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NDE Reliability – continuous improvement

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NRC / Industry
NDE Technical Information Exchange Meeting
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Topics

- This presentation discusses selected projects designed to improve the reliability of NDE performed in the field
- Such projects include technology, tools to help utility staff, and training tools

- Included today:
  - Ultrasonic examination simulator
  - Remote visual examination CBT*
  - Cast stainless steel UT CBT
  - Phased array ultrasound CBT
  - Guide for compliance with NDE requirements

** Computer-based training*

Ultrasonic Simulator

Simulator topics

- Overview
- Software and Hardware Functions
  - User Interface and Scanning
- Looking into the Future

Project Overview

Project Overview

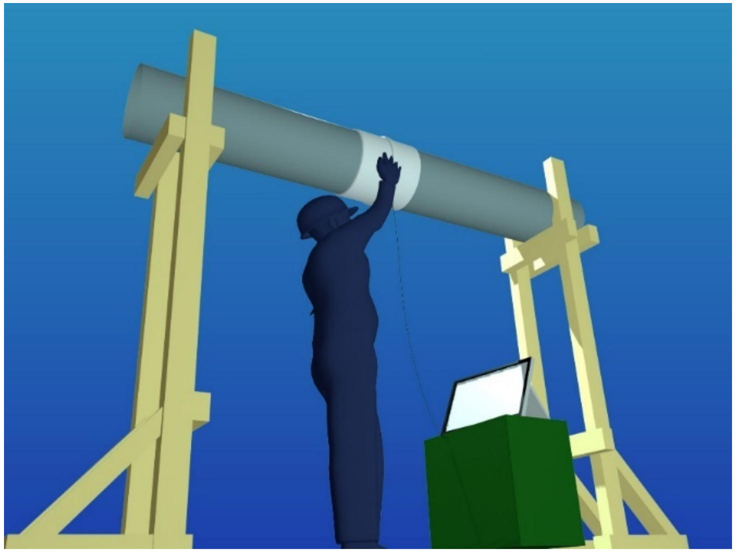
PHYSICAL		VIRTUAL
Limited Often non-specific Often unavailable for education	**INVENTORY**	Unlimited Can be specific Available for education
Specific locations Inconvenient	**ACCESS**	Virtual library At your convenience
Limited opportunities Often disruptive to work schedule	**TRAINING/PRACTICE**	Diversified opportunities Minimal disruption to work schedule
Difficult to share Limited incorporation into training	**OPERATIONAL EXPERIENCE**	Easy to share Enhanced incorporation into training

Virtual does not completely replace physical, but it can be used as an extension

An Example of Addressing Human Factors with Technology Innovation

Laboratory Environment

Simulated Environment



Field environment

An ultrasonic testing simulator is a missing link!

Software and Hardware Functions

Software Overview

- The Virtual NDE: Ultrasonic Data Player (VNDE) is a windows-based software that allows users to simulate conditions of manual ultrasonic examinations on their personal computers, providing practice opportunities without requiring access to physical ultrasonic instruments or pipe specimens.
- The Virtual NDE: Ultrasonic Data Player (VNDE) Version 1.0
  - Product ID 3002005493
  - Software comes with several datasets encompassing three different applications:
    - Stainless steel piping (Non-IGSCC)
    - Stainless steel piping (IGSCC)
    - Dissimilar metal weld piping
  - Desktop version only

UT Simulator Software Release

- **Virtual Ultrasonic NDE Version 2.0**
  - Final in November 2018 – Product ID **3002013243**
  - Includes the desktop software and supports the hardware version

- **Data Sets:**
  - Rompas block to simulate ultrasonic calibration
  - 12.75-inch (323 mm) diameter pipe (stainless steel and dissimilar metal weld applications)

- **New Features:**
  - Probe skewing capabilities
  - Calibration simulation
  - User interface improvements
  - Simulated specimens and weld crowns
  - Capture, save and report user activity for posterior analysis
  - Increased usability

Scanning with the UT Simulator

- Simulated hardware contains a 3D printed plastic specimen and probe.
  - Gives a realistic look and feel when scanning.
- The specimen and probe contain an electromagnetic sensor that is tracking all 6 degrees-of-freedom with respect to each other.
  - The specimen and probe can be moved relative to each other.

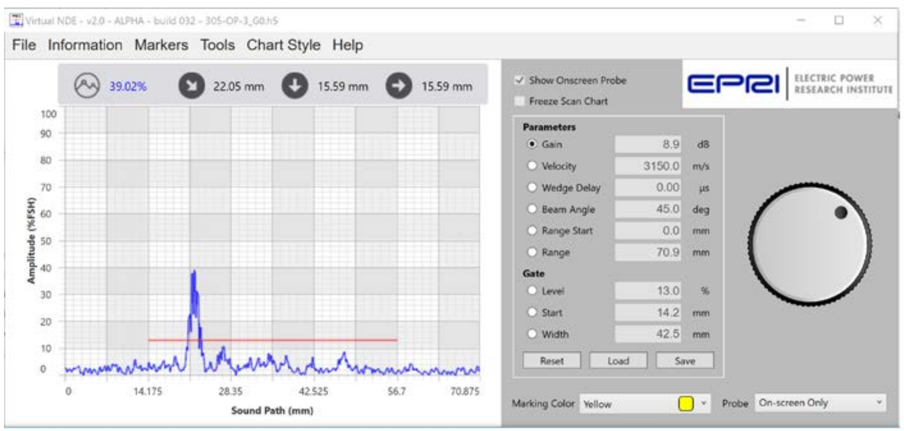
Hardware Scan: Half Pipe

Hardware Scan: Rompas Block

User Interface

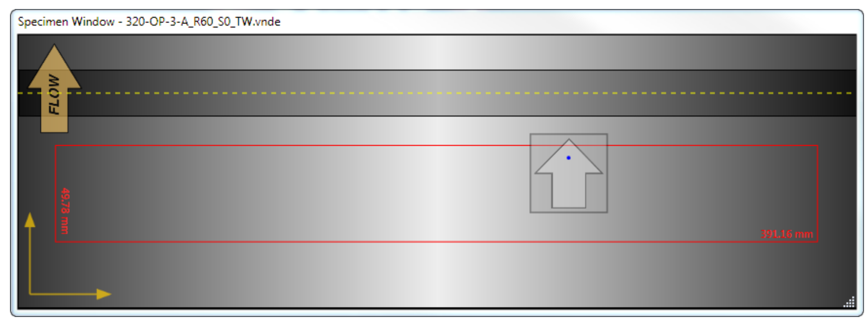
Main Window

- Software control interface (menus)
- Live A-Scan
- Display read outs
- Parameter & gate control



Specimen Window

- Represents top, roll-out view of virtual specimen with a virtual weld if applicable.
- Only visible when a file is open
- Contains a virtual probe
- Scan data is available in red box.



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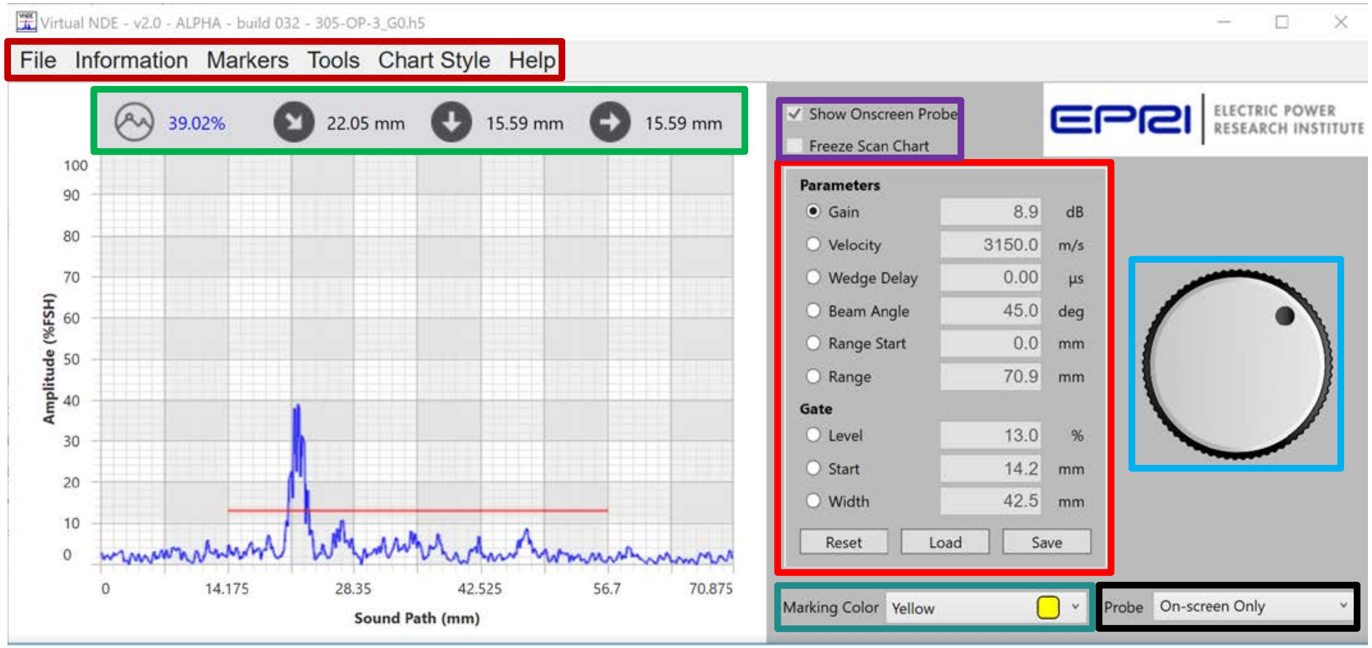
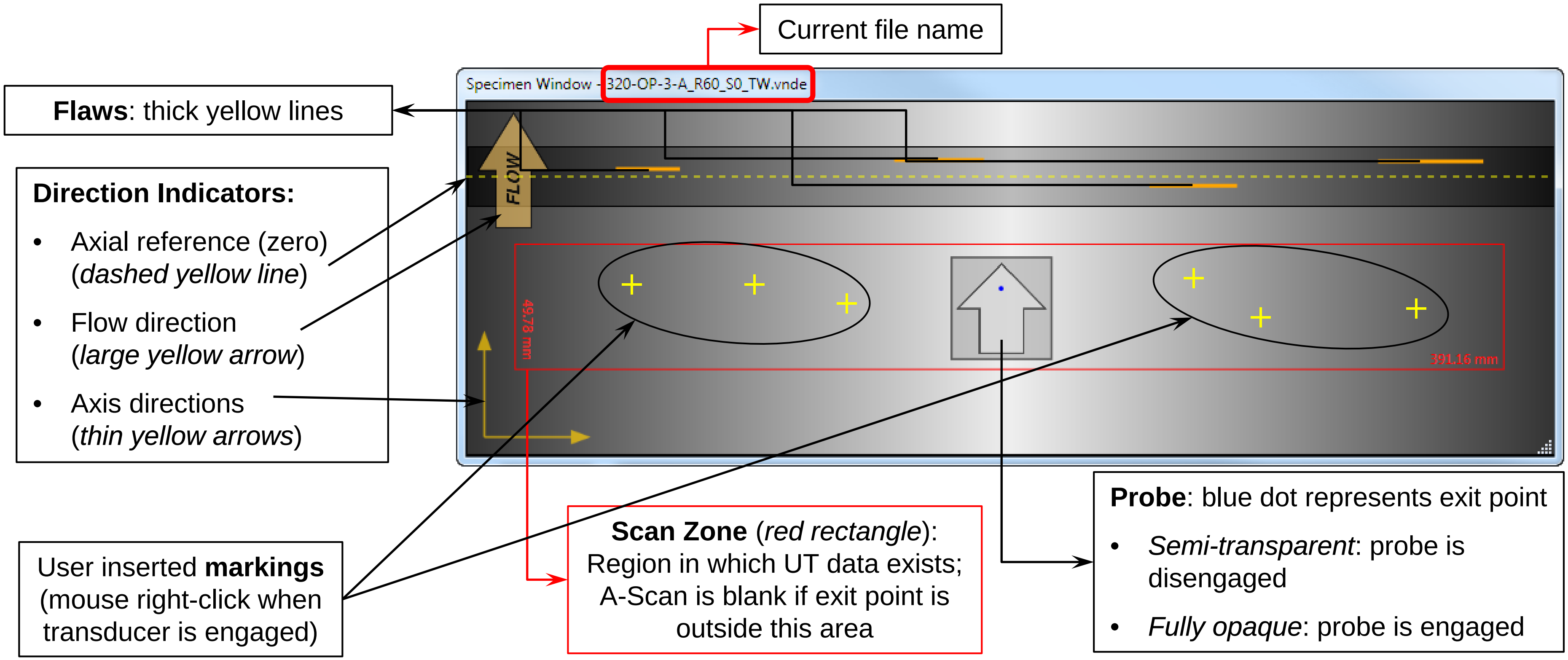
Summary of User Interface Controls

- Parameter and Gate Control Panel
- Control Knob
- Gate-crossing peak parameters
- Show On-Screen Probe and Freeze A-Scan
- Probe Select
- Marking color
- Menus



The Specimen Window

- Visual components:



Looking into the Future

Improvements/Features under Consideration

- New graphic geometry and data visualization
  - Live cross-sectional views, top, side, or end views
- Support for multiple gain levels
  - Necessary to relate ultrasonic calibration to actual specimen data
- New applications (simple & complex geometries)
  - Simple: RPV, WOL
  - Complex: tapers, nozzles, saddle welds
- Phased array applications

Prioritization is under way; not all will be implemented

UT Simulator - discussion

Remote VT Computer Based Training (CBT)

Remote VT CBT

- **Background**
  - The need for additional VT training was a major takeaway from the VT Round Robin Studies, noted by both EPRI and Pacific Northwest National Laboratory (PNNL)
  - Examiners who participated in the VT Round Robin studies all commented on the value of the VT specimens used during testing
  - There is not an abundance of training specimens for remote VT available to the examiner population
    - Especially at the difficulty level of the specimens created for the VT Round Robin

Remote VT CBT

- **Project Approach & Scope:**
  - Develop a computer-based training application for NDE personnel in the evaluation and analysis of remote visual examination data
    - To be useful for both initial training and proficiency maintenance training
  - Make use of recently developed open VT specimens as the primary source of information and data for the training
    - Videos of these specimens will be performed in the EPRI lab and then used to build the application
  - HD video capture should allow the user the resolution needed to be able to magnify the image at their own discretion, a feature which would have been very limited with standard camera video capture

Remote VT CBT

- **Value Proposition:**
  - A CBT application will make training convenient and economical by eliminating costs and delays associated with:
    - Shipping of specimens and equipment
    - Personnel travel expenses
    - Use of training facility
  - Users can achieve instant access from the convenience of their desktop (Members both domestic and international)
  - A CBT application also will help in preserving the integrity of the specimens over time

Remote VT CBT

- **Current Status:**
  - Currently selecting a vendor to develop the CBT
  - Open specimens have been fabricated and videos will be recorded in first quarter of 2019
  - CBT planned to be completed by end of 2020

Visual CBT - discussion

CBT-Ultrasonic Phased Array Technology with Nuclear Focus

Outline:

- What is this CBT – its benefits and value
- Objectives and Approach
- General CBT information, status and platform requirements
- Deliverable and accessing the training materials
- Recommended approach and take-away goal

What is this CBT – it's benefits and value

- This is a module for Ultrasonic Phased Array Technology with specifics to the nuclear industry when possible
  - The content of this CBT is based on EPRI's previous training courses on this subject matter along with updated perspectives and the presentation of new content

- Benefit: Phased array technology has become widespread; utility staff need to be well-informed in order to manage NDE contractors effectively

- Value: Members will now have the opportunity to access EPRI's training content flexibly and without travel

Objectives and Approach

- Approach:
  - EPRI's classroom training course is 40 hours at EPRI Charlotte, NC or delivered at the customer site
  - Expensive due to customer travel costs (course at Charlotte) or to EPRI travel costs and costs of transporting the required training materials (course at customer site)
  - CBT condenses the classroom portion and delivers it to the customer through on-line access. The CBT does not include hands-on lab opportunities
- There are no prerequisites that the user should have prior to taking this training

General CBT information, status and platform requirements

“Ultrasonic Phased Array Technology with a Nuclear Focus - Computer Based Training” October 2018 3002013159

Platform Requirements:

Windows 7 (32-bit and 64-bit)

Windows 8, 10 Screen Resolution: 1024 X 768

Hard Drive Space: 70MB of storage

Adobe Flash Player 11.0

Windows Media Player

Supported by: Internet Explorer 11, and current version of Chrome and Firefox

Recommend approach and take-away goal

- For most users the CBT is most beneficial if the user starts at the beginning and follows the order presented

- The user's take-away goals for this training should be:
  - Become acquainted with ultrasonic phased array technology
  - Understand the advantages and benefits that it brings to the nuclear power industry

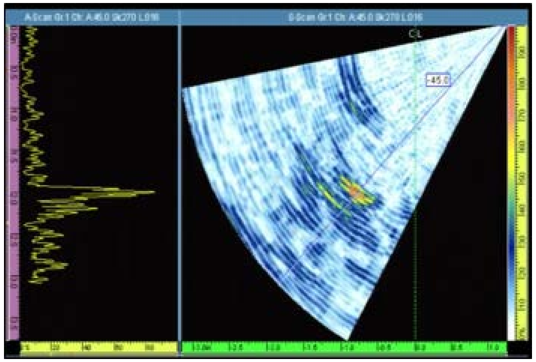
Phased array UT CBT - discussion

CBT – Ultrasonic Examination of Cast Austenitic Stainless Steel Welds

Ultrasonic Examination of Cast Austenitic Stainless Steel Welds

Computer Based Training Course

- Objective
  - Provide quality NDE/ISI computer based training (CBT) course materials that address the current and emerging technologies associated with the ultrasonic examination (UT) of cast austenitic stainless steels (CASS).

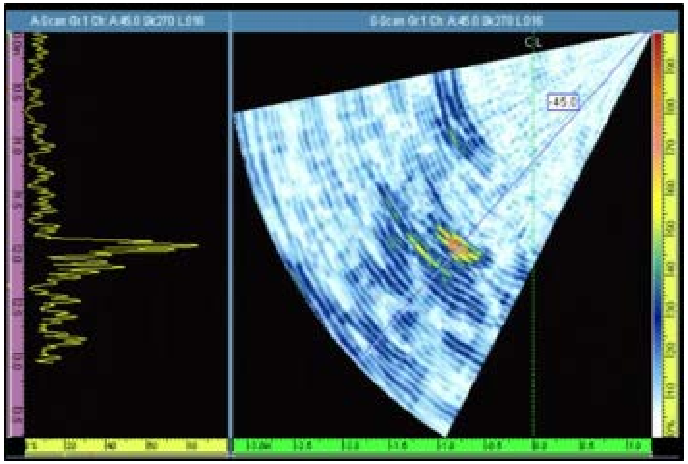


- Approach
  - Cast stainless steels are very difficult to examine ultrasonically due to highly attenuative materials and complex configurations.
  - Project captured important information, theory and concepts from research conducted by EPRI on cast stainless steels (e.g., TR 1026773, Recent Developments in the Inspection of Cast Austenitic Steel Components).

