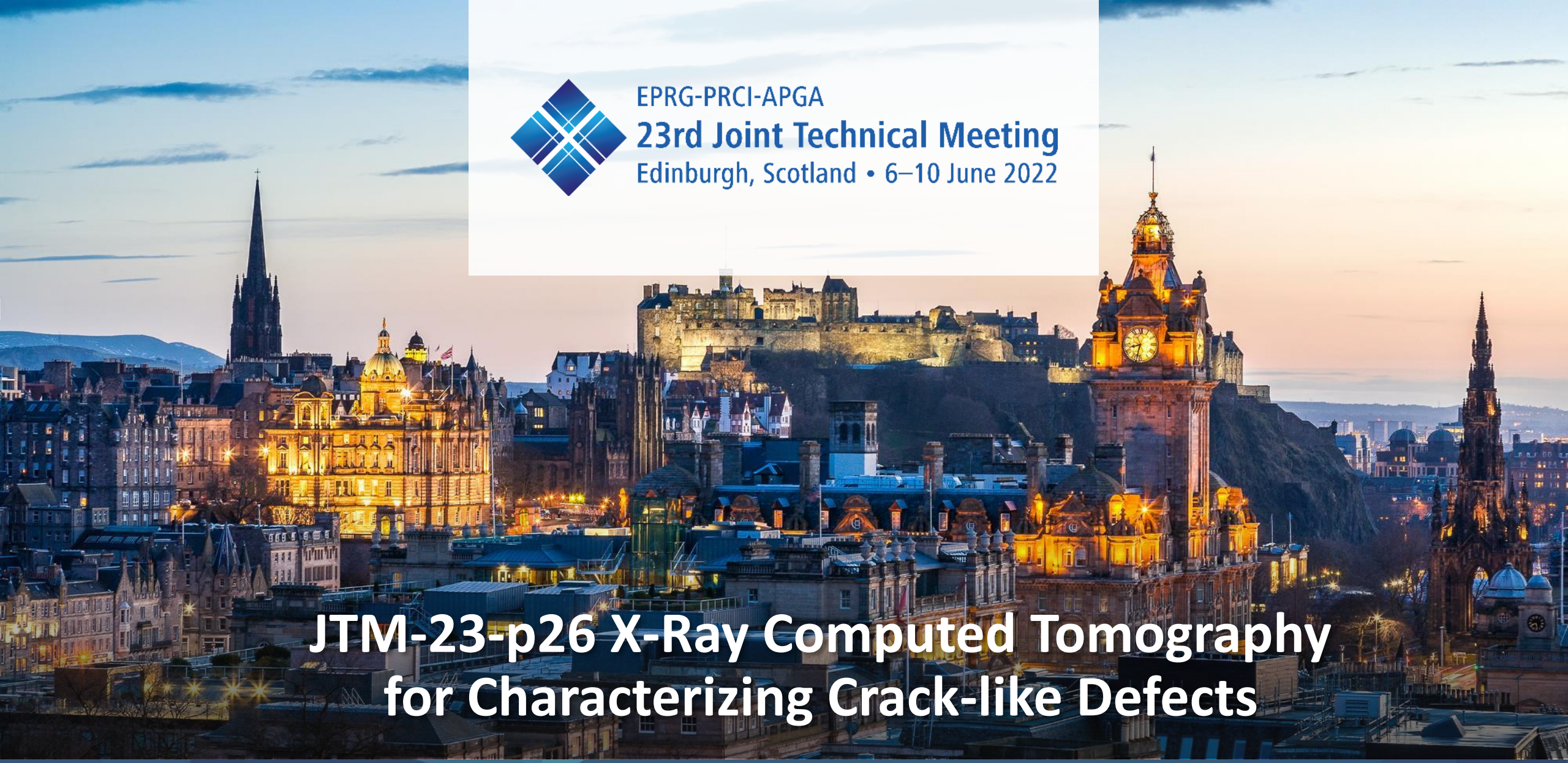

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JTM-23-p26 X-Ray Computed Tomography for Characterizing Crack-like Defects

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08 June 2022

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Project Objectives and Background

- Research Objectives/Project Deliverables: The objective of the project was to advance the use and understanding of X-ray Computed Tomograph (XRCT) technology for establishing industry reference standards against which ILI and NDE technologies can be evaluated.

- Background: This paper combines the findings from two extensive bodies of works undertaken at PRCI through projects NDE-2-11 and NDE-2-12. Combined, these projects accomplished an XRCT technology state-of-the-art overview including a literature review, industry discussions, and trials with select providers. To facilitate this, sets of “truth data” based on synthetic (manufactured) and real-world crack-like features were scanned and destructively tested to determine crack geometries.

Project Tasks

- **Task 1** – Manufacturing of synthetic flaws: this task involved fabrication of notches on pipe samples using EDM. These pipe samples were pressure-cycled to grow fatigue cracks from the EDM notches.

- **Task 2** – Inspection of synthetic flaws: this task involved inspection of the synthetic flaws fabricated in Task 1 using in-the-ditch NDE as well as XRCT technology.

- **Task 3** – Verify XRCT inspection performance: this task involved destructive sectioning of the synthetic flaws for confirmation against the XRCT data.

- **Task 4** – Apply XRCT technology to real-world features: this task involved destructive sectioning of the real-world flaws for confirmation of the results.

Workflows Associated with Project Tasks

Task 1
Task 2
Task 3

Synthetic

Synthetic features → CT inspection with detailed analysis → Conventional NDE → Freeze breaking

