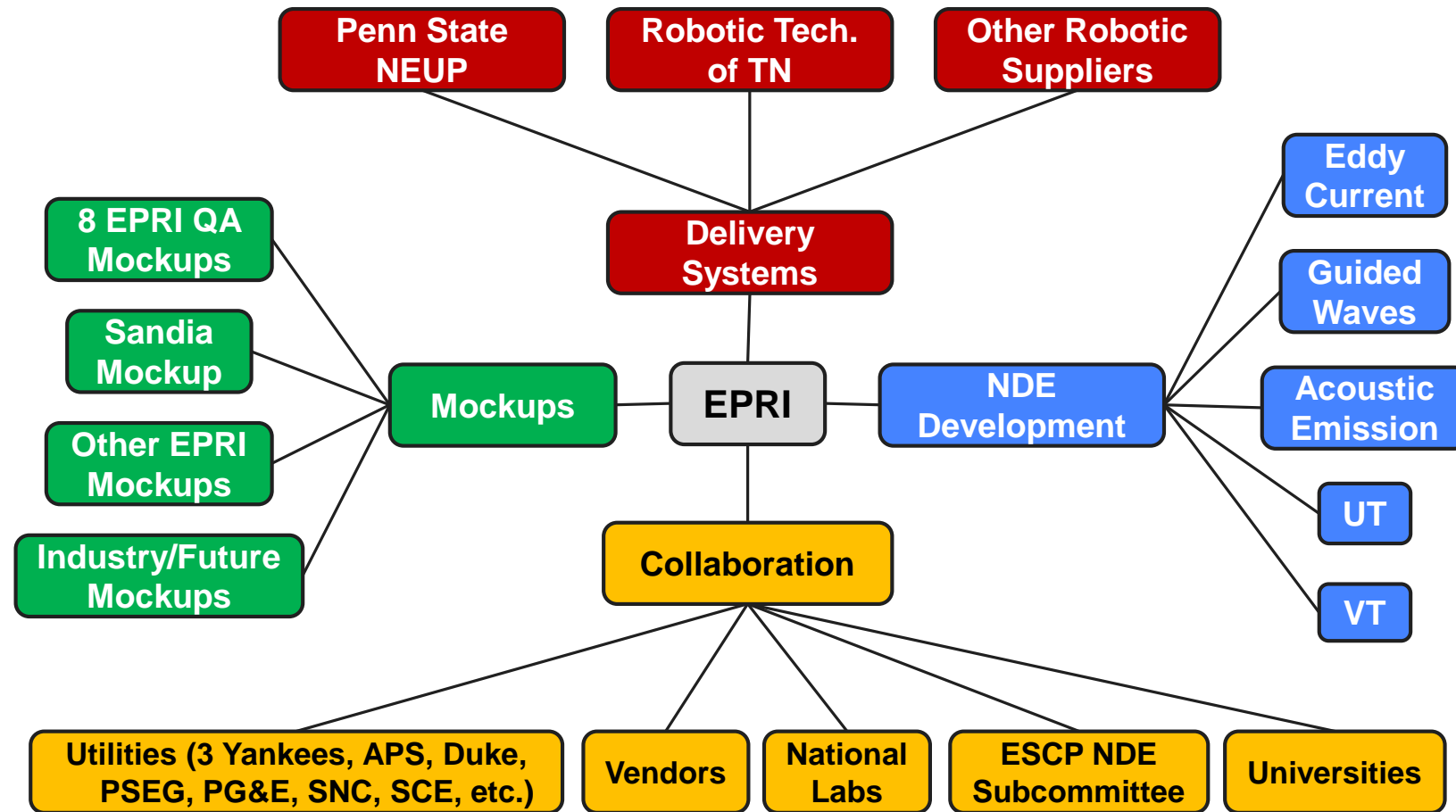
Many inspection tools available



Inspection is becoming a routine task



Mitigation and repair efforts are ongoing



Significant collaboration and support received from many organizations, especially utilities

Mockup Development

EPRI working to assemble a list of all available mockups across industry

**Over 125 mockups/
samples identified
for inspection efforts**

**Over 100 mockups/
samples identified
for mitigation and
repair efforts**



QA Flaw Mockups

8 flaw mockups with a range of flaw sizes, orientations, etc.



Non-QA Flaw Mockups

6 additional flawed and unflawed mockups are available



Sandia Mockup

SNL donated a full-diameter mockup and PNNL funded flaw implantation



Acoustic Emission Mockups

EPRI is growing SCC in 5 flaw mockups



CISCC Mockups

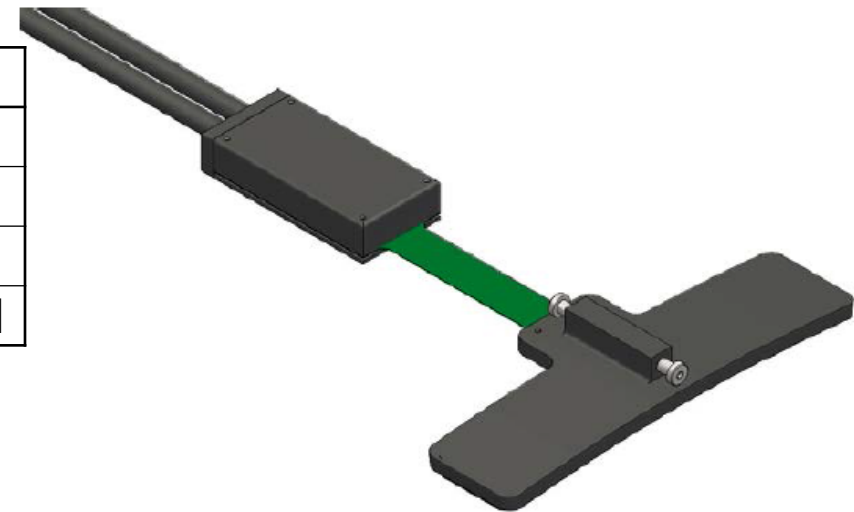
EPRI has 3 mockups with laboratory-grown CISCC