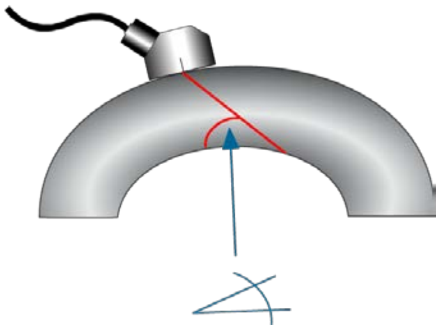
Ultrasonic Examination of Cast Austenitic Stainless Steel Welds

Computer Based Training Course

- Product
  - Computer based training course consisting of several modules and numerous lessons addressing these topics
    - Codes, Standards and Specifications
      - ASME, Section XI, Appendix III
      - Code Case N-824
        - As modified by 10CFR50.55a
    - Cast austenitic stainless steel materials
      - Material properties and characteristics
      - Impact on ultrasonics
    - Phased array examinations of CASS
      - Equipment selection and calibration
      - Scanning techniques
      - Signal discrimination and characterization

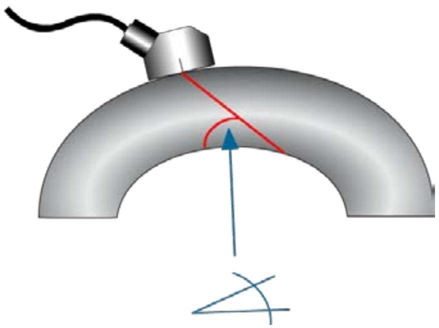


- Product (continued)
  - Fabricated several flawed CASS samples to coincide with the training
    - Hands-on open and closed **practice** samples
      - 8 new CASS open practice samples were added to the existing CASS sample set
      - Total of 22 CASS practice samples
      - Diameter range: 12"- 36"
      - Thickness range: 1.3" – 2.8"



  - Implementation
    - Individuals go through the CBT at their convenience
      - Schedule time at EPRI for hands-on practice on CASS practice samples
      - Alternative – ship open practice samples to member's site

- Status
  - Computer Based Training (CBT) for the Ultrasonic Examination of Cast Austenitic Stainless Steel Welds (UTCASS-CBT), v1.0
    - EPRI Product # 3002014180
      - Download from www.epri.com
        - Available to EPRI members
    - Practice samples
      - Available for scanning



CBT – Ultrasonic Examination of Cast Austenitic Stainless Steel Welds

-- discussion

NDE Guide for Compliance of Class 1, 2, 3, IWF, and common Augmented Inservice Inspection Requirements

NDE Guide for Compliance of Class 1, 2, 3, IWF, and common Augmented Inservice Inspection Requirements

- Background
  - Determining the requirements of any given American Society of Mechanical Engineers (ASME) nondestructive evaluation (NDE) inspection can often be a complicated and time-consuming endeavor, even for the most experienced industry people
  - Continual changes can make this process even more challenging

- Objective
  - Develop a tool for utility staff to use in planning examinations, designed to help the utility ensure that all examinations are executed in compliance with technological and schedule requirements

NDE Guide for Compliance of Class 1, 2, 3, IWF, and common Augmented Inservice Inspection Requirements

- Development
  - EPRI developed "NDE Guide for Compliance of Class 1, 2, 3, IWF, and Common Augmented In-Service Inspection Requirements" to assist plants in navigating the requirements in a more efficient manner
  - The guide is intended to provide a single source, easy to use document, which takes the end user through all the NDE requirements pertaining to a plant component, to help ensure that no pertinent rules or requirements are ever missed or forgotten
  - In Excel spreadsheet form, the guide lays out components in the same basic format provided in ASME Section XI
    - Provides links to not only the NDE requirements within the Code
    - Provides links to other industry guidelines and requirements that pertain to that location (i.e., 10CFR50.55a, NEI 03-08, MRP, SGMP, BWRVIP, and ASME Code Cases)
    - Provides references to all ASME Section XI, Appendix VIII qualified ultrasonic procedures that pertain to any particular Code Category component

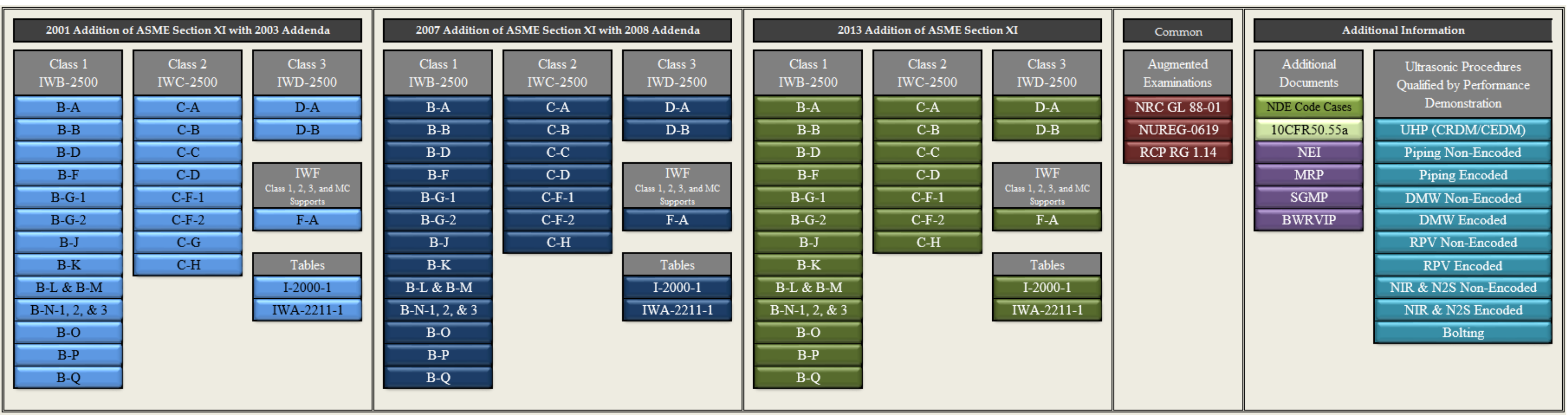
NDE Guide for Compliance of Class 1, 2, 3, IWF, and common Augmented Inservice Inspection Requirements

- Phase 1 – "NDE Guide for Compliance of Class 1 Inservice Inspection Requirements"
  - Published in December of 2015
  - Included the Class 1 requirements for ASME Code years 2001 with 2003 Addenda, and 2007 with 2008 Addenda.

	Tab (Hyperlink)	Description
ASME Section XI, IWB-2500, Code Category Class 1	Code Category	List of ASME Section XI, IWB-2500, Class 1 Code Category
	B-A	Pressure Retaining Welds in Reactor Vessel
	B-B	Pressure Retaining Welds in Vessels Other Than Reactor Vessels
	B-D	Full Penetration Welded Nozzles in Vessels
	B-F	Pressure Retaining Dissimilar Metal Welds in Vessel Nozzles
	B-G-1	Pressure Retaining Bolting, Greater Than 2 in. (50 mm) in Diameter
	B-G-2	Pressure Retaining Bolting, 2 in. (50 mm) and Less in Diameter
	B-J	Pressure Retaining Welds in Piping
	B-K	Welded Attachments for Vessels, Piping, Pumps, and Valves
	B-L & B-M	Pressure Retaining Welds in Pump Casings, Pump Casings, Pressure Retaining Welds in Valve Bodies, Valve Bodies
	B-N-1, 2, & 3	Interior of Reactor Vessel, Welded Core Support Structures and Interior Attachments to Reactor Vessels, Removable Core Support Structures
	B-O	Pressure Retaining Welds in Control Rod Drive and Instrument Nozzle Housings
	B-P	All Pressure Retaining Components
	B-Q	Steam Generator Tubing
Additional Requirements	ISI Code Cases	List of ASME Section XI Code Cases that relate to ISI
	10CFR50.55a	10 CFR 50.55a Published December 11, 2014 in Outline Format
	NEI	Materials Initiative Documents
	MRP	PWR Materials Reliability Program
	SGMP	Steam Generator Management Program
	BWRVIP	BWR Vessel and Internals (BWRVIP) Guide
Ultrasonic Procedures Qualified by Performance Demonstration	UHP (CRDM/CEDM)	Ultrasonic Procedures Qualified for PWR Upper Head Penetrations (UHP)
	Piping Non-Encoded	Ultrasonic Procedures Qualified for Non-Encoded Piping Examination
	Piping Encoded	Ultrasonic Procedures Qualified for Encoded Piping Examination
	DMW Non-Encoded	Ultrasonic Procedures Qualified for Non-Encoded Dissimilar Metal Weld (DMW) Pipe Examination
	DMW Encoded	Ultrasonic Procedures Qualified for Encoded Dissimilar Metal Weld (DMW) Pipe Examination
	RPV Non-Encoded	Ultrasonic Procedures Qualified for Non-Encoded Examination of Reactor Pressure Vessel (RPV) Plate
	RPV Encoded	Ultrasonic Procedures Qualified for Encoded Examination of Reactor Pressure Vessel (RPV) Plate
	NIR & N2S Non-Encoded	Ultrasonic Procedures Qualified for Non-Encoded Examination of Nozzle Inner Radius (NIR) and Nozzle-to-Shell (N2S)
	NIR & N2S Encoded	Ultrasonic Procedures Qualified for Encoded Examination of Nozzle Inner Radius (NIR) and Nozzle-to-Shell (N2S)
	Bolting	Ultrasonic Procedures Qualified for Non-Encoded Examination of Bolting

NDE Guide for Compliance of Class 1, 2, 3, IWF, and common Augmented Inservice Inspection Requirements

- Phase 2 – "NDE Guide for Compliance of Class 1, 2, 3, IWF, and common Augmented Inservice Inspection Requirements"
  - More comprehensive than the Phase 1 previous version
    - Includes Class 1, 2, 3, IWF, and common Augmented Inservice Inspection requirements for ASME Code years 2001 with 2003 Addenda, and 2007 with 2008 Addenda, and 2013
    - "Additional Documents" section
      - List of all ISI NDE related Code Cases and the latest version of 10CFR50.55a in outline format
      - List with links to NEI, MRP, SGMP, and BWRVIP related documents
    - "Ultrasonic Procedures Qualified by Performance Demonstration" section provides a list and information on every PDI qualified procedure



NDE Guide for Compliance of Class 1, 2, 3, IWF, and common Augmented Inservice Inspection Requirements

- Desktop Resource
  - The NDE Guide is an Excel spreadsheet which can be maintained in the corner of your desktop for ease of access.
- Dynamic Document
  - The NDE Guide is published in an unlocked Excel spreadsheet which will allow you to make changes to better suit your needs within your company.
- Training tool
  - Thinking about retirement? Your replacement may not have your extensive knowledge of the ASME Code, Code Cases, or 10CFR50.55a.

NDE Guide for Compliance of Class 1, 2, 3, IWF, and common Augmented Inservice Inspection Requirements

- Deliverable
  - This product was delivered as a Technical Report (TR).
    - "Nondestructive Evaluation Guide for Compliance of Class 1, 2, 3, IWF, and Common Augmented In-Service Inspection Requirements" March 2018 (Product # 3002010307)
- Usability/Feedback
  - This product has been highly praised by our US and international members.

Guide for Compliance - discussion

Together…Shaping the Future of Electricity

Technical Basis for Eddy Current Code Cases, Qualification, Acceptance Criteria

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NDE Technical Information Exchange Meeting
Washington, DC
January 2019

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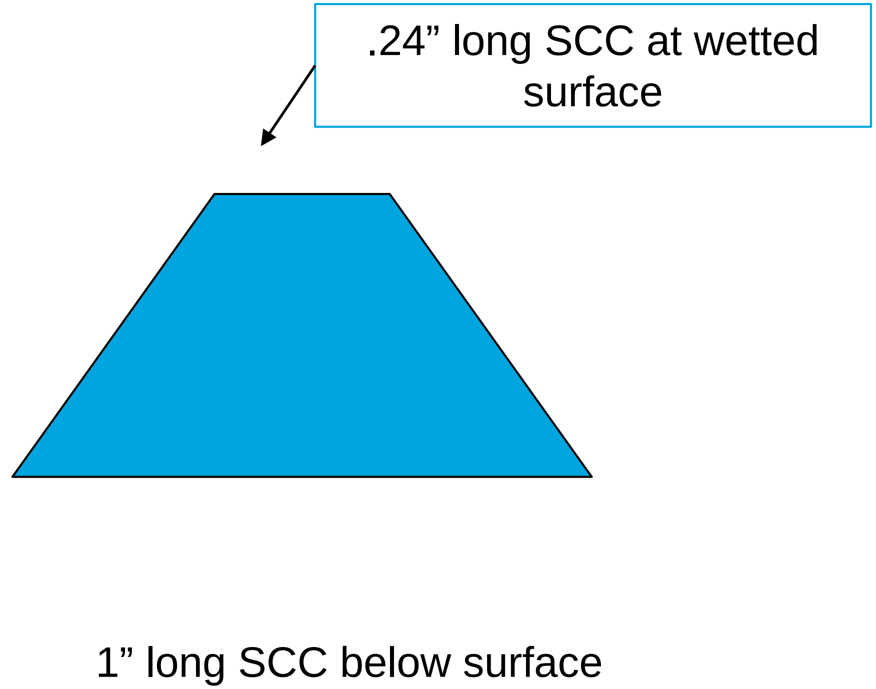
Background

- In 2017, a technical basis document (MRP-423) was developed to be used as guidance to revise Section XI, Division 1, Appendix IV, Eddy Current Examination, demonstration requirements
  - Current "short defect" requirements have driven some ET equipment designers to develop probes with high sensitivity that are prone to false calls
  - Demonstration test sets should include defects with subsurface morphologies instead of small shallow surface flaws or notches
- This technical basis document will also be used to revise relevant Code documents that provide acceptance criteria for ET surface examinations in the context of newly available surface examination results
  - These requirements are an incomplete representation of SCC
  - Some requirements are based on PT

MRP-423 Report

- Materials Reliability Program: Eddy Current Surface Examination Demonstration Technical Basis (MRP-423) 3002010710

- Flaws of interest



Project Status and Schedule

- Presented basis for the need to revise Appendix IV Supplement Section XI in 2017 Section XI Working Groups (WG) and NDE Sub Group
- Submitted draft of new Supplement 5 for Appendix IV at May 2018 at the WG Personnel Qualification, Surface, Visual, and Eddy Current meeting
  - Item Number 18-1186: Appendix IV, SUPPLEMENT 5 QUALIFICATION REQUIREMENTS FOR SURFACE EXAMINATION OF PIPING AND VESSELS WELDS IN SERVICE FABRICATED WITH AUSTENITIC STAINLESS STEELS OR NICKEL ALLOYS SUSCEPTIBLE TO STRESS CORROSION CRACKING
- Accordingly revise Code Cases relevant to Alloy 600 Examinations
  - Revise references and acceptance criteria
  - N-729 (upper head penetrations)
  - N-770 (DM Welds)
  - N-766 (Onlay and Inlay mitigation)
  - N-773 (ET to supplement ID UT)

discussion

Together…Shaping the Future of Electricity

Hyperspectral Imaging

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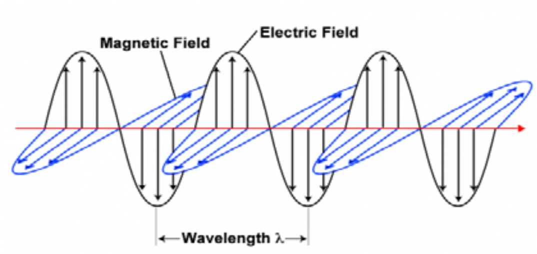
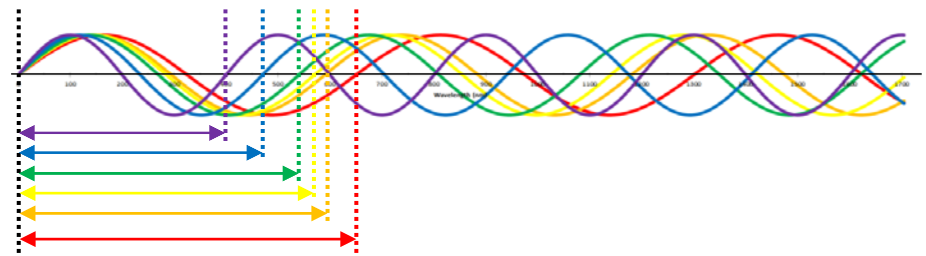
NRC / Industry
NDE Technical Information Exchange Meeting
Washington, DC
January 2019

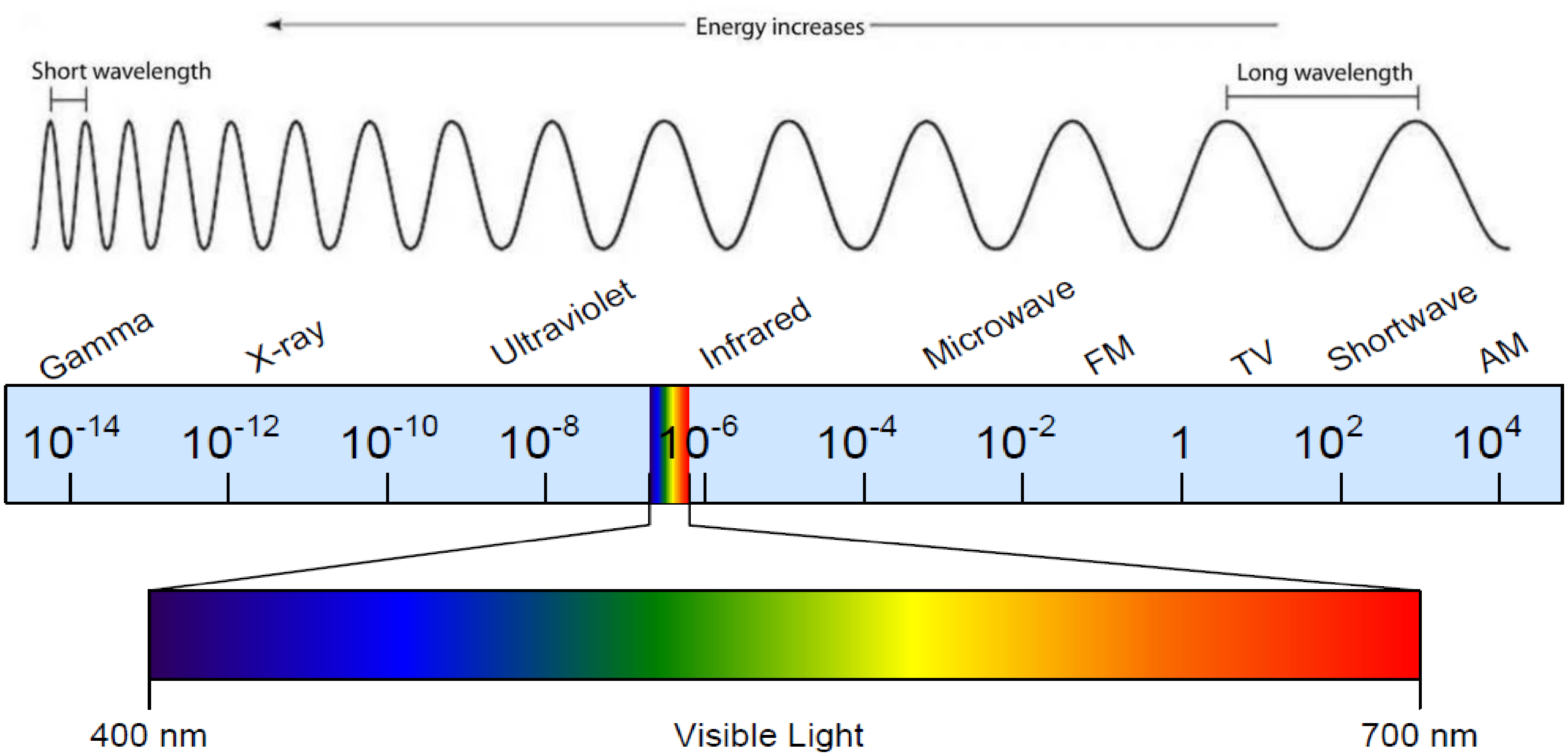
Topics for Discussion

- Spectral imaging, what is it?
  - Background
  - Brief overview of the technology
- Involvement with spectral technologies
  - Capital procurement (Hyperspectral scanning system)
  - ***Boric Acid Discrimination***
- Nuclear inspection application
  - Boric acid corrosion programs
  - Address RIS 2018-06
  - Concrete
  - Other