40 features

Task 4

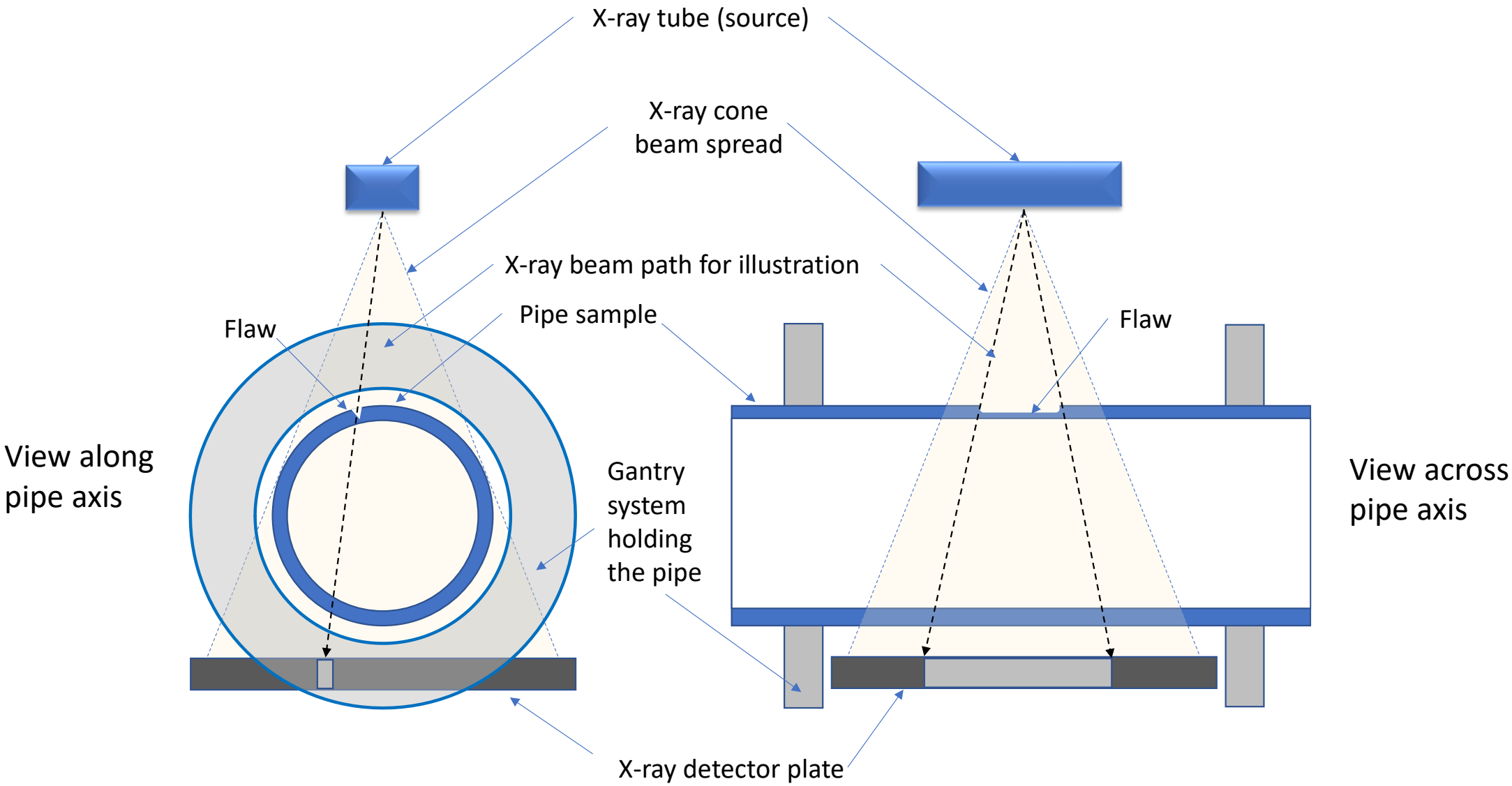
Real-world

Real world features → Conventional NDE → Review and select regions for CT inspection → CT inspection → Correlate back to conventional NDE → Detailed CT analysis for selected → Prioritize features for sectioning/ freeze breaking → Freeze break or Section → If no features visible in micrograph, adjust sectioning

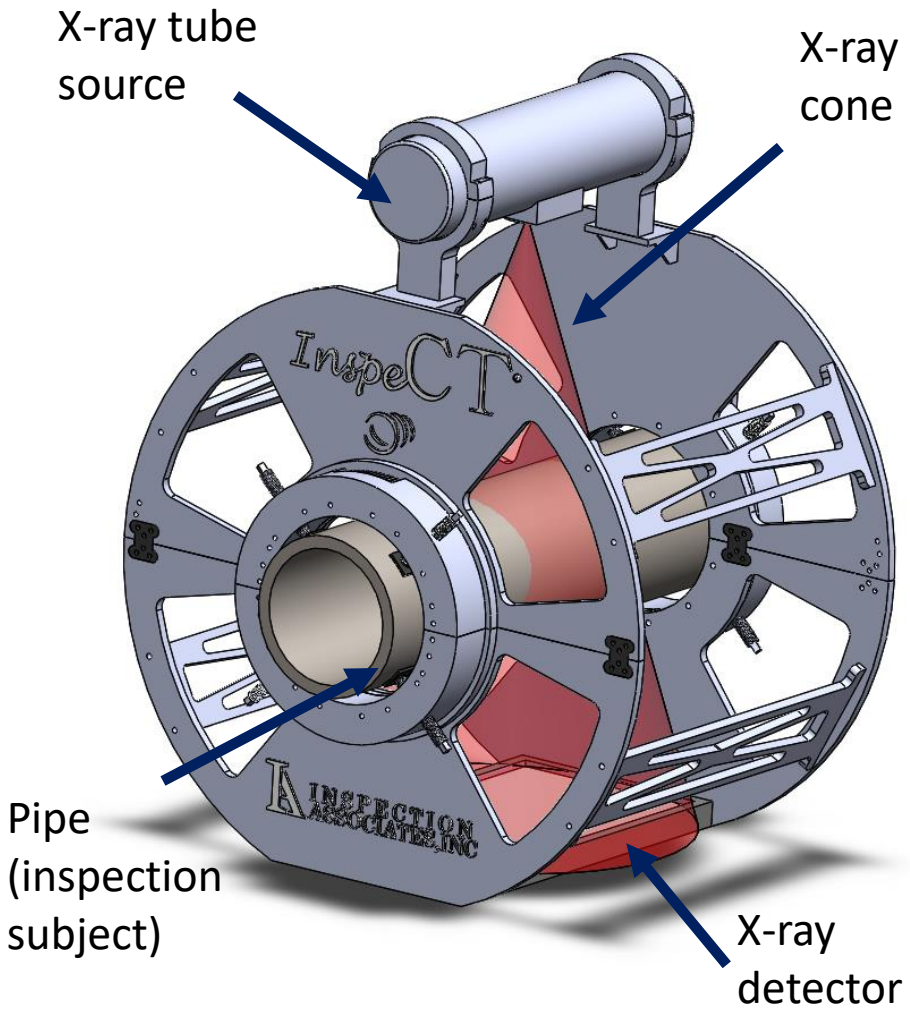
Resource constraints

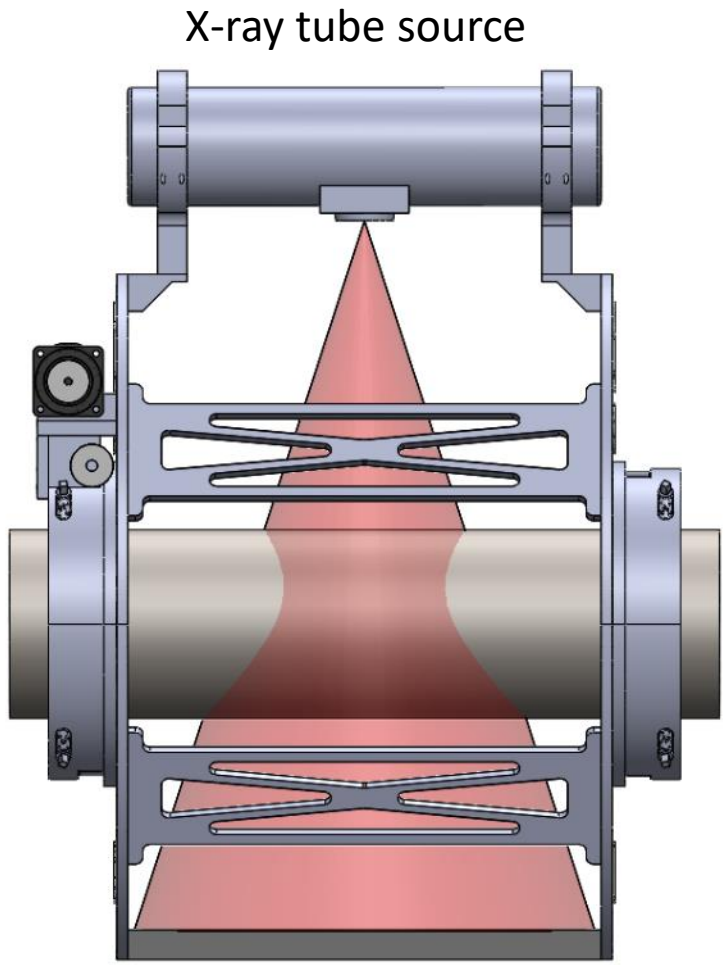
Initial target of 20 features; 6 additional features were processed

