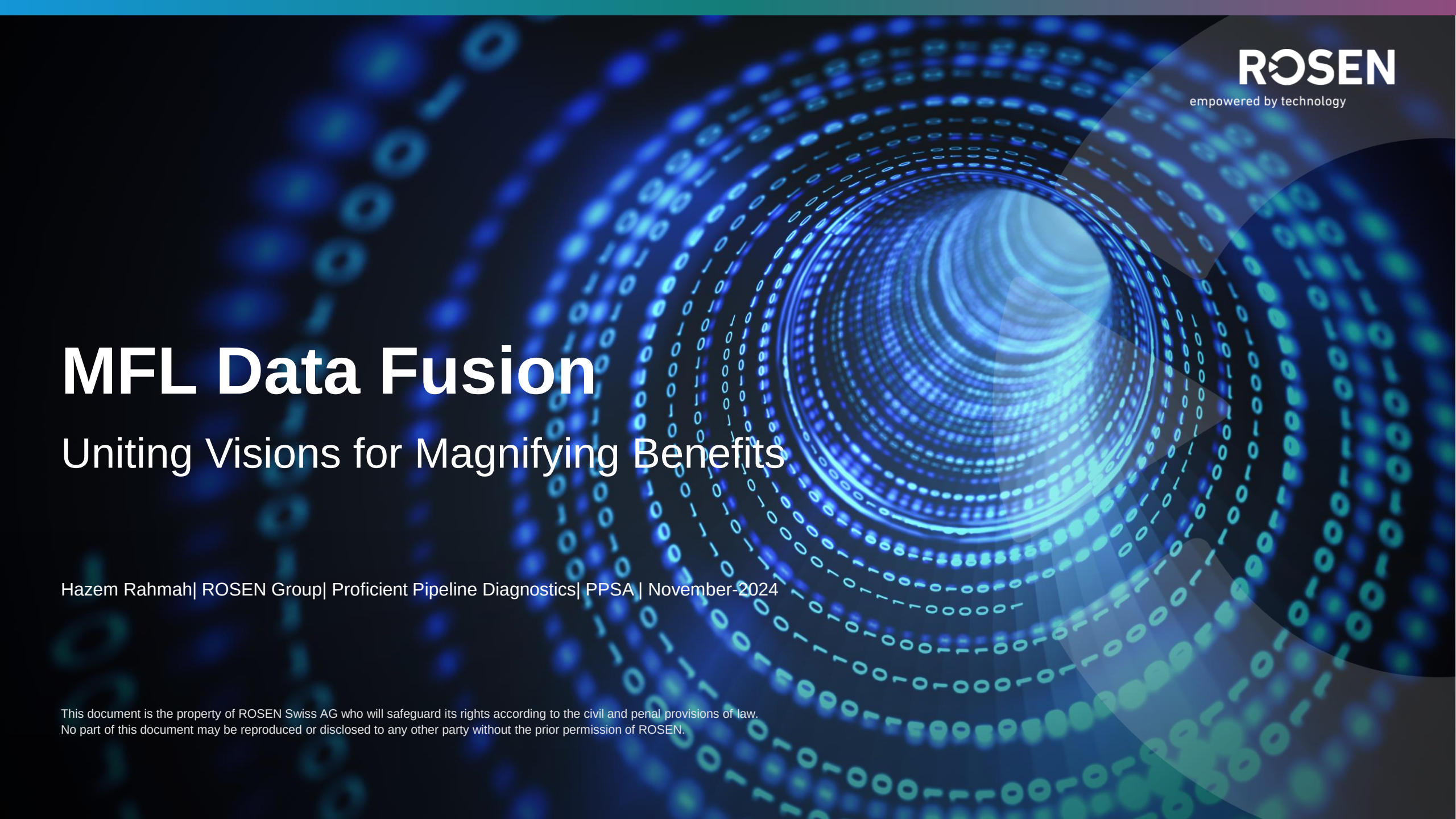


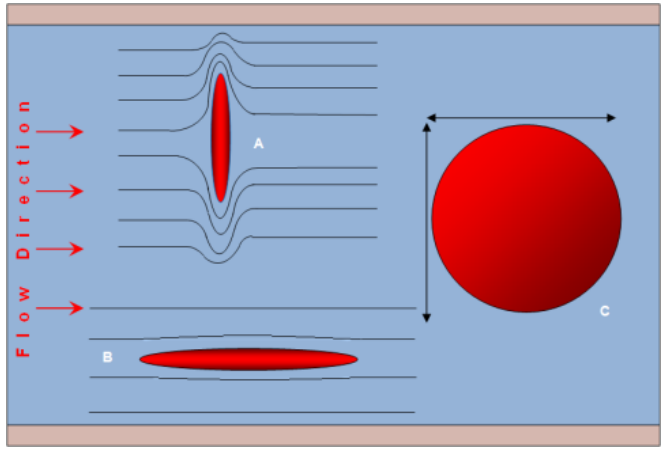
MFL Data Fusion

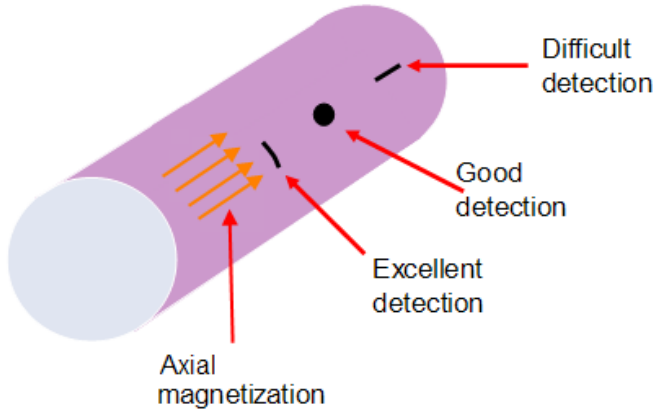
Uniting Visions for Magnifying Benefits

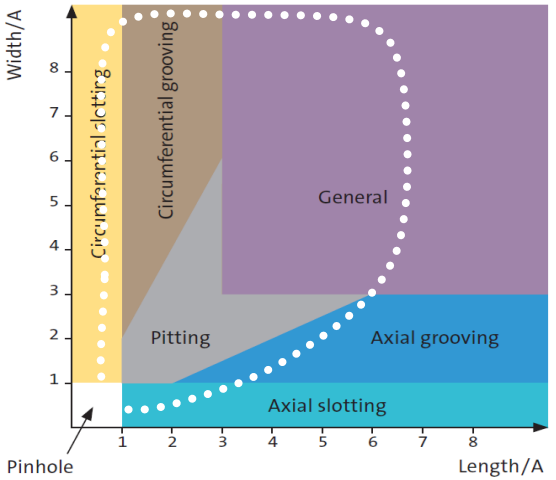
Hazem Rahmah| ROSEN Group| Proficient Pipeline Diagnostics| PPSA | November-2024