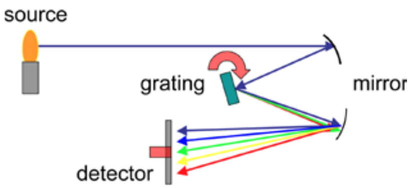
Electromagnetic Spectrum

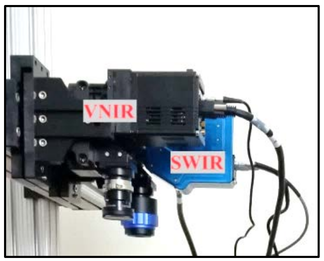


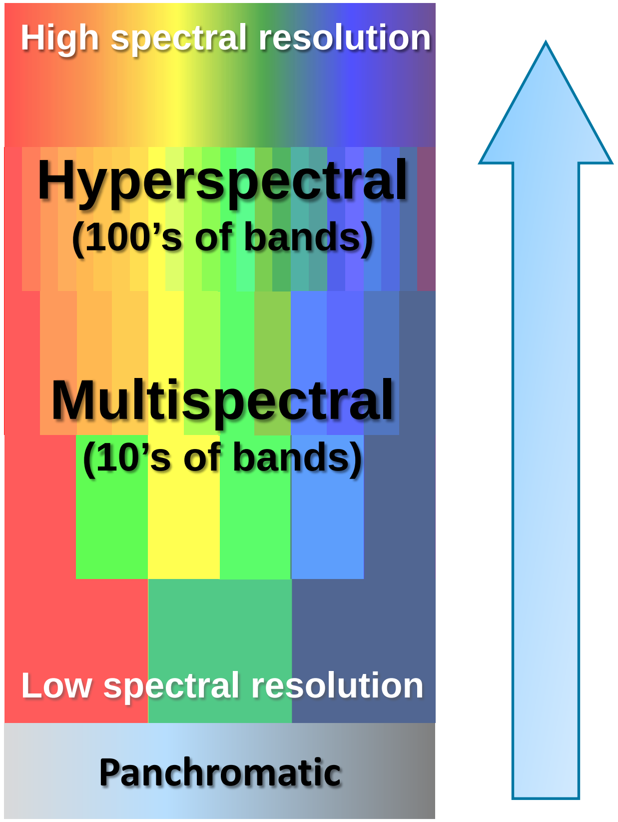


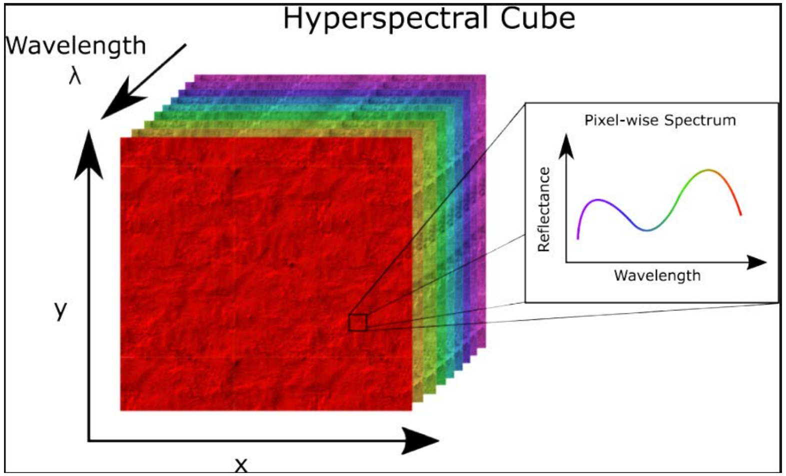


Basics of Reflectance Spectral Imaging







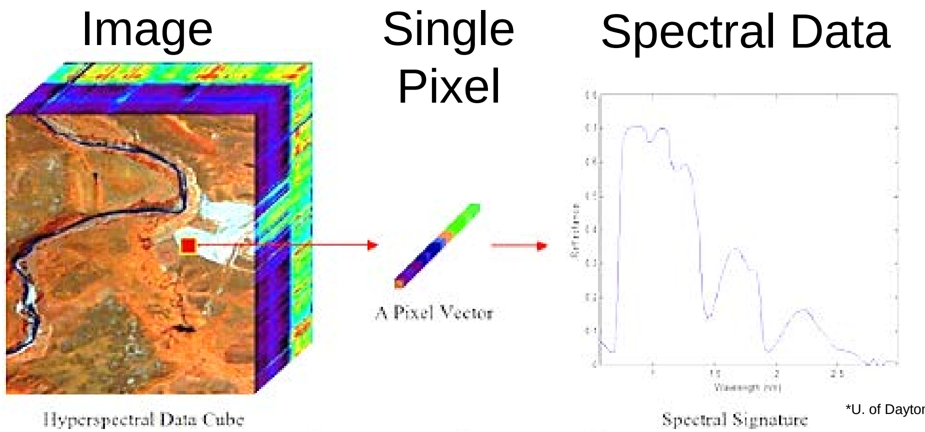


Key benefits

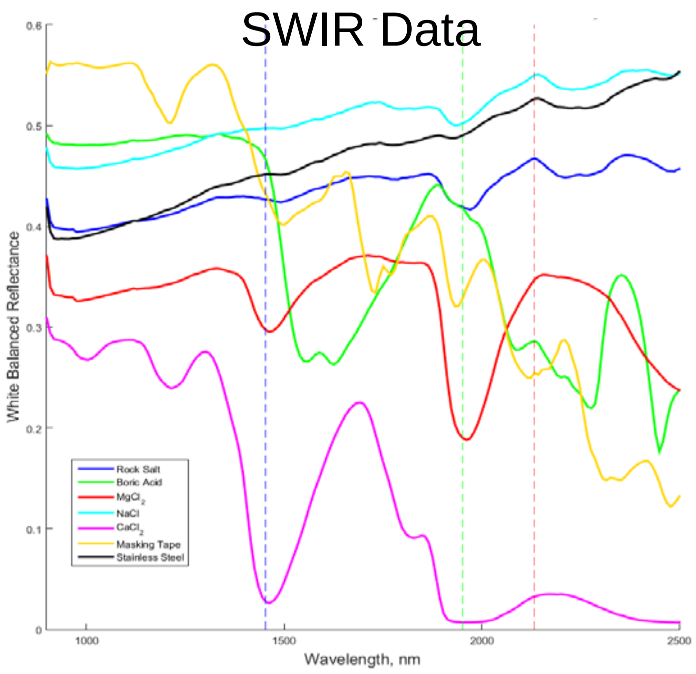
Quantification
Characterization
Discrimination
Classification
Detection

Hyperspectral Imaging

- Reflected spectral signatures are powerful discriminators
  - Materials (based on chemistry at the surface) reflect light differently
- Utilize visible (VNIR) and short wave infrared ranges (SWIR - beyond visible light spectrum)
- Used to classify substances that have similar 'visual' appearance
  - White residues/powders, other…



The Concept of Hyperspectral Imaging



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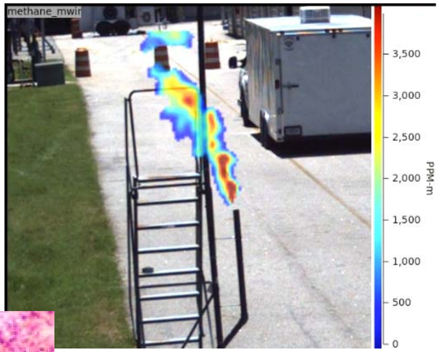
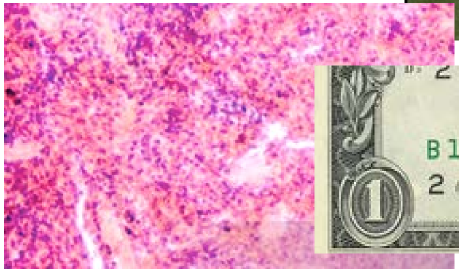
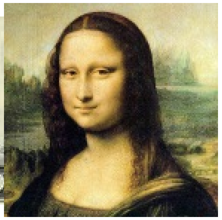
Uses of Hyperspectral Imaging

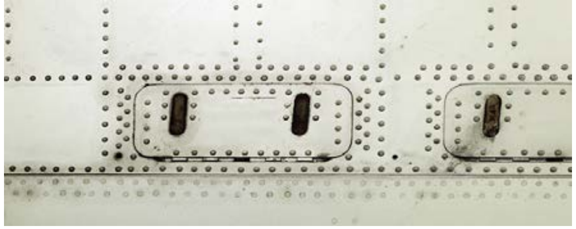
"Identify/classify materials and targets by chemistry (not shape)"

- Remote Sensing
  - Agriculture, vegetation management
  - Environmental monitoring
- Advanced Machine Vision
  - Production line quality, recycling, forensics
- Biomedical Applications
  - Biological microscopy, pharmaceuticals
- Government & Defense
  - Corrosion Detection
  - Chem/Bio threats









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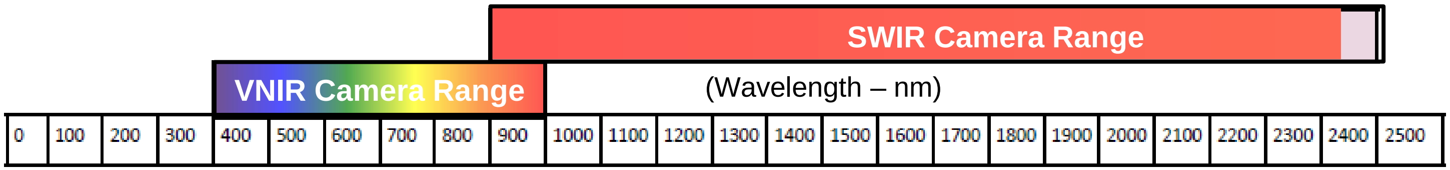
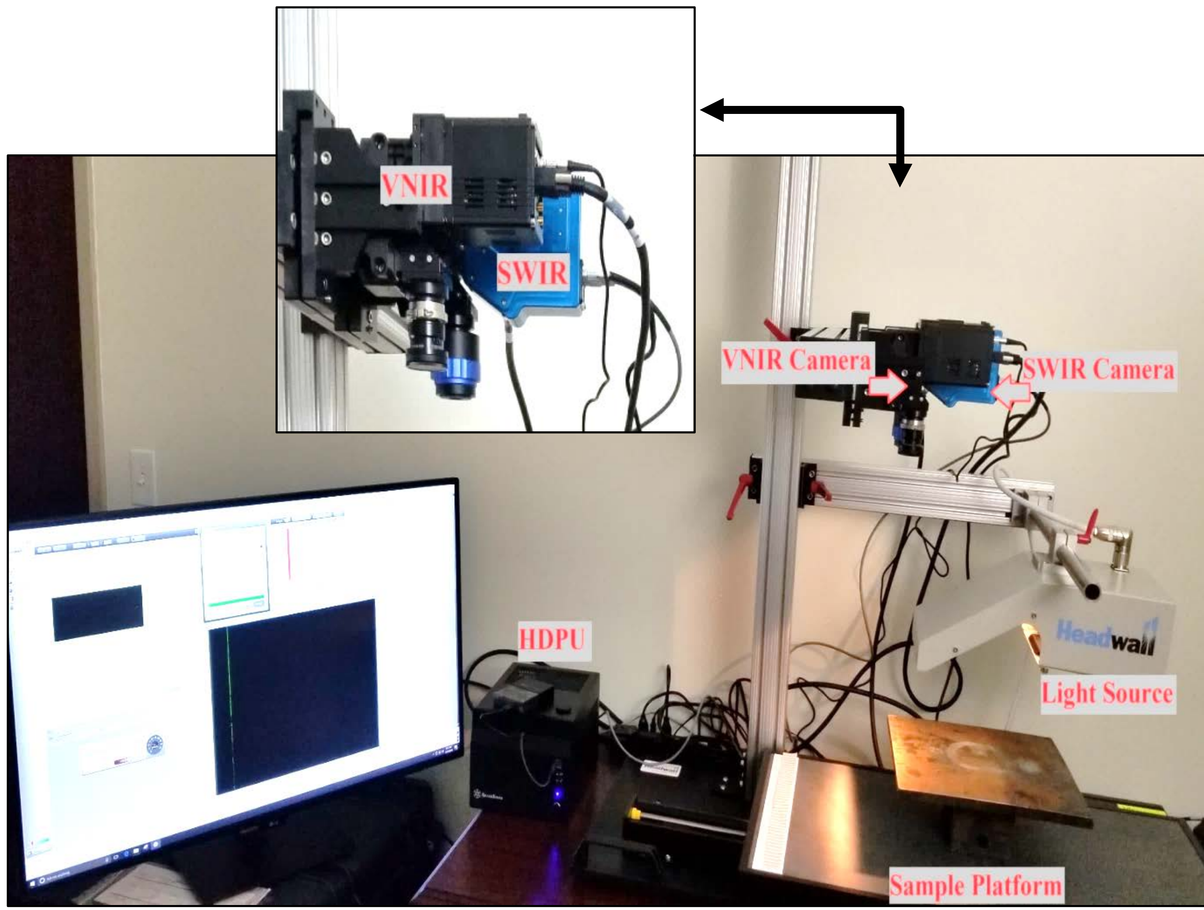
Benchmarking the Equipment

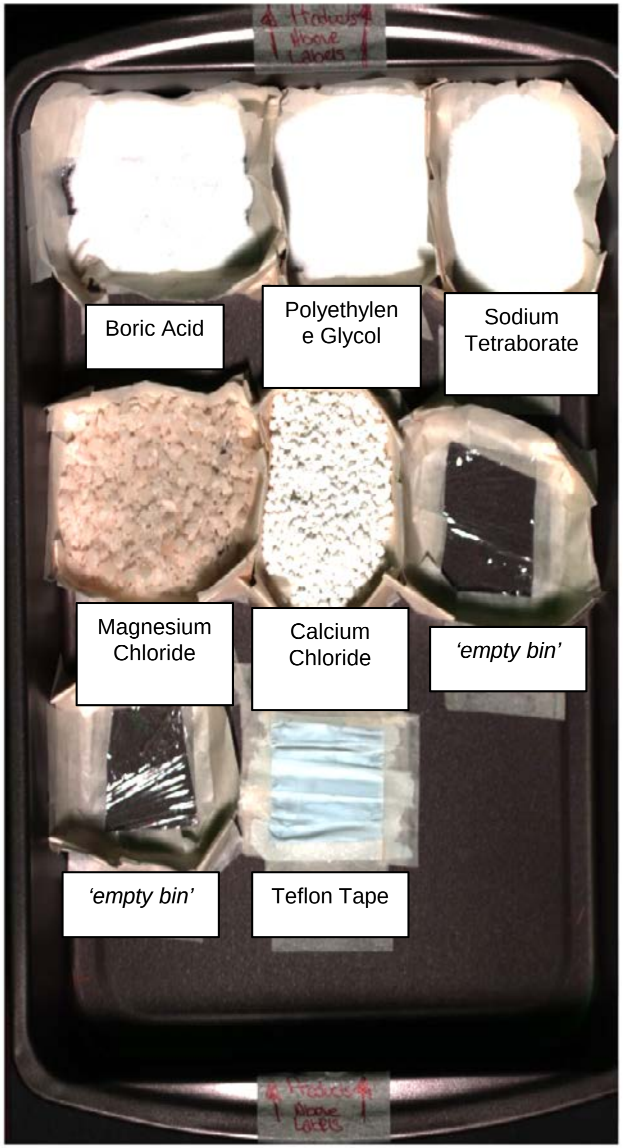


- Dual Camera Scanning System
  - VNIR (visual near infrared) 400-1000nm
  - SWIR (short wave infrared) 900-2500nm
- Linear translation
  - Scanning
- Data acquisition and analysis software

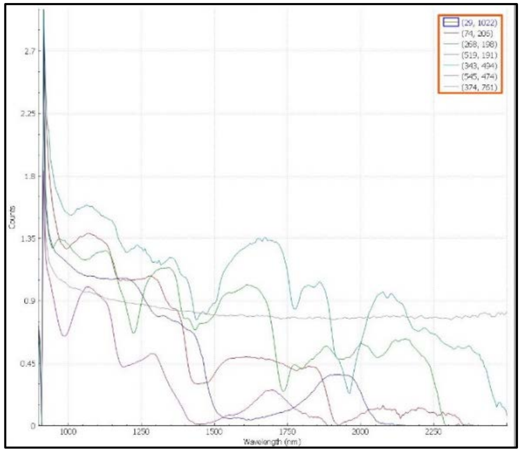


Hyperspectral Classification (Dry Materials)

Raw Image

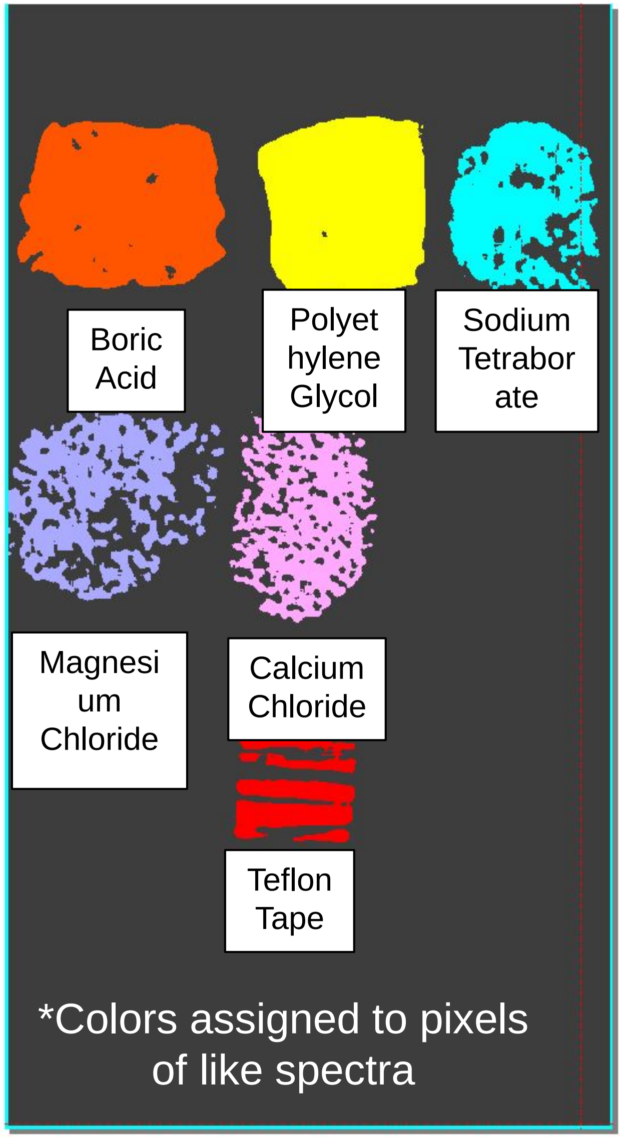


Spectral Data



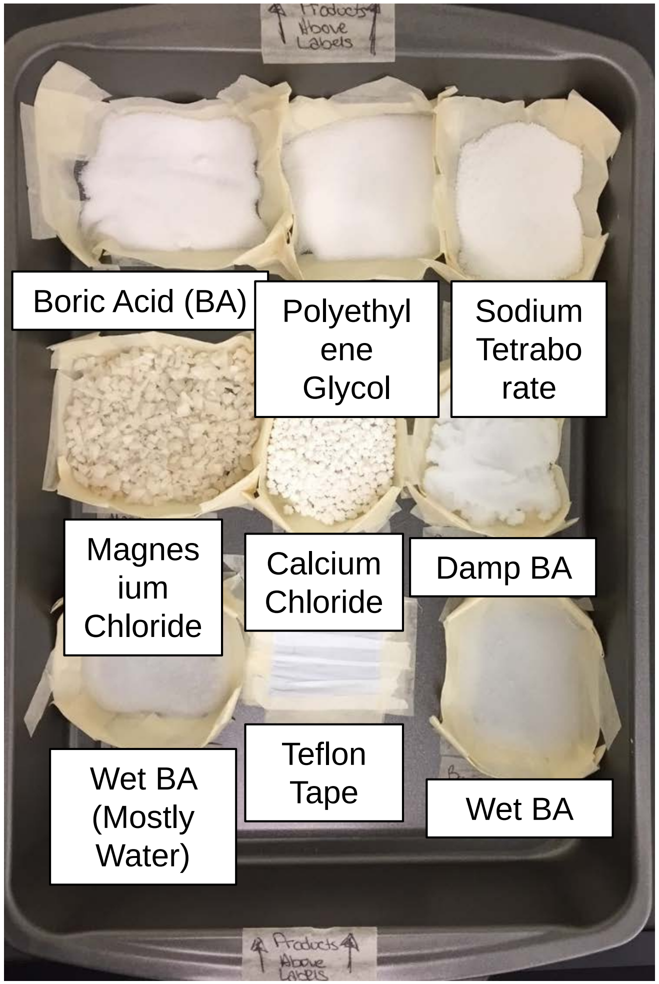
Use spectral data and apply a spectral angle mapping based classifier to image