XRCT Inspection System Overview – Basic Elements

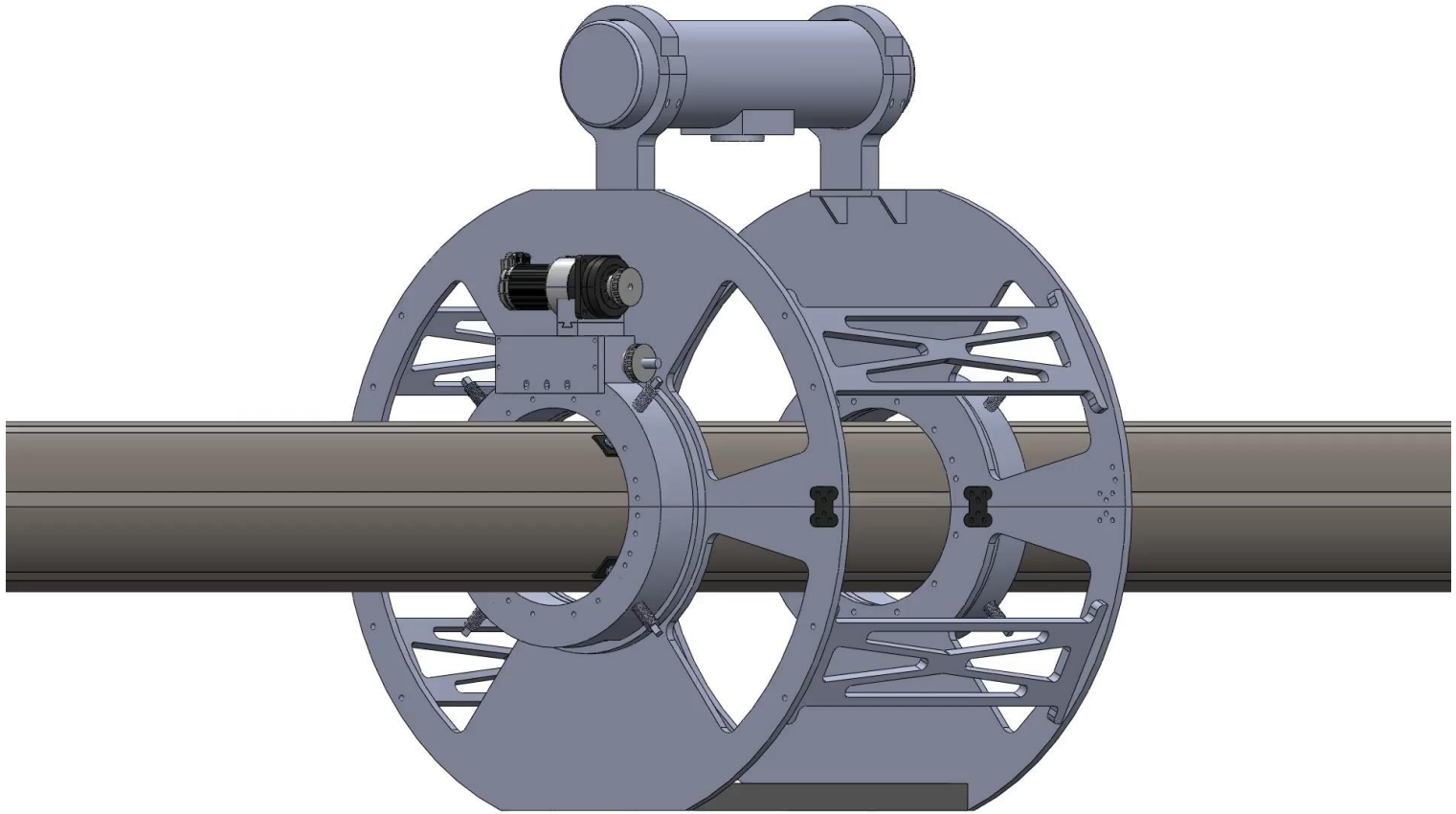


XRCT Inspection System – Schematic of InspeCT System

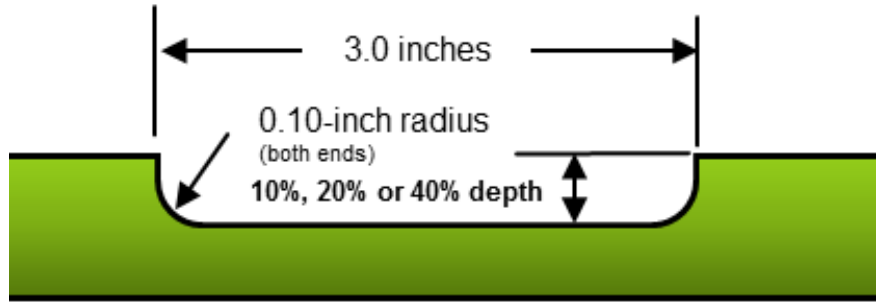




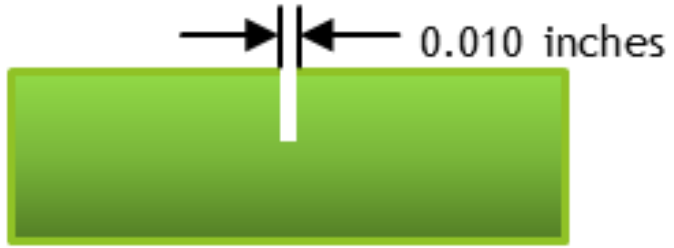
XRCT Inspection System – Scanning Process



Synthetic Features - Cutting EDM Notches



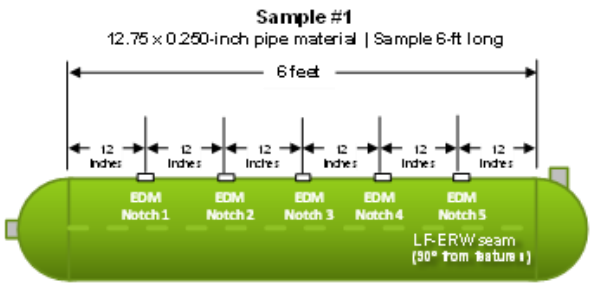
EDM Notch Details

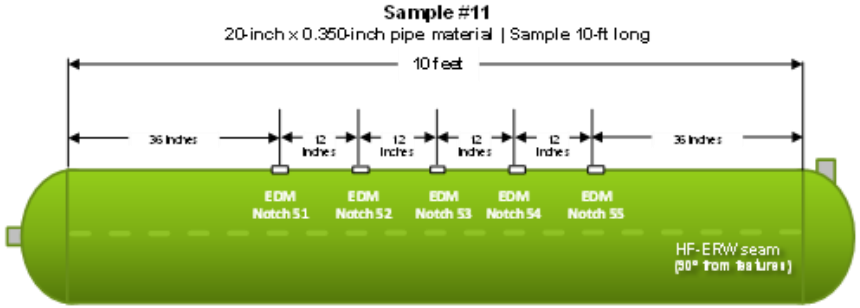


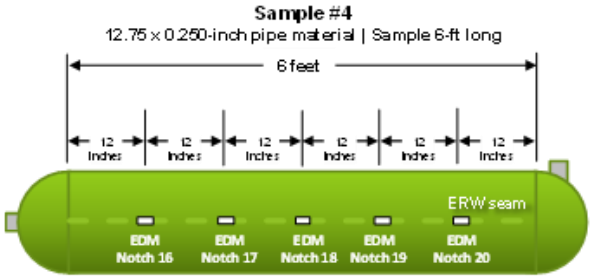
Cross-sectional profile

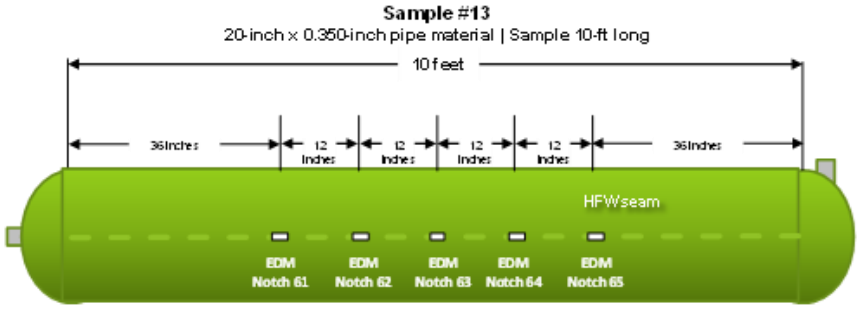
Synthetic Features – Full-scale Testing

Fabricate samples with end caps, instrument → Load in test chamber → Apply pressure cycles until a feature fails



