# Maximising Accuracy of MFL Pipeline Inspection

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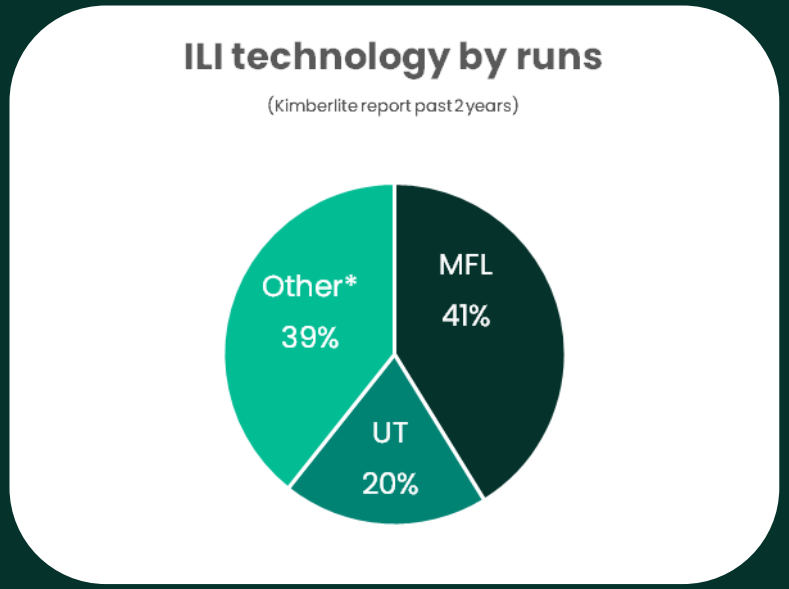
PIGGING PRODUCTS & SERVICES ASSOCIATION

# Introduction

## Pipeline Operator Challenges:


## Role of Inline Inspection (ILI):

- Significant contribution to input data
- Contributing since the 1970s
- **Reliable & Accurate** data has a major impact in pipeline integrity management outcomes




- MFL technology is most run ILI service
- Vehicle / Hardware gets most focus
- Other factors play important role in providing **reliable and accurate data:**
  - ✓ Software & feature recognition
  - ✓ Data analysis: People & Process
  - ✓ Algorithms & sizing models
  - ✓ Performance validation, verification & improvement

* Other = Hi/low res Caliper, Eddy current, etc

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# Maximising accuracy of MFL pipeline inspection

Introduction

**1. Accuracy**

2. The inspection vehicle

3. Software & feature recognition

4. Data analysts & the data analysis process

5. Algorithms & sizing models

6. Performance validation, verification & improvement

Conclusions




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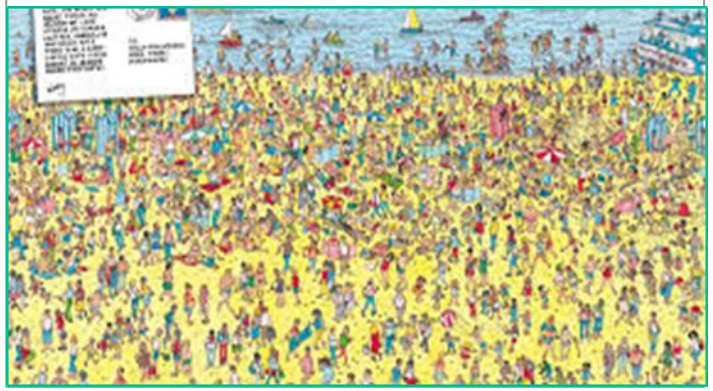
# MFL Accuracy

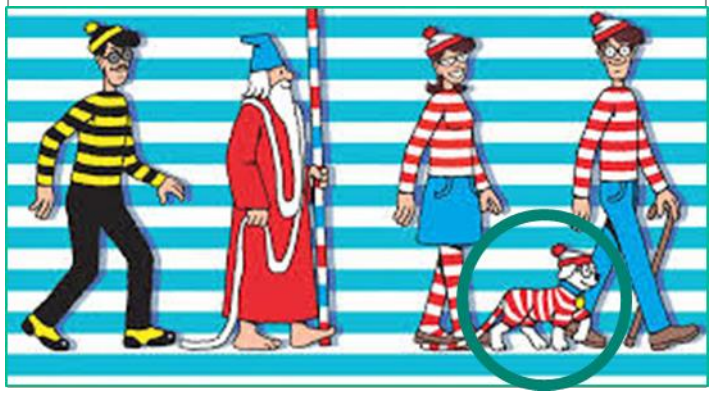
Detection or **POD**

***Will 'it' be seen?***



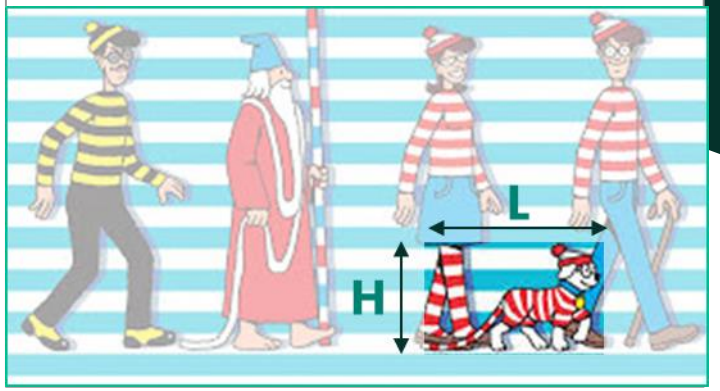
Identification or **POI**

***What is 'it'?***



Sizing or **POS**

***What size is 'it'?***







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# Accuracy

Detection or **POD**

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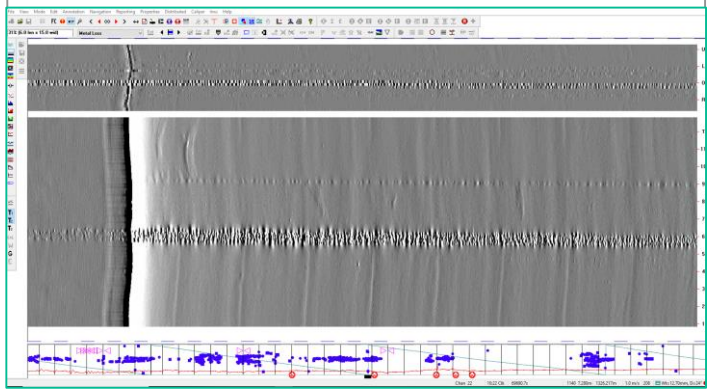

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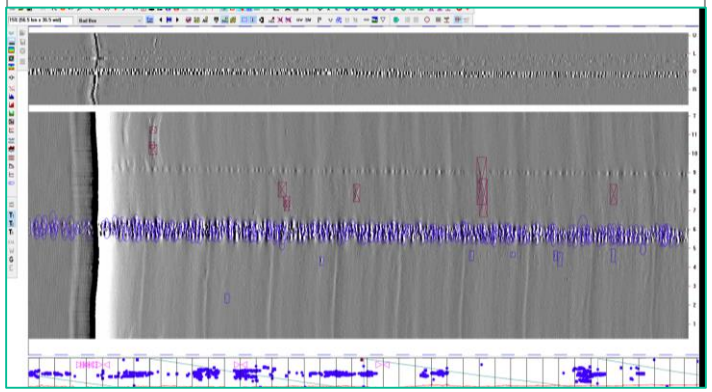

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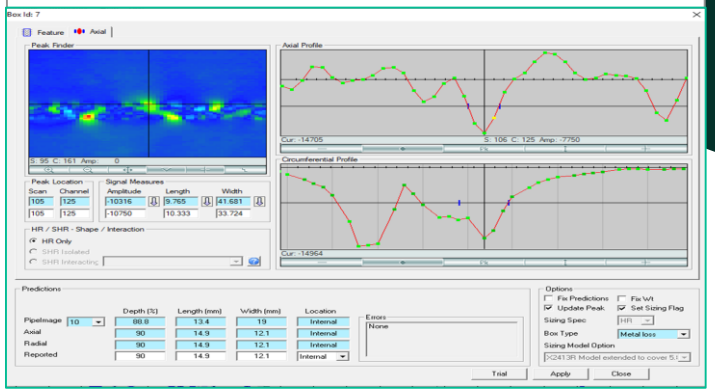
***What size is 'it'?***



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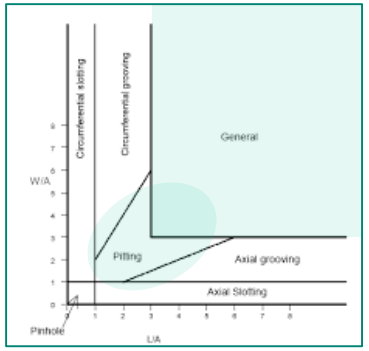
# Accuracy evolution

## 1990s

| | METAL LOSS CATEGORY | | |
|---|---|---|---|
| | Pitting <(3tx3t)* | General >(3tx3t)* | Gouging |
| Minimum Depth for Accurate Sizing | 0.5t with surface dimension greater than: (t/2+10mm)x(t/2+10mm) | 0.3t | If w>2t or 15mm**=0.5t<br>If w>3t or 25mm**=0.3t |
| Sizing Accuracy *(Depth)* | ±0.2t | ±0.15t | If w>2t or 15mm**=±0.2t<br>If w>3t or 25mm**=±0.15t |
| Sizing Accuracy *(Length)* | ±10mm | ±20mm | ±20mm |
| Location Accuracy *(Axial)* | ±0.2m between the feature and the reference girthweld and ±1% of stated distance between reference upstream girthweld and identification location reference | | |