Post Classification

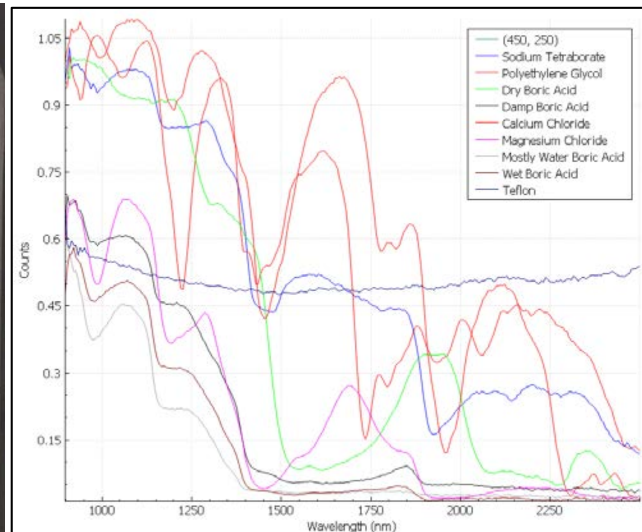


Hyperspectral Classification (Wet Boric Acid)

Raw Image

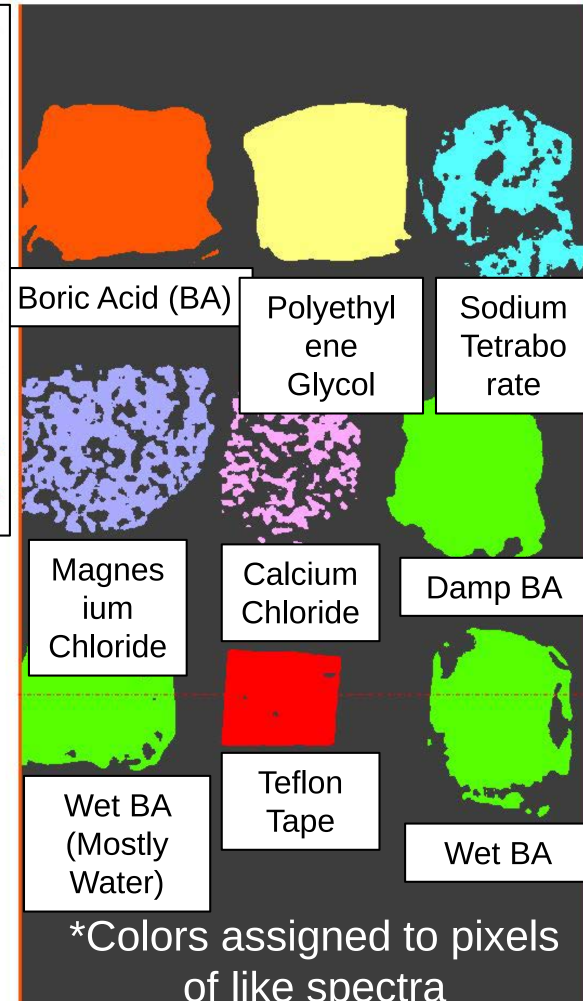


Spectral Data



Use spectral data and apply a spectral angle mapping based classifier to image

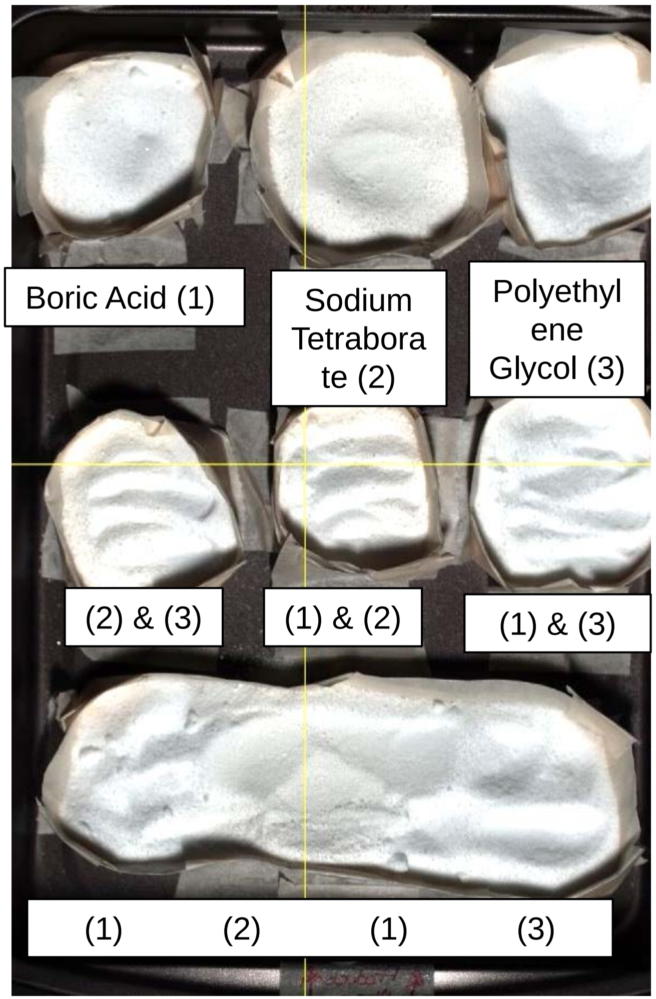
Post Classification



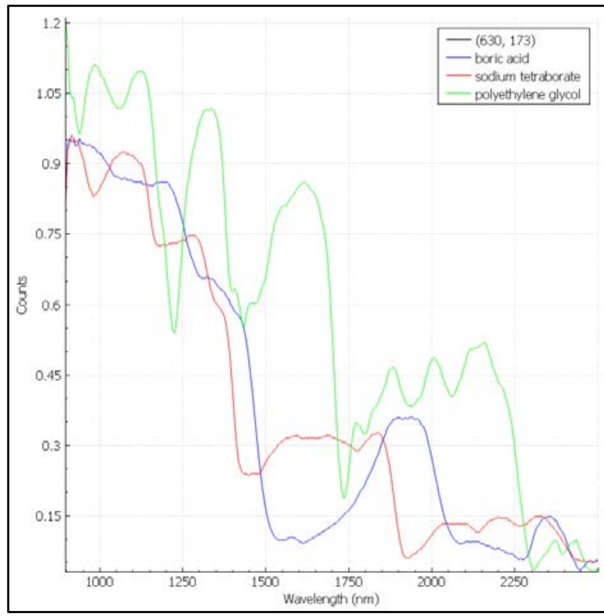
*Colors assigned to pixels of like spectra

Hyperspectral Based Classification (Mixtures)

Raw Image



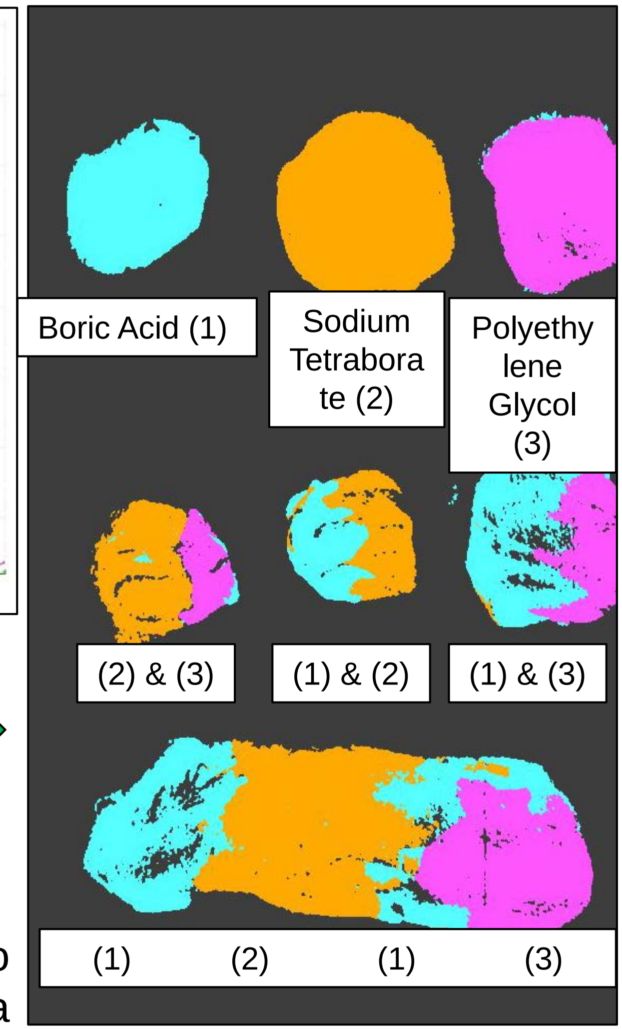
Spectral Data



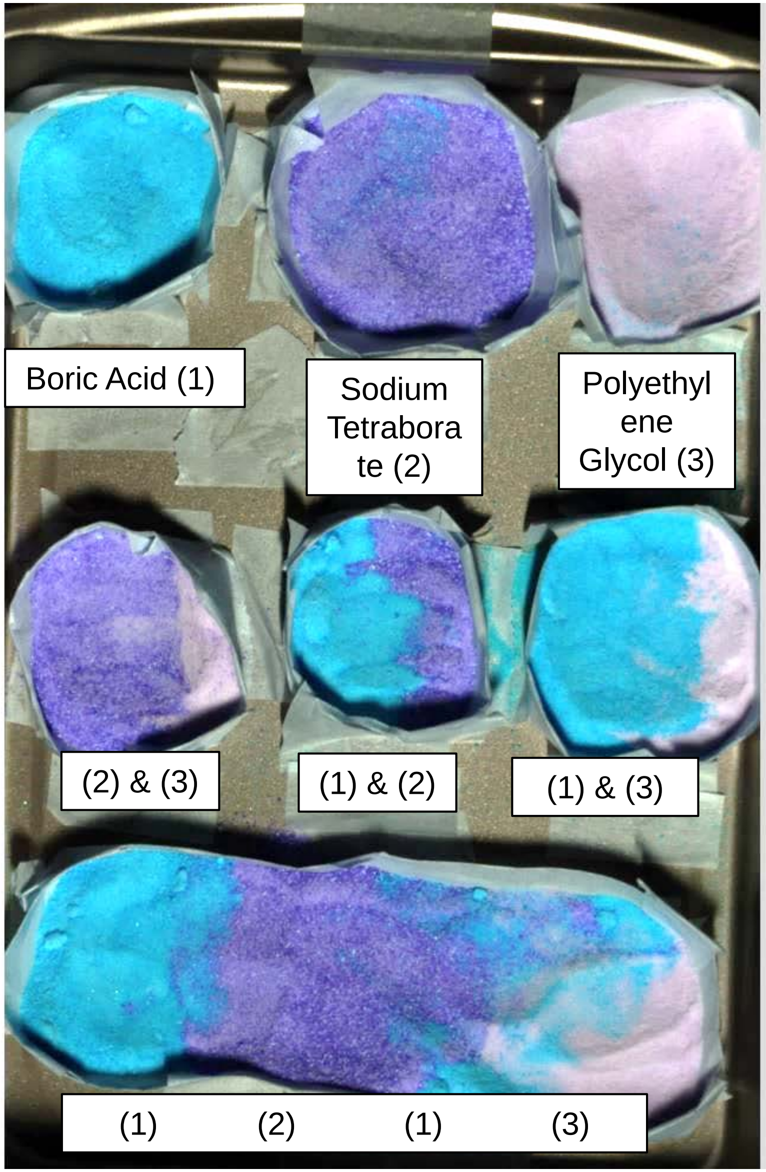
Use spectral data and apply a spectral angle mapping based classifier to image

*Colors assigned to pixels of like spectra

Post Classification



Looking Ahead; Next Steps



Potential Nuclear Applications – Visual Examinations

- RIS 2018-06 – "Clarification of the requirements for reactor pressure vessel upper head bare metal visual examinations"
  - N-729-4 Relevant conditions:
    - Corrosion, boric acid deposits, and discoloration
    - May require additional analysis including UT of partial penetration welds and/or relief request for startup
- Non-RPVUH Boric Acid Corrosion Programs, and Other Applications
  - Spectral imaging could be a supplemental visual examination (VE) to differentiate boric acid from other surface residues/substances
  - Distinguish between reactor water and non-reactor water additives (sodium nitrite)
  - Distinguish between insulation material and boric acid, other

discussion

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Development of Technical Bases for Optimization of Examination Requirements

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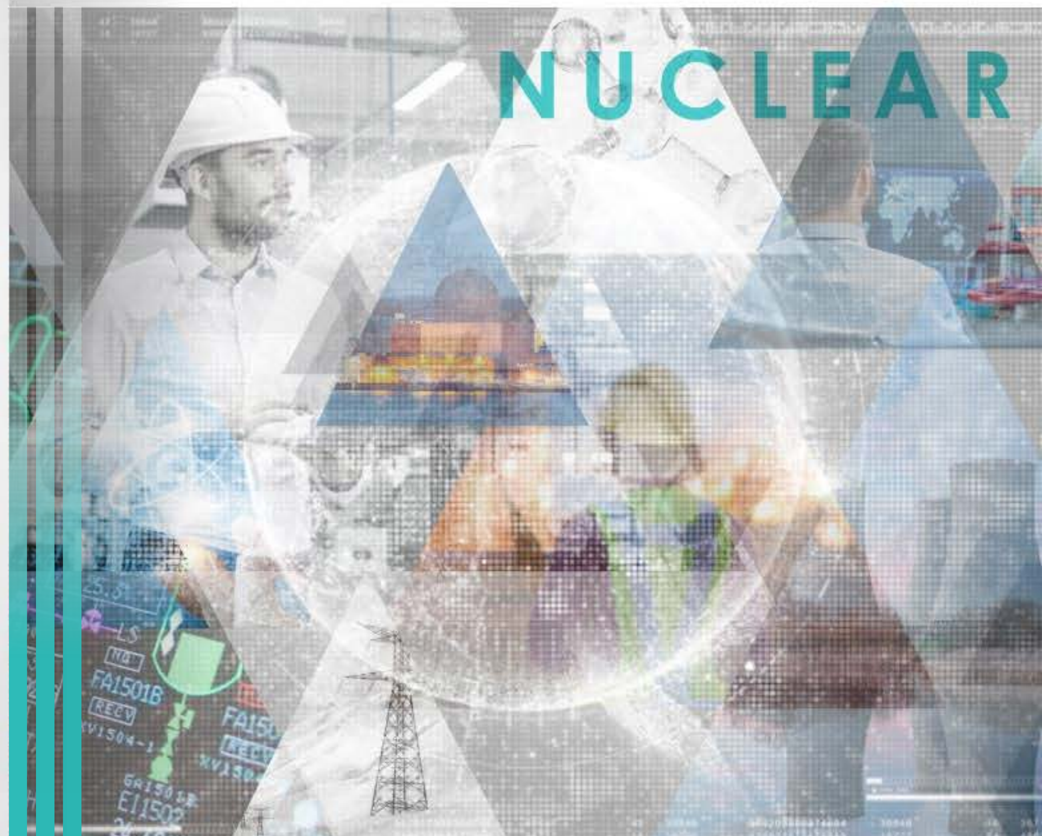

Kevin Hacker
Dominion Energy

Gary Lofthus
Southern Nuclear

Robert Grizzi
EPRI

NRC / Industry
NDE Technical Information Exchange Meeting
Washington, DC
January 2019

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Topics

- Background
- Project Scope
- Project Objective and Approach
- Project Implementation
- Project Status
- Questions / Discussion

Background

- Many examinations are considered to have low value due to the history of few or no relevant indications being identified

- Some of these examinations also have a high outage impact due to personnel safety, radiation dose concerns, outage schedule associated with preparing and performing the examinations (scaffolding, insulation removal, weld surface preparation, insulation reinstallation, and scaffold removal)

- Initiated by the 2016 NDE Work Plan project '*Identification and Assessment of Low-Value Examinations with High Outage Impacts*'
  - Surveyed utility members, ranked and prioritized results

Project Scope

- Conducting research on the top-ranked examinations (2017-2019)
  - **Reactor Vessel Interior Inspections (B-N-1 Exams)**
  - **Class 1 & 2, Pressure Retaining Bolting Greater Than 2" in Diameter**
  - **Class 1 & 2, Non-Reactor Vessel - Nozzle Inner Radius, Nozzle to Shell, and Vessel Weld Examinations (Grouped by Components)**
    - Steam Generator Main Steam and Feedwater Nozzle to Shell and Inner Radius
    - Steam Generator Primary Nozzle to Shell, Inner Radius, and Pressure Vessel Welds
    - BWR Heat Exchanger Nozzle to Shell, Inner Radius, and Pressure Vessel Welds
    - Pressurizer Nozzle to Shell, Inner Radius, and Pressure Vessel Welds

Project Objective and Approach

- Objective
  - Develop technical bases for optimization of selected examination requirements; publish publicly
- Approach
  - Identify applicable components
  - Identify original bases for examinations (if available)
  - Research all applicable degradation mechanisms
  - Compile operating experience, examination data, and results (fleet survey)
  - Compile existing documentation:
    - Previous relief requests and associated NRC safety evaluations reviews
    - Applicable industry guidance documents
    - Redundancy of inspections due to other industry activities (e.g. BWRVIP, MRP)
  - Compile existing Code Cases for target Code items
  - Perform component-specific fracture mechanics (probabilistic and deterministic) and engineering analyses

Project Implementation

- Technical bases must be reviewed by each utility that wishes to apply the results
- Plant-specific applicability of analyses must be determined by the individual utility
  - For example, plant-specific loads and stresses must be assessed against the loads evaluated in the technical basis
- Technical basis is useful for:
  - Support a plant-specific relief request (to be modeled after the relief submitted by the pilot plant)
  - Revise code requirements