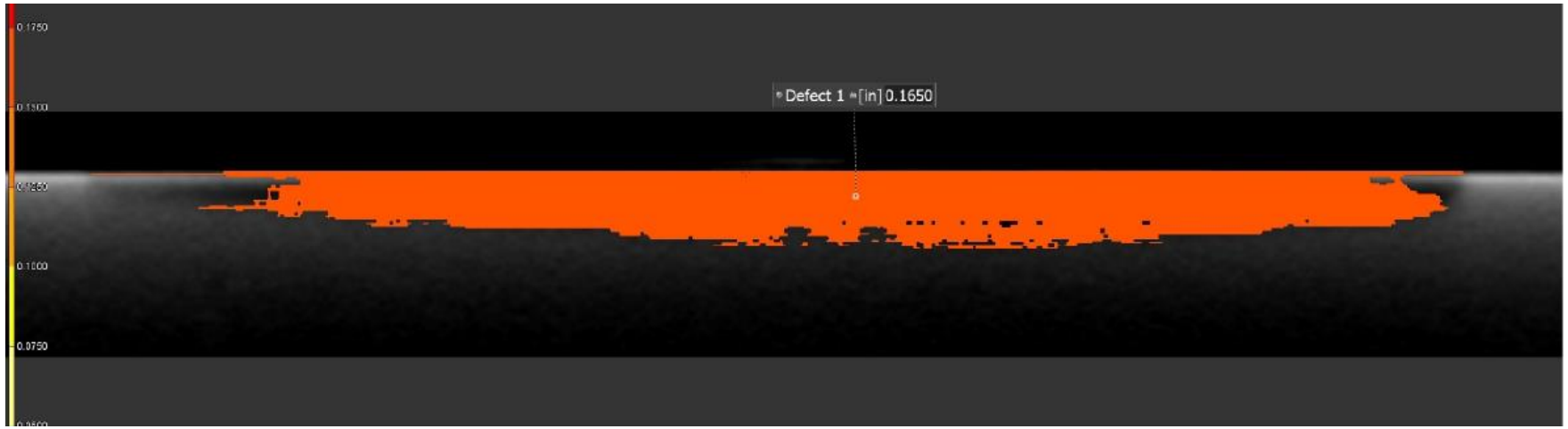


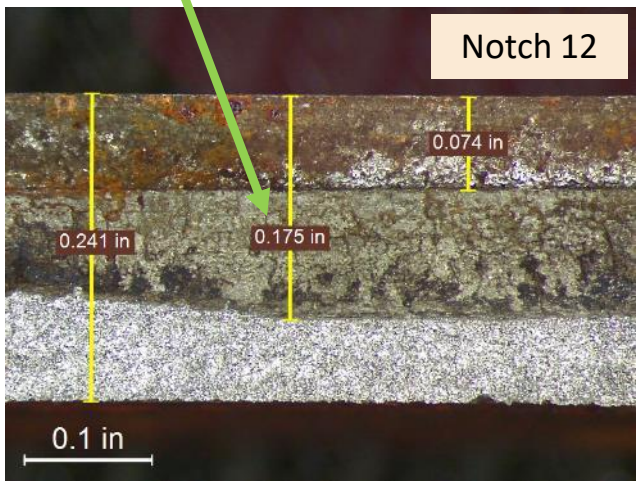




XRCT Inspection Results, Notch #12 Example

Line/Joint Ident.	Field Ident.	Feature Number	Label	Feature Location				Axial Length		Width		Height		Circ Extent	
				Start (in) from USGW	Start (mm) from USGW	Stop (in) from USGW	Stop (mm) from USGW	in	mm	in	mm	in	mm	in	mm
ADV-PHMSA # 12	F1	Defect 1	0	-1.425	-36.2	1.558	39.6	2.983	75.8	0.013	0.3	0.165	4.2	0.050	1.3

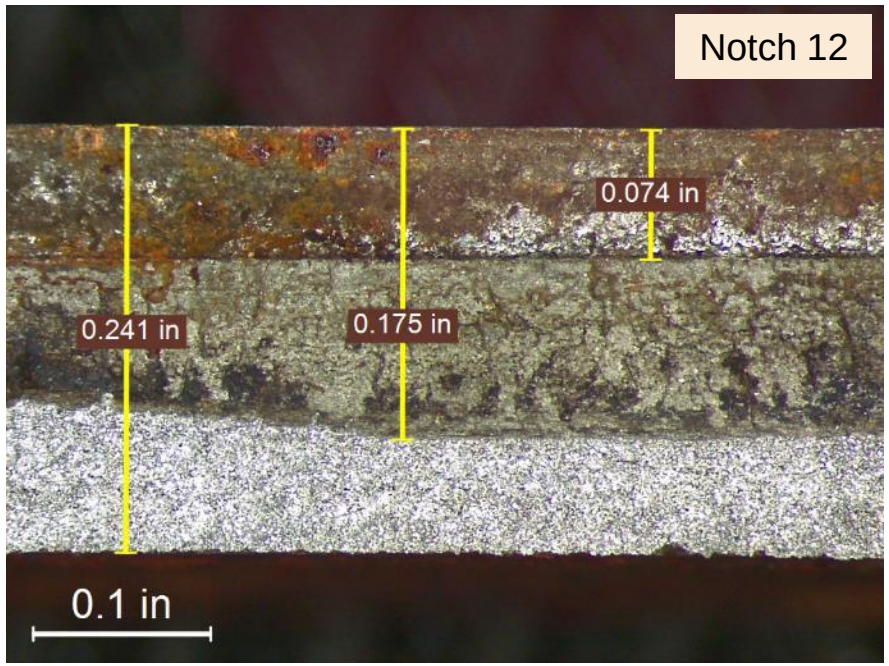




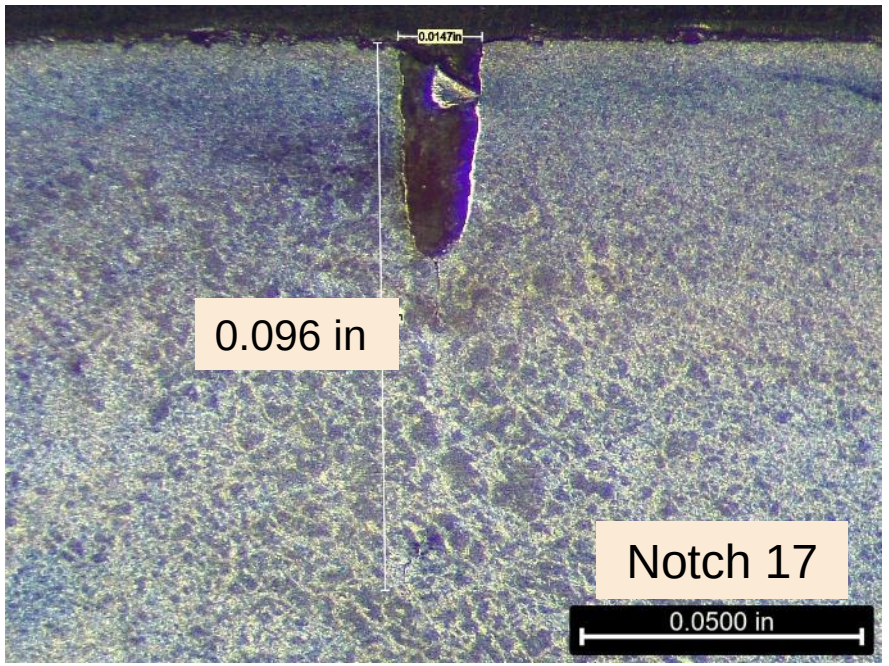
Synthetic Features – Generating "Truth" Data