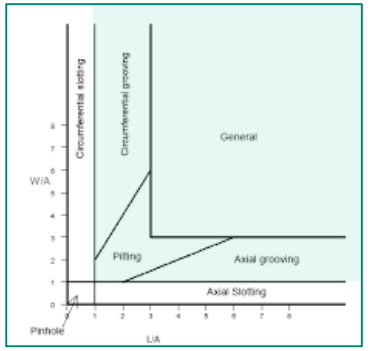
- Detect pits from 50% wt
- Detect GML from 30% wt
- Depth sizing from +/-15%
- No width sizing accuracy
- **Pre-POF defect types**




## mid 2000s

| Property | Full detection and sizing accuracy or metal loss in body of pipe | | | | |
|---|---|---|---|---|---|
| | Certainty (Probability) | General Metal loss | Pitting | Axial Grooving | Circumferential Grooving |
| Min. Depth At 90% POD | | 10% | 20% | 20% | 10% |
| Depth Sizing Accuracy | 80%<br>90% | ±10%<br>±15% | ±10%<br>±15% | -15%/+10%<br>-20%/+15% | -10%/+15%<br>-15%/+20% |
| Width Sizing Accuracy | 80%<br>90% | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm |
| Length Sizing Accuracy | 80%<br>90% | ±15 mm<br>±20 mm | ±10 mm<br>±15 mm | ±20 mm<br>±25 mm | ±20 mm<br>±25 mm |

- Detect pits from 20% wt
- Detect GML from 10% wt
- Depth sizing from +/-10%
- Width sizing as std
- **Valid for 4 POF defect types**

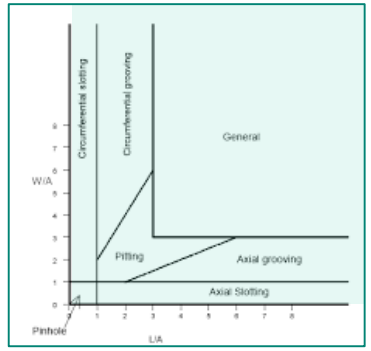



## Today (2019)

| | | General metal loss | Pitting | Axial grooving | Circumferential grooving | Pin hole | Axial slotting | Circumferential slotting |
|---|---|---|---|---|---|---|---|---|
| Reference dimensions (length x width) | | 4t x 4t | 2t x 2t | 4t x 2t | 2t x 4t | 0.5t x 0.5t | 2t x 0.5t | 0.5t x 2t |
| Super High Resolution *Plus* | Min. Depth At 90% POD | 4% | 6% | 6% | 4% | 13% | 13% | 4% |
| | Depth Sizing accuracy | ±8% | ±8% | -13%<br>+8% | -8%<br>+13% | -13%<br>+8%* | -18%<br>+8% | -8%<br>+13% |
| | Width Sizing accuracy | ±12mm<br>±0.47 in | ±12mm<br>±0.47 in | ±12mm<br>±0.47 in | ±12mm<br>±0.47 in | ±7mm<br>±0.28 in | ±12mm<br>±0.47 in | ±12mm<br>±0.47 in |
| | Length Sizing accuracy | ±7mm<br>±0.28 in | ±4mm<br>±0.16 in | ±7mm<br>±0.28 in | ±7mm<br>±0.28 in | ±4mm<br>±0.16 in | ±7mm<br>±0.28 in | ±7mm<br>±0.28 in |

- Detect pits from 6% wt
- Detect GML from 4% wt
- Depth sizing from +/-8%
- **Valid for 7 POF defect types**

+ other anomalies…







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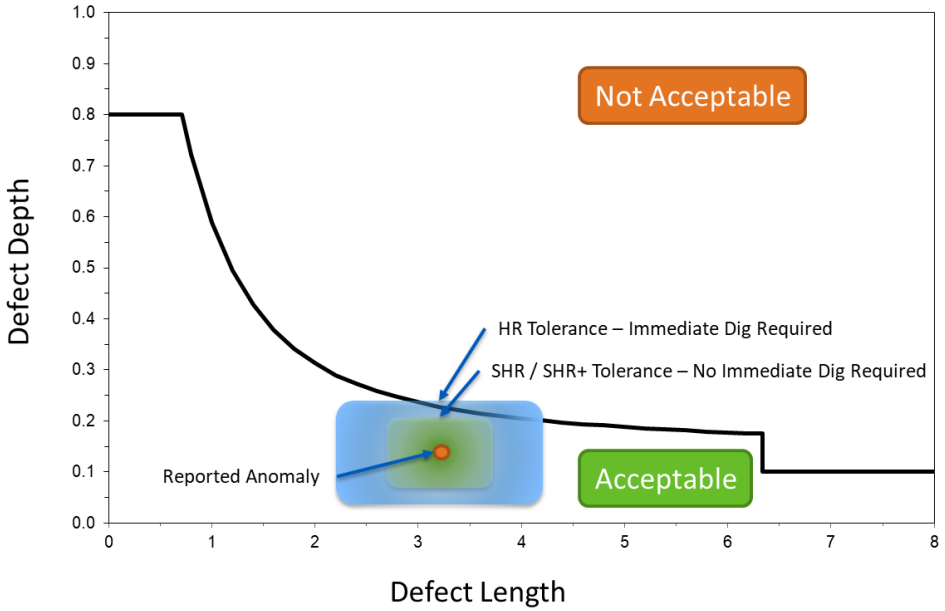
# Impact of changing MFL accuracy

## North America pipeline example:

### Effect of improved accuracy on a single defect:




### How this affects inspection results & outcome:

| Immediate Dig Criteria | HR Specification | SHR or SHR+ specification |
|---|---|---|
| ≥ 70% | 16 | 29 |
| RPR ≤ 1.00 | 71 | 51 |

13 additional safety related immediate digs found

20 unnecessary digs removed

**In this example:**

- ✓ Caught additional potential health & safety risks
- ✓ 20 unnecessary digs removed. At $25k/dig, **saving = $0.5M**

**Investing in ILI accuracy upfront leads at least 10x saving later**

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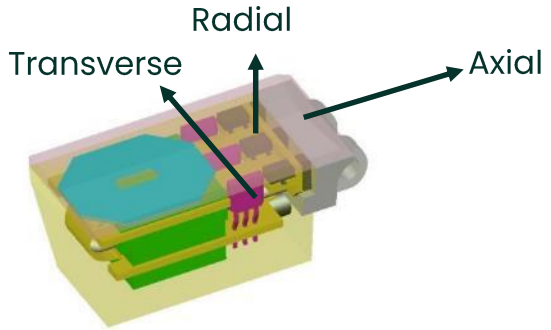
# Inspection Vehicle

## MagneScan

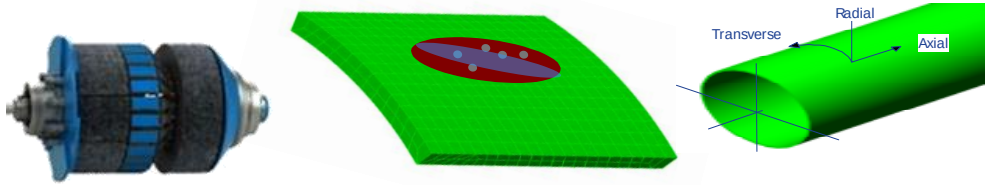
Example: 6” MagneScan system delivering ‘Super High Resolution Plus (SHRP) service

## VECTRA Gemini

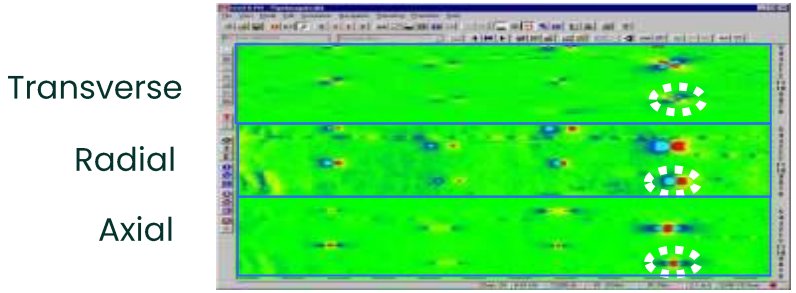
Example: 24” VECTRA GEMINI system delivering ‘HD’ service




High density multiple ‘Triax’ sensor head




Optimised Magnetizer (ride, geometry, dynamics)