Overview of NDE Technology Developments

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						

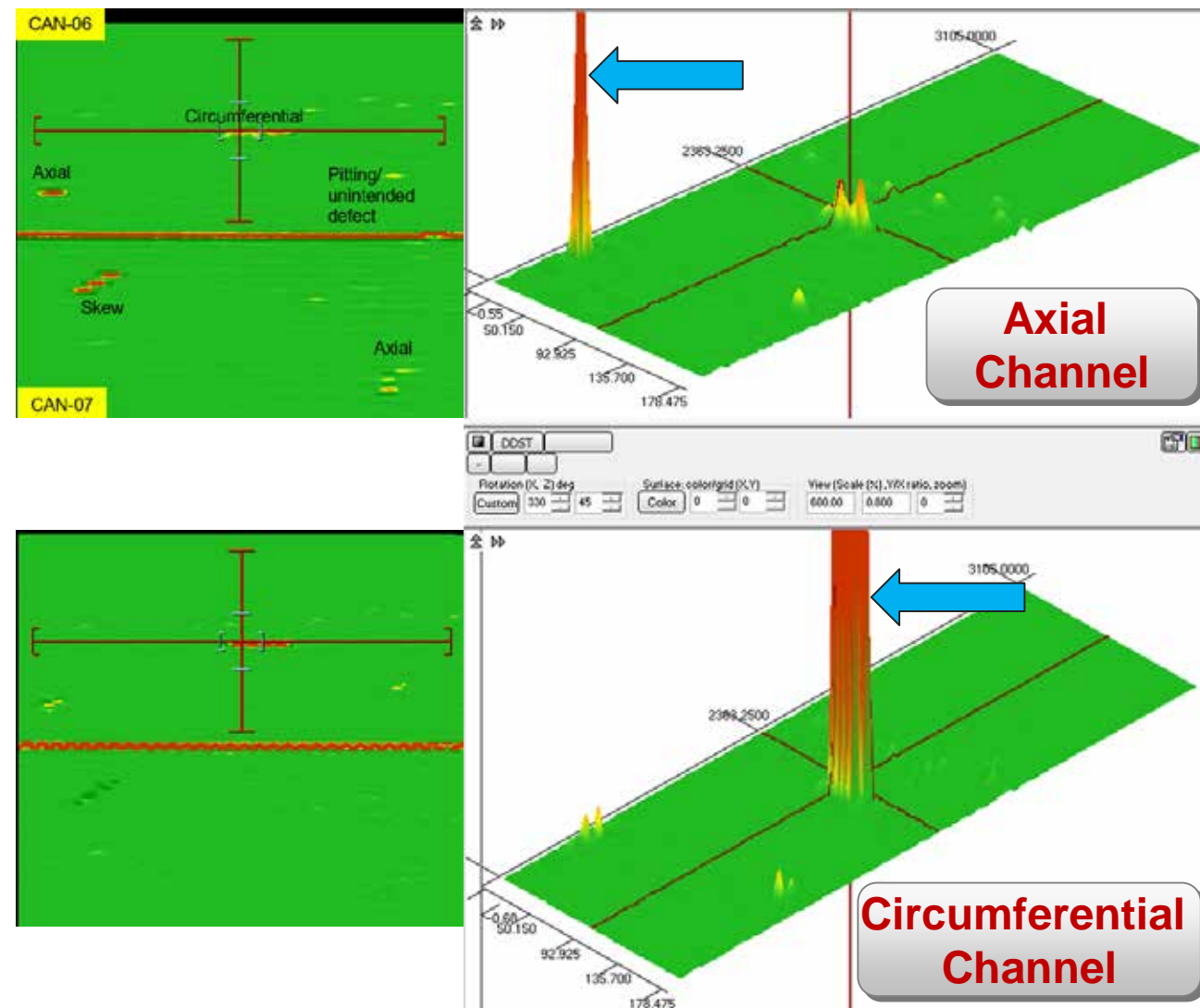
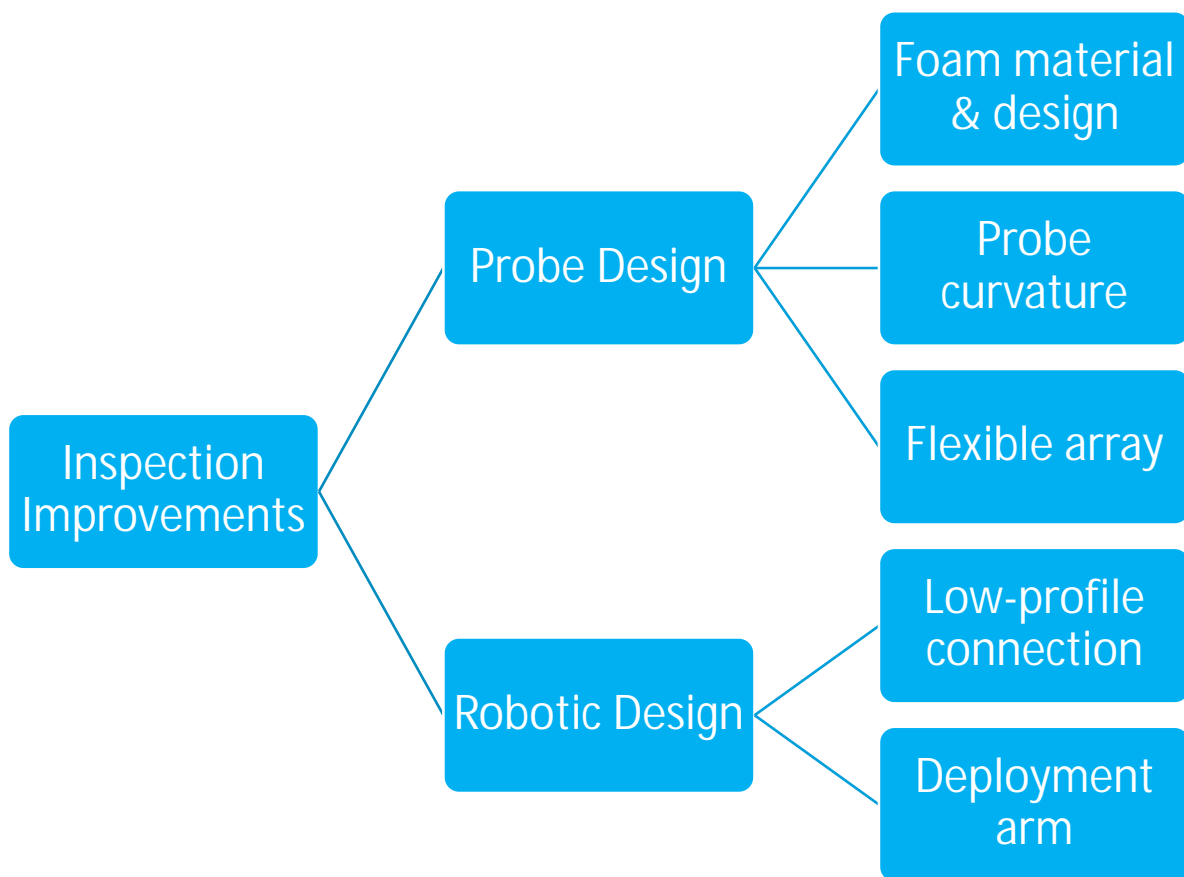
Timing		Technical Capability
		Not Applicable
Now or < 1 year		Good Performance / Yes
< 3 years		Fair Performance / Maybe
4+ years or N/A		Poor Performance / Not Well Suited