Traditional MFL Technology
Detection

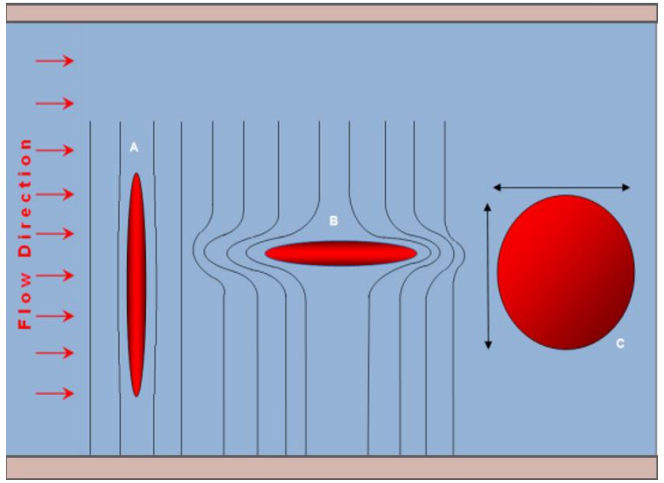
MFL-A

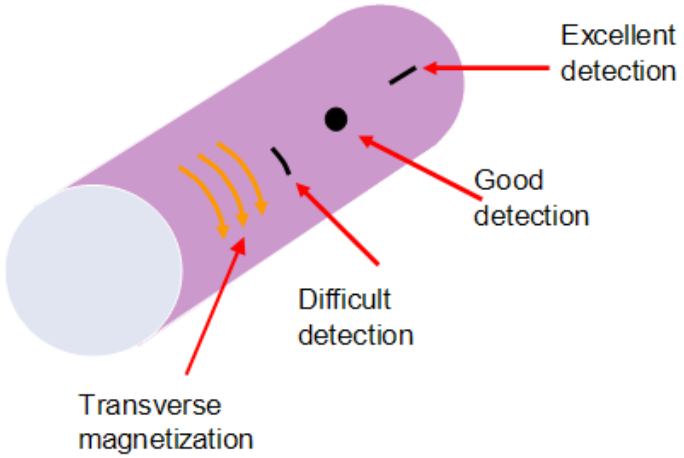


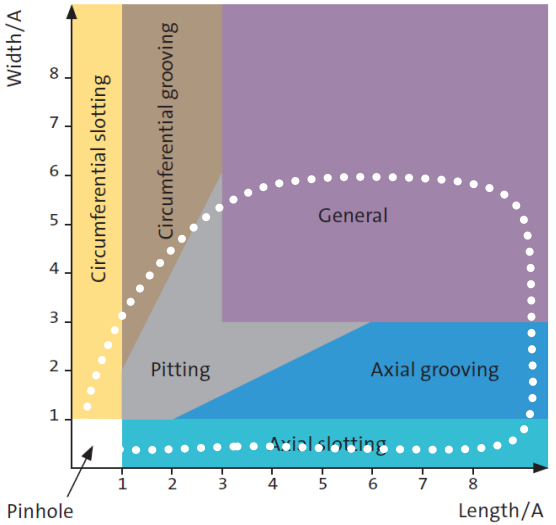




MFL-C

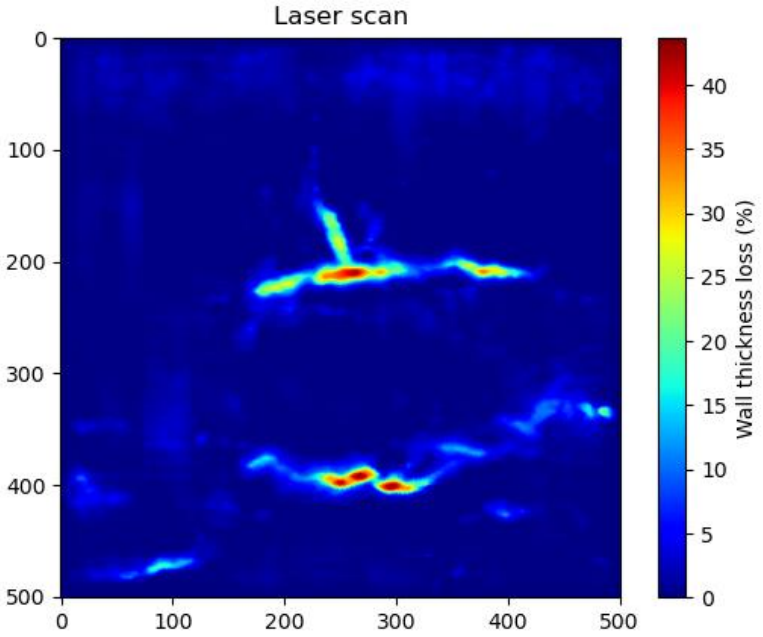


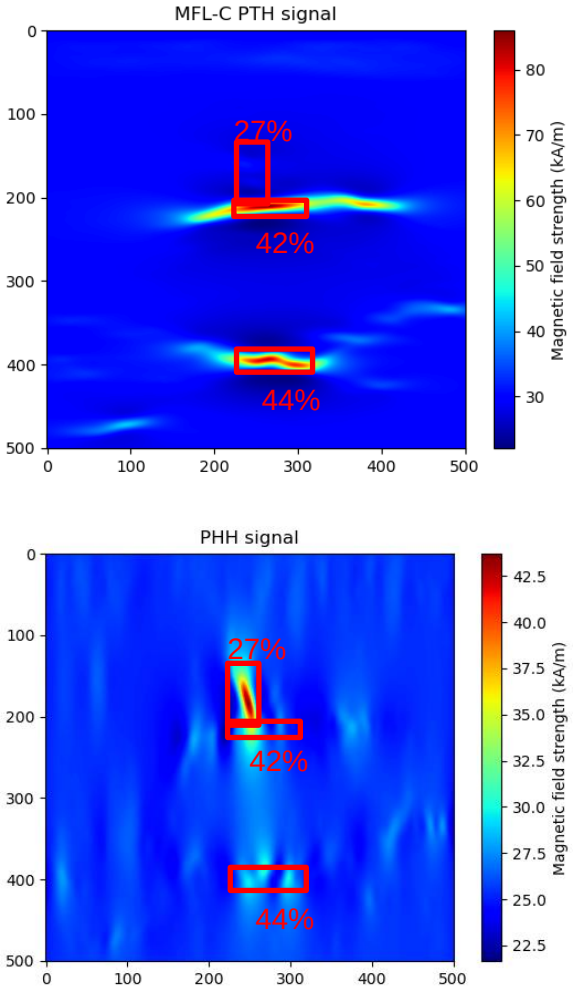


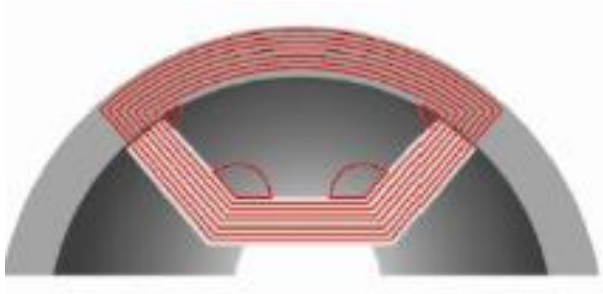


Traditional MFL Technology

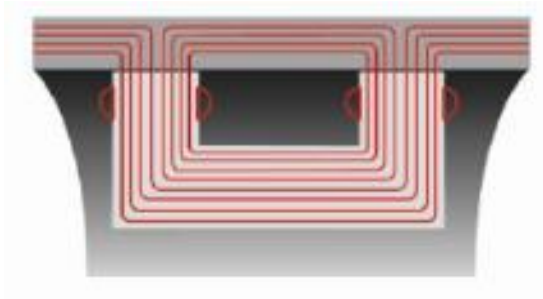
Laser vs. Traditional MFL







MFL-C



MFL-A

Two magnetization directions are needed to capture all the defect information

The Issue
Integrity Management Challenges

Spending on Unnecessary Digs

- ILI Results and Integrity studies with uncertainties are resulting in directing in-ditch investigation to no threating defects. No need for spending on.
- Focus, Money and Effort are wasted away from the real threats.

Complex Anomalies Identifications Challenges

- Length and width limitations / inaccuracies
- Deepest part identification within general defect
- Inaccurate ERF calculations.