Freeze break → Clean → Observe under microscope

Section (across flaw length) → Clean, mount, and polish → Observe under microscope

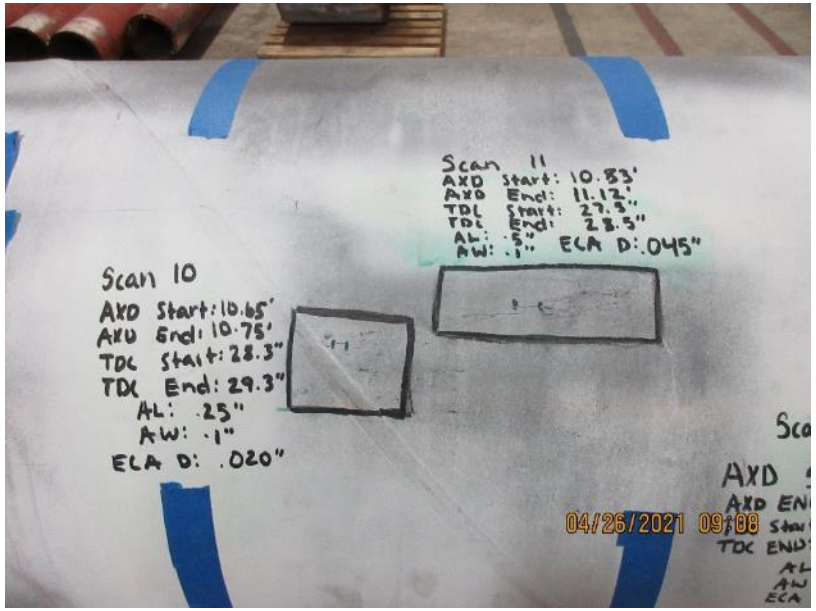


Freeze break example

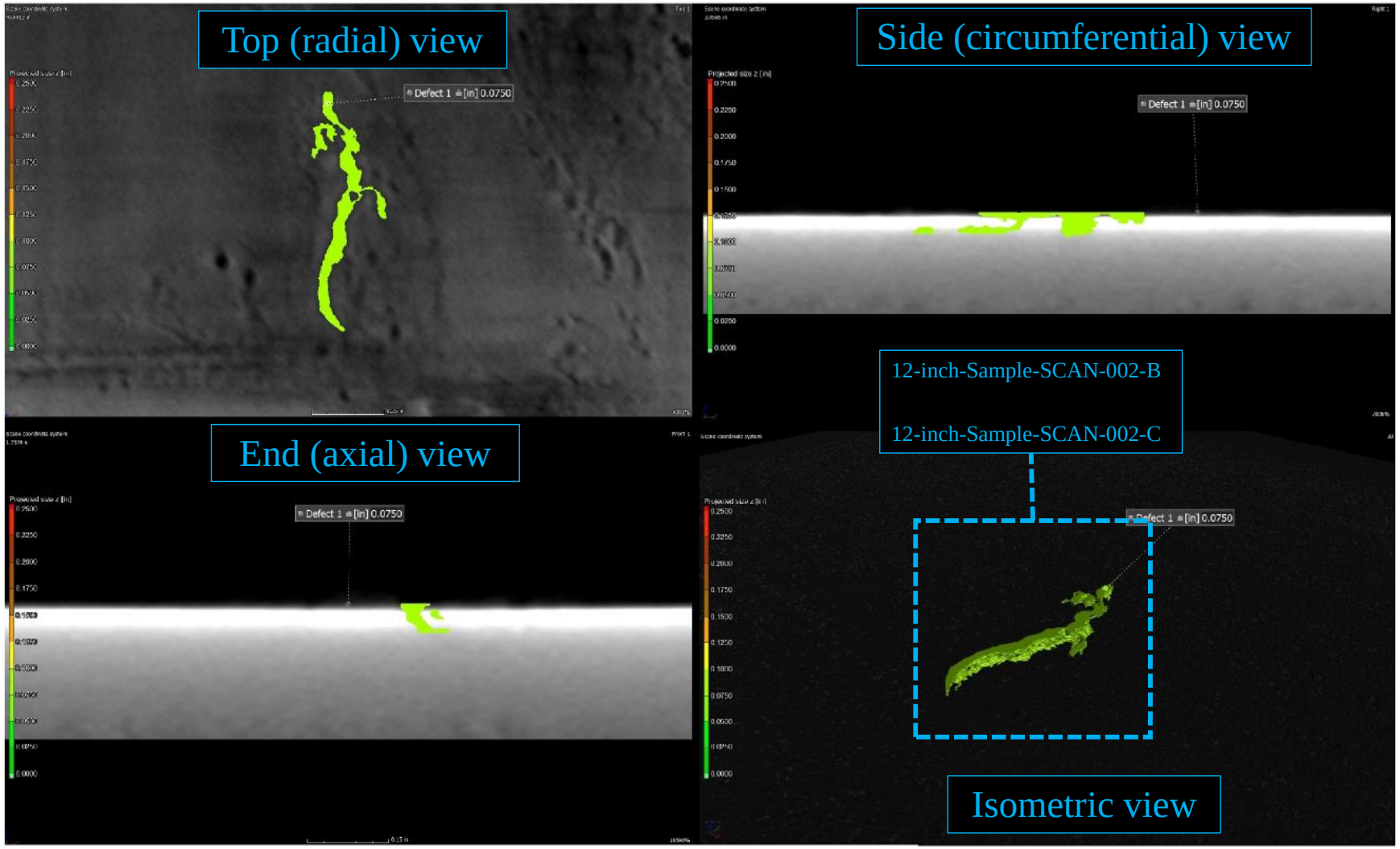