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



Robotically-Scanned Eddy Current NDE Data

Robotically-scanned data quality comparable to hand-scanned data with high signal-to-noise ratio



Robotic Development

Goal: Develop and Deploy Robots Capable of Performing Required Dry Storage System Inspections

Upgrade/Retrofit

VT, UT, and eddy current devices
Temp. & Dose Measurements
Surface Cleaning
Robot Upgrades

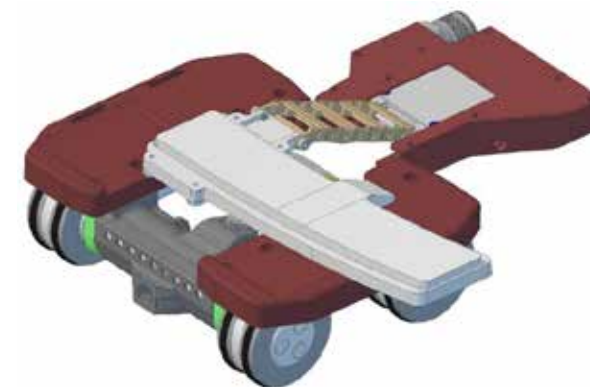
Field Trials

Work with utilities and vendors to deploy and upgrade developed systems

Implementation

Work with Vendors to deploy developed technologies

<u>Item</u>	<u>NAC Robot</u>	<u>Holtec Robot</u>	<u>TN Dual Robot</u>	<u>TN Top Vent Robot</u>
VT Inspection	Done	Done	Done	Done
Eddy current inspection	Done	Done	Done	Done
Dose Measurement	Done	Done	Done	Done
RTD Measurement	Done	Done	Done	Done
Non-Contact Thermal	Done	Done	Done	Done
Surface Cleaning Capability	Done	Done	Done	Done
Field Trial(s)	Done	Done	More Tests Needed	More Tests Needed
Surface Sampling Test	Done	Done	2nd Tier Need	Done



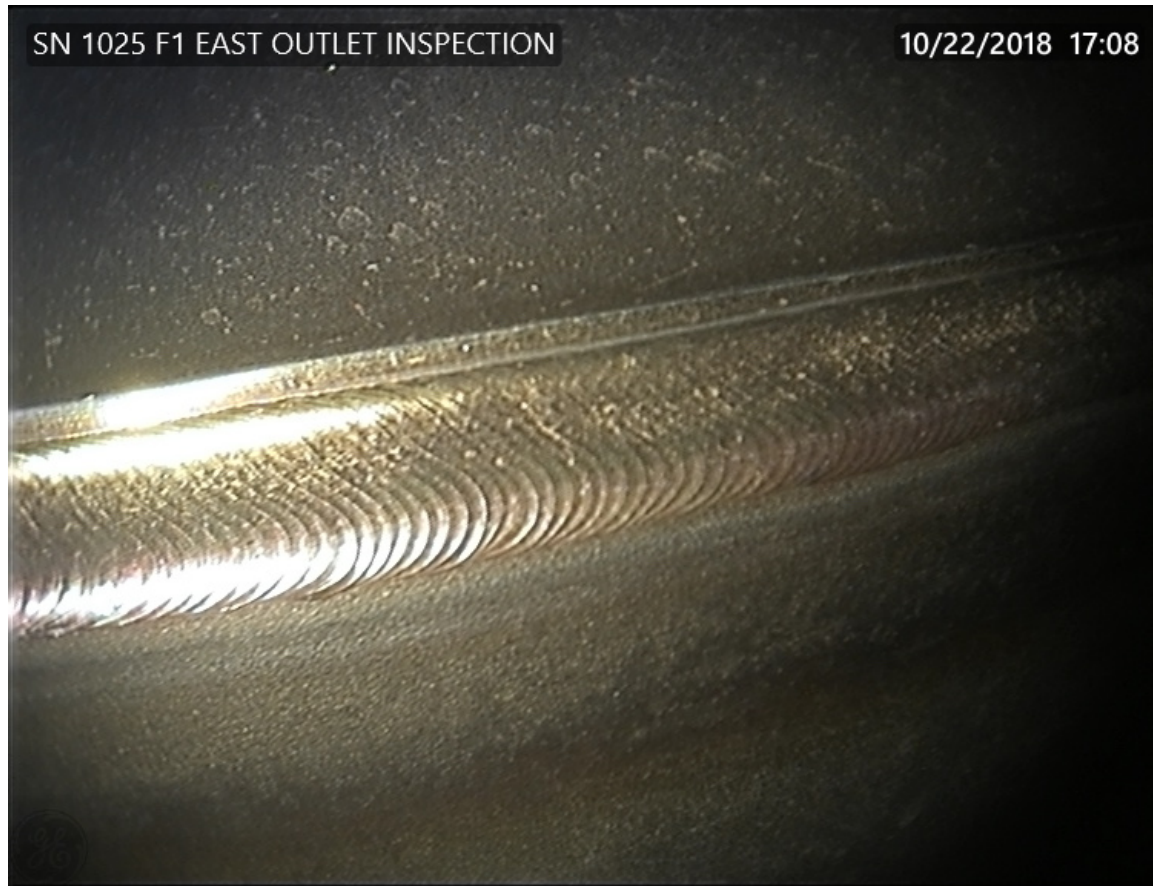
Field Trial Summary



- 1 AREVA's Aiken Facility
- 2 APS – 2nd Fuel-loaded canister – Trojan
- 3 Duke Energy – 4th/5th Loaded canisters – Vermont Yankee
- 4 9 – 6th-8th Loaded canisters – SONGS
- 5 Southern Co. – 9th-13th Loaded canisters – SONGS (2)
- 6 11 – Fuel-loaded canister – Trojan
- 7 PNNL Blind Inspection Demonstration