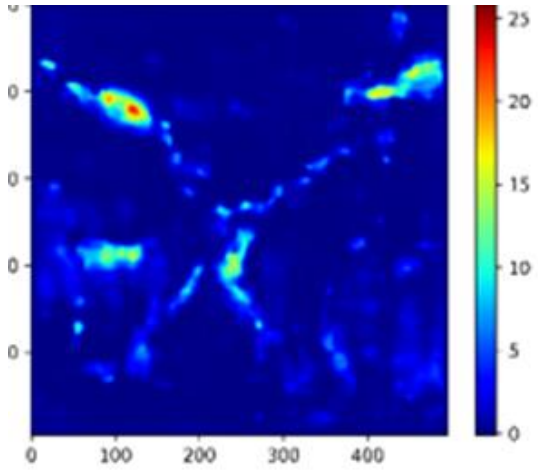
Uncertainties in Sizing

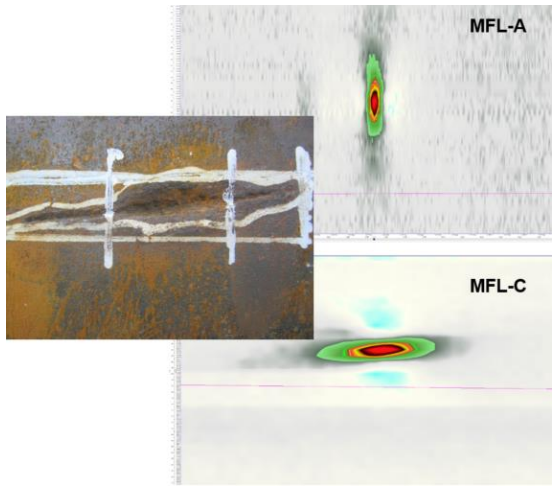
- Inaccurate failure pressure calculation.
- Pipe Threats analyze is impacted by individual standard ILI limitation vs. Anomalies characteristics (e.g. Direction).

Pipeline Inspection Planning Suitability

- ILI Technologies selection does not fit pipe's threat.
- Inspection plans are based on inaccurate assumptions / input.
- Critical defects are not monitored due to used technology physical limitations.

How to solve the Issue
Solution Approach





Major Enhancement on the Input ILI data

- Different ILI data are fused to provide a perfect visualization at of the pipe condition, at a quality similar to in ditch laser profiling along the pipeline.

  Better visualization of the data by operators.

Minimize impact of physical limitation of Standard MFL Technologies

- One ILI signal data obtained from different technologies is overcoming limitation of each alone and increasing detection and sizing capabilities to cover all categories of metal loss threats despite their directions and dimensions.

New Approach of Anomalies Reporting

- Move from “Anomaly Boxes” to “Anomaly Profiles” reporting.
- Individual Profile based “Failure Pressure” is calculated directly during reporting.
- Move from “Box / Depth /ERF” focus reporting to “Profile Failure Pressure” Focus.

Minimize subjectivity in Analysis

- Enhanced Analysis Approach that minimizes Human impact on ILI results by conscious use of AI

  Additional focus on “real severe” pipe threats during analysis.
- Focusing on “Profile Edges” Analysis

The Solution : MFL DATA FUSION
New service provided by ROSEN

ROSEN
empowered by technology

Fusing MFL-A /C Data

A system to fuse MFL-A and MFL-C signals obtained from in-line inspection services and provide 3D depth profile , similar to in ditch laser profiling, for metal loss integrity assessments including failure pressure assessments.

Features

- Anomaly Boxes based on the Data Fusion result (not the MFL-A or MFL-C signal),
- Significantly Improved Anomalies Identification and Sizing accuracies.

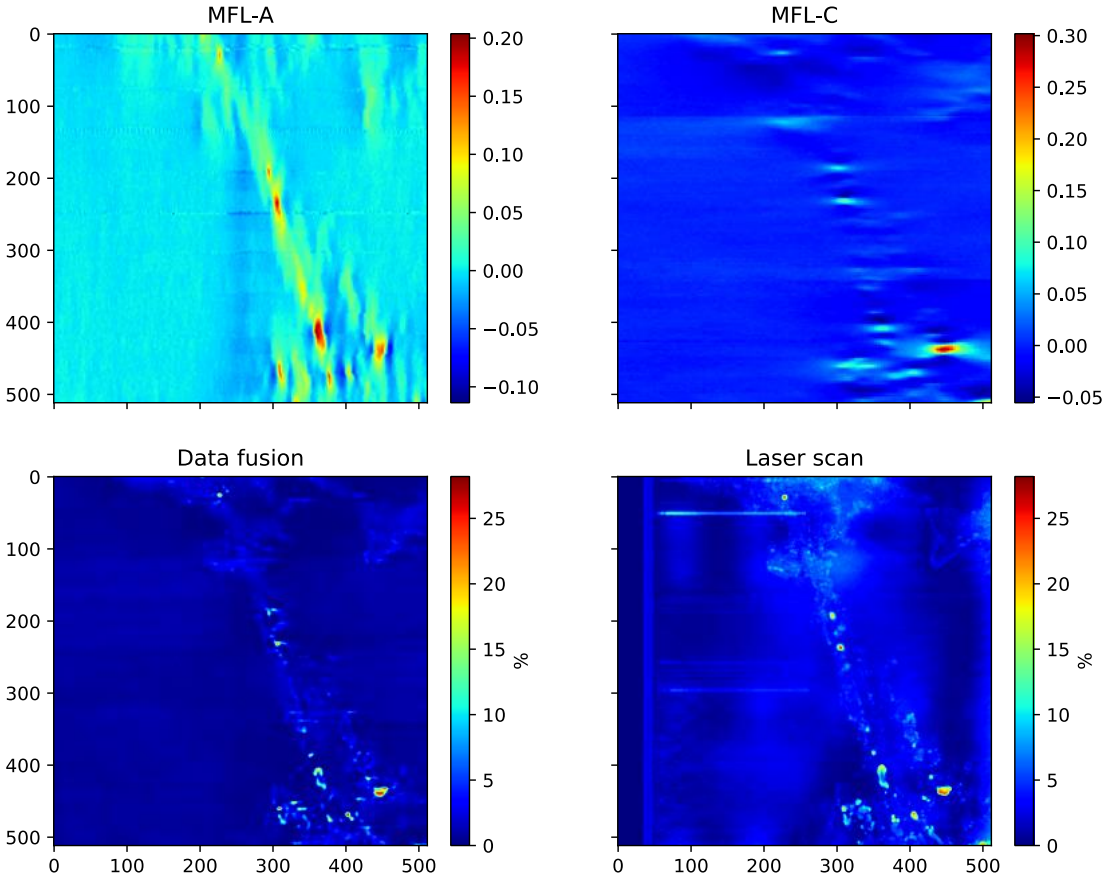
Deliverable

- Enhanced plus individual anomaly profile
- Failure Pressure assessments based on 3D depth profiles
- New benchmark for certainty and accuracy