Sectioning example

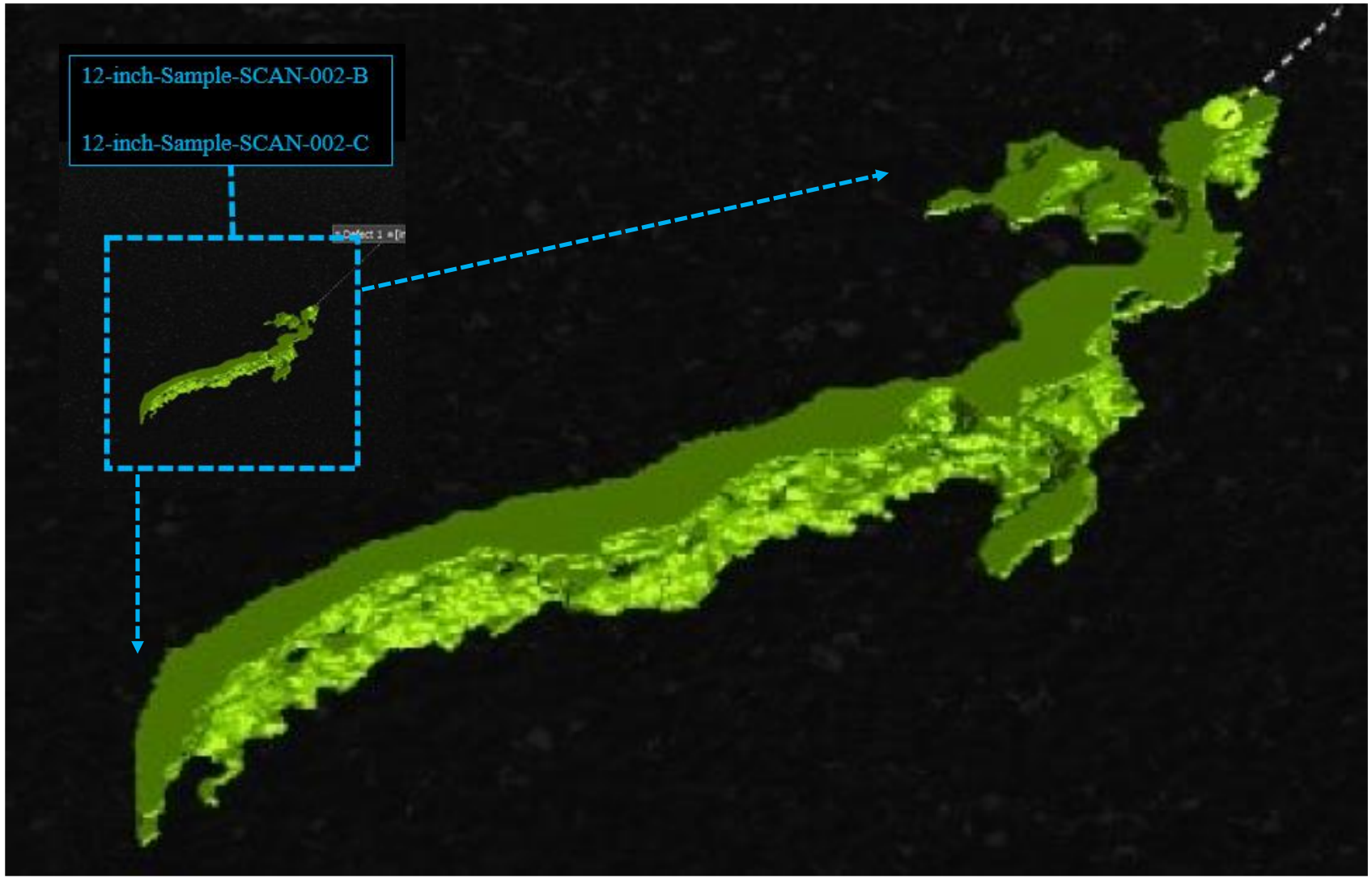
Real-World Features



Real-World Features - XRCT Inspection

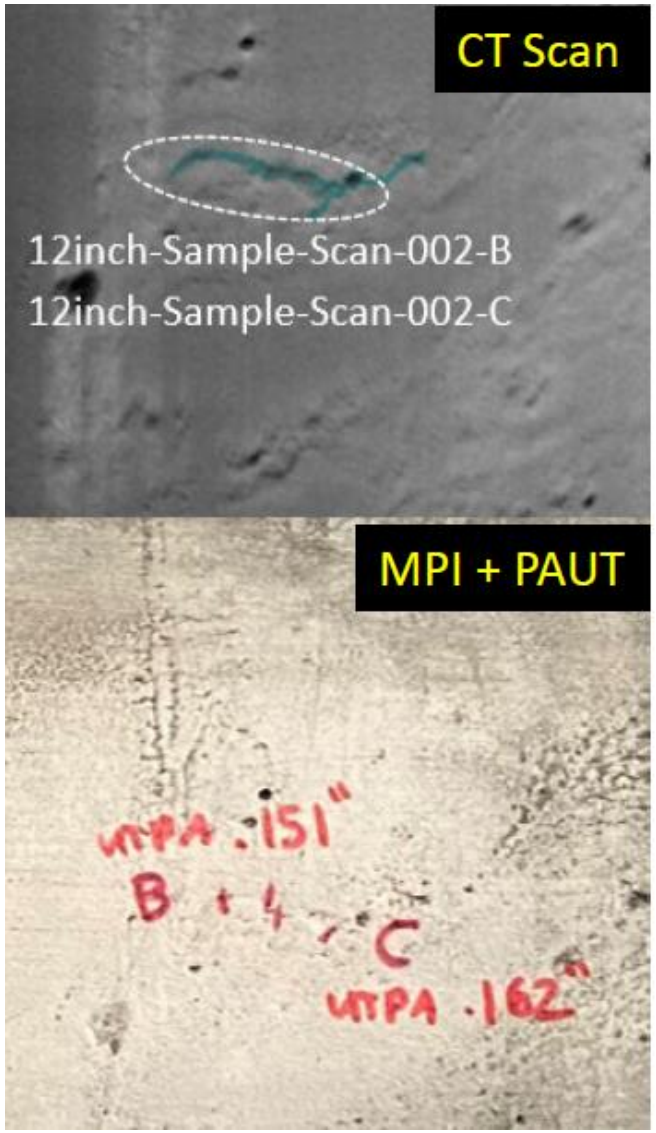


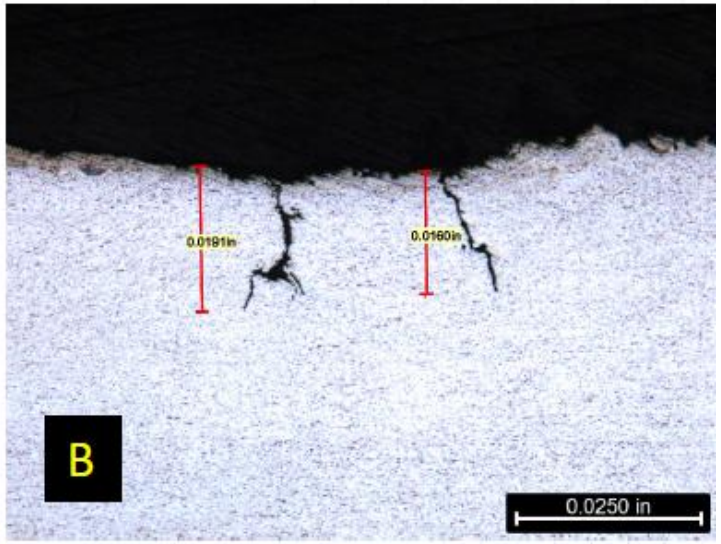
Real-World Features - XRCT Inspection Details