EPRI welcomes participation – Technology transfer to the industry is the goal

DCSS Visual Inspection – Lid Weld



Freshly-loaded canister

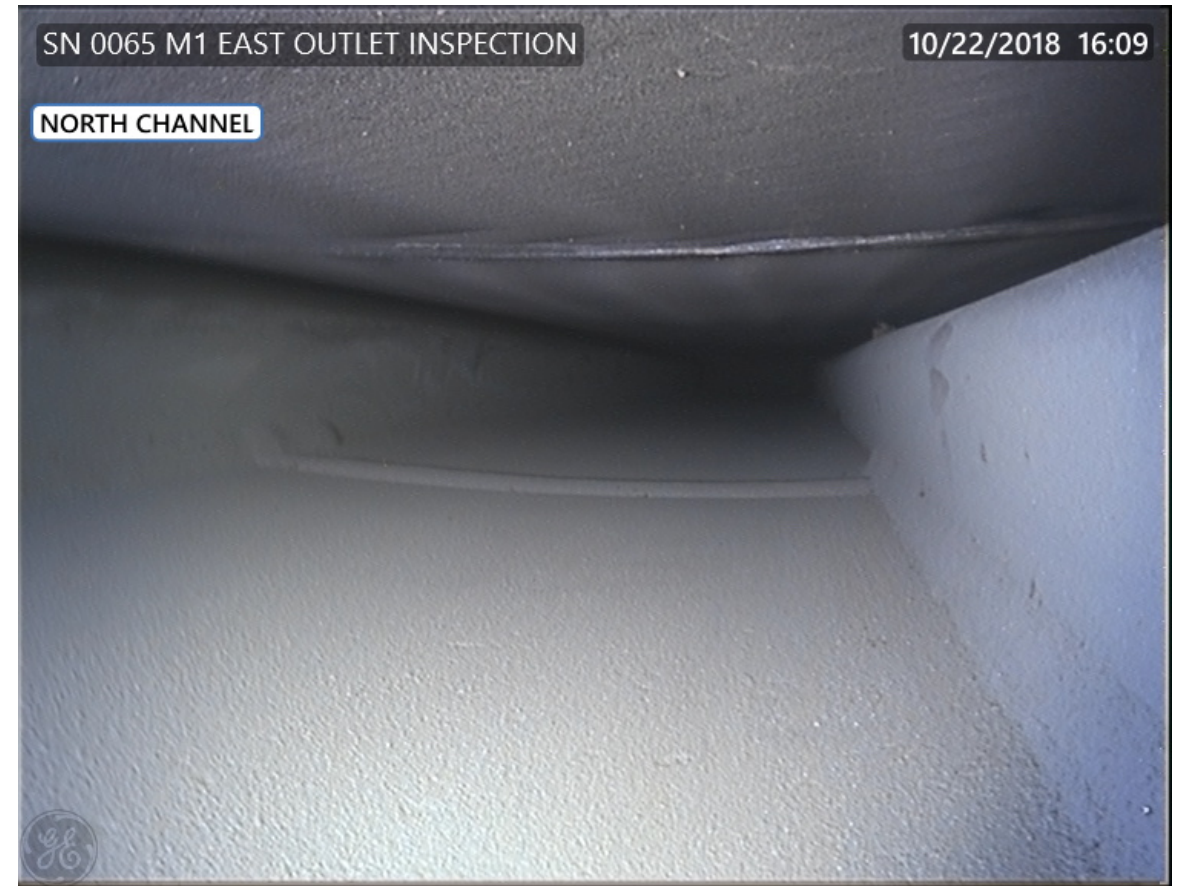


DCSS loaded in 2008

DCSS Visual Inspection – Shell Welds



Freshly-loaded canister

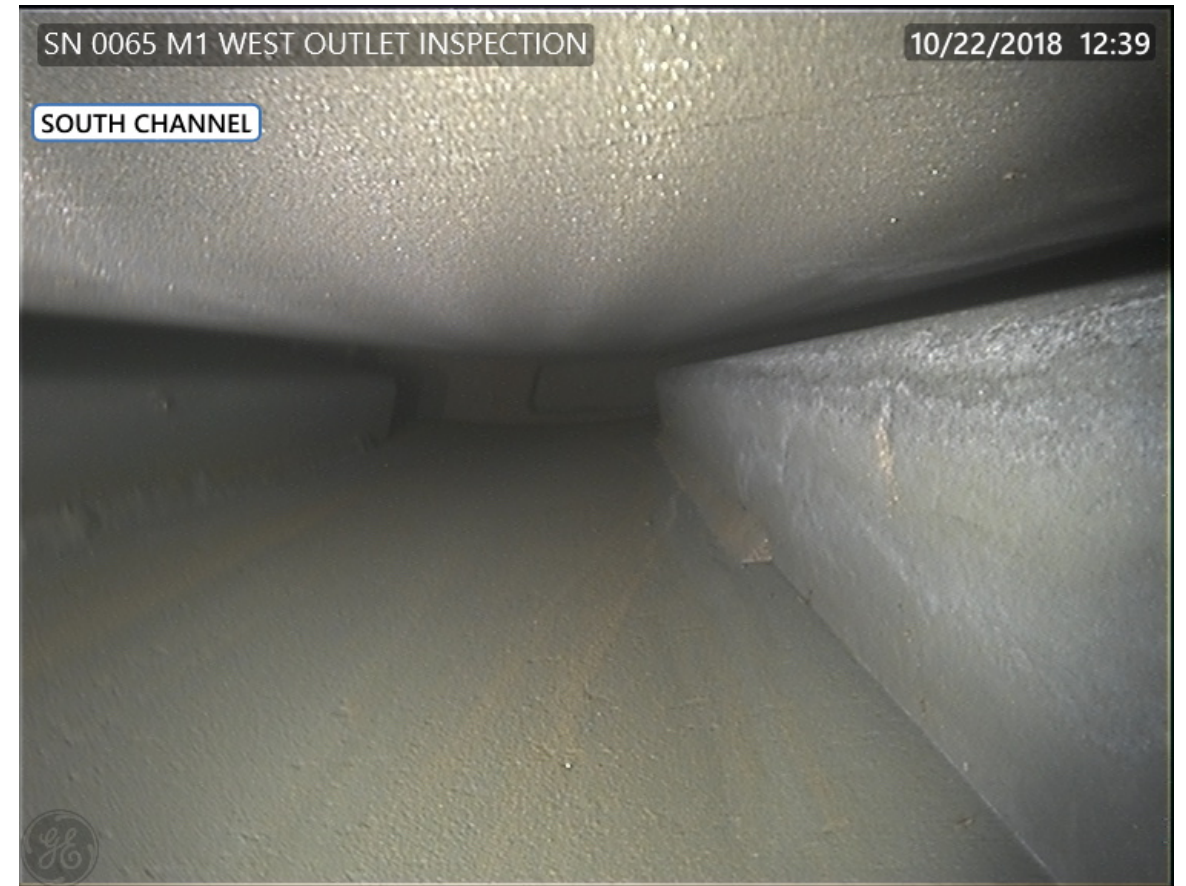