MFL Data Fusion

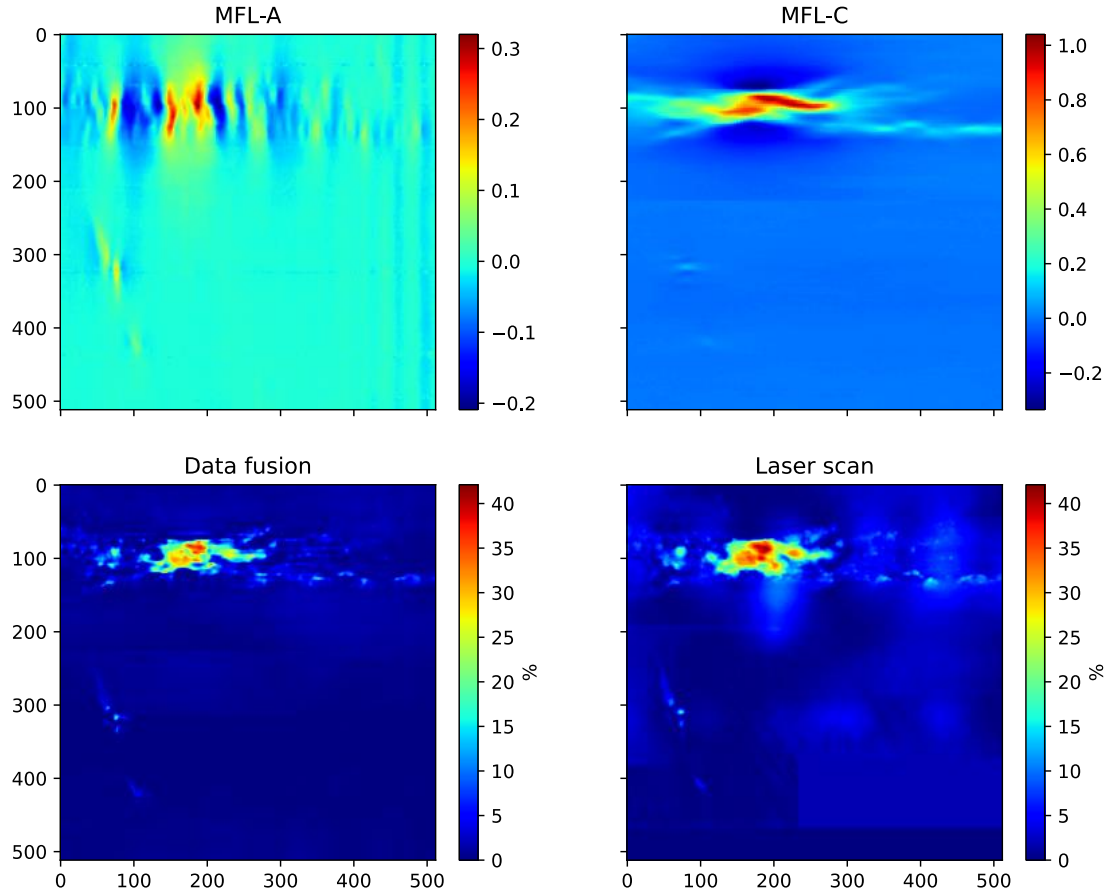
Leverage the information from both tools and make a single call