Synthesised interpretation to maximise insight and measures

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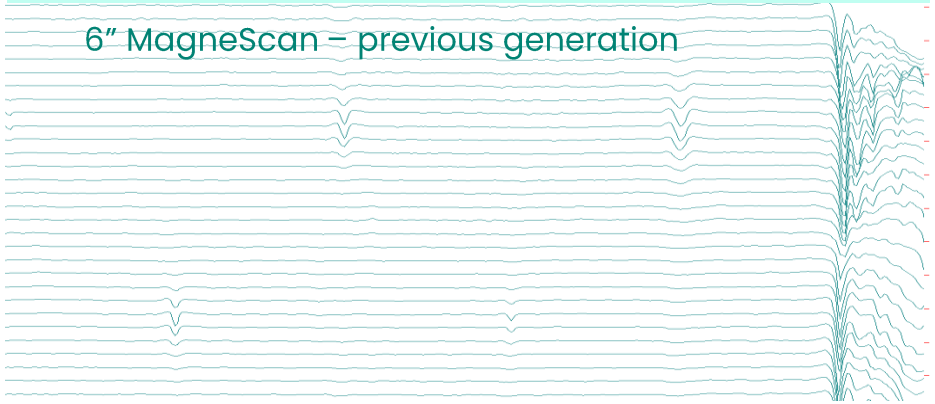
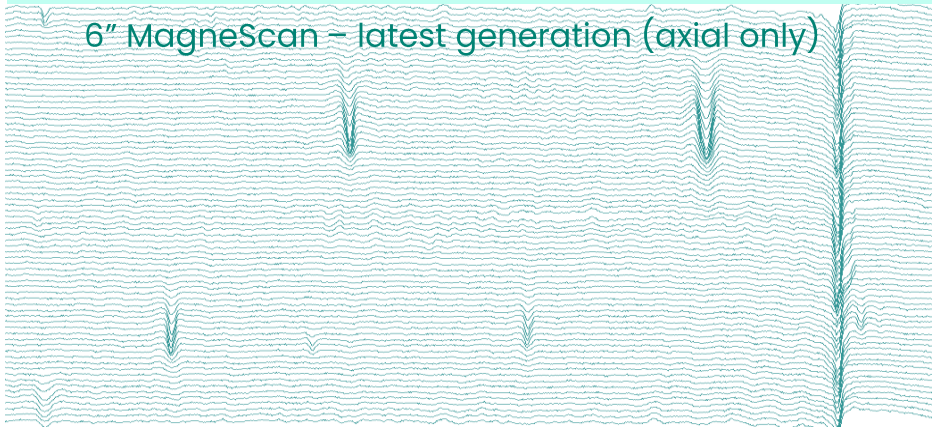
# MagneScan example

## 30 tracks recorded every 3.3mm




## 72 tracks recorded every 2mm







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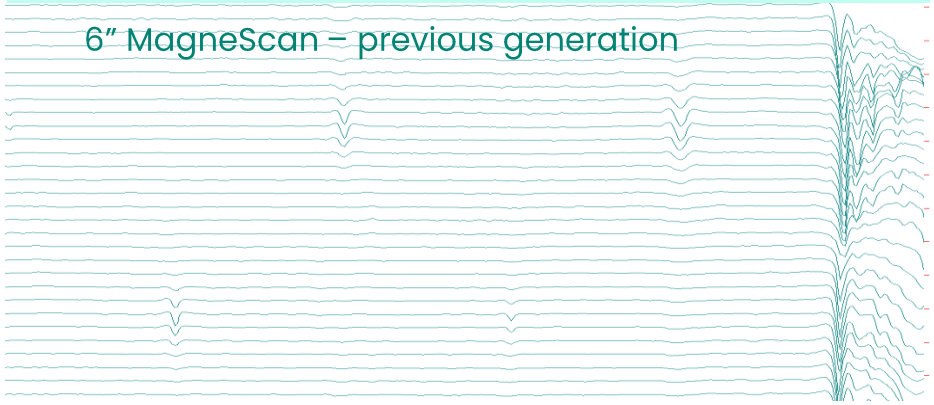
# MagneScan example

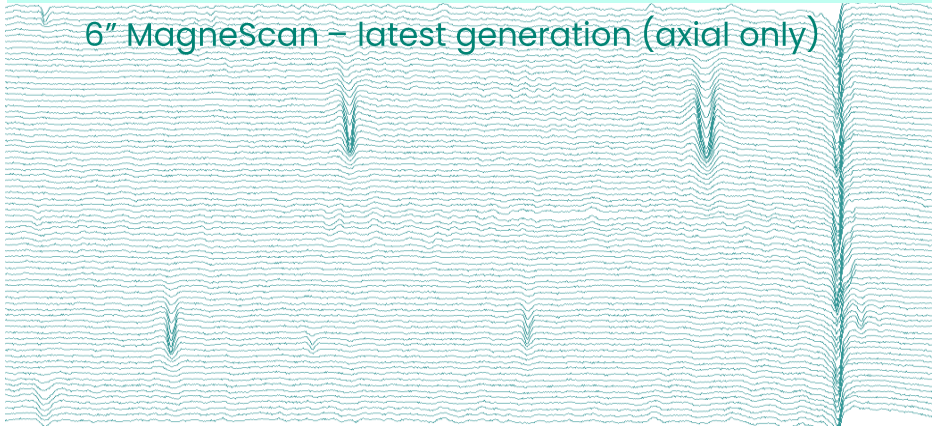
## 30 tracks recorded every 3.3mm

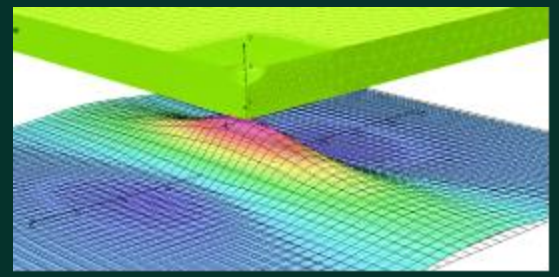
6" MagneScan – previous generation



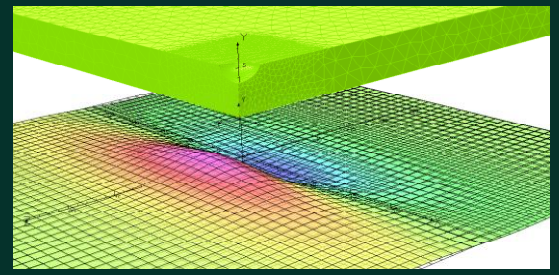
## 72 tracks recorded every 2mm

6" MagneScan – latest generation (axial only)

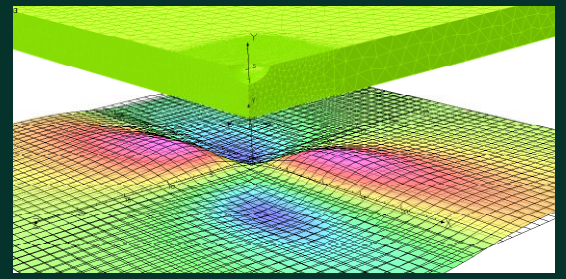




**Axial MFL** Component of Pinhole feature



**Radial MFL** Component of Pinhole feature



**Transverse MFL** Component of Pinhole feature

**Research Conducted:**

- Pull testing data compared with **extensive FEA models**
- **Wide range** of defect types
- **Optimal sensor density** identified
- **'Tightening the net' further** will not significantly improve sizing performance

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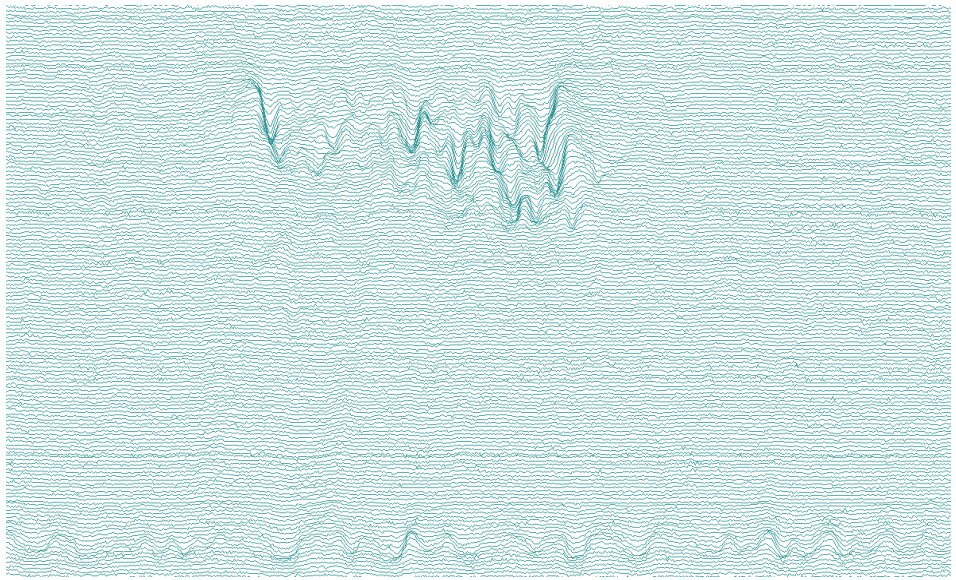
# MFL Data



e.g. typical sample of external corrosion

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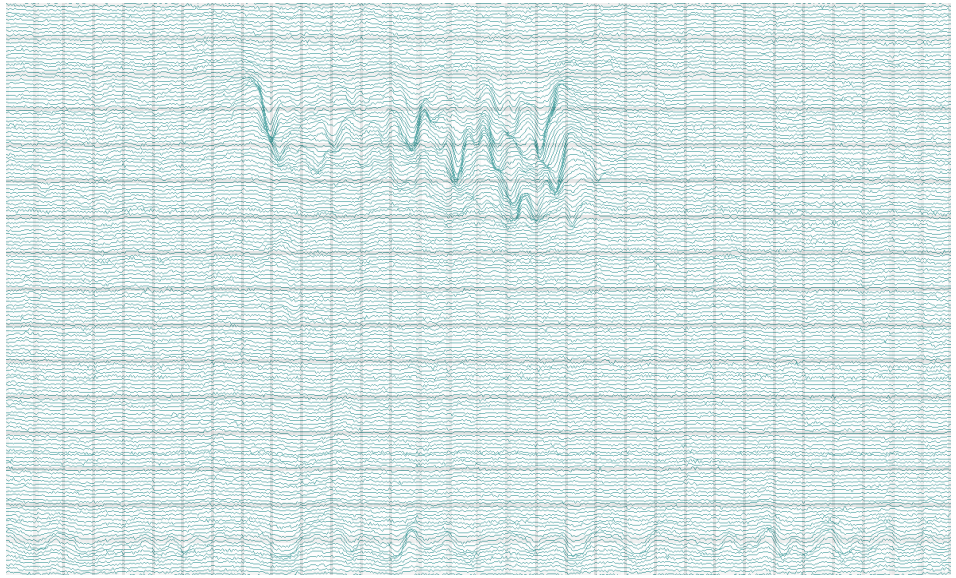
# MFL Data