DCSS loaded in 2008

DCSS Visual Inspection – Base Metal



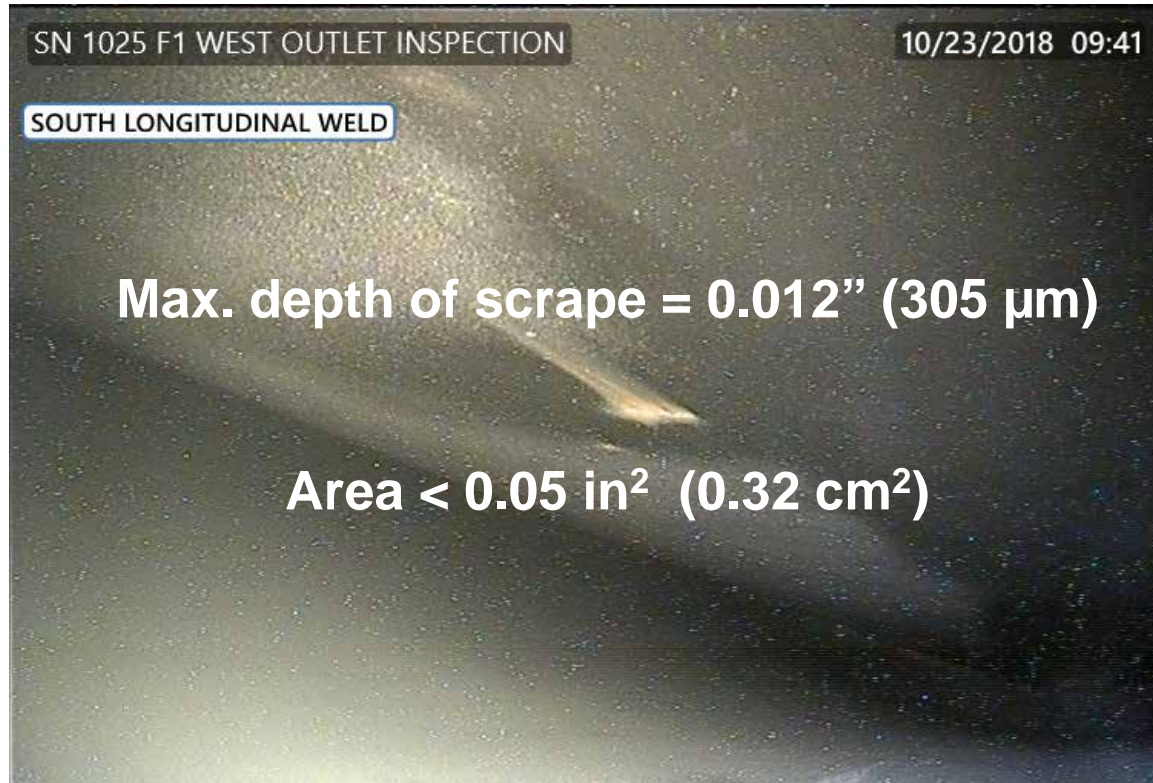
Freshly-loaded canister



DCSS loaded in 2008

What Has Been Observed?

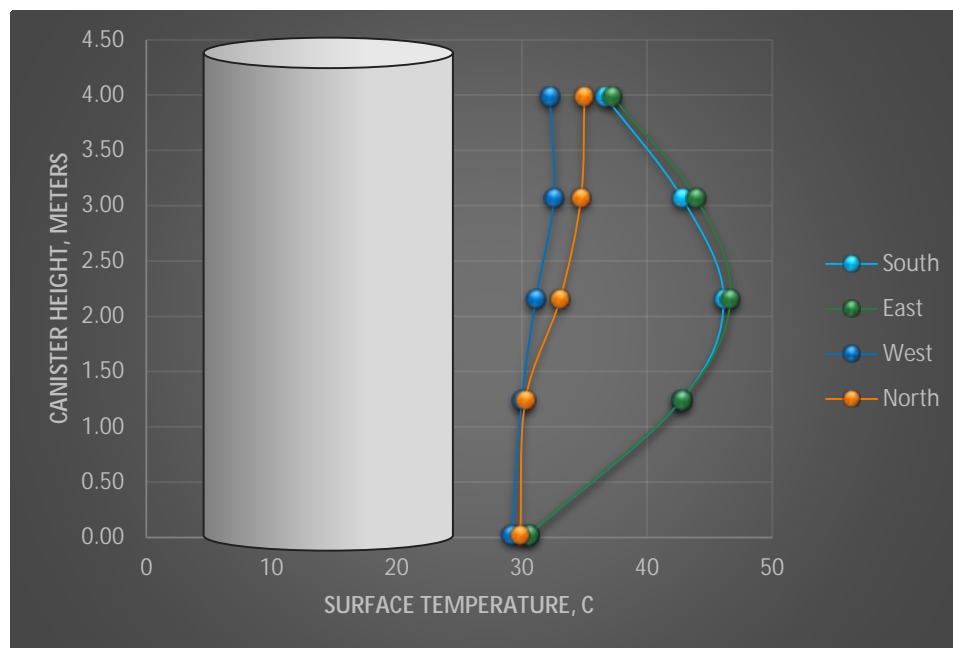
Overall, not much – bright, shiny metal surfaces similar to the top, right image