Project Status - Reactor Vessel Interior Inspections

- EPRI Report 3002012966 - Evaluation of Basis for Periodic Visual Examination of Accessible Areas of Reactor Vessel Interior per Examination Category B-N-1 of ASME Section XI, Division 1
  - Publicly available; download at www.epri.com
  - Historical evolution of Code Inspection (Cladding vs. Debris)
  - Engineering analysis (corrosion and cracking of low-alloy steel)
  - Technical basis for ASME Code Section XI Action 10-123
    - Unanimously passed SC XI letter ballot; Code Case N-885 to be published in next Supplement
  - Combined Categories B-N-1, B-N-2, and B-N-3 into one B-N category and eliminated Category B-N-1
- A template is being developed for a Pilot Plant Relief Request submittal:
  - Utility commitment for a BWR-5 design
  - Applies technical basis to a plant-specific Relief Request submittal
  - Expected submittal date 1Q 2019

Project Status - Class 1 & 2, Pressure Retaining Bolting Greater Than 2” in Diameter

- Reactor Pressure Vessel (RPV) Studs Technical Basis
  - EPRI Technical Report 3002014589 - Technical Basis for Optimization of the Volumetric Examination Frequency for Reactor Vessel Studs
    - Report and supporting stress/deterministic fracture mechanics analysis underwent independent 3rd party technical review
  - Pilot Plant identified (PWR)
  - Expect submittal in first half of 2019
- Component Studs and Bolting Technical Basis
  - Reactor coolant pumps, recirculation pumps, steam generator manways, piping flanges, etc.
  - EPRI Technical Report publication planned for 06/2019
  - Template Relief Request to follow

Project Status - Class 1 & 2, Pressure Retaining Bolting Greater Than 2" in Diameter

- Summary of RPV Studs Technical Basis:
  - Summary and discussion of all applicable degradation mechanisms:
    - <u>Fatigue</u>
    - Stress Corrosion
    - Boric Acid Corrosion
    - Steam Cutting
  - Discussion of analysis considerations:
    - Identification and assessment of design basis loads and transients
    - Finite element models used for stress evaluation
    - Definition of flaw stability criteria and limits
    - Crack growth analysis of postulated flaw (<u>fatigue)</u>
    - Summary of analysis
  - The time necessary for a postulated flaw to reach the allowable flaw size limit were determined using Section XI, Appendix G methods

Project Status - Class 1 & 2, Nozzle Inner Radius, Nozzle to Shell, and Vessel Weld Examinations

- Develop technical basis for Steam Generator Main Steam and Feedwater Nozzle to Shell and Inner Radius component grouping
  - EPRI Technical Report in final publication (1/30/2019)
  - Pilot plant identified (Westinghouse 4-loop design) for template RR to follow; expected transmittal 2Q or 3Q 2019
- Technical bases to follow:
  - Steam Generator Primary Nozzle(s) to Shell, Inner Radius, and Vessel Weld Technical Basis - EPRI Technical Report planned for 07/2019
  - BWR Heat Exchanger Nozzle to Shell, Inner Radius, and Vessel Weld Technical Basis - EPRI Technical Report planned for 07/2019
  - Pressurizer Nozzle to Shell, Inner Radius, and Vessel Weld Technical Basis - EPRI Technical Report planned for 08/2019
- Template RRs to follow

Project Status - Class 1 & 2, Nozzle Inner Radius, Nozzle to Shell, and Vessel Weld Examinations

- Summary of technical basis report contents:
  - Introduction
  - Review of Previous Related Work
  - Review of Inspection History and Examination Effectiveness
  - Survey of Components and Selection of Representative Components for Analysis
  - Material Properties, Operating Loads and Transients
  - Evaluation of Potential Degradation Mechanisms
  - Component Stress Analysis
  - Probabilistic and Deterministic Fracture Mechanics Evaluation

discussion

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Cast Stainless Steel NDE update

Kevin Hacker
Dominion Energy

Doug Kull
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EPRI

NRC / Industry
NDE Technical Information Exchange Meeting
Washington, DC
January 2019

CASS Strategy

Approaches to Manage Welds with CASS

NDE – Nondestructive Evaluation

- Inspection technologies/methodologies to perform periodic volumetric ISI inspections
  - Traditional Techniques
    - Ultrasonic based
  - Advanced NDE methods/analyses
  - Continuous Structural Health Monitoring

EES – Engineering Evaluation Solutions

- Risk informed inspection practices
- Engineering solution(s)
- Material characterization
- Probabilistic Fracture Mechanics (PFM)

MM – Manage by Mitigation

- Full/Optimized structural weld overlay
- Component replacement
- Excavate Weld Repair (EWR)
- New mitigation technique (s)

Defense in Depth Safety Route

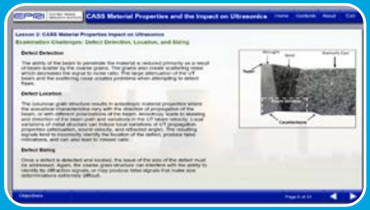
GOAL

Continued safe and reliable operation of nuclear power plants with safety related CASS components

Recently Completed CASS Projects

Single Source Cast Austenitic Stainless Steel Research

Cast Austenitic Stainless Steel Round-Robin Study-Summary of Results, Revision 1



Computer Based Training (CBT) for the Ultrasonic Examination of Cast Austenitic Stainless Steel Welds (UTCASS-CBT), v1.0

Single Source Cast Austenitic Stainless Steel Research

Single Source Cast Austenitic Stainless Steel Research: Summary of EPRI Research and Relevant Sources

Product ID:3002010315

Date Published: 20-Dec-2017

The CASS research material from more than 100 reports is summarized and organized by topic in one convenient location

Report also contains a bibliography of references spanning more than 50 years

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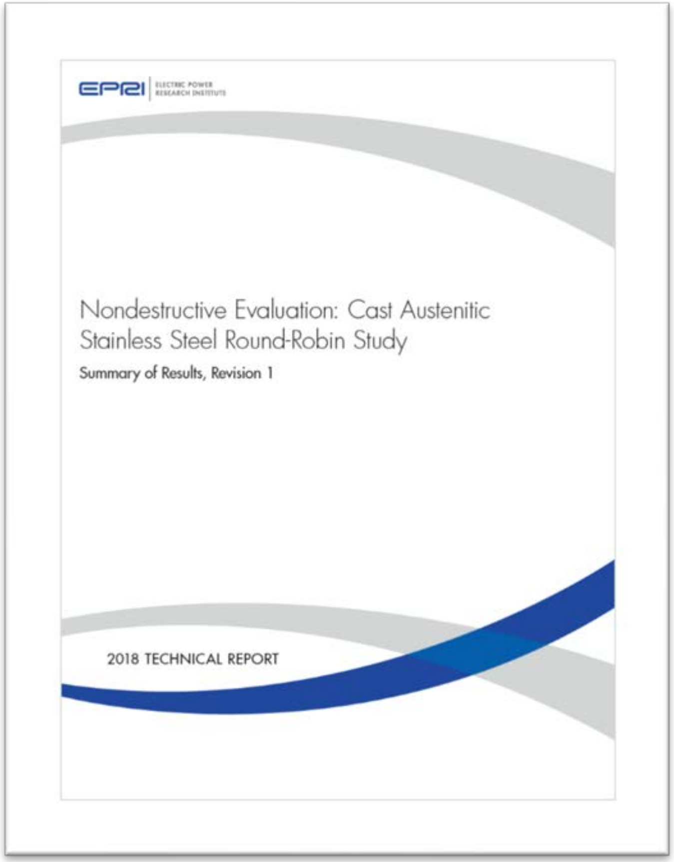
Cast Austenitic Stainless Steel Round-Robin Study-Summary of Results, Revision 1

Nondestructive Evaluation: Cast Austenitic Stainless Steel Round-Robin Study Summary of Results, Revision 1

ID: 3002010314 (publicly available)

Date Published: 25-Apr-2018



The revision was necessary to correct FCP reported in Table 5-1 & 5-2 as well as Figures 5-3 and 5-6.

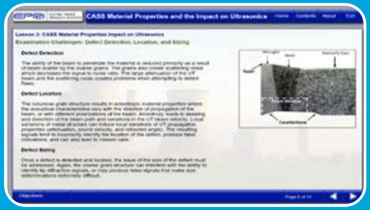
Additional content was also added on a number of topics that included: specimen geometry, flaw depth distributions, development of unflawed grading units and future research opportunities.

(See Report for a complete list of changes)

Current CASS Projects

Technique Enhancements for CASS Examinations

Ultrasonic Characterization and Acoustical Equivalency of CASS



Potential Engineering/Analytical Solutions for CASS

Technique Enhancements for CASS Examinations (1 of 2)

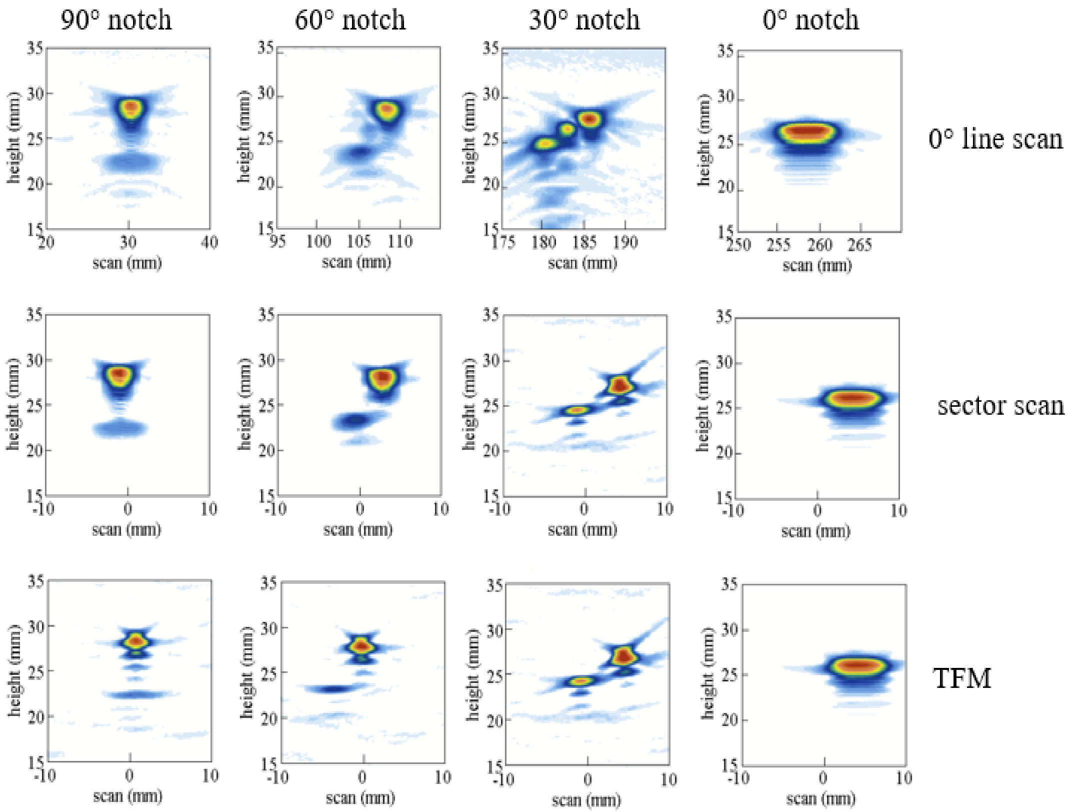
- Based on independent review and analysis of best three (3) data sets from the CASS RR Study the following recommendations for further work were made:
  - **UT Probe** size shall be optimized to minimize sound path and maximize weld coverage due to weld crown limitations. The size of the probe shall be optimized to ensure a natural focus (near field) of the 50-degree focal law at inside surface.
  - **Scanning** shall be performed in raster pattern and it is necessary to extend scan distance away from weld to allow the counter bore examined with higher beam angles. If possible scanning over weld is recommended to hit the weld root with low beam angles (shorter sound path) and to see upper tips of very deep flaws.
  - **Focusing** - all angles shall be focused at ID for detection/length scan. Focusing for depth sizing scan shall be determined based on qualitative measurements taken from the detection scan data.

Technique Enhancements for CASS Examinations (1 of 2)

- Based on independent review and analysis of best three (3) data sets from the CASS RR Study the following recommendations for further work were made:
  - **Refracted and skew angles** - electronic skew steering of sound beam -15,0,+15 degrees shall be performed to minimize ID geometric surface responses. Electronic steering of refracted angles: 30, 35, 40, 45, 50, 55, 60, 65, 70 degrees.
  - **Wedges** shall be constructed to produce natural refracted angle of approximately 45 to 50 degrees in CASS material.
  - **Depth calibration** must be as precise as possible.
    - Utilizing side drilled holes placed in a custom block
    - Depth calibrations shall be performed
    - Dynamic scans shall be utilized
    - Delays shall be adjusted based on the qualitative measurements taken from the detection data
  - **Advanced techniques** - Evaluate the use of Full Matrix Capture (FMC), Total Focusing Method (TFM) and Synthetic Aperture Focusing Technique (SAFT) with Phased Array (PA) search units.

Technique Enhancements for CASS Examinations
Next Steps

- Evaluation of beam interaction in the CASS material
  - Changes to refracted angle?
  - Changes to focal spot?
  - How much attenuation compared to traditional wrought materials?
- Compare reactions of various probes in beam interaction studies
  - Can improvements be made?
  - Is there basis for running multiple frequencies?
  - Advanced techniques / TFM – FMC – High Voltage UT is there a role?



- After evaluations are complete reapply the techniques on the entire sample set to determine if the performance is enhanced

Technique Enhancements for CASS Examinations
Specimen Enhancements

- Weld crown removal
  - Determine if improvement can be realized if the weld crowns are removed
    - It is understood that this may not be practical for some field conditions but will be evaluated to determine the impact of weld crowns

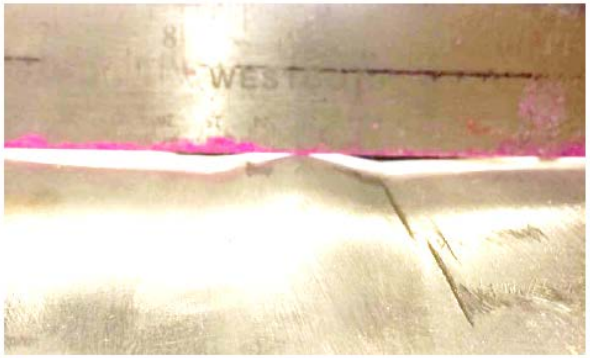


Figure 2-8
As-Found Weld Crown on 12-in. Specimen

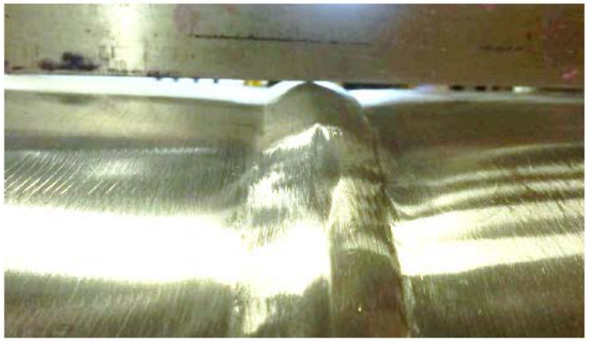


Figure 2-9
Manufactured Weld Crown on 28-in. Specimen

Technique Enhancements for CASS Examinations
Destructive Testing – Specimens / Flaws

- Destructive testing will be considered
  - Some specimens may be destructively tested based on results after all other technique and specimen enhancements have been applied
- Input from NRC/PNNL is considered in the selection of the flaws

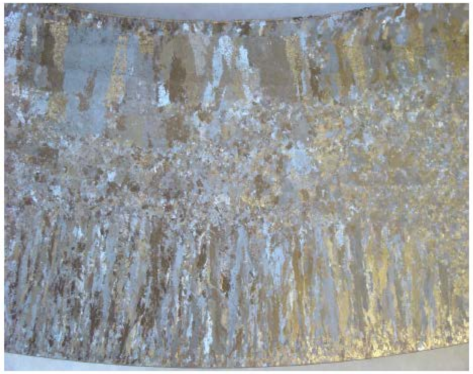
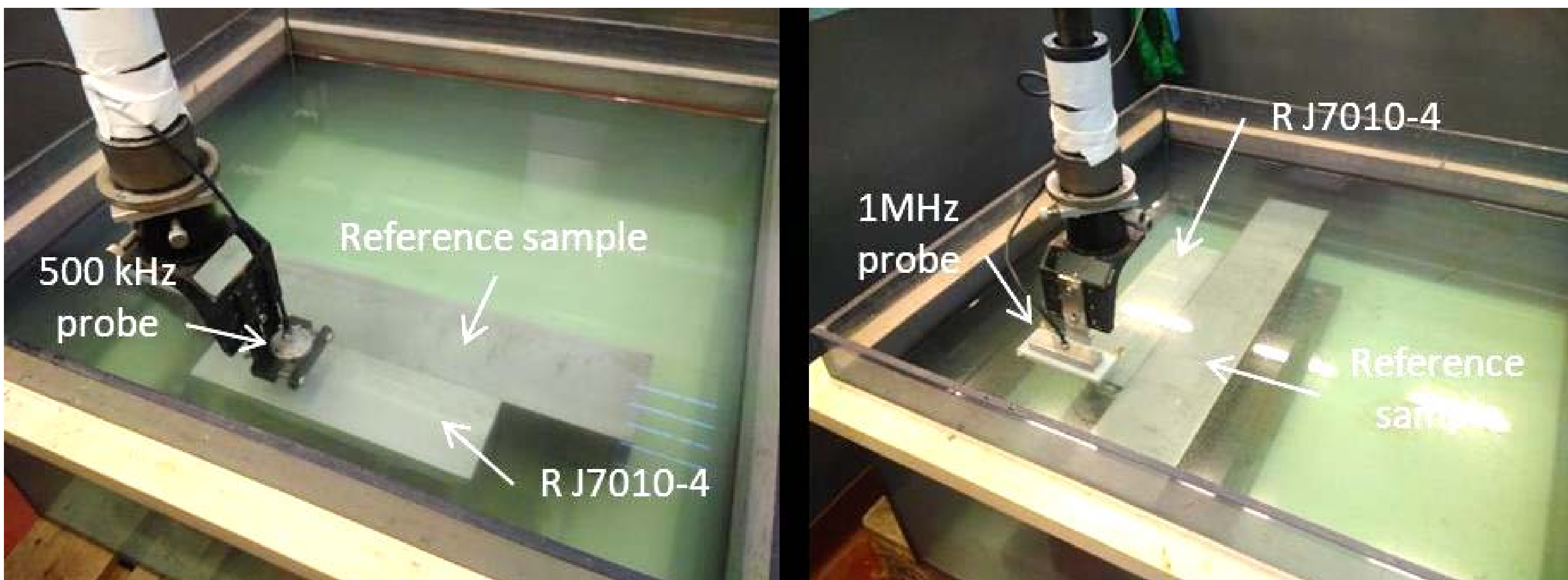


Figure 2-6
Microstructure from Downstream Side of 28-in. Specimen Material (vintage material from pipe manufacturer)

Figure 2-7
Microstructure from 36-in. Specimen Material (vintage material from canceled plant)

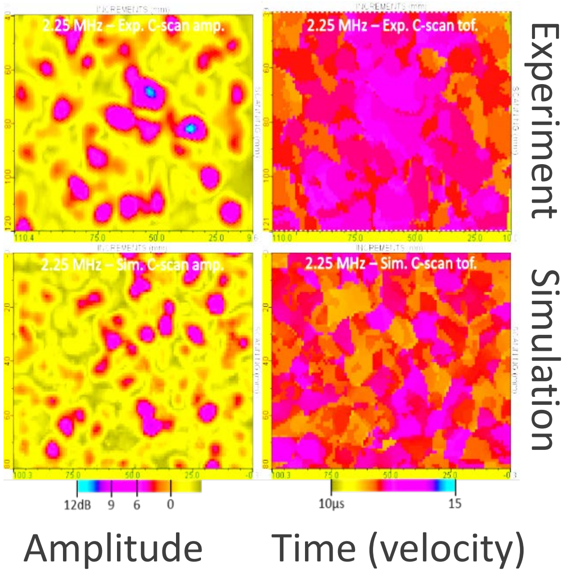
Ultrasonic Characterization and Acoustical Equivalency of CASS

- Project - Ultrasonic Characterization and Acoustical Equivalency of CASS for improved UT Inspection
- The purpose of this research is to develop a proposed workflow and set of recommended practices to use when modeling coarse grain components such as CASS



Ultrasonic Characterization and Acoustical Equivalency of CASS

- Studies used the commercially available software CIVA.
- Quantitative comparisons are made between experimental and simulation results on a CASS specimen with known defects.
  - Simulations were a good qualitative and quantitative match to experiment, using four comparison metrics:
    - Mean amplitude
    - Amplitude standard deviation
    - Mean homogenized velocity
    - Homogenized velocity standard deviation
    - SNR was not used, but it was concluded that it would be a useful metric in further research
  - Several limitations were noted, chief among them:
    - Actual grain distribution in the mockup is unknown
    - Compromises made in designing the modeling approach
- Development and setup guidance for CIVA coarse grain models, with detailed descriptions of primary modeling inputs.