Note: Grid for illustrative purposes only. Not representative of true scan/spacing dimensions

e.g. **100km pipeline**:

- +500 pixels high (# of sensors)
- 50 million pixels wide (# of scans)
- 100s GB of raw data
- Looking for defects as small as 5mm x 5mm

  (seeing even smaller 2mm x 2mm)

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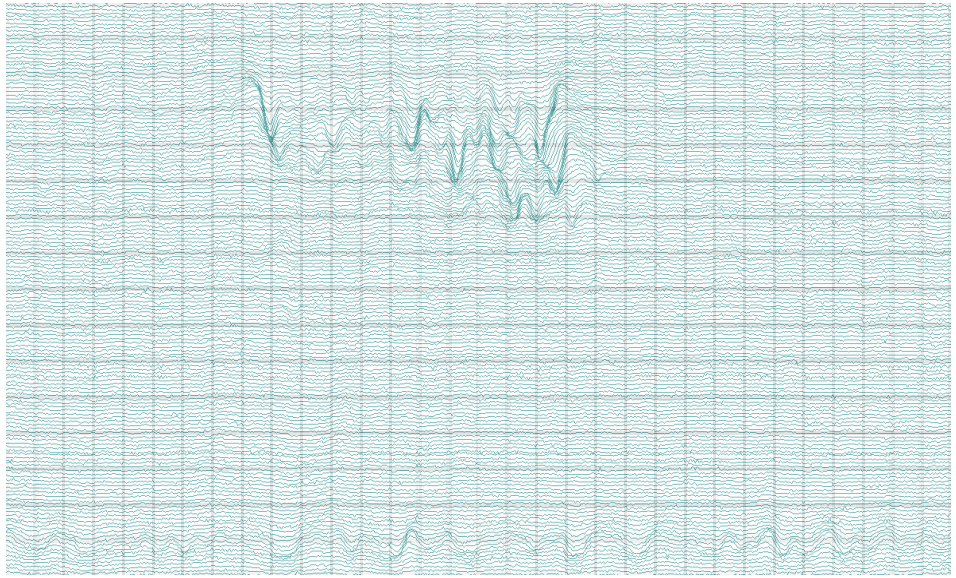
# MFL Data



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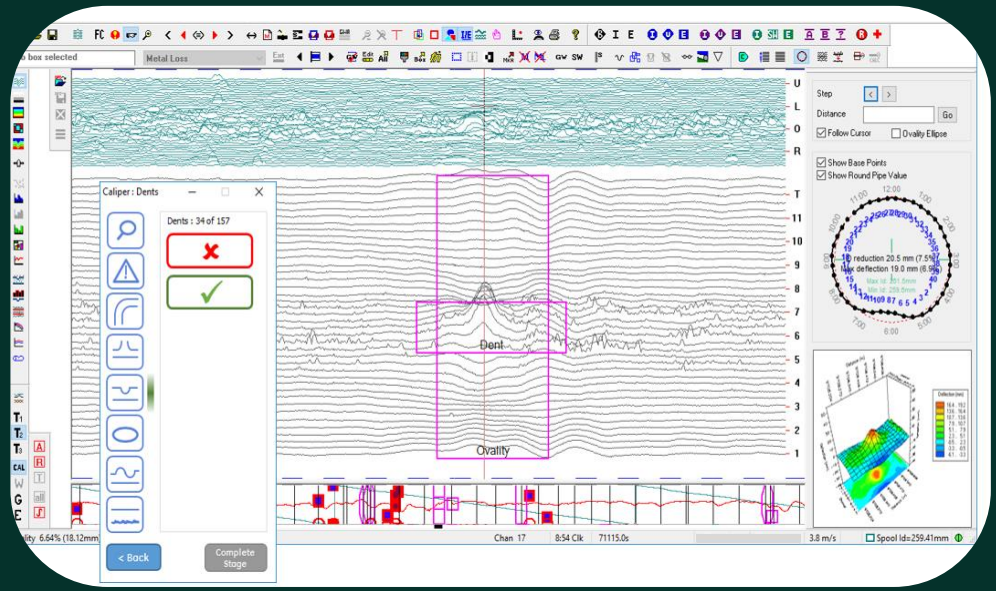
# Software & Feature Recognition

**Goals:**

- ✓ Identify
- ✓ Classify
- ✓ Quantify
- ➢ Allow the Data Analyst to **focus** on most **critical features** and where **manual expertise** adds most value

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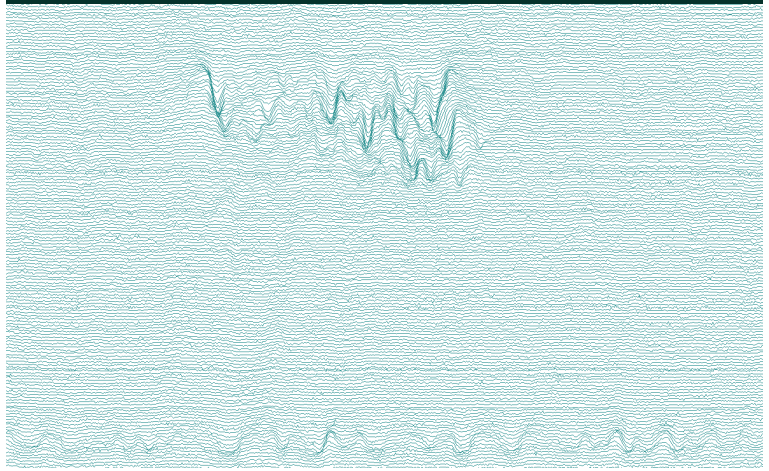
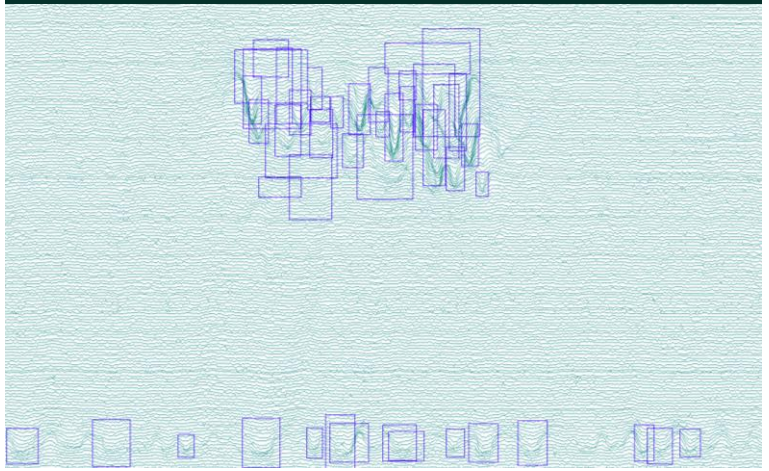
# ‘Boxing’ Corrosion

## Detect



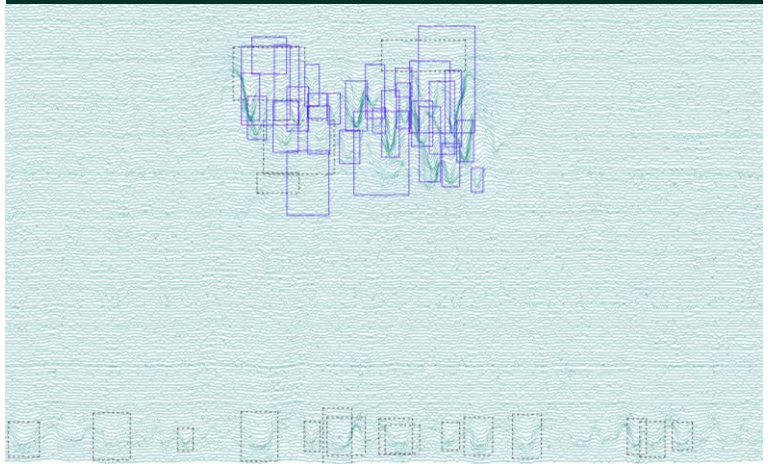
- Typical area of external corrosion
- Seam weld indication

## Identify



- Software ‘boxes’ every area it thinks is corrosion
- Making an ‘internal / external’ call