Case 1



Circumferential Metal Loss

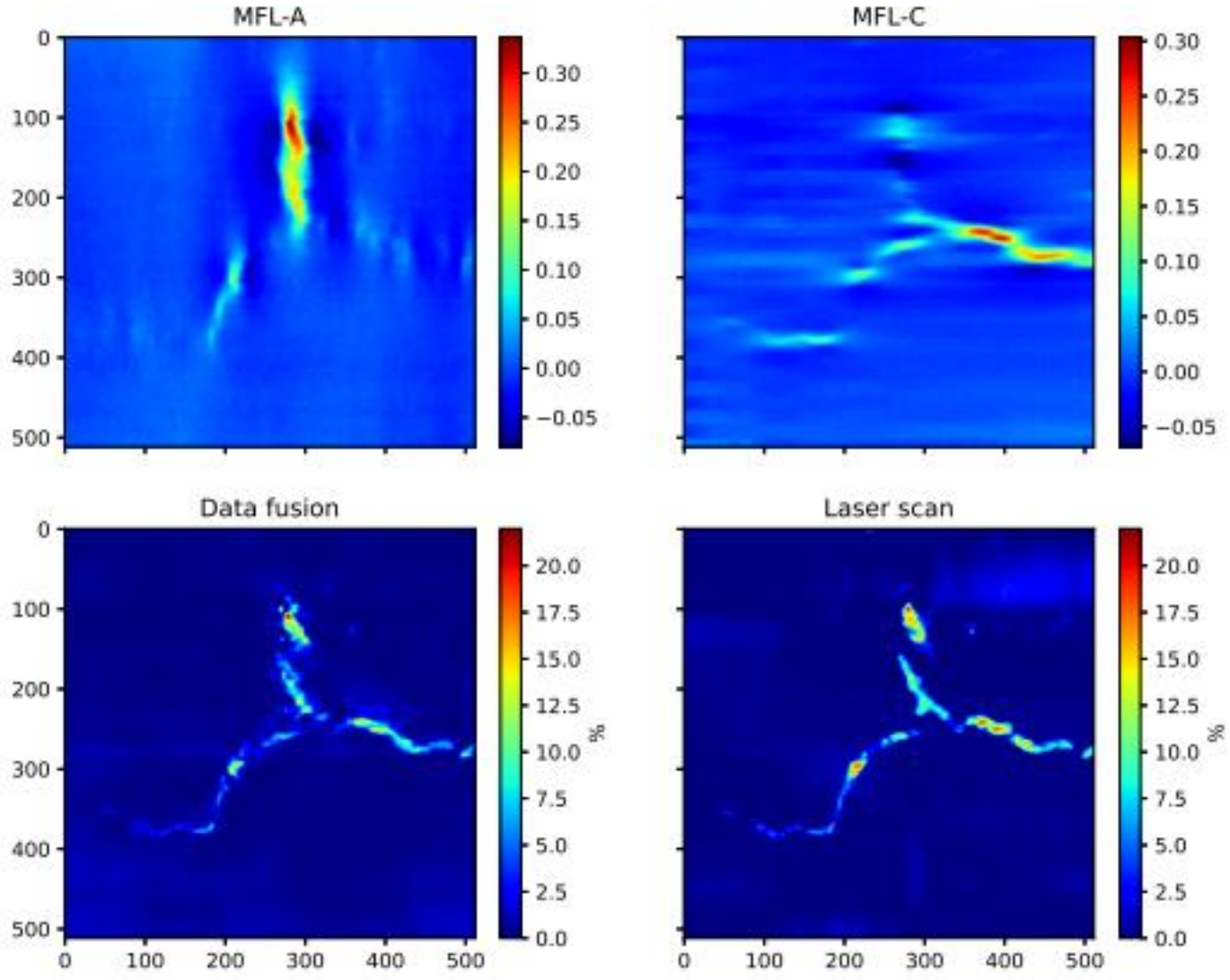
Case 2



Axial Metal Loss

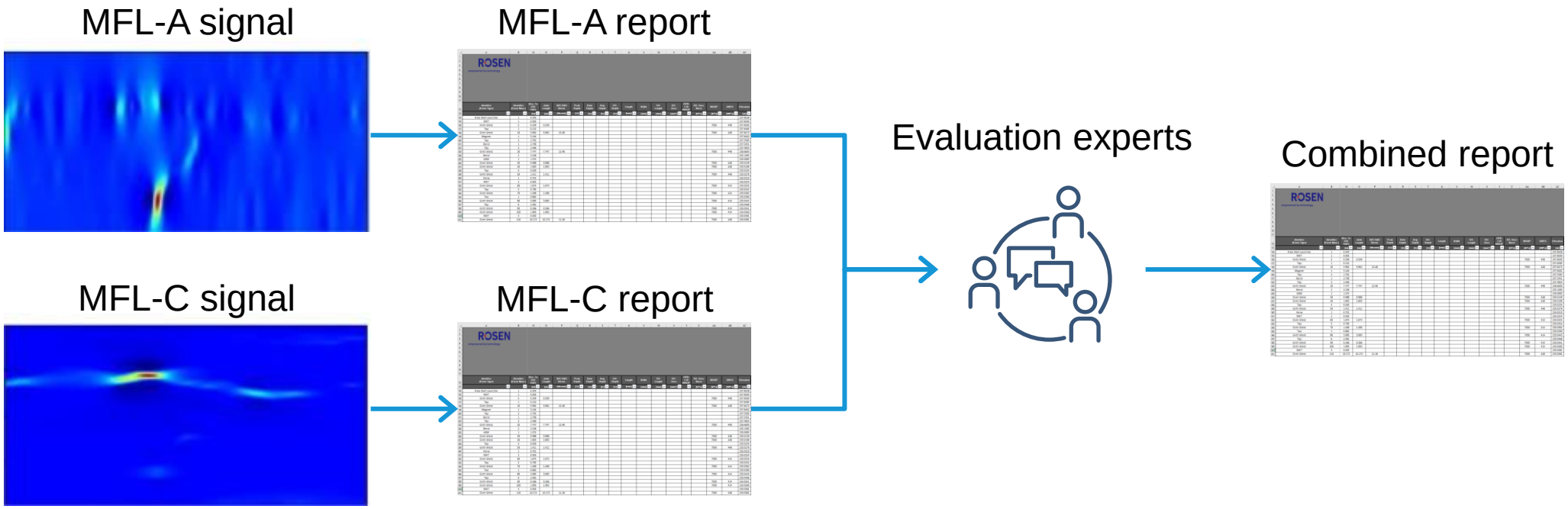
MFL Data Fusion

Characterize all morphologies with high accuracy



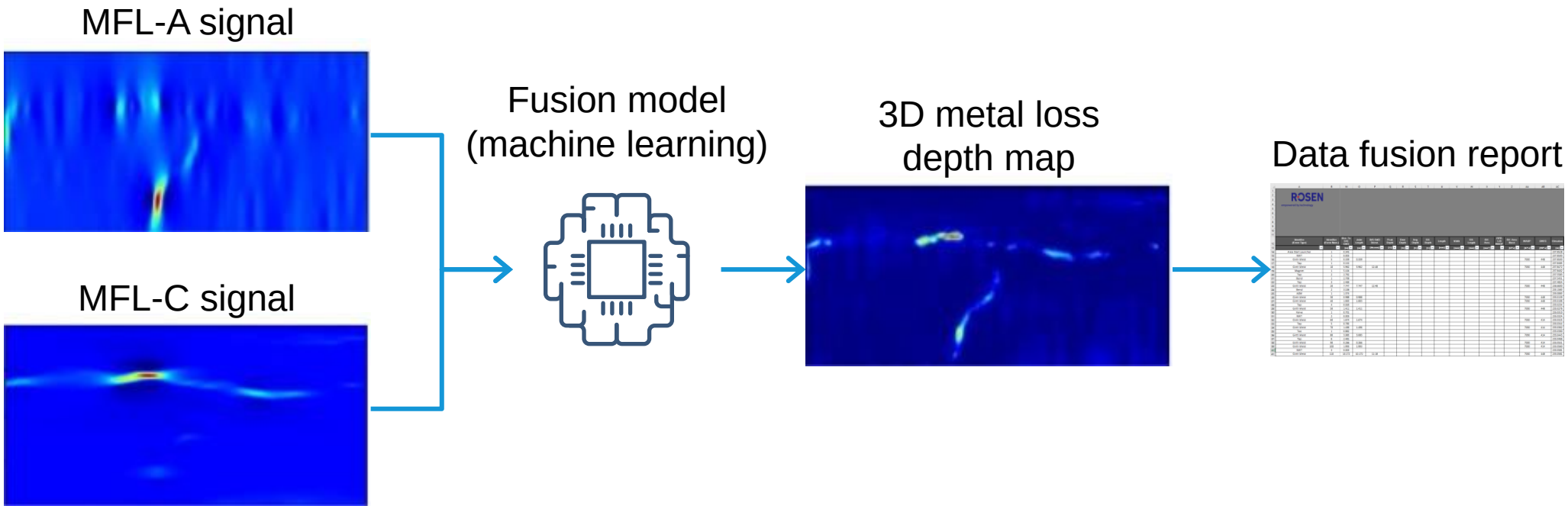
Case 3

Reporting
Current Situation – Combined Reporting



- Subjective
- Time consuming
- Another pipe tally

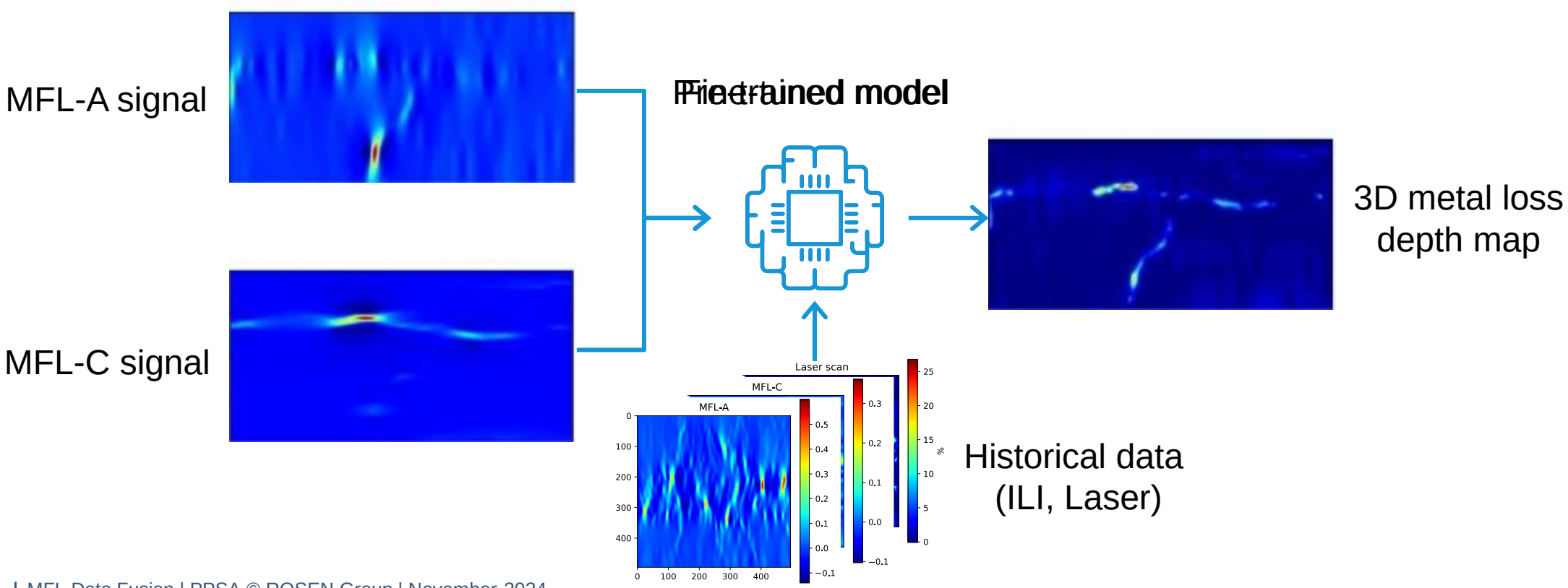
Reporting
New with MFL Data Fusion



- Objective
- Efficient fusion report generation
- Resulting in a 3D metal loss depth map (detailed morphology and depth information)

MFL Data Fusion
Use of Historical Data

- Input: aligned MFL-A and MFL-C signals
- Structure: U-Net
- Fine-tune: making the model specific to the pipeline of interest