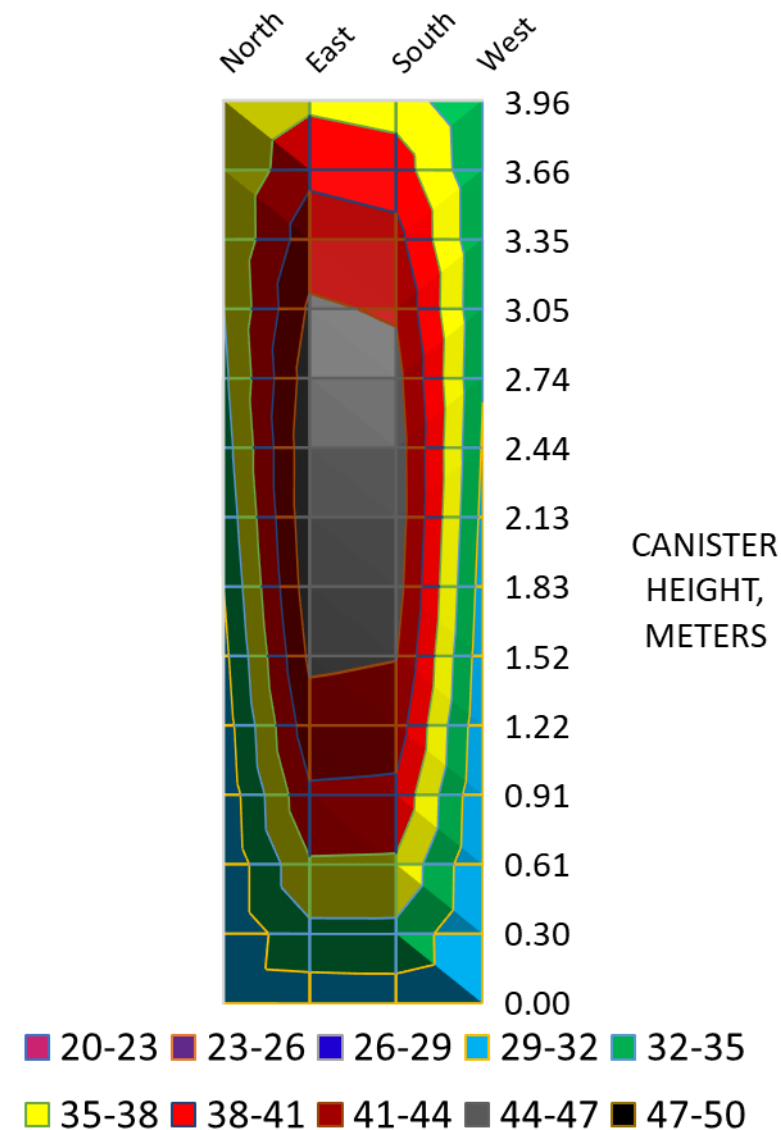
A small scrape mark was identified at one site and evaluated with a high-resolution probe tip

Measured Canister Surface Temperatures

- § Adapted inspection tools to measure canister surface temperatures and dose rates
- § Data from a 16-year-old canister (4.27 kW) is shown here (temperatures in degrees Celsius)



Temperature Data - Site 1, Canister 1

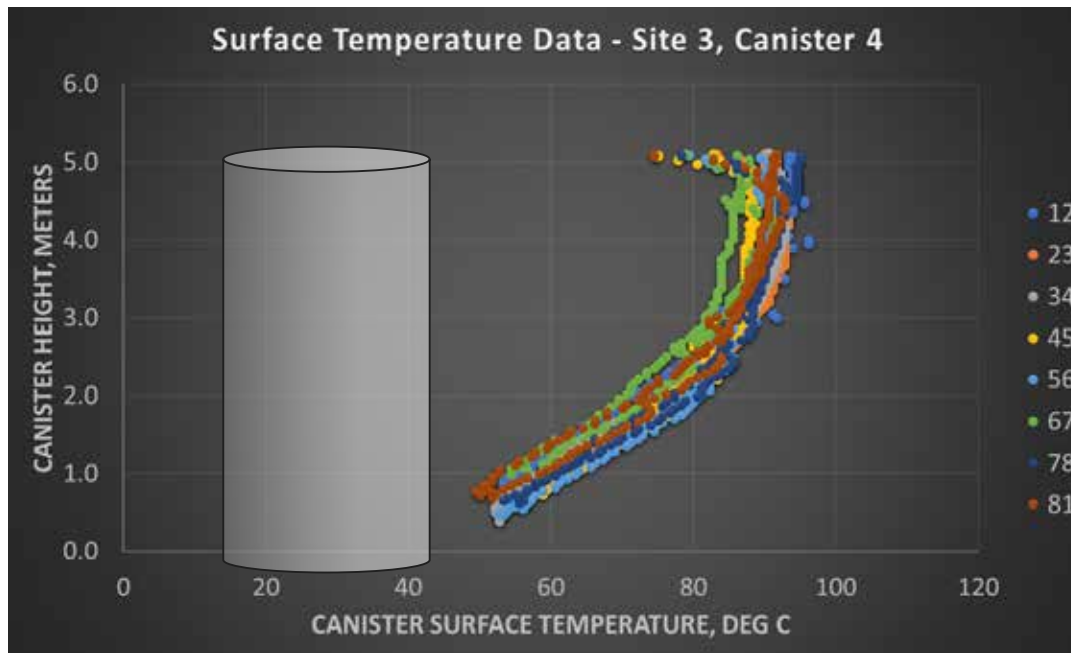


- § Team received ~4 mrem of dose from this activity (inspecting 1 canister)