## Classify



- ✓ Removing the seam weld boxes
- ✓ Removing the ‘false’ metal loss boxes

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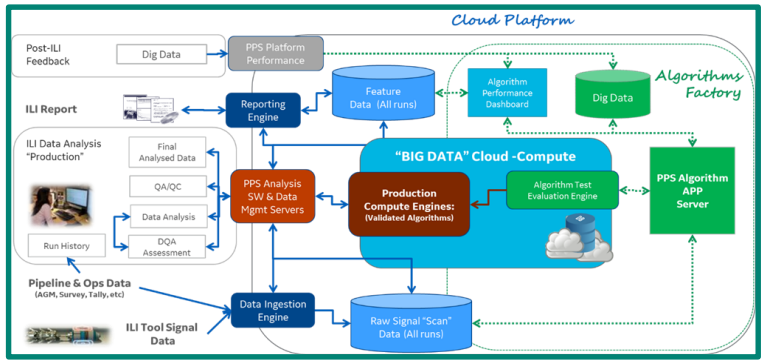
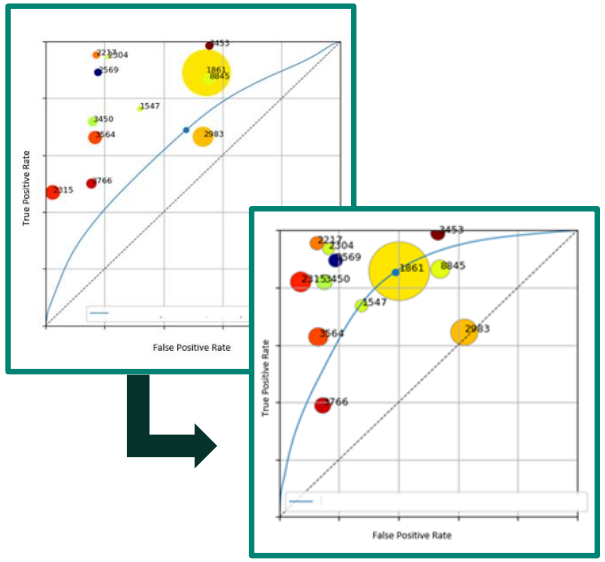
# ‘Big Data’ Supporting the evolution

## Cloud Architecture




- Scalable, fast, secure
- Baker Hughes has 1PB of historic data
- 1 billion signals validated by analysts
- Metal Loss detection using **250,000,000** detected features

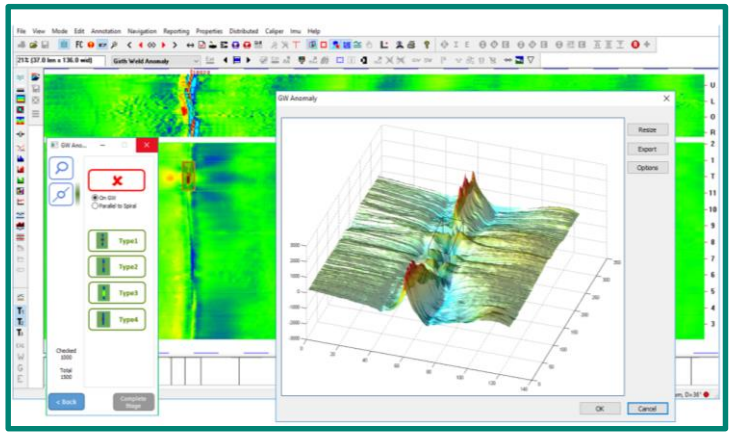
## Continuous Improvement




- Managing sensitivity to pipeline variations
- Measuring and ensuring repeatability
- Updating & Improving performance over time

## ‘New Features’

Girth Weld Anomalies



- Being developed on challenging data set
- High volume of ‘black’ or poorly constructed welds
- Allowing focus on the ‘real’ pipeline threats

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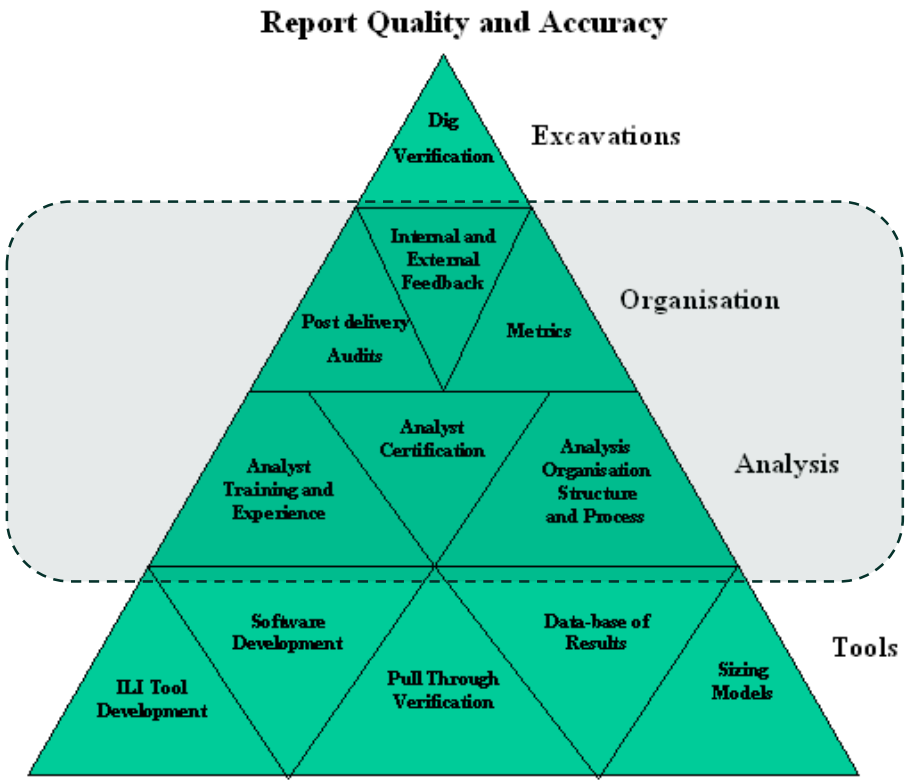
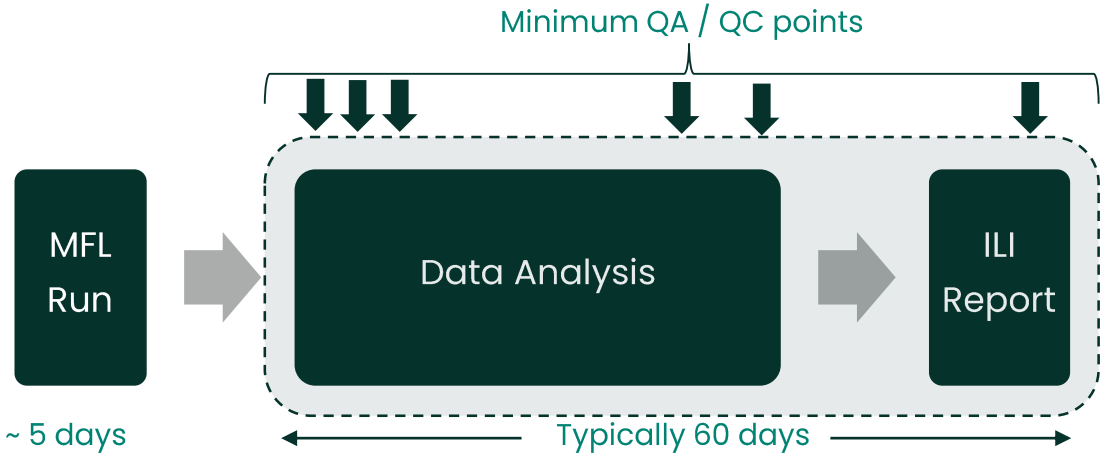
# Data Analysis: Process




Holistic View of factors influencing ILI report Quality




- Typically 60 days from receipt of data (or up to 100 days for +150km)
- Every inch of pipe is visually assessed
- Software & feature recognition helping analysts focus on areas of importance
- Multiple QA/QC checkpoints
- **Right people / Robust Process**

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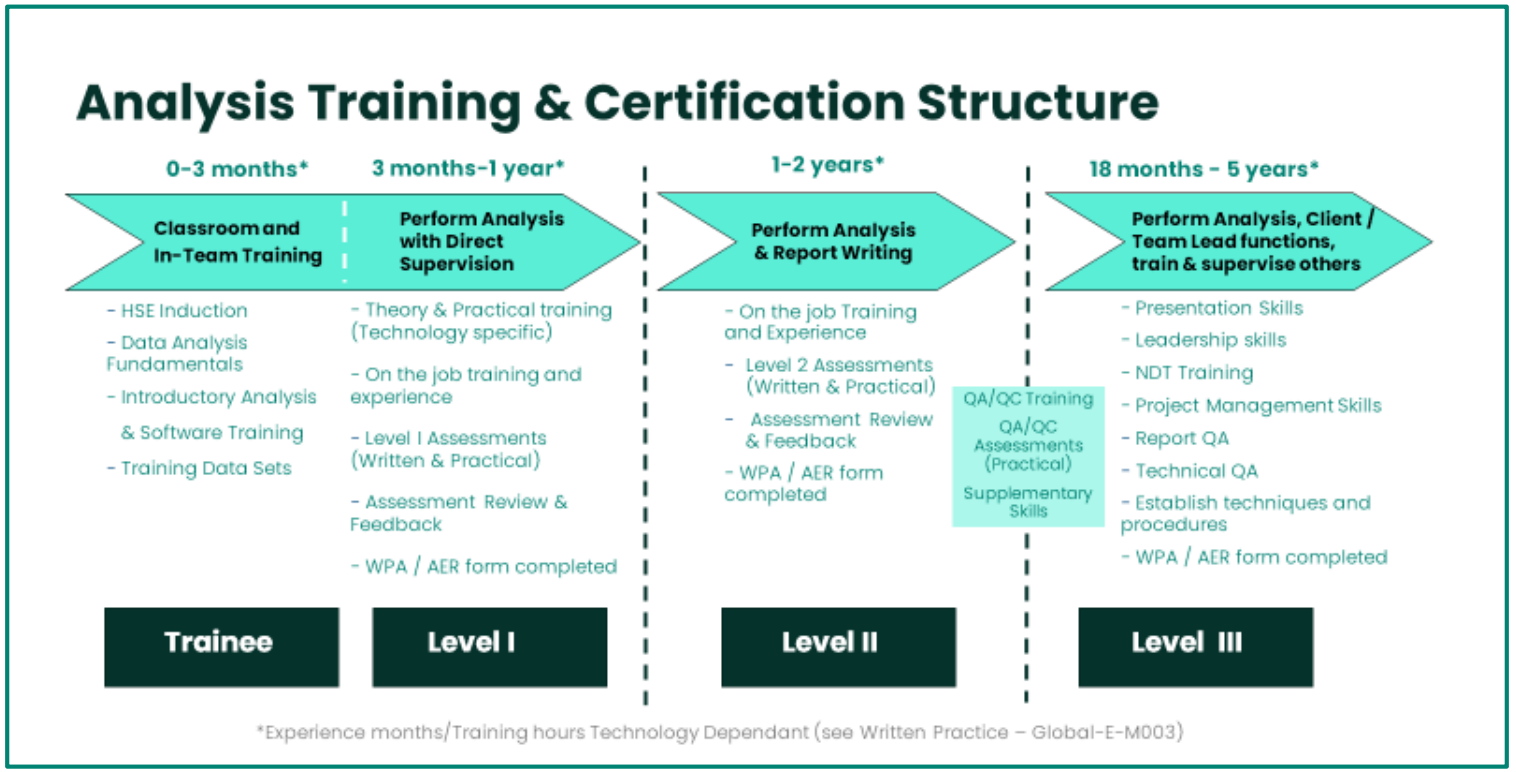
# Data Analysis: People