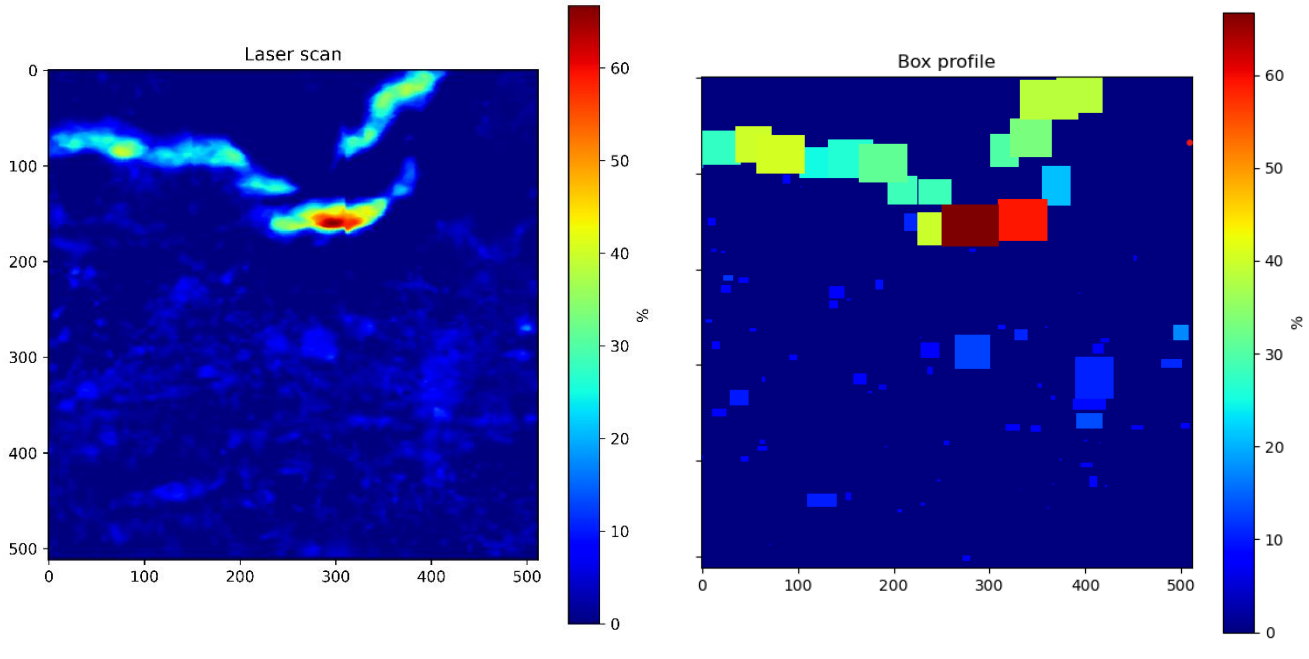


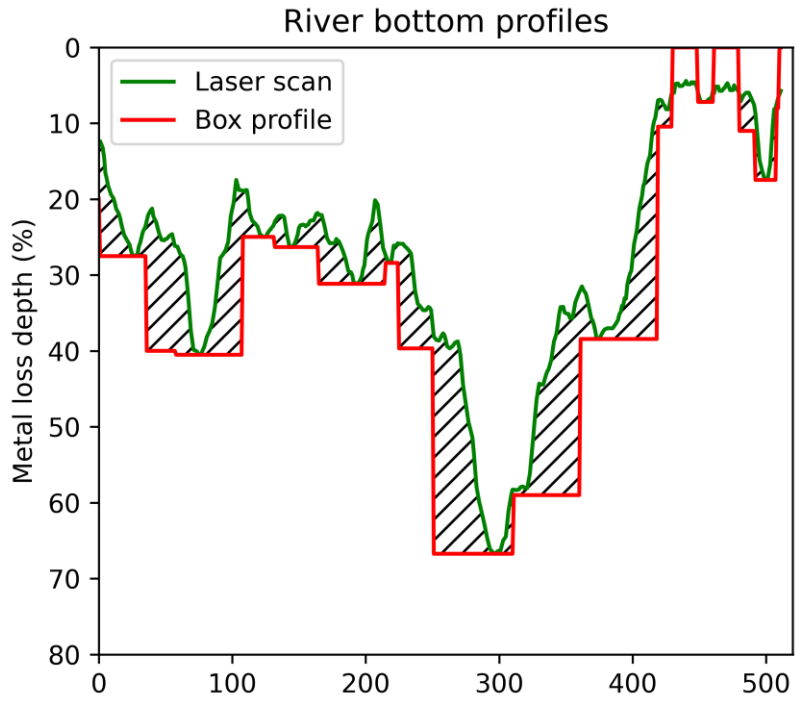
Validation
Depth Accuracy

- Validated results for 21461 anomalies from 6 pipelines
- 97.5% of features were within ±10%
- Calculated tolerance of ±5.19% at 80% certainty
- Slight bias towards oversizing of 1.78%
- Significant increase in accuracy
- Likelihood of +/- 20%:
    - Standard Spec: 1 in 192
    - Data Fusion: 1 in 2.54 million

	Number of features	Bias / *wt*	Tolerance / *wt*	Tolerance interval / *wt*
Pipeline 1	1935	1.96%	+/- 4.41%	[-2.45%, 6.37%]
Pipeline 2	11923	1.62%	+/- 4.19%	[-2.57%, 5.81%]
Pipeline 3	5570	3.79%	+/- 4.2%	[-0.41%, 7.99%]
Pipeline 4	450	-1.05%	+/- 6.56%	[-7.62%, 5.51%]
Pipeline 5	1432	-4.22%	+/- 7.47%	[-11.7%, 3.25%]
Pipeline 6	151	3.12%	+/- 9.76%	[-6.63%, 12.88%]
All pipelines	21461	1.78%	+/- 5.19%	[-3.41%, 6.96%]