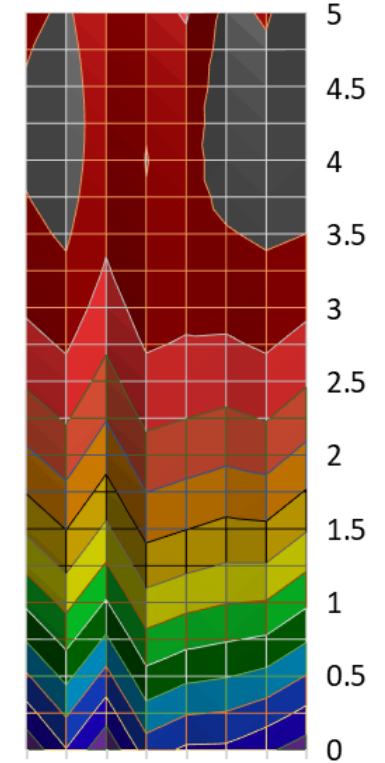
Measured Canister Surface Temperatures

- § Adapted inspection tools to measure canister surface temperatures and dose rates
- § Data from a 1.5-year-old canister (27.8 kW) is shown here (temperatures in degrees Celsius)

Surface Temperature - Site 3, Canister 4



81 78 67 56 45 34 23 12



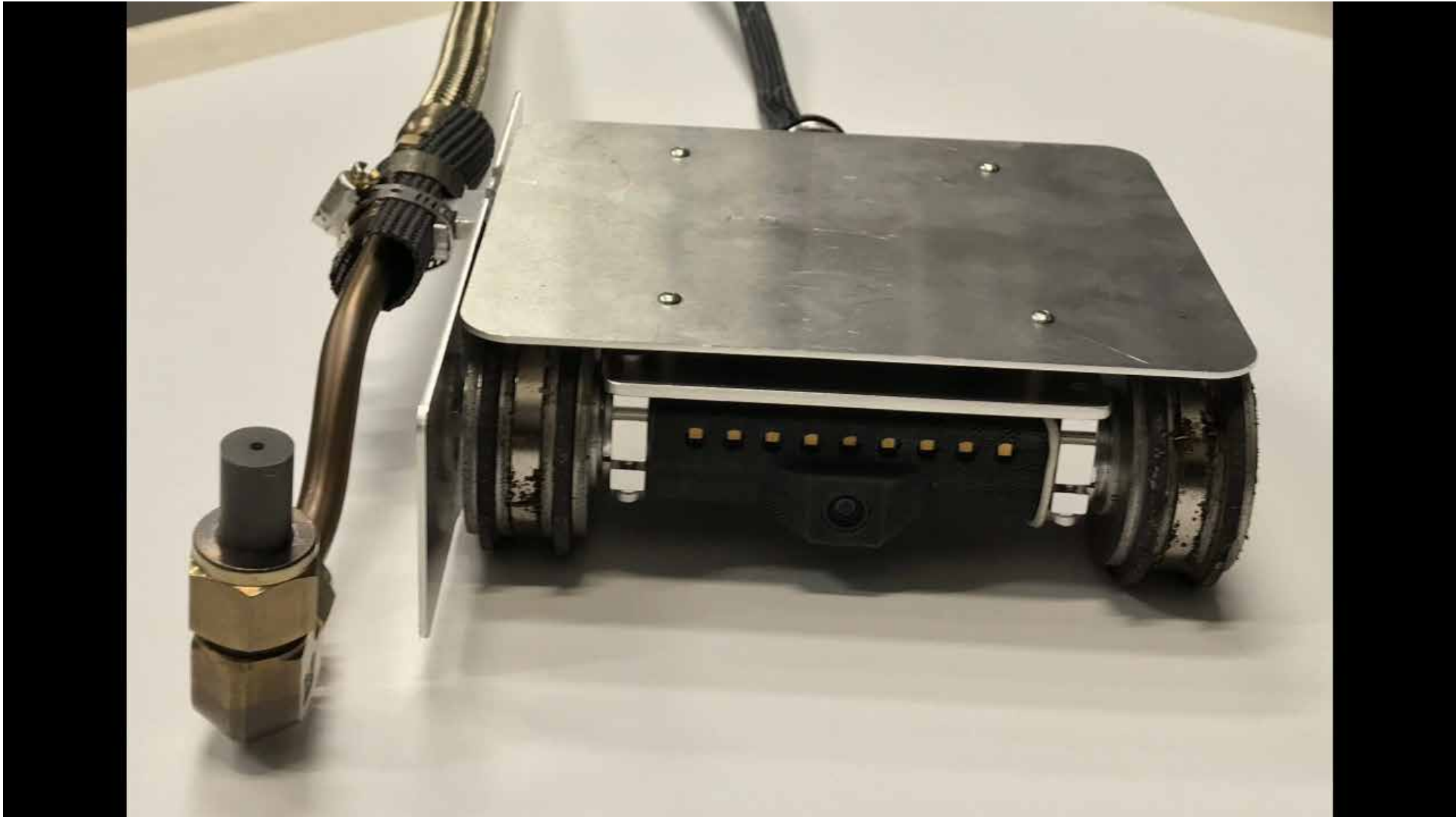
Team received
~176 mrem of
dose from this
activity (inspecting
8 canisters)

Collaborating with Mitigation/Repair Subcommittee

- § EPRI is helping to organize industry efforts on mitigation and repair technologies via the Extended Storage Collaboration Program (ESCP)
- § Collaborations between organizations can accelerate development
- § Helps to avoid duplication of effort
- § Cold spray application to be demonstrated at EPRI by VRC Metal Systems as a part of the next ESCP Meeting on November 8, 2019