- **Recruitment**
  - Right 'minds' for the job
  - SC/ENG Degree qualified
- **Training**
  - Long term investment
  - Global standard
  - On-job
- **Ongoing Assessments**
  - Re-certification every 2 years
- **Long term career paths**
  - Different technologies
  - Additional skills
  - SMEs
- **Report Audits**
  - Included in company KPIs
  - Conducted regularly

Global ILI Analyst training




| Level | Experience (months) | Training (hrs) | Formal Education |
|---|---|---|---|
| Level I | 6 | 80 | Degree Qualified |
| Level II | 18 | 160 | Degree Qualified |
| Level III | 36 | 500 | Degree Qualified |

<- Baker Hughes MFL qualification & certification requirements

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# Example: Report Audits

- ✓ Report audit program implemented across **all ILI technologies**
- ✓ Each analysis centre leads the yearly audit programme, **governed by global technology lead**
- ✓ **Yearly target: 2% global MagneScan reports**
- ✓ RCA conducted on all learnings
- ✓ Conducted on top of all other Quality reviews:
  - ➢**Concerns**
  - ➢**QMS findings**
  - ➢**Customer feedback**
  - ➢**External Audits**

## Example Report Audit from 2018

| | | |
|---|---|---|
| **Auditor Name:- Matias Alfonso** | | **Analysis Center: - Calgary** |
| **Contract Number:- 450242_10A** | | **Client: - XXX** |
| **Date of Audit:- 14 Nov 2018** | | **Region: - Canada** |
| **Re-issue required:- No** | | **Date of re-issue (if applicable):- N/A** |
| **Feedback Date:- N/A** | | |

| | Defects | Comments |
|---|---|---|
| **QMS** | 0 | All sections completed in the QMS |
| **Prelim** | 0 | No Prelim Report delivered fo[redacted] No feature meets prelim requirments. |
| **Report** | 6 | Disprepancy found in the deepest dent reported (11.11% data vs 10.61% report).<br>A comment about the 1.3 hs pig stop should had been included in the executive summary.<br>Incorrect Draft Listing date included in the report, should be Jan 24 2018.<br>Previous inspection was carried out between 30 and 31 May 2012, not on 31 May 2012.<br>Dent evaluation threshold in the report is 1% but we reported everything greater than 0.5%.<br>There is a Check Valve (GW 25760) and the section is not included.<br>Comment - Not sure where "Construction Year" was confirmed |
| **E'Delivery Analysis** | 0 | Ok |
| **Metal loss** | 0 | Ok |
| **Inspection Sheets** | 0 | No inspection sheets required |
| **Wall Thickness** | 0 | Ok |
| **Pressure Sentencing Parameters** | 1 | Comment - Different MAOPs found in the line.<br>Not client confirmation found regarding background:10% used. |
| **Dents & GMA** | 1 | Incorrect GW association on dent located in GW 20980. |
| **GWA** | 0 | No GWA reported |
| **Mob** | 0 | Correct |
| **Ecc** | 0 | No Ecc casing reported. |
| **Repairs** | 0 | Correct |
| **Valves** | 0 | Correct |
| **O/T** | 0 | Correct |
| **Bends** | 0 | Correct |
| **Other Fittings** | 0 | Correct |
| **One km Data check** | 0 | Correct - Range: 18740 to 19740m |
| **One km Data check for boxes** | 0 | Correct - Range: 18740 to 19740m |
| **Comparison** | 2 | Incorrect # of previous dents informed in Comparison Table, should be 15 dents not 13. Consecuently dent comparison comments are incorrect. |
| **Pipe Types** | 0 | Correct |
| **Overall Score** | **10** | |

**Analysis Acceptable if Overall Score < =10 providing none of the errors warrant a re-issue (for example a dent with metal loss has been missed)**

If Overall Score is > 10 then detailed feedback to be provided to the analyst and QA checker and consideration should be given to whether the report should be re-issued
Explanations for the errors should be documented and filed with the audit report.
All re-issues should be entered into the feedback tab within Edelivery
All audit findings should be sent to Angeles Martinez and Regional Manager




Baker Hughes

# Maximising accuracy of MFL pipeline inspection

Introduction

1. Accuracy

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Conclusions




Baker Hughes

# Algorithms & Sizing Models

Pull Through set up in Cramlington, UK

**Sizing, or 'POS' process has 2 aspects:**

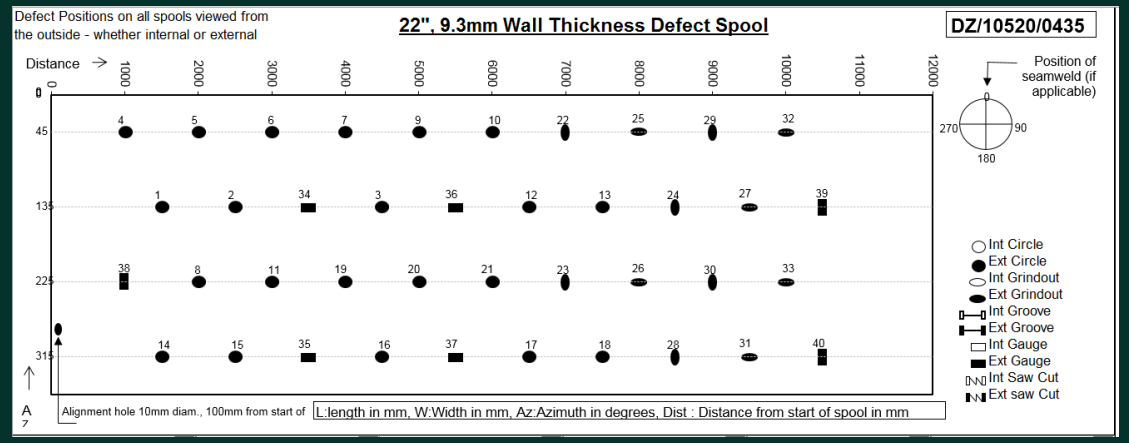
- Characterise defect using several descriptors
- Predict the defect dimensions statistically using a sizing model

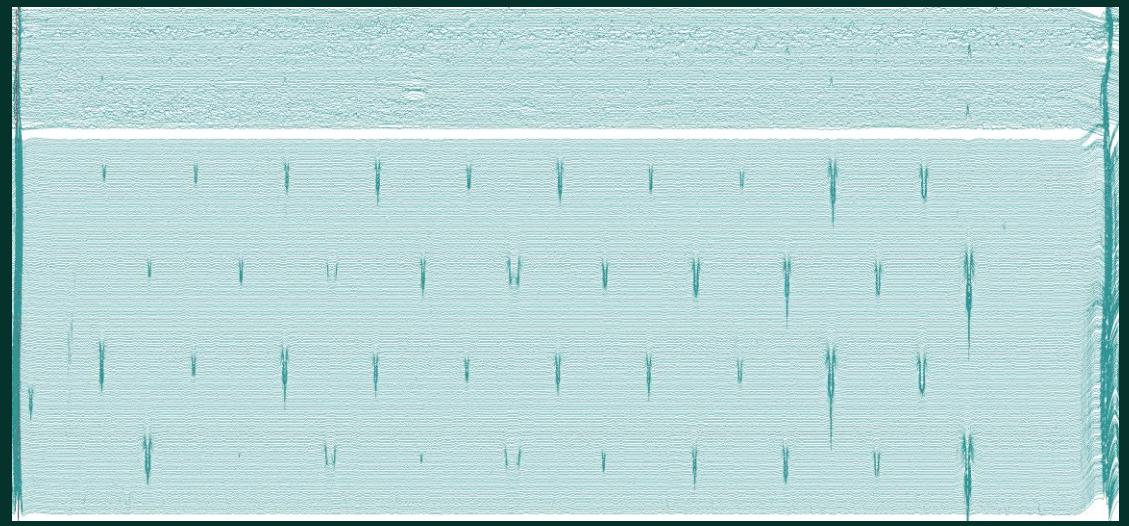
**Relationship between recorded MFL and actual dimensions is complex and non-linear.**