Anomalies Reporting
Profiles vs. Boxes

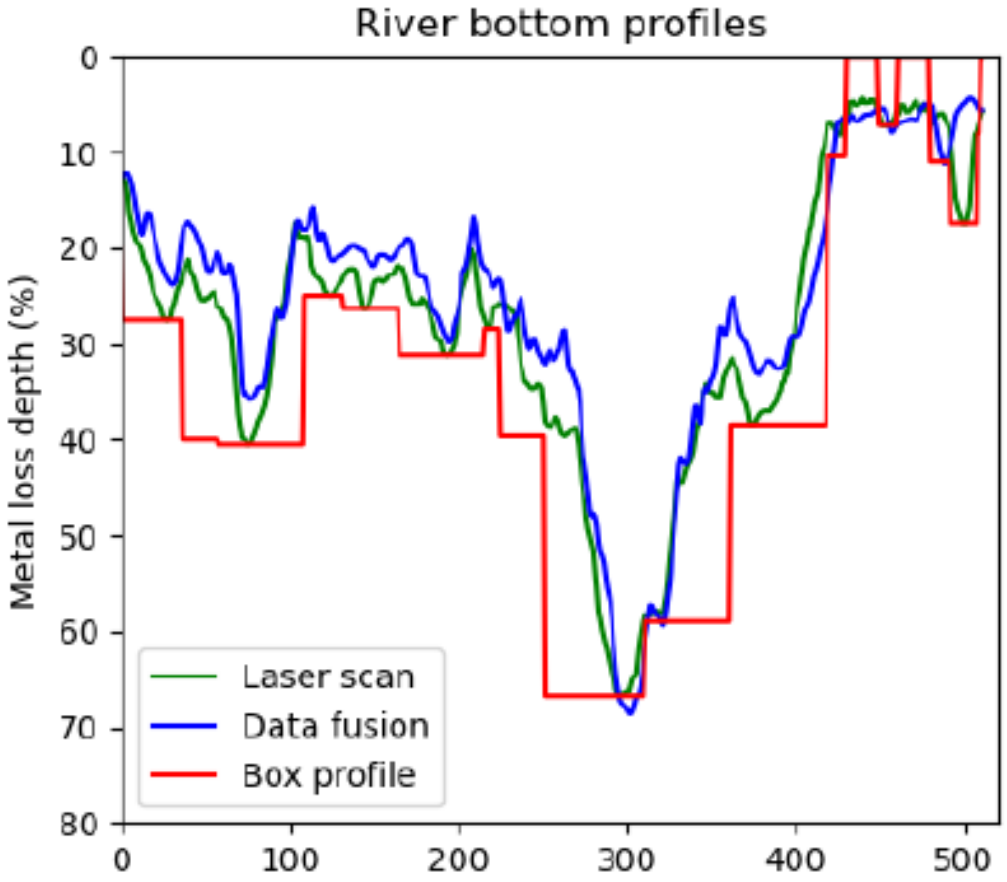




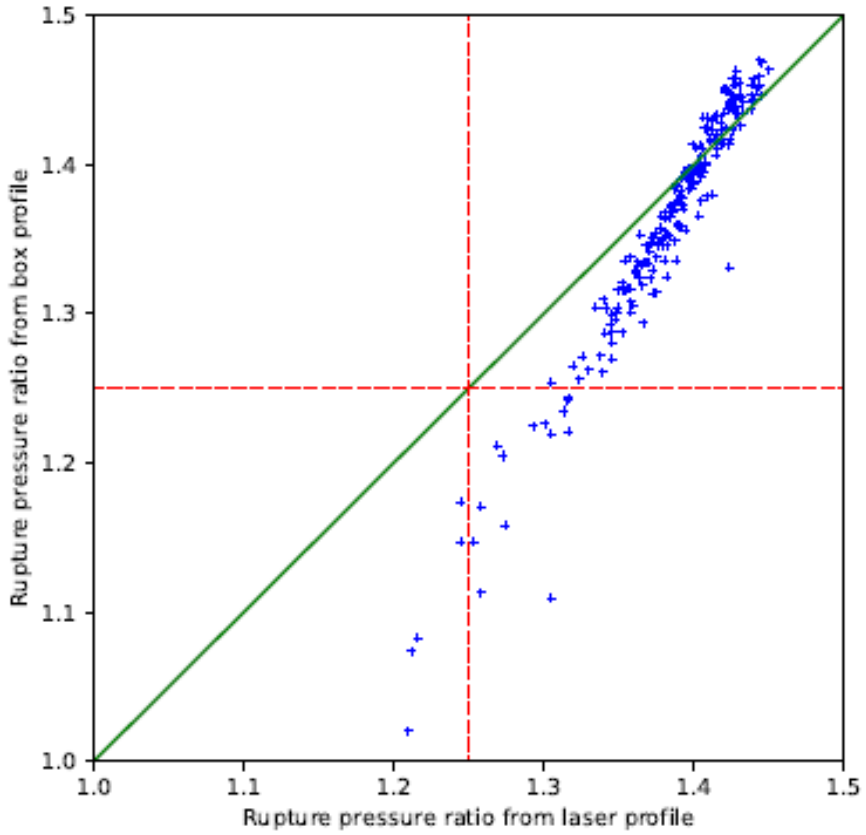
Box profiles are inherently more conservative than 3D depth profile

Results
River Bottom Profiles

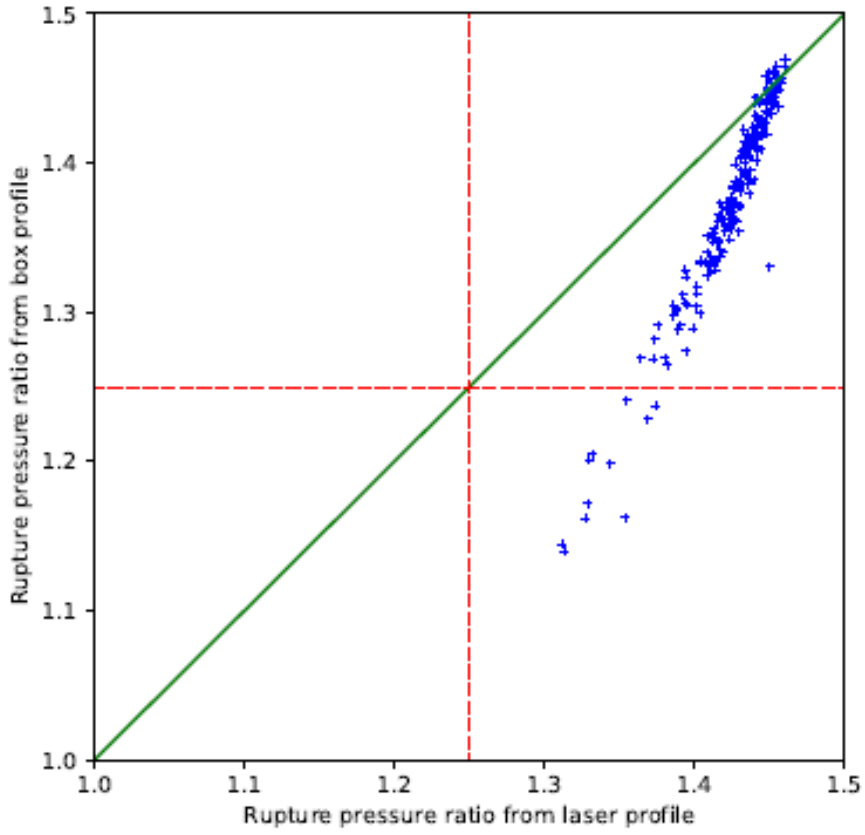
- Data fusion produces laser–like profiles
- Profiles provide access to advanced assessment methods
  - ‘True’ RSTRENG
  - Plausible profiles (P^2)
- Advanced methods provide significant opportunity for investigation/dig reduction
- Increased accuracy provides significant opportunity for optimized investigations/digs



Results
Burst Pressure Boxes vs. Laser



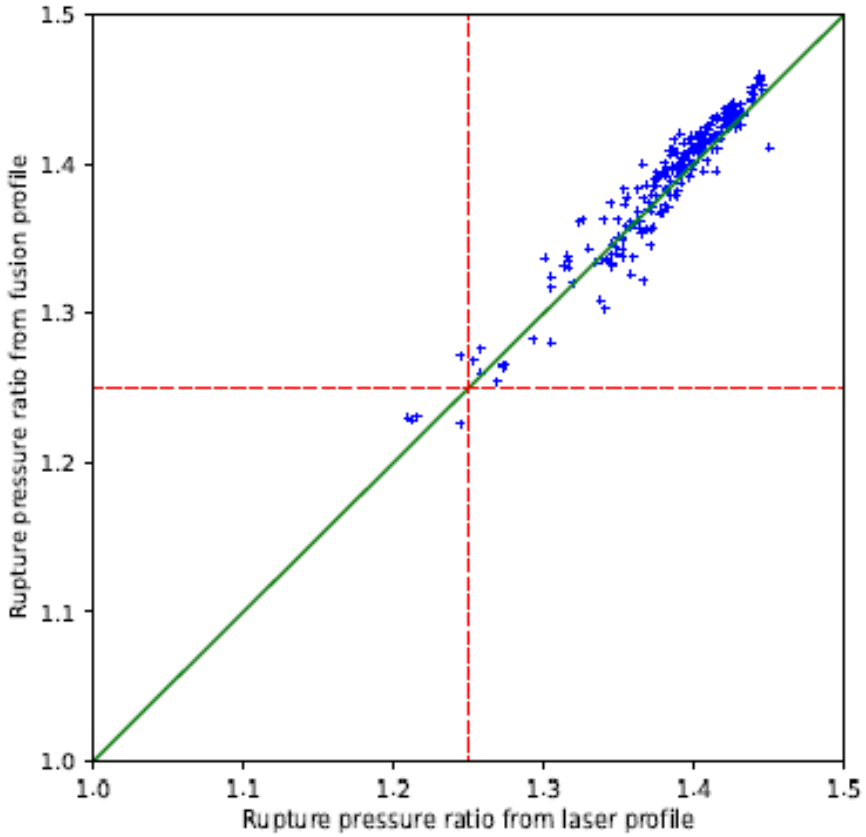
(a) *RSTRENG* for box data vs laser scans