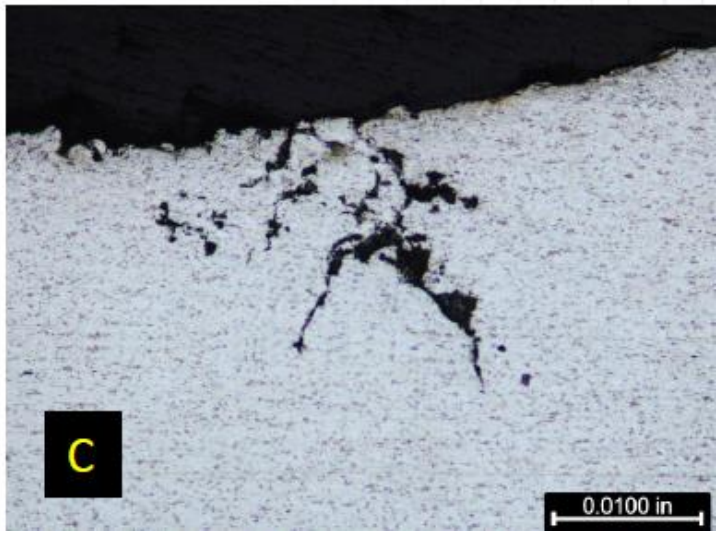


Real-World Features – Sectioning for “Truth” Data

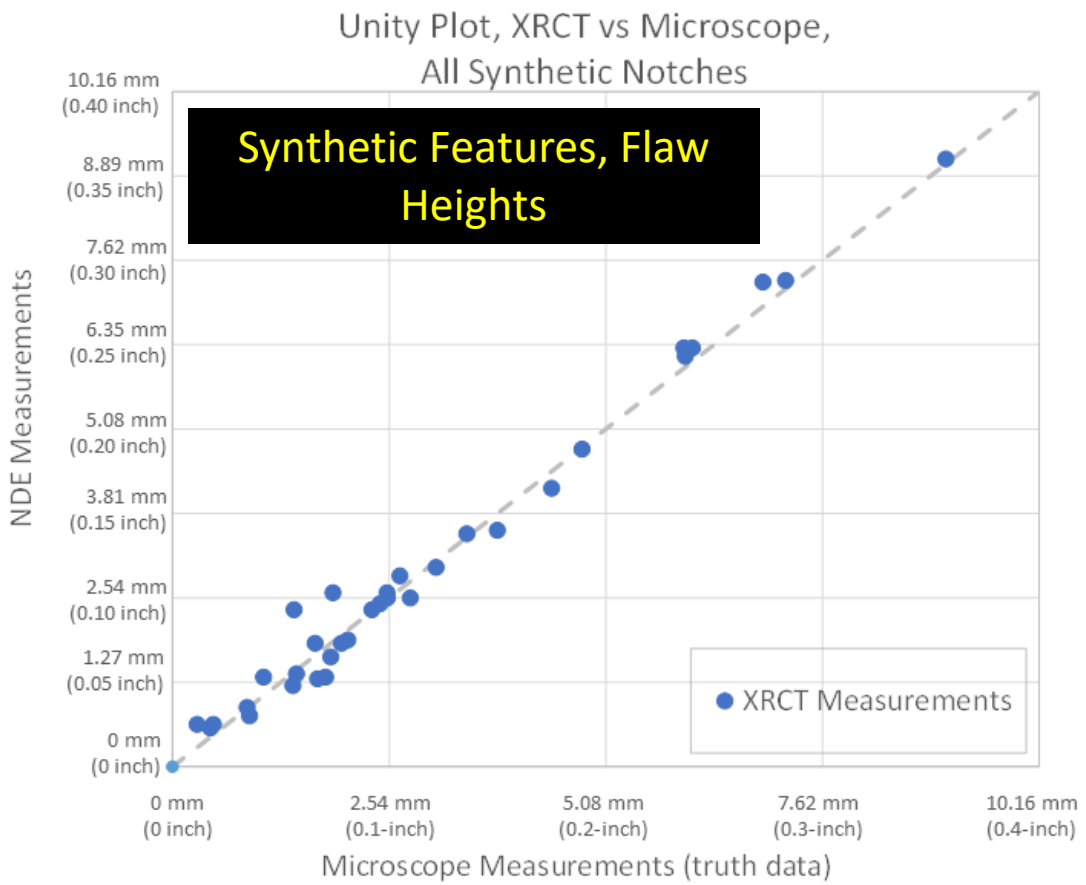
Real-World Features – Sectioning for "Truth" Data