**Impacted by a number of factors:**

- Vehicle build
- Magnet strength
- Pipe wall thickness & material
- Vehicle speed
- Defect shape

Example defect spool plot (22" MagneScan)



Corresponding MFL data

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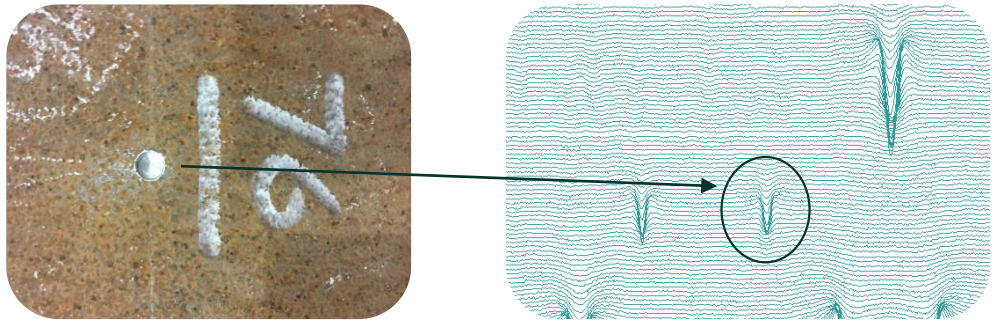
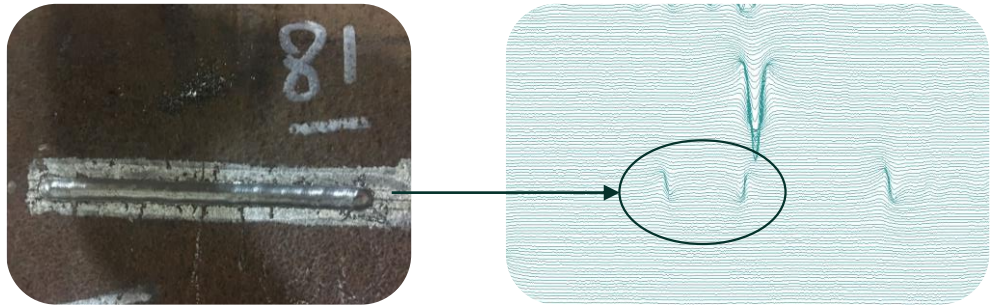
# 22” MagneScan example



Actual pull through defects

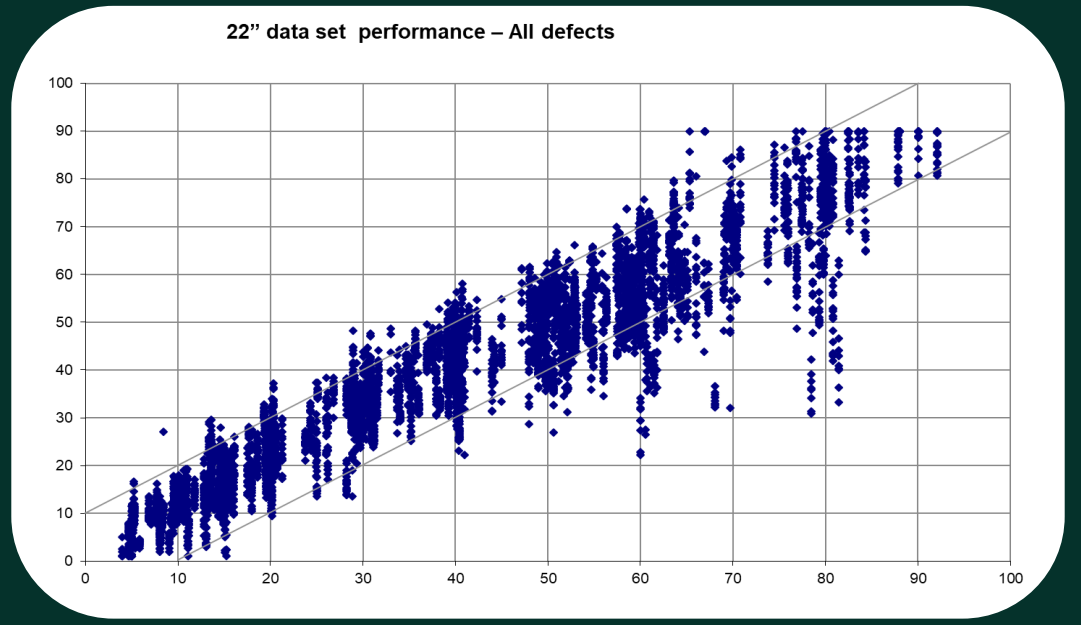


**Sizing model data set consists of:**

- Multiple pulls
- Wide speed range (0.2m/s – 7m/s)
- Multiple defect types

**Resulting in over 10,000 defects**

Example pull through results (22” MagneScan)




| Defect Type | Performance vs 90% | Specification level |
|---|---|---|
| Axial Slots | exceeded | SHR/SHRP |
| Axial Grooves | exceeded | SHR/SHRP |
| General ML | exceeded | SHR/SHRP |
| Pitting | exceeded | SHR/SHRP |
| Pinhole | exceeded | SHR/SHRP |
| Circ. Grooves | exceeded | SHR/SHRP |
| Circ. Slots | exceeded | SHR/SHRP |
| **All** | **Exceeded - 92%** | **SHR/SHRP** |

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# Case Study: Bespoke sizing models

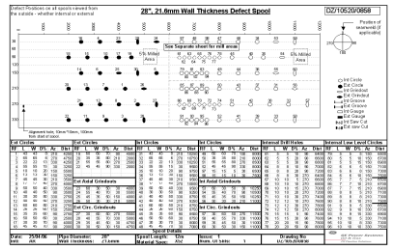
## Customer Challenge:

- Early onset of internal corrosion
- Very high volume of specific pit & pinhole type defects

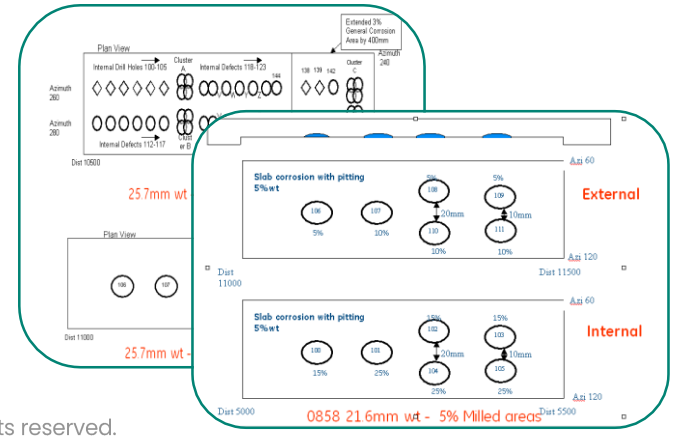
## Solution

- Sizing model built to target:
  - ➢ specific defect types
  - ➢ Specific depth ranges

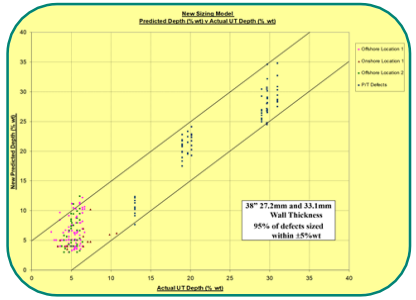
## Defect Spools

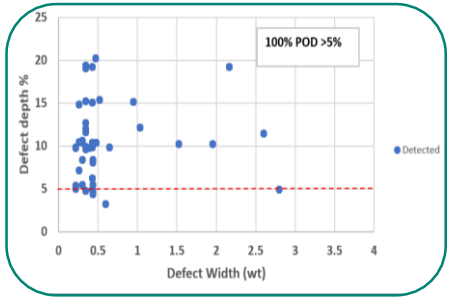


- Defect machining to fit corrosion profile
- Increased population of low-level pitting defects
- External Mill overlapping with internal pits
- Overlapping pitting defects