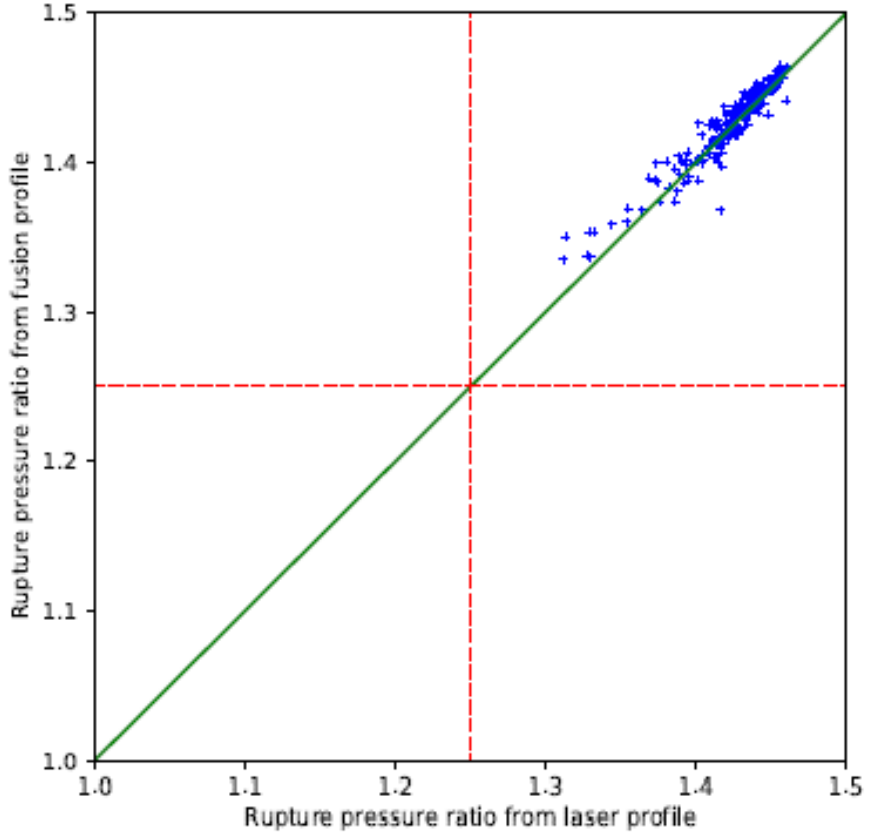
(b) P^2 for box data vs laser scans

Results

Burst Pressure 3D Depth Maps vs. Laser



(c) *RSTRENG* for 3D depth maps vs laser scans



(d) P^2 for 3D depth maps vs laser scans

Safe Remaining Life
Impact of Improved Depth Tolerance

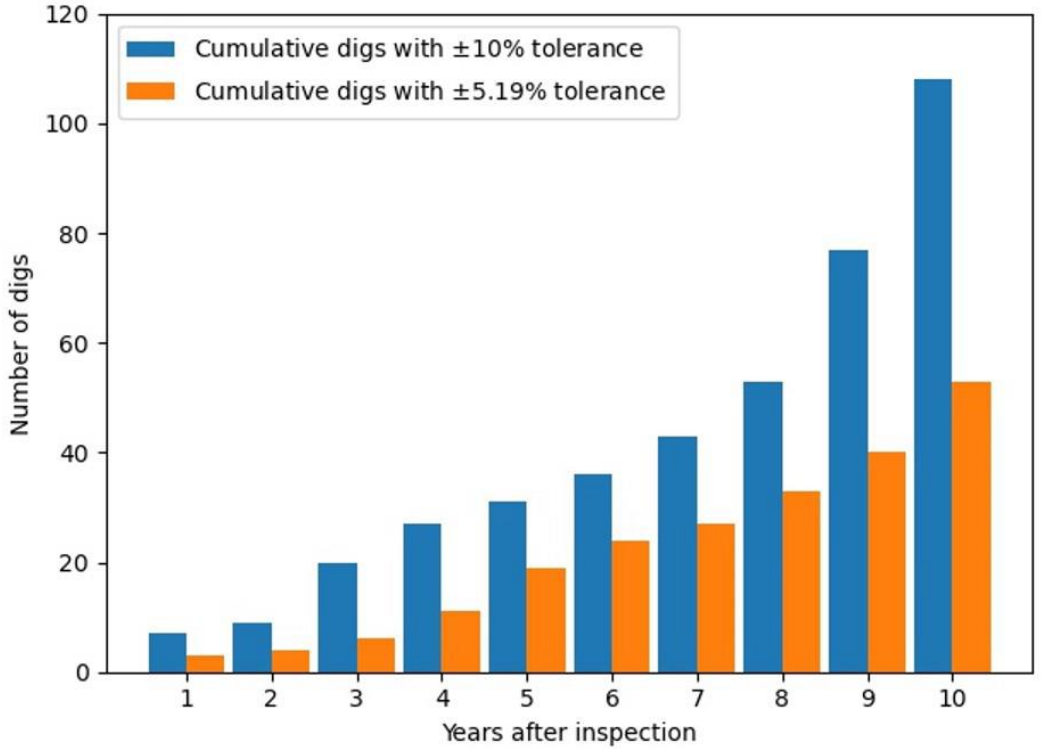
Statistical Study

- Adjust remaining ligament with new tolerance
- Everything else remains the same
  - Modified B31G
  - CGR

Year 1 dig reduction of 4

Year 5 dig reduction of 12
Year 10 dig reduction of 55

Less Depth Tolerance & Optimized Burst Pressure will further enhance digs programs over years.



Cumulatively reduced digs										
Years after inspection	1	2	3	4	5	6	7	8	9	10
Reduction in digs	4	5	14	16	12	12	16	20	37	55

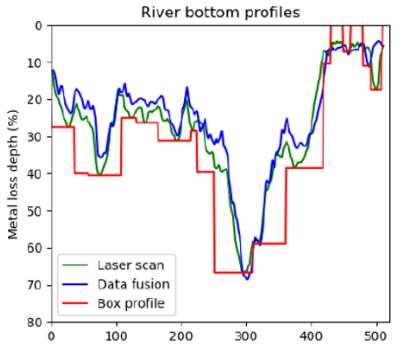
MFL Data Fusion
Conclusion

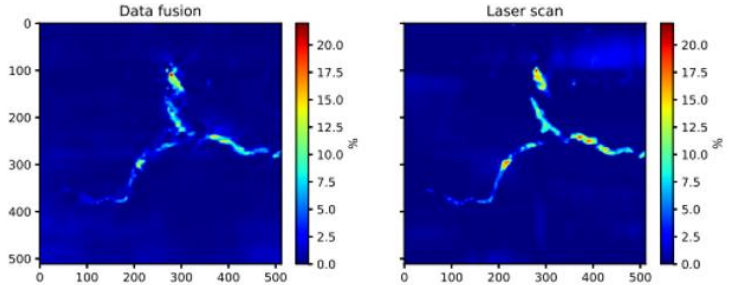
- Data Fusion leverages information from both MFL-A and MFL-C
  - Need Magnetic Field in Axial and Circumferential directions
  - Information will be missing if only one magnetic field direction is used

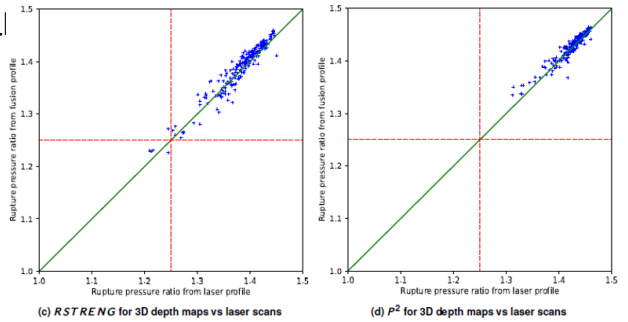
- Data Fusion generates a 3D Depth Profile
  - UNET Neural network
  - Efficiently for the entire line

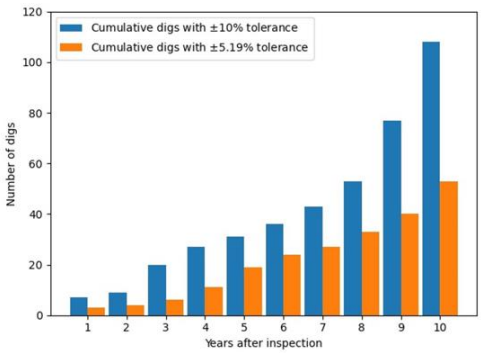
- Increased certainty in depth measurements
  - API 1163 Level 3 - ±5.19% at 80%
  - Reduces the number of digs in a safe remaining life a

- Non-conservative failure pressure calculations
  - Fusion Profiles do not need to be boxed









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