Ultrasonic Modeling and Simulation of Cast Austenitic Stainless Steel

November 2018
(3002013160)

Publicly available

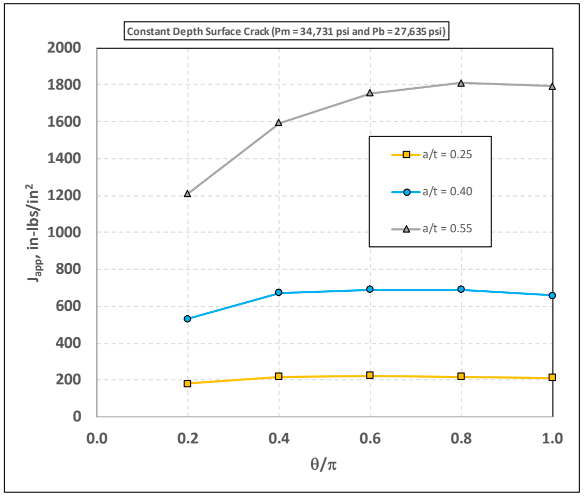
ELECTRIC POWER RESEARCH INSTITUTE

Potential Engineering/Analytical Solutions for CASS
Analytical Issue #1:

- Do We Need to Examine for Axially Oriented Flaws?
- **Proposal: No, inspect only for circumferential flaws**
- **Basis**: Circumferentially oriented flaws are the safety significant flaws
  - Circumferential flaws can lead to potential guillotine break
    - Axially oriented flaws can *potentially* lead to leaks
  - Allowable axial flaw lengths are generally long, so they would grow through wall and leak before failure (leak-before-break)
  - Axial flaw growth is limited (across the width of the weld material)
  - Operational experience
- **Proposed Engineering Solution**: Use probabilistic fracture mechanics (PFM) and risk-informed analysis methodologies to determine if inspection ONLY for circumferentially oriented flaws provides reasonable and adequate assurance of piping integrity

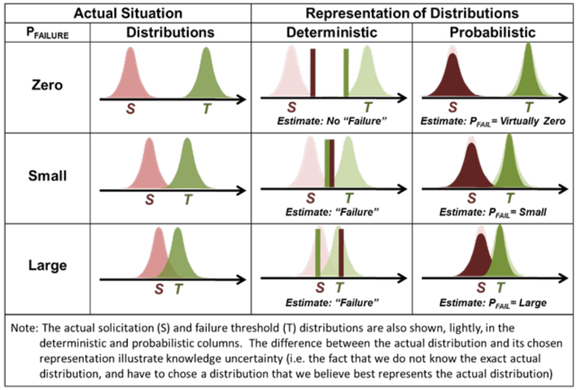
Potential Engineering/Analytical Solutions for CASS
Analytical Issue #2:

- **Can We Assume a Flaw Depth from Measured Crack Length in the Absence of Flaw Depth Sizing?**
- **Proposal: Yes, evaluate for bounding or typical flaw aspect ratio**
- **Basis**: Use the length of a detected flaw to estimate the through-wall extent and/or determine flaw impact on service life
  - Make use of flaw characteristics that can be measured
  - Operational experience; limited studies on fabrication flaw sizes
  - Bounding analytical assumptions; distinguish between leakage crack sizes vs. rupture flaw sizes
- **Proposed Engineering Solution**: Explore deterministic fatigue crack growth calculations paired with variable plant loads to determine whether structural integrity of the component against unstable rupture and/or a LOCA is maintained using flaw length inputs and reasonable assumptions on flaw aspect ratio
  - This could support addressing flaw depth analytically in the absence of a qualified NDE depth sizing technique



Potential Engineering/Analytical Solutions for CASS Analytical Issue #3:

- **Proposal: Optimize the examination based on current limitations and realistic expectations**
- **Basis**: Utilize analytical evaluation to justify a smaller sample and augment the NDE examination requirements for those welds
  - Material characteristics/fracture toughness properties of CASS
  - PFM (e.g., xLPR) principles
  - Develop models to evaluate material aging effects
- **Proposed Engineering Solution**: Investigate a risk-informed technical basis developed using PFM to support optimized CASS weldment examinations as follows:
  - Perform NDE on a sampled basis (reduced frequency and/or sample size)
  - Perform targeted inspections of risk-significant components
  - Relax the UT qualification requirements in areas where there is negligible impact on plant risk; complement this with conservatism in Section XI flaw evaluation procedures where necessary



*NRC PFM Public meeting Graphic 12/12/2017

discussion

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Draft 10CFR50.55a Condition on Code Case N-770 Related to Cast Austenitic Stainless Steel

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Dominion Energy

Doug Kull
Carl Latiolais
EPRI

NRC / Industry
NDE Technical Information Exchange Meeting
Washington, DC
January 2019

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2018 Draft Rule Condition for Alloy 600 DM Welds Involving CASS

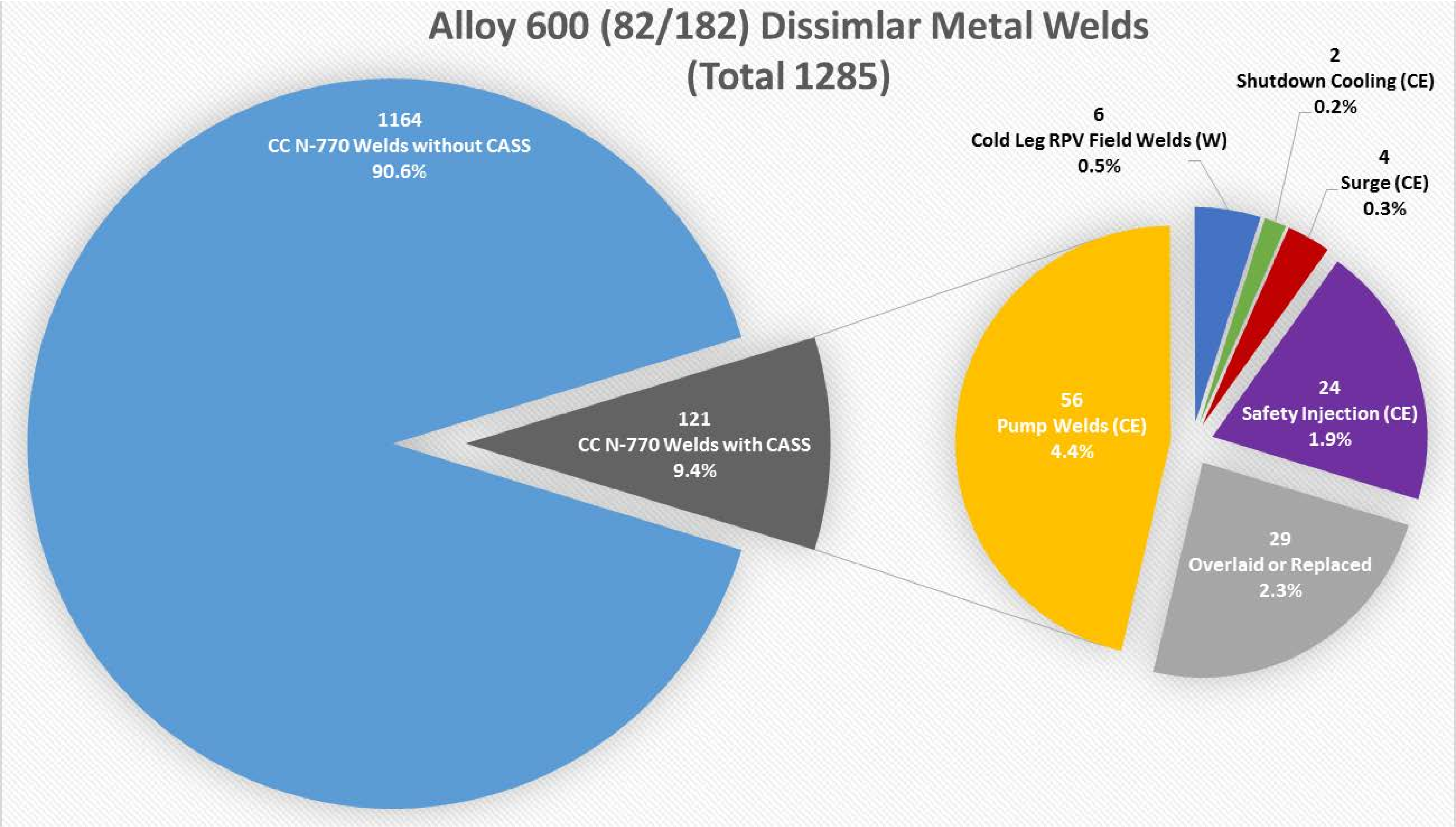
- At an NRC public meeting on April 17, 2018 the NRC, EPRI and Industry representatives discussed
  - The estimated number of welds that would be covered by the proposed condition
  - The current qualification program, including the dissimilar metal weld samples fabricated using cast material
  - The additional estimated coverage that would be obtained by having a cast qualification
- Based on the information presented, the Industry concluded that UT examinations of DM welds involving CASS materials satisfies the NRC condition imposed by the 2017 Final Rule for Alloy 600 DM Welds Involving CASS

2018 Draft Rule Condition for Alloy 600 DM Welds Involving CASS

- Draft Rule 10CFR50.55a Dated: 09 November 2018*
  - *50.55a(g)(6)(ii)(F)(11) - Cast stainless steel. Examination of ASME BPV Code Class 1 piping and vessel nozzle butt welds involving cast stainless steel materials, will be performed with Appendix VIII, Supplement 9 qualifications, or qualifications similar to Appendix VIII, Supplement 2 or 10 using cast stainless steel mockups no later than the next scheduled weld examination after January 1, 2022, in accordance with the requirements of Paragraph –2500(a) or, as an alternative, using inspections that meet the requirements of ASME Code Case N–824 as conditioned in Regulatory Guide 1.147.*
- As written this condition will force licensees spend time and dose to examine components with 2 separate procedures and techniques for minimal increases in acquirable coverage (as little as a fraction of 1%)

*Text in RED denotes the additional provisions added in the last draft of 10CFR50.55a

Existing Alloy 600 (82/182) DMWs Involving CASS Material for the US PWR Fleet

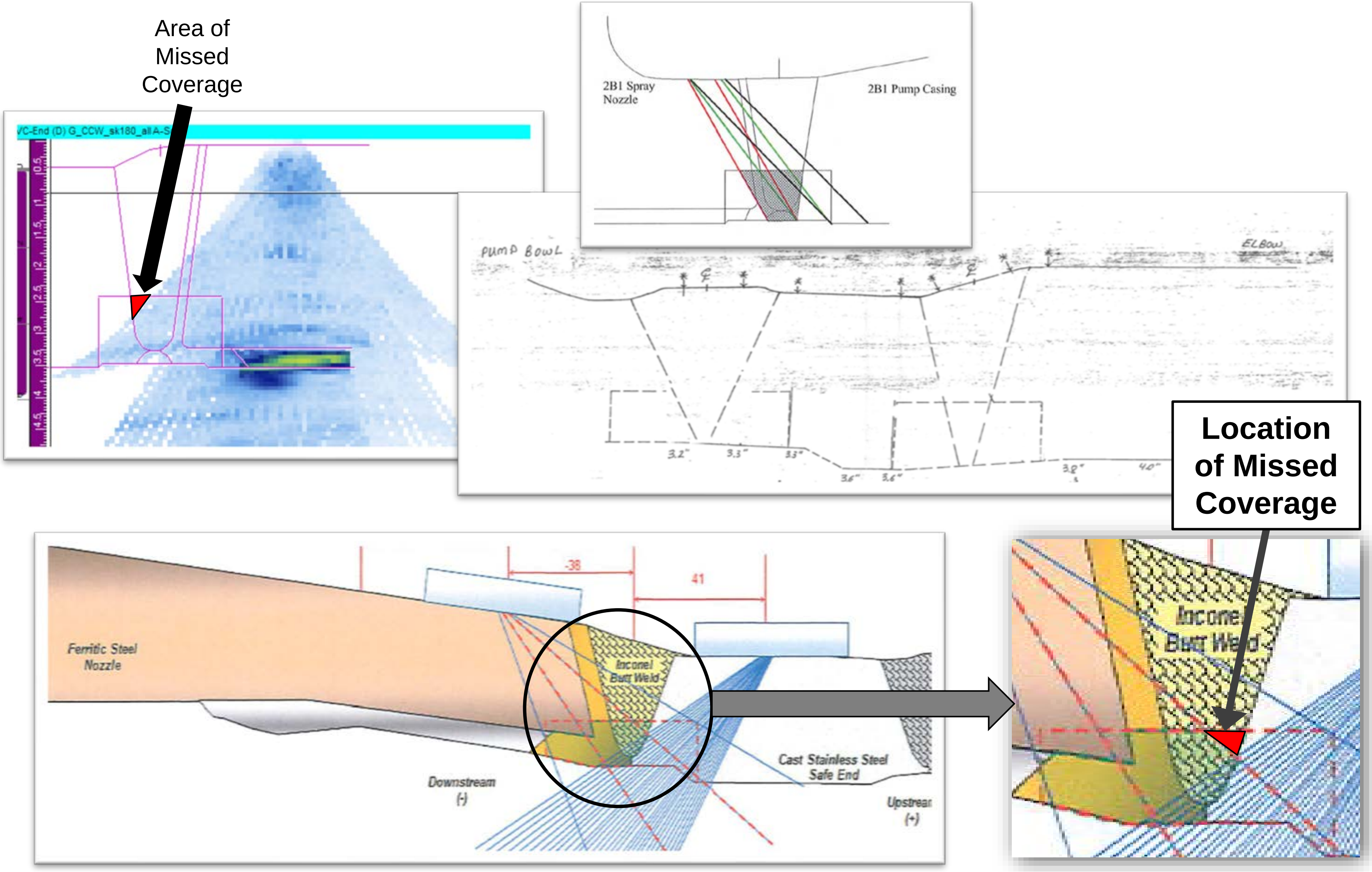


Summary of Missed Coverage

Component	Welds in the fleet	Avg. Circ. Flaw Coverage	Welds with <100% Circ. Flaw Coverage	Average Ax Flaw Coverage	Welds with <100% Axial Flaw Coverage
CE RCP	56	97.5%	21	99.8%	8
CE SI	24	99.8%	1	99.6	3
CE Surge	4	100%	0	100%	0
CE SDC	2	100%	0	100%	0
W RPV Cold Leg	6	100%	0	100%	0

- Missed coverage most often due to obstructions (e.g. long seams and nozzle penetrations)
- In the case of RCP welds, examinations from CASS side will not provide additional coverage of susceptible material due to scan access (i.e. short safe-ends)

Examples of Limited CC N-770 Examinations



Summary

- Alloy 600 DMWs involving CASS material is limited to a small number of welds (92) for the PWR fleet
  - Excluding the CE RCP welds and RPV Cold Leg Welds examined from the inside surface, there are 17 unmitigated Alloy 600 DMWs involving CASS material
- Procedures used to examine these Alloy 600 welds involving CASS material have been demonstrated in accordance with Appendix VIII, Supplement 10 with mockups containing CASS material
- Additional coverage of susceptible material would be minimal with UT technique from the CASS material side of the welds and would provide no significant increase in safety, but would increase the time and dose required to perform these examinations
- It is recommended that the NRC consider removing the conditions included in the proposed rule for Alloy 600 welds involving CASS material

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Encoded UT without Robotics

Thomas Stafford
EPRI

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NRC / Industry NDE Technical Information
Exchange Meeting
Washington, DC
January, 2019

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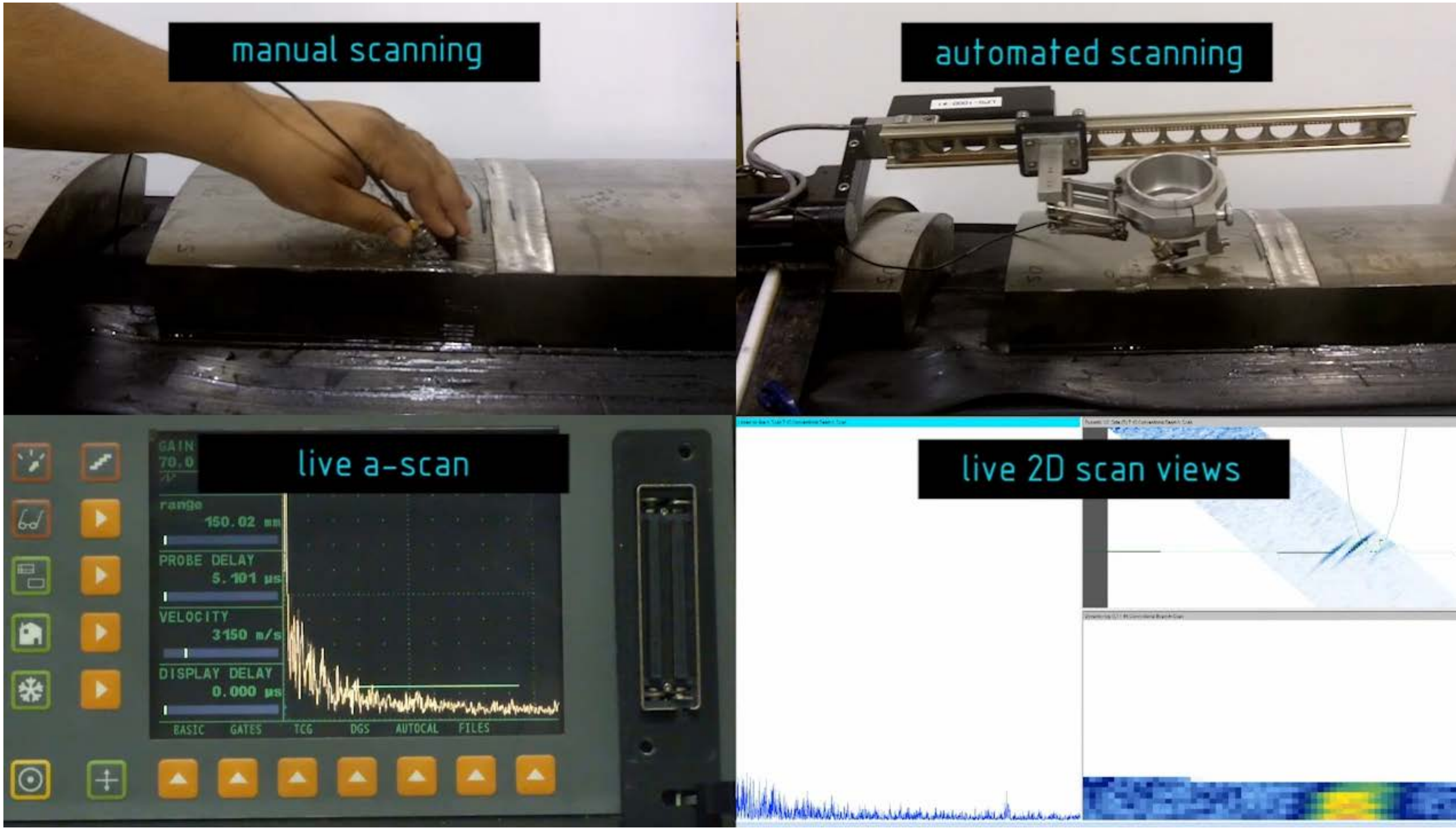
Agenda