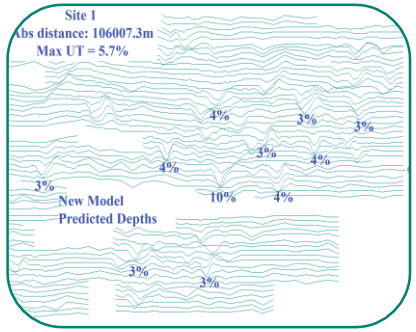


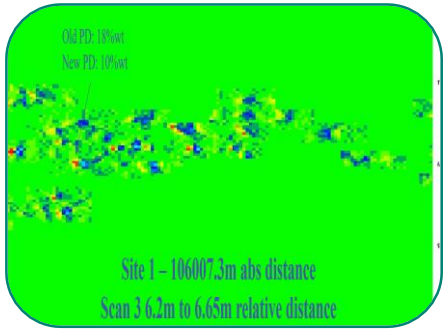

## Results




- **POD 100% >5%**
- **POS +/-5% @ 97% confidence**




- **Validated performance using UT probes**

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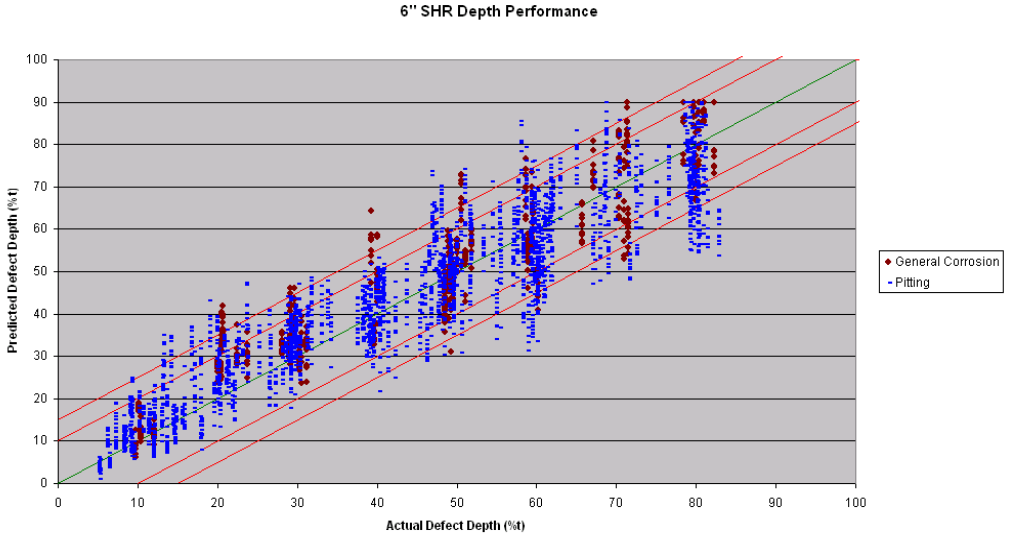
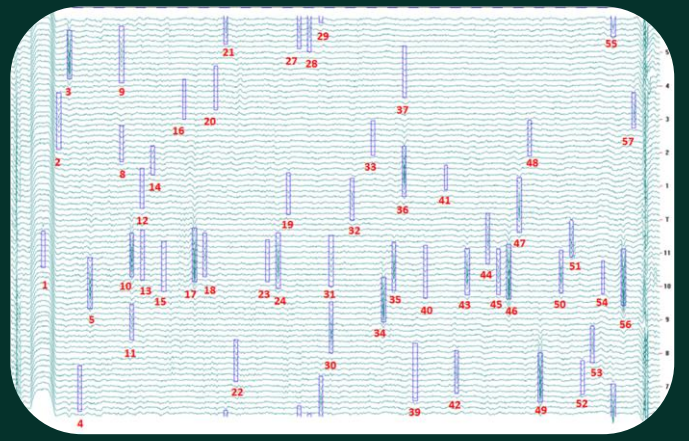
# Validation

## Recap: 6” Latest Generation MagneScan




✓ **Overall performance exceeding the target specification**

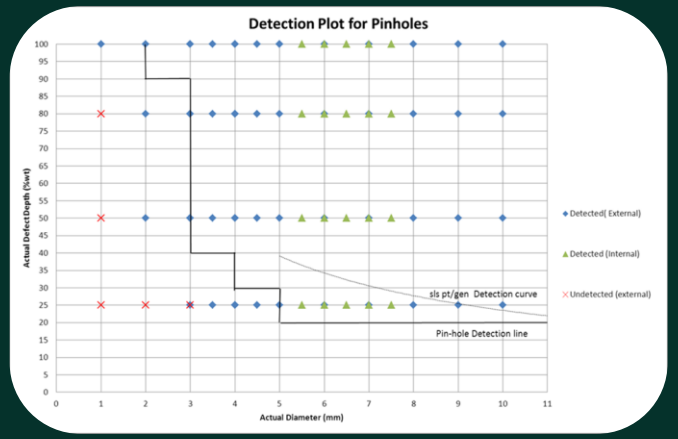
# Customer challenge



Specific defect spools where ‘blind testing’ was carried out

**100% detection** of features above published specification

Repeatable results on defects below specification (e.g. 2x2mm)

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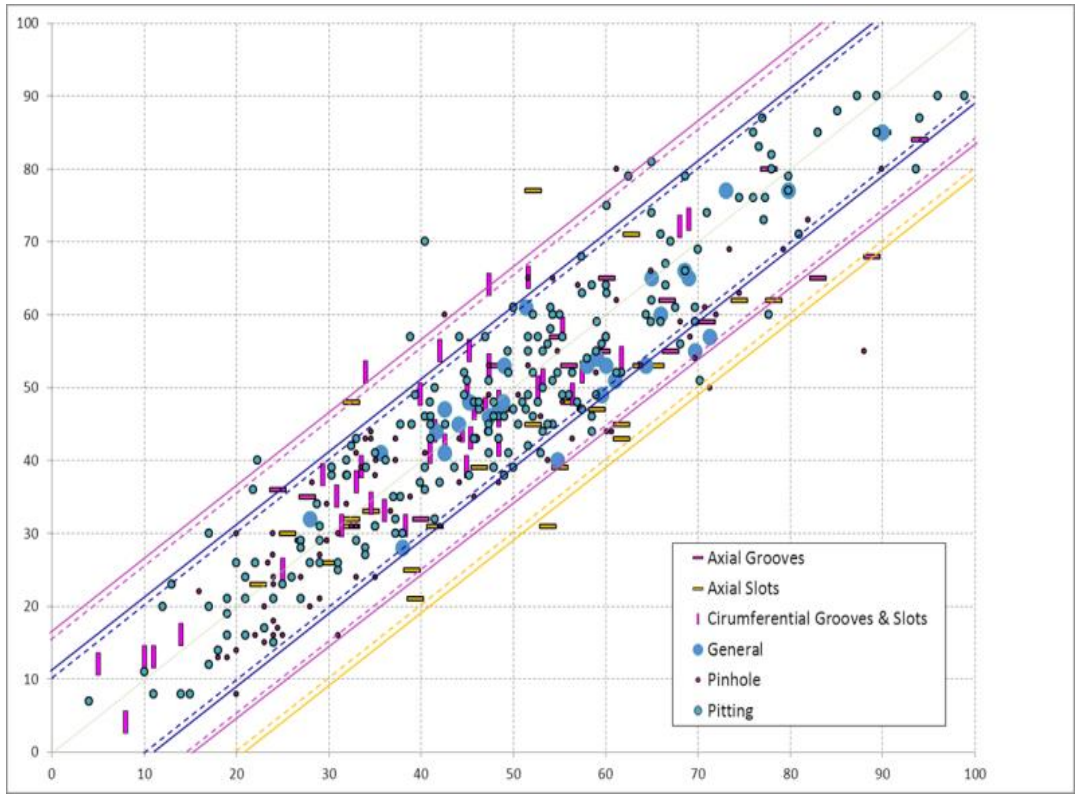
# Verification

## MagneScan ILI data vs Dig data




## Extensive Verification:

- **Thousands** of data points
- Range of diameters from **6-36”**
- Ranging across **all 7 POF** defect types
- Feedback provided by operators from **Asia, Europe & North America**

➢ **Consistently beating published POS (+90%)**

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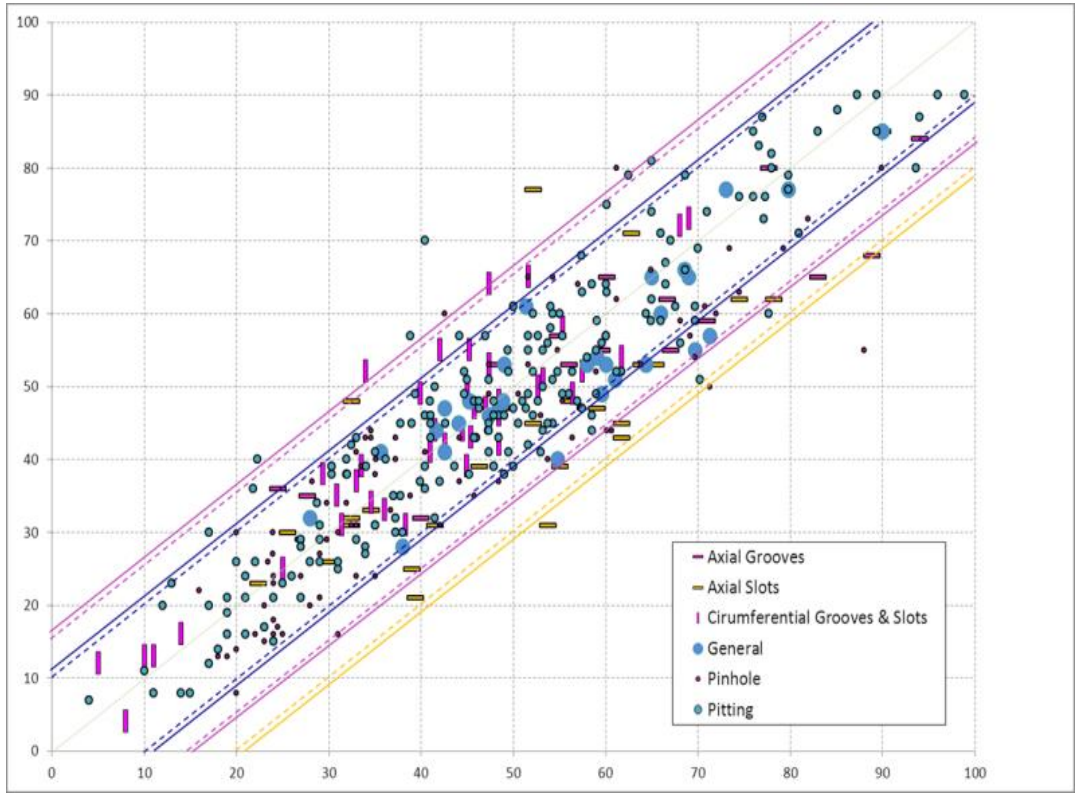