Laboratory Evaluation of Cold Spray Repair



Example Mitigation/Repair Technologies Under Evaluation



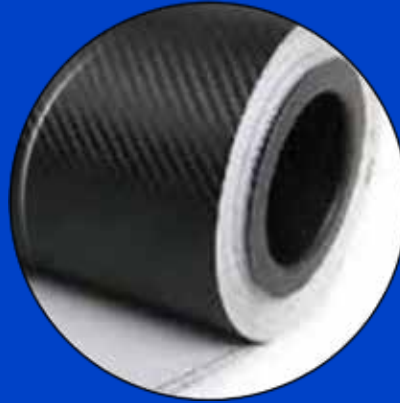
GTAW "TIG" Welding

- Standard industry technique
- Low-heat input techniques under development



Cold Spray

- High-potential process for mitigation and repair
- Demonstrated on robotic delivery system in DSS environment



Non-metallics

- Potential for very long-term repair patch
- Potential to mitigate an active flaw



Friction-stir welding

- Low heat input, full structural repair
- Non-susceptible, repairs flaws



Surface Stress Improvement (i.e. peening)

- Reduces susceptibility to CISCC
- Can be performed pre-service or in-service



Inspection Collaboration



EPRI Report 3002010617 contains information on NDE developments for dry storage canisters

Contributions from 22 organizations from around the world

Freely available to the public from www.epri.com

<https://www.epri.com/#/pages/product/000000003002010617>

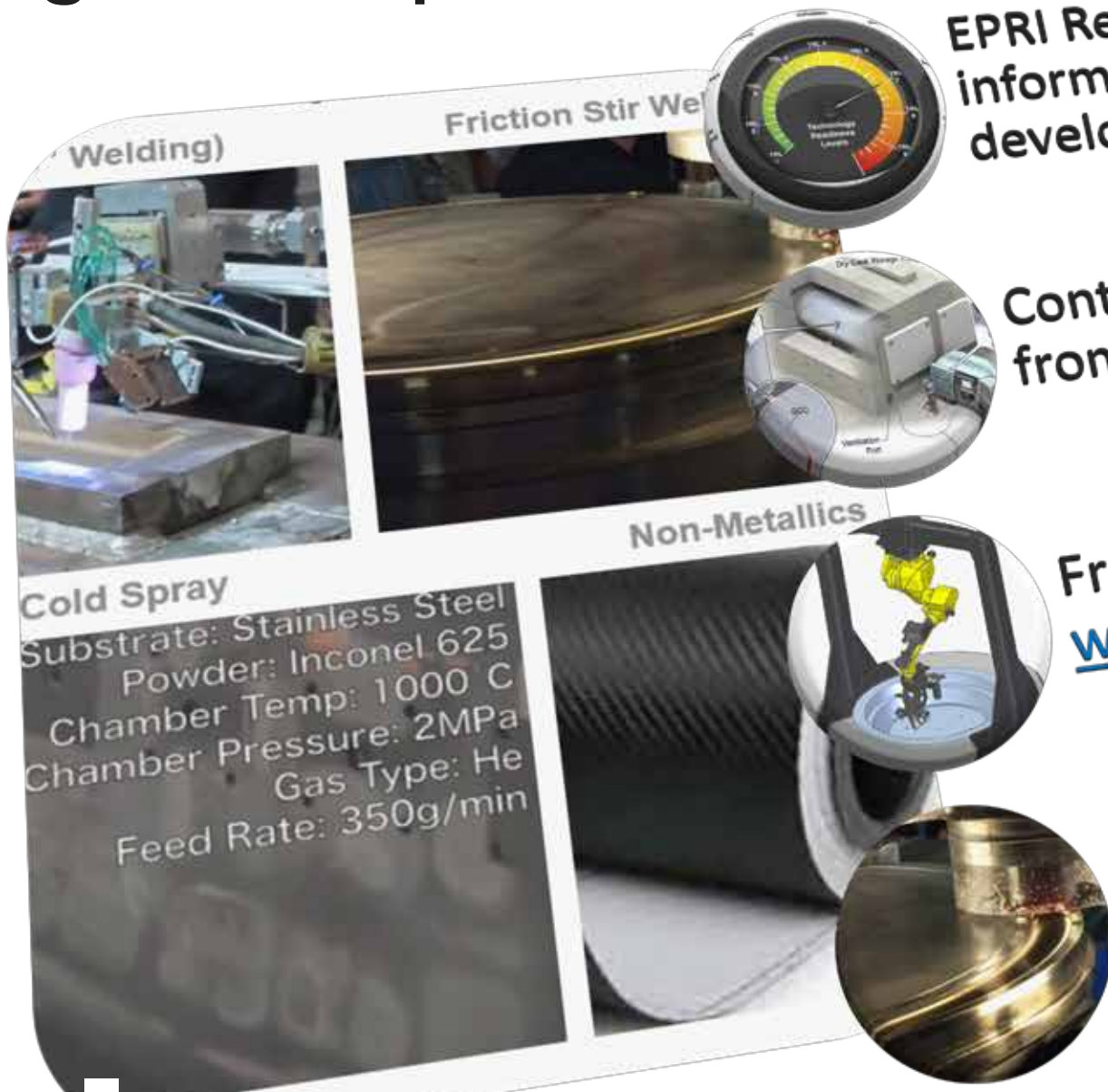
Mitigation/Repair Collaboration

EPRI Report 3002013130 contains information on mitigation and repair developments for dry storage canisters

Contributions from 12 organizations from around the world

Freely available to the public from www.epri.com

<https://www.epri.com/#/pages/product/000000003002010617/>



Summary – working towards DCSS Inspection Solutions



Collaboration

- Working with many organizations via the ESCP NDE Subcommittee
- ESCP NDE Subcommittee Report Published; subcommittee nearing an end



NDE Development

- Visual, eddy current, ultrasonic, and acoustic emission work are ongoing or completed
- Inspection has become a routine task



Robotic Development

- Eleven field trials/inspections have been completed, inspecting 13 fuel-loaded canisters
- Additional inspections planned



Mitigation and Repair

- Many different technologies being evaluated and mockups available for testing
- Robotic systems available for field deployment

Results available in: [3002008234](#), [3002010617](#), [3002010621](#), and [3002016034 \(9/30/19\)](#)



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