- Background
  - Current examination types
- Research Scope
  - Improve reliability
- Solution
  - Motion Sensor Unit (MSU)
- Status and Future work
  - Qualification (Industry Acceptance)
  - Technology transfer
- Other Technologies
- Q&A

Background - Examination Types

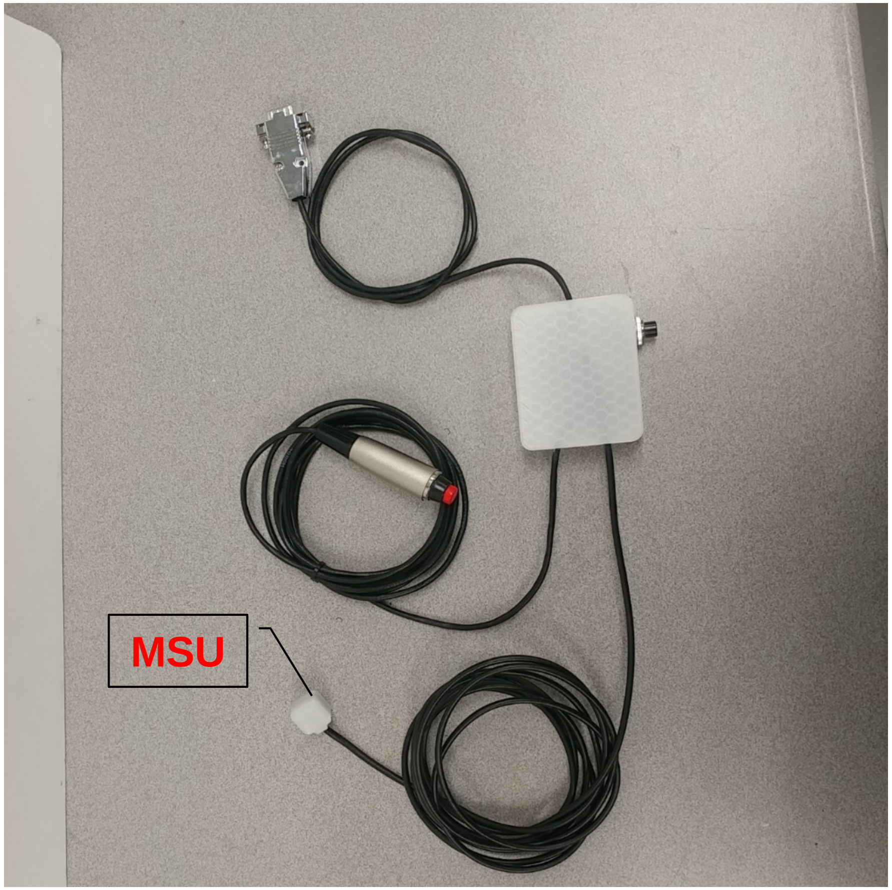


Research Objective

- Develop ultrasonic examination technologies that would provide the benefits of encoded examinations, while maintaining the efficiencies of manual examinations.
  - Easy to use
  - Improved reliability
  - Reviewable permanent data

Motion Sensor Units

- Motion Sensor Units (MSUs)
  - Low cost
  - Applicable to any cylindrical or spherical geometry
  - Works with existing instruments which have encoder I/O
  - Minimal encoder calibration required
  - Supports line scan techniques
    - Scanning guides are recommended for multiple scan lines
  - Evaluating accuracy but anticipating an average 2° error in circ position (linear surface distance error increases with pipe diameter)



Simple Mechanical Setup

Motion Sensor In Action

MSU Accuracy

Flaw Length Sizing Results

	Circ Flaw Truth Information								
Flaw ID	US/DS	Center°	Length°	Start°	End°	OD Start (in)	OD End (in)	OD Length (in)	ID Length (in)
Flaw A	DS	327.2	14.01	320.19	334.21	35.63	37.19	1.56	1.391
Flaw B	US	80.9	31.81	65.00	96.80	7.23	10.77	3.54	3.157
Flaw C	DS	207	51.51	181.24	232.76	20.17	25.90	5.73	5.113
Flaw D	US	290	15.06	282.47	297.53	31.43	33.10	1.68	1.495

	PAUT with MSU Near Side Results From Looking Downstream and Upstream Scans – Circ Flaws						
Flaw ID	US/DS	UT Start°	UT End°	UT Length°	Length Diff°	OD Length Error (in)	OD Length Error (mm)
Flaw A	DS	321.50	337.60	16.10	2.09	0.23	5.8
Flaw B	US	63.91	96.11	32.20	0.39	0.04	1.0
Flaw C	DS	181.50	231.20	49.70	-1.81	-0.20	-5.1
Flaw D	US	281.71	297.81	16.10	1.04	0.12	3.0

Length sizing results using the data acquired during the scan shown on the previous slide – average absolute length error = 0.15 inch

MSU Limitations

- Only applicable to spherical or cylindrical components which are in a horizontal orientation.
- Typically produces 1–2° error in circumferential position; however, larger errors may be observed depending on the scan surface and roundness of the component.
- During a line scan, it is important for the ultrasonic technician to maintain a constant axial distance from the weld centerline.
- Software changes are needed to prevent the user from inadvertently overwriting existing data when using the index clicker button.

MSU Deliverables and Future Work

- Deliverables
  - *2017 Report: "Alternatives to Automated Scanners for Ultrasonic Data Collection: Summary of Recent Results"* (3002010405)
  - *2018 Report: "Motion Sensor Units for Ultrasonic Data Collection: Summary of Recent Results"* (3002013239)
- Future Work:
  - Qualification
    - Piping Qualification (ongoing)
      - Goal is to make the procedure generic with respect to the encoding technology.
    - Field deployment and trial use
  - Technology Transfer
    - Specifications for equipment needed to manufacture MSU encoder

Other Technologies

- Structural Integrity
  - LATITUDE
  - Transmitter attached to the ultrasonic probe.
  - Receiver collar mounted on the pipe.
  - Zetec TOPAZ and Zircon instruments
  - Two axis encoder tracking with probe skew tracking capabilities
  - Qualified for dissimilar metal weld ultrasonic examinations

further information available at http://si-latitude.com/

- IHI Corporation
  - ARMUT
  - Uses a thin sheet with printed positional information which is read by a camera attached to the ultrasonic probe.
  - ARMUT 64/64 PR instrument
  - Two axis encoder tracking with probe skew tracking capabilities
  - Qualified for dissimilar metal weld ultrasonic examinations

further information available at https://www.ihi.co.jp/var/ezwebin_site/storage/original/application/ca355113a615e6a94bc70be9e4dc1b3b.pdf

Questions & Answers

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Aging Management of Concrete Structures

Kevin Hacker
Dominion Energy

Sam Johnson
EPRI

NRC / Industry
NDE Technical Information Exchange Meeting
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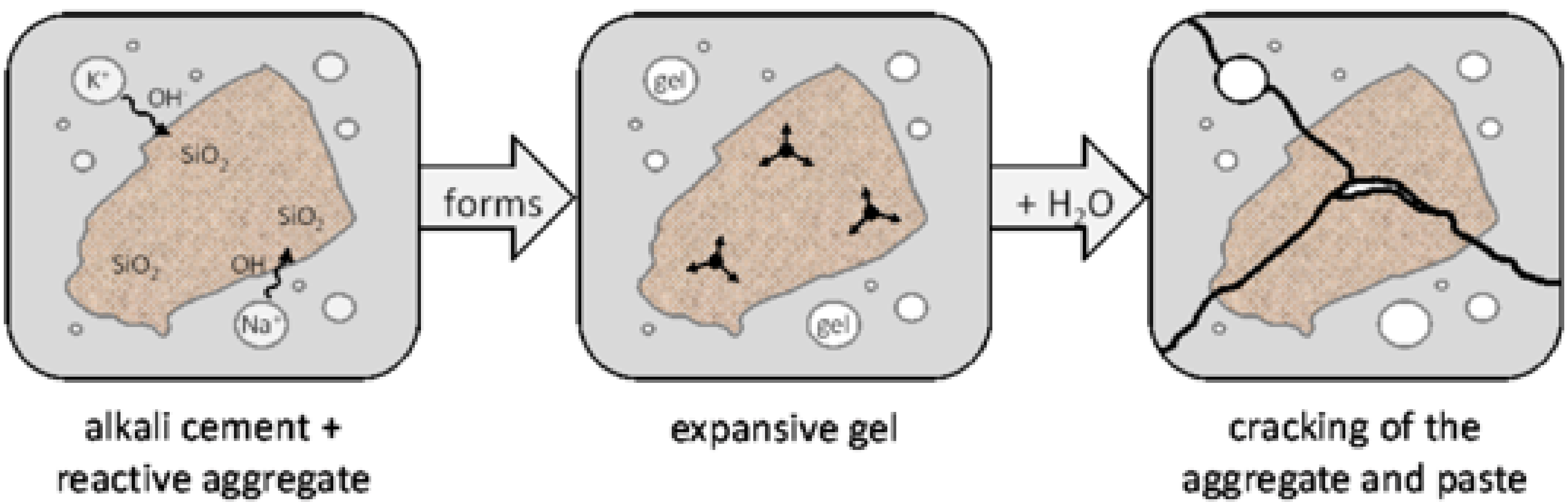
Research on Alkali Silica Reaction (ASR)

ASR Overview

- ASR occurs in concrete when reactive silica in the aggregate react with hydroxyl ions (OH^-) and alkali ions (Na^+, K^+)
- The reaction produces a gel that expands as it absorbs moisture.
- The expansion exerts tensile forces on the concrete, which can result in cracking.



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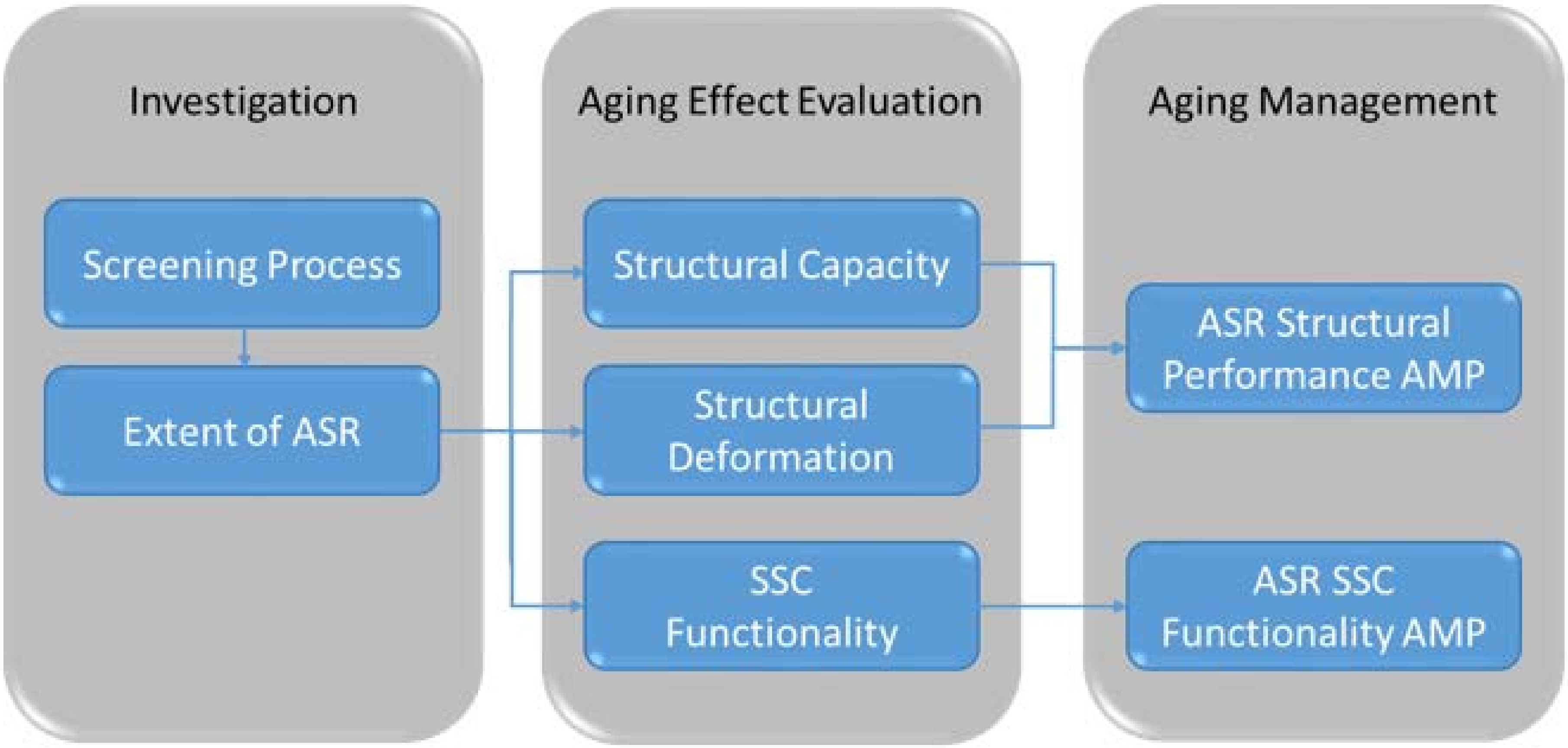
Overview of ASR Evaluation



EPRI Technical Reports on ASR

Deliverable #	Title
3002005389	Tools for Early Detection of ASR in Concrete Structures
3002007806	Concrete NDE for Damage due to pattern Cracking
3002010091	Long Term Operations: Literature Review of Structural Implications of Alkali Silica Reaction
3002010093	Long Term Operations: Aging Management of Concrete Structures Affected by Alkali Silica Reaction
3002010300	Mitigation and Repair of Concrete Structures Affected by Alkali Silica Reaction
3002013192	Evaluation of laboratory Tests to Detect Up-to-Date Expansion and Remaining Expansion in Concrete Structures Affected by Alkali Silica Reaction
3002013190	Modeling Concrete Structures Affected by Alkali Silica Reaction: Hydro-Quebec Approach for Hydraulic and Nuclear Power Plants

Computer Based Training for ASR

- **3002013106 - Module 1: Overview of ASR**
  - Short video explaining what ASR is and why the industry should care about it
- **3002013107 - Module 2: Detection and Confirmation of ASR**
  - Computer Based Training Module to provide knowledge and check for understanding
- **3002013108 - Module 3: Evaluating and Managing Impacts**
  - Computer Based Training Module to provide knowledge and check for understanding
- **3002013109 - Module 4: Developing and Aging Management Program for ASR**
  - In person workshop (March 19th 2019 – EPRI Charlotte Offices)

Course Details

Course Details | About EPRI | Acknowledgements | Disclaimer

Course Details

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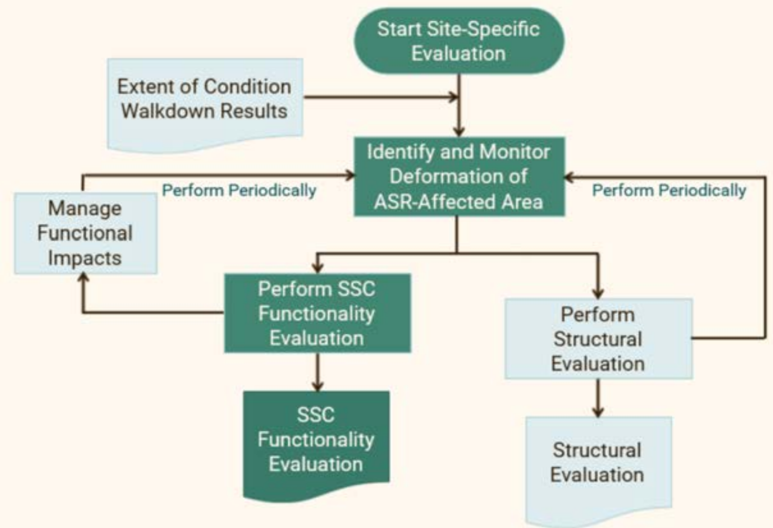
Alkali Silica Reaction Training Module 3 - Evaluating and Managing Impacts of ASR

EPRI Product ID # 3002013108

Perform SSC Functionality Evaluation



Select visual symptoms of unusual offset or evidence of structural/ component movement.

Drag the correct choices to the clipboard, then click Submit to check your answers.

- ✓ Displacement or warping of doorways
- ✓ Offset rod hangers
- ✓ Misaligned pipe flanges, gates, or expansion joints
- ✓ Water ingress through construction joints
- ✓ Crimped tubing

Symptoms

SUBMIT

Select visual symptoms of unusual offset or evidence of structural/ component movement.

Drag the correct choices to the clipboard, then click Submit to check your answers.

Symptoms

- ✓ Displacement or warping of doorways
- ✓ Offset rod hangers
- ✓ Misaligned pipe flanges, gates, or expansion joints
- ✓ Crimped tubing

- ✓ Water ingress through

Correct

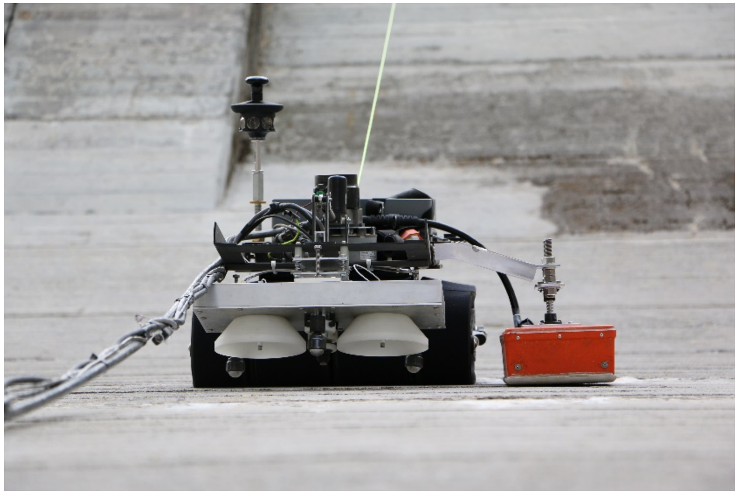
That's right! These symptoms could all be caused by deformation of the concrete structure the components are attached to.

Continue

Deployment Technologies for Concrete NDE

Concrete Crawler

- Uses vacuum suction to navigate vertical surfaces.
- Large payload to carry and deploy concrete NDE techniques.
- Research included proof of concept and various field trials.
- Technical Report 3002003030
- International Utility has looked at using the technology for cooling tower inspections.



Underwater ROVs

- Used for remote visual inspection and mapping
- Payloads available include camera systems, lidar, acoustic sensors, etc.
- Research included landscape study of commercial available products.
- Technical Report 3002006799
- Future Research will look into visual acuity and acceptance criteria for underwater inspections.

Unmanned Aerial Vehicles

- Currently being used in the industry for visual inspections to reduce risk to personnel.

- Payloads can include IR cameras, hyperspectral cameras, and radiation sensors

- Currently conducting research on how UAVs can be used in the nuclear industry

- Technical Report 3002013193

- Future Research will look into deploying other NDE methods (UT, GPR, etc.)

discussion

Together…Shaping the Future of Electricity

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Use of Unmanned Aerial Vehicles (UAVs) for NDE

Kevin Hacker
Dominion Energy

John Lindberg
Tony Cinson
EPRI

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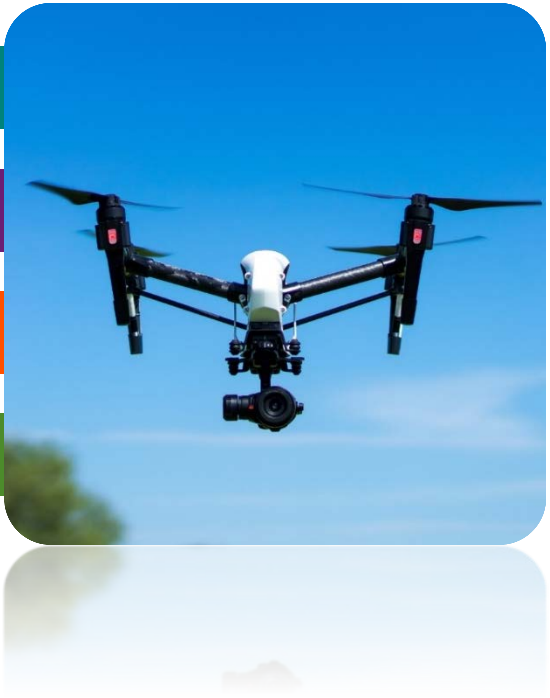
Topics

- Introduction/Overview of EPRI's leadership in UAV arena
  - Motivation, multi-sector approach
- Ongoing nuclear related research for remote visual inspection development and applications
  - Visual inspection of containment structures
  - Visual acuity testing
  - Plant incident response, spent fuel storage monitoring
  - Remote vibrational imaging/UAV integration

UAS: Strategic Objective

Autonomous & Intelligent Infrastructure/Component Inspection/Monitoring with UAS

Safe	Embrace Safety-First Principles
Reliable	Perform More Efficient & Thorough Inspections
Affordable	Optimize Manpower
Valuable	Enhanced Monitoring



UAS = Unmanned aerial systems

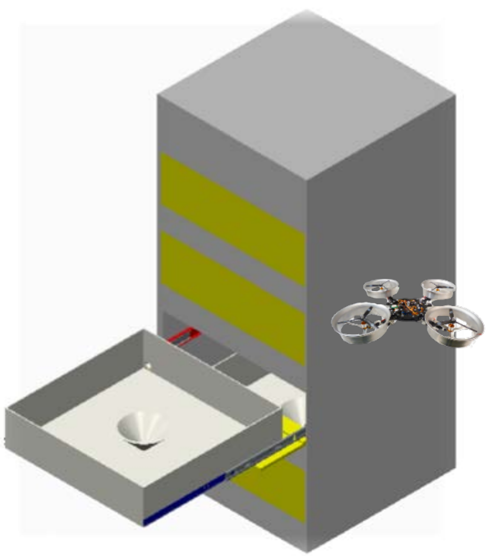
Cross-Sector Technology Innovation Research - UAS

- Leveraging foundational research across EPRI sectors:
  - UAS Automation Technologies (Nuclear - Plant Support, Plant Engineering)
  - Image Processing Technologies (Transmission & Distribution)
  - Confined Space & Indoor Navigation of UAS (Generation)
  - Advanced UAS Payloads (Groundwater and Land Management)

- Nuclear sector is focused on future automation applications of UAVs along with image and data processing; to lead the energy industry in reliable & effective use of UAV technology to reduce O&M costs, improve safety, optimize inspection approaches, and make better informed decisions.

Severe Accident Mobile Investigator (SAMI)

- This project creates a redundant drone system that can maneuver within indoor plant environments during normal and accident scenarios, provide real-time environmental data for parameters (e.g., temperature, pressure, humidity, radiation level), and transmit the data to a data transfer location for assessment and decision making purposes.
- Eliminates placing personnel into an environment with unknown safety & radiation risks.



Remote Visual Inspection Technologies and Image Analysis for Concrete Containment Structures

- **Project Description:**
  - **Technology Investigation**
    - Different UAV technologies were investigated for usefulness in performing remote visual inspections of containment structures to satisfy ASME Section XI IWL.
    - Performance of Visual acuity testing with different camera systems
    - Image Analysis technologies will also be investigated.
  - **Blind Demonstration**
    - Promising technologies were tested and demonstrated for adequacy of detecting concrete defects and the potential for sizing defects.
  - **Research Outlook**
    - Lessons learned from the research and demonstrations will help focus future research on which parameters need to be improved for future use of the technologies.
    - EPRI Report - December 2018 – #3002013193, *"Remote Visual Technologies for IWL Inspections"*

Contact:
Sam Johnson
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Containment Building Inspection

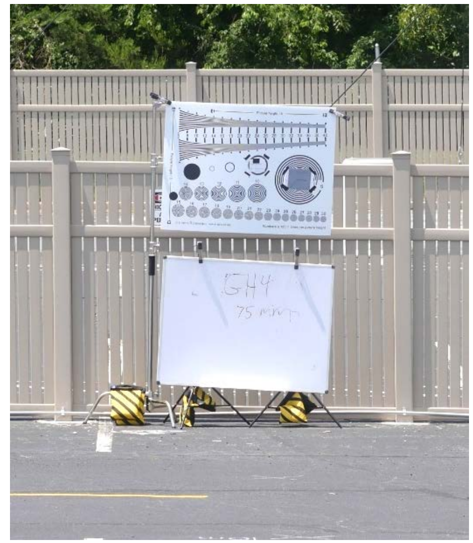
UAV video of containment structure

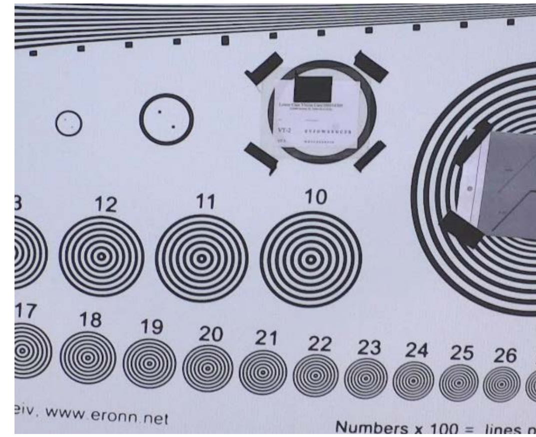
Thermographic Examination

3-D Structural

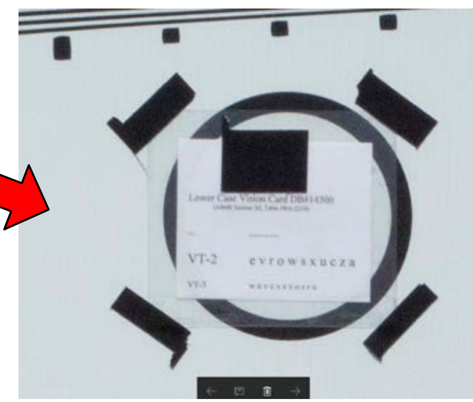
Mapping and Photogrammetry

Remote Visual Acuity Testing





ASME Visual Testing
Acuity Card



Upcoming UAS Radiation Applications

Radiation Detection Monitoring – Spent Fuel Storage

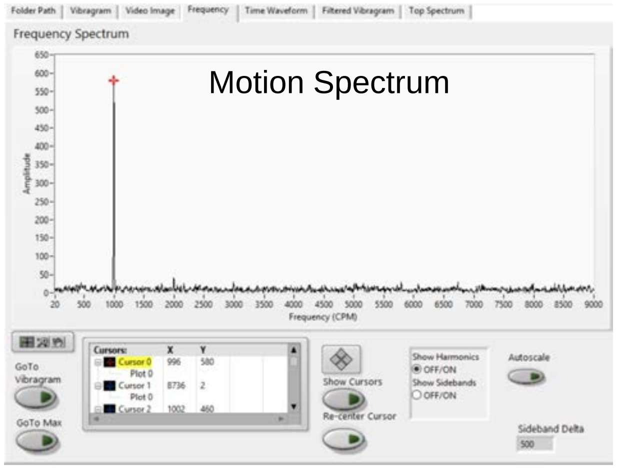
- Survey radiation zone; optimize costs, reduce personnel risk
- Assist with required daily spent fuel walk-downs to ensure cooling vents are not damaged or blocked.

Decommissioning Support (2019 start)

- UAVs may be used to deploy radiation detection equipment to difficult-to-reach/inaccessible areas
- UAV swarm/team technology may be a potential solution

Featured Technology: 3D Vibrational Imaging

- OptiVibe technology is a picture comparator at the pixel level!
- Every pixel of the image is analyzed for motion information
- Motion spectrum produced for every pixel
- Auto analysis & manual
- Vibragram image produced with false coloring to indicate detected vibrations
- Pixel selection tool to navigate vibragram

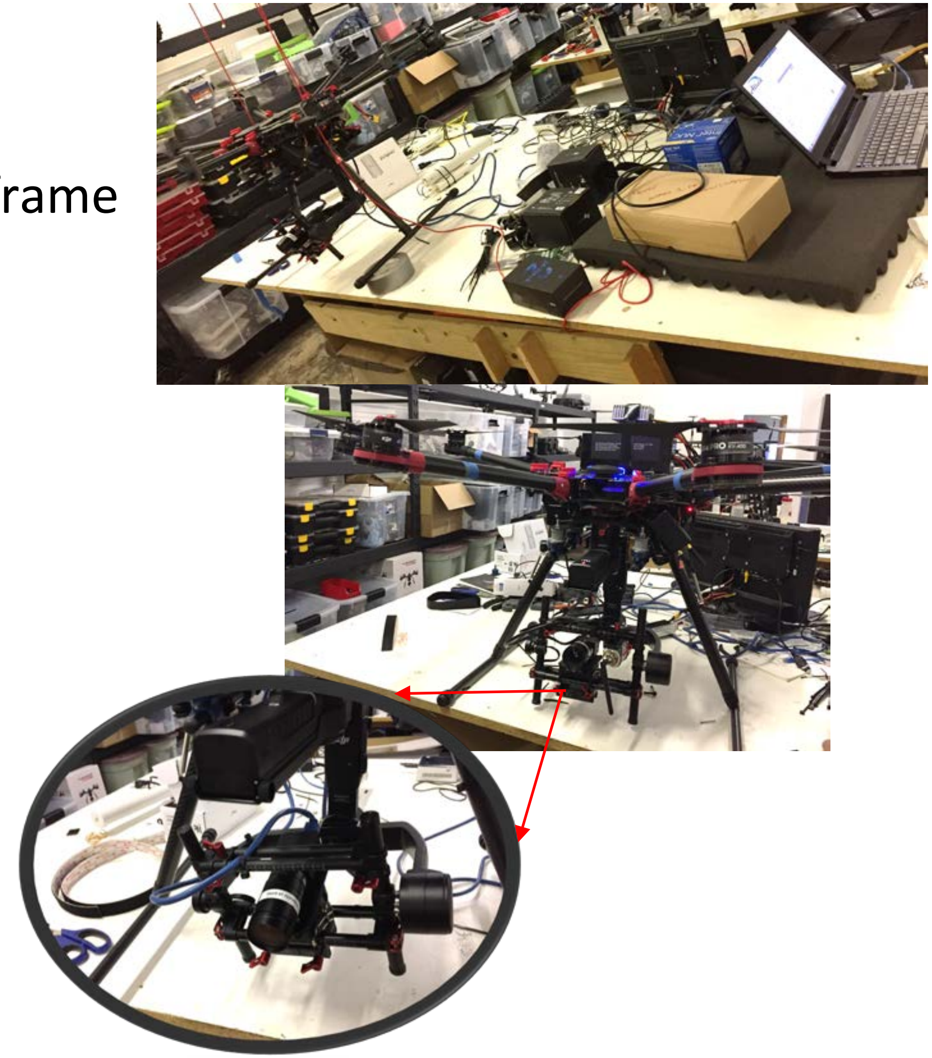


Raw Image

Contact:
Tony Cinson (tcinson@epri.com)

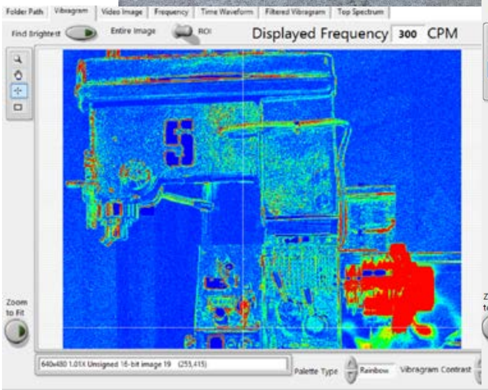
UAV Integration

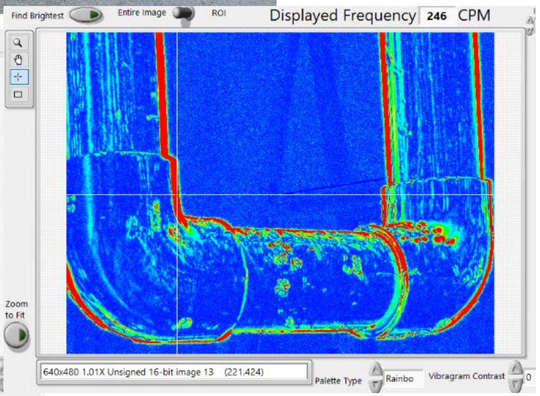
- UAV Platform
  - DJI Spreading Wings S1000+ frame
  - Up to 11Kg at takeoff
  - Mission Planner based flight control
- Camera + lens
- 4-Axis gimble/stabilizer
- Intel NUC 5i7
  - Onboard brains, Software
- Wireless communications
  - 5.8GHz WiFi Secure Link



Vibration Imaging Results & Next steps

- Successfully demonstrated the performance of the OptiVibe system
  - Laboratory measurements
  - Initial field testing
    - Machine shop equipment
- Wireless data acquisition
- Underwater parametric study
- Flow loop system testing
- Integrated into UAV Platform
- Airborne data acquisition challenging
  - Stable flight required
- Integration into SHM initiatives





EPRI Technical Report

ECD 1st quarter 2019

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Integrated UAS Testing

Perspectives

- UAV industry growing, innovating and developing very fast
- Utilities implementing use of UAVs:
  - Utilities w/corporate UAV groups
    - Southern – corporate group
    - Duke – corporate group
    - Exelon – Exelon Aero Labs
    - OPG – corporate
  - First Energy – site use
  - Diablo Canyon PP – site use
  - South Texas Project – site use
- Communicating and engaging w/all interested parties.
  - ASME Code on UAV for inspection guidance document
  - Energy Drone Coalition (EDC)

First EPRI Project

Current EPRI Project

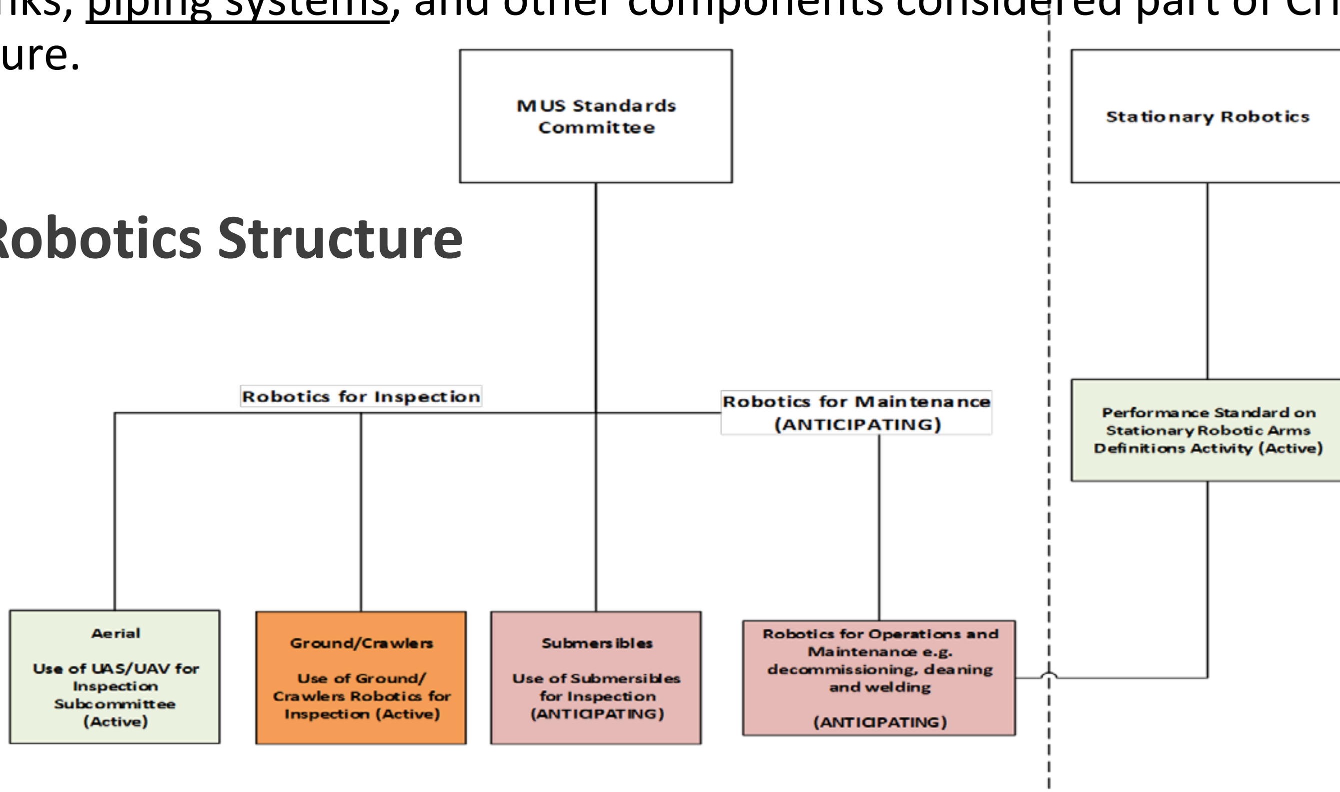
- UAV equipment and service provider mergers and acquisitions increasing
- UAV future is automation, image processing and data analytics
- Many new applications to explore with UAVs and MUS (mobile unmanned systems)
  - Plant security
  - Monitoring outdoor and indoor safety and non-safety systems vs. operator rounds

ASME Special Working Group: UAVs for Inspections

Mobile Unmanned Systems: UAVs

- **<u>Charter:</u>** Application of Mobile Unmanned Systems (MUS) for inspections, monitoring, and maintenance of industrial facilities and <u>power plants</u> as well as equipment, transmission lines, and pipelines
- **<u>UAV/UAS Guideline (under construction):</u>** This document provides guidelines and requirements for the utilization of Unmanned Aerial Systems to safely and reliably perform inspections and examinations of fixed equipment including <u>pressure vessels</u>, tanks, <u>piping systems</u>, and other components considered part of Critical Infrastructure.

ASME Robotics Structure



Energy Drone Coalition

Energy Drone Coalition

ENERGY DRONE COALITION™

ENERGY Robotics & AI NETWORK

- *<u>Objective:</u> Focused on the Business & Technology of Drones/UAS/UAV/Robotics & AI for Oil & Gas, Power, Industrial and Chemical Markets*
- *<u>Participants in EDC:</u> are those currently utilizing drones/UAVs/ robotics in their energy operations, as well as the energy asset owners and future end users who are evaluating their next steps for successfully integrating drones/robotics/AI into their energy facility inspections and asset management procedures.*

discussion

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