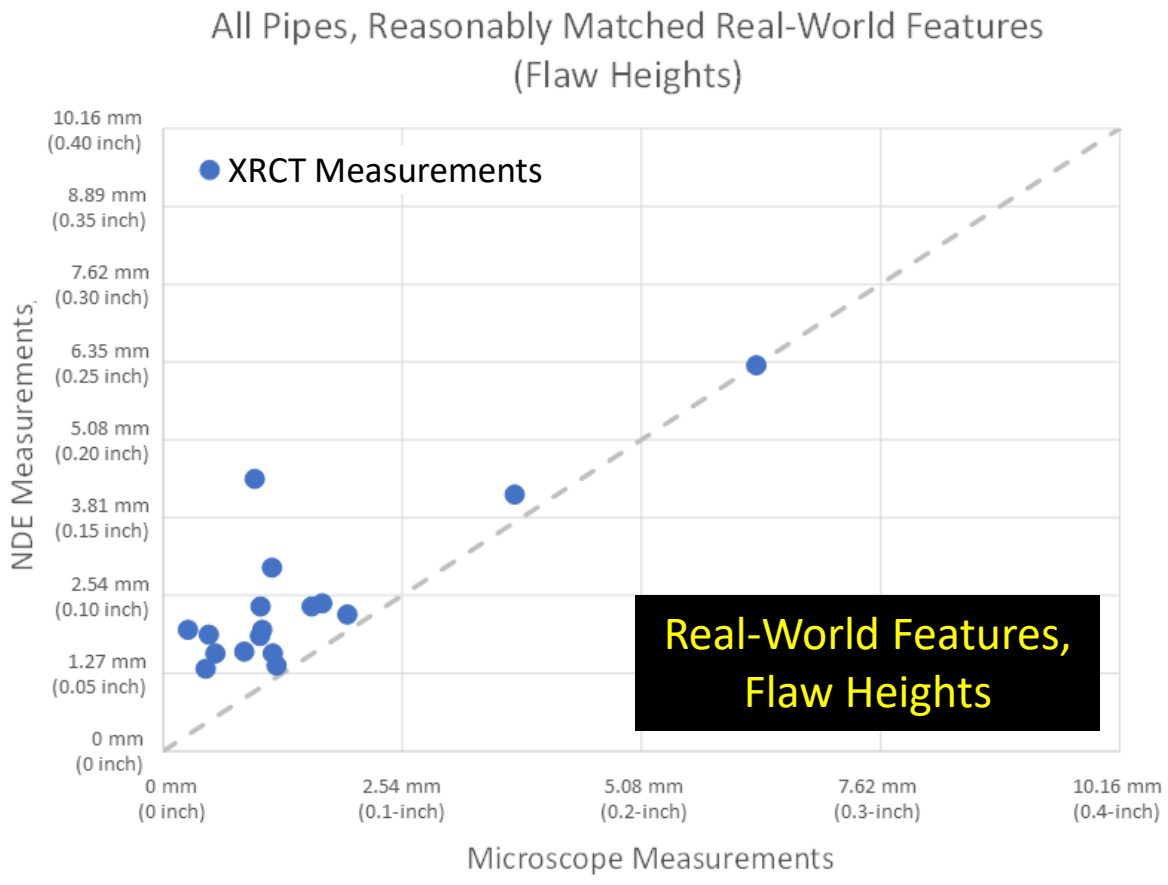




Results Summary: All Samples



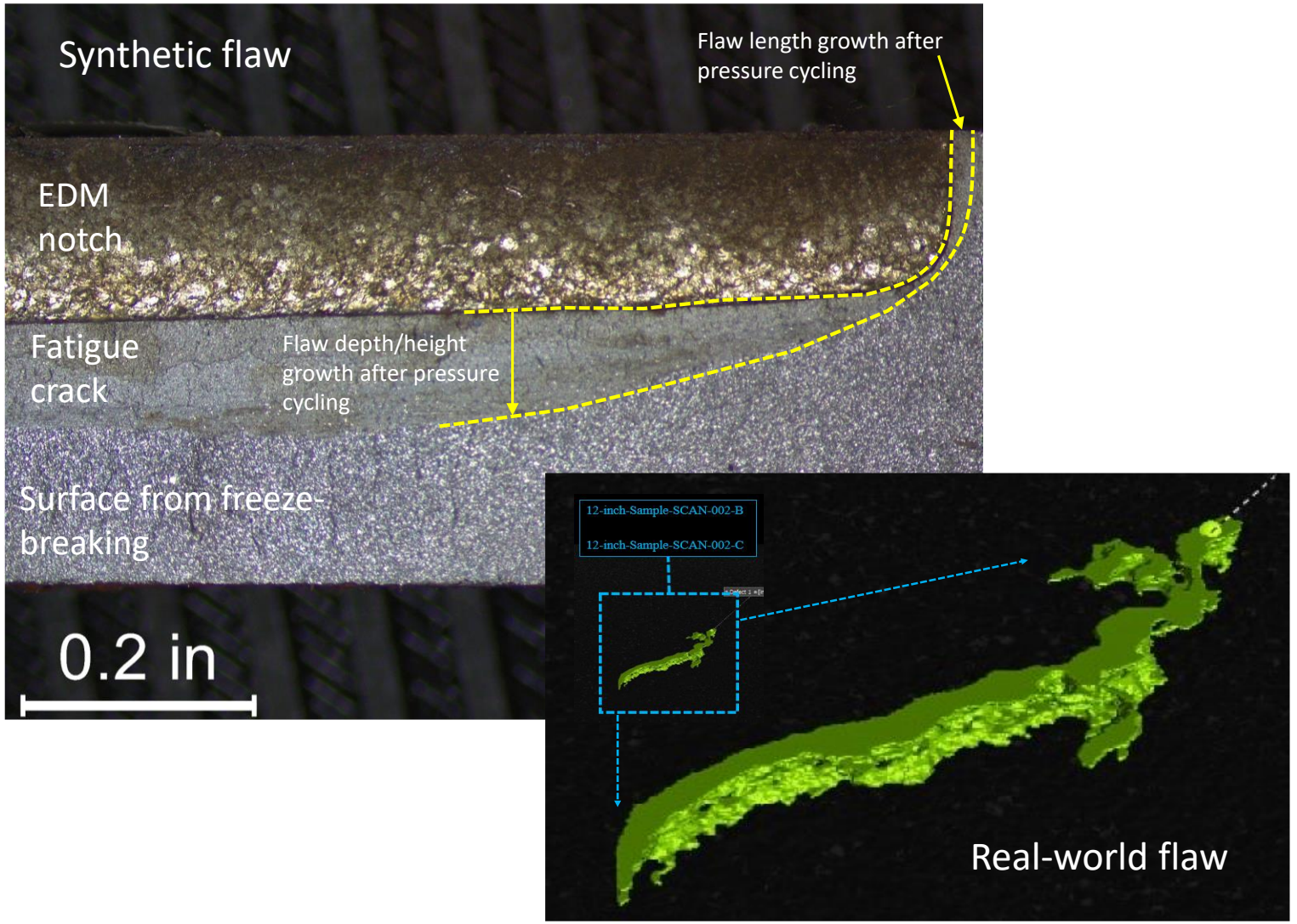
XRCT measurements matched reasonably well with measured flaw heights for **synthetic features**



XRCT measurements did not match as well with measured flaw heights for **real-world features**

Results and Conclusions - 1

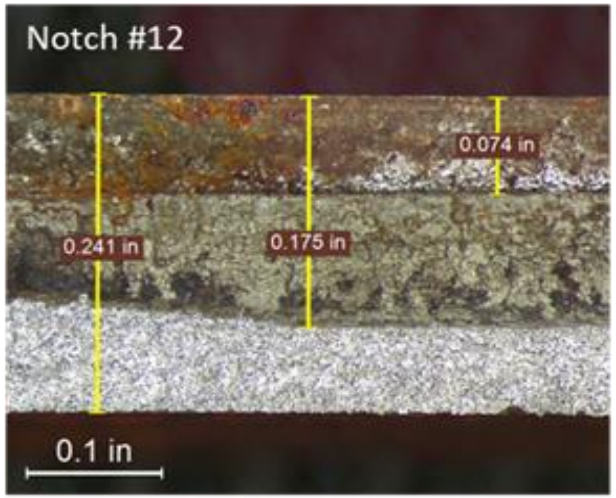
- Challenges associated with confirmation of lengths
  - For synthetic features, sharp crack growth in the axial direction is significantly smaller – so the “crack” tip is very close to the notch tip
  - For real-world features more intensive definition and verification approaches are necessary

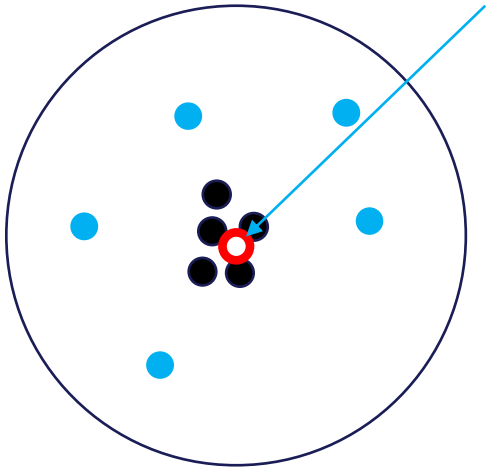


Results and Conclusions - 2

Reference Standards - Flaw-Type Perspective

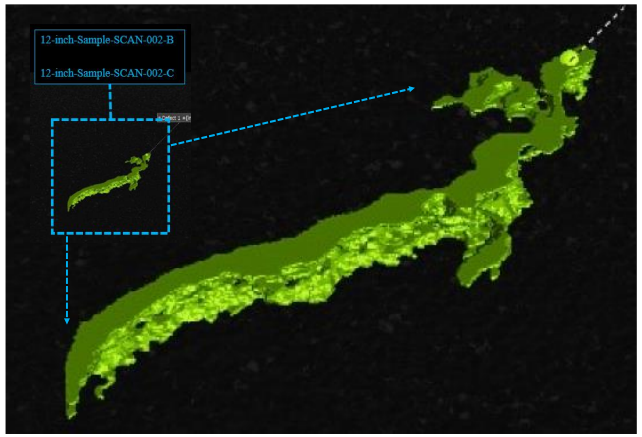
Example Synthetic Feature

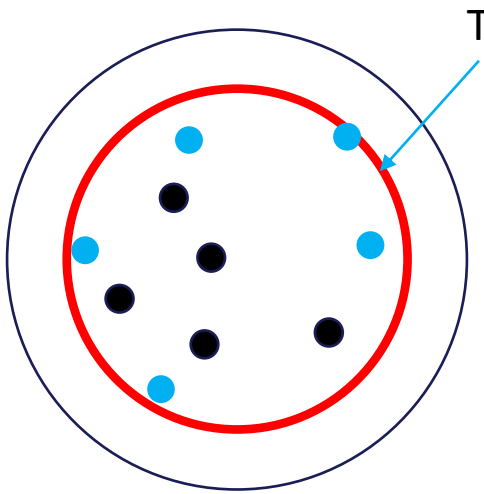




High precision;
Great for developing reference standards

Example Real-world Feature





Low precision; Developing reference standards is challenging

Results and Conclusions - 3

- Additional work will be required for reference standard development using real-world features
  - Including more detailed profile-matching, instead of just depth verification
- Current XRCT inspection system (specific system used for this project) and analysis process is resource-intensive and needs development from software and data processing side to align with requirements for reference standard development
- Additional confirmatory work will be needed for liquid lines (detection is easier when medium inside the pipe is gas)

Thank you for your attention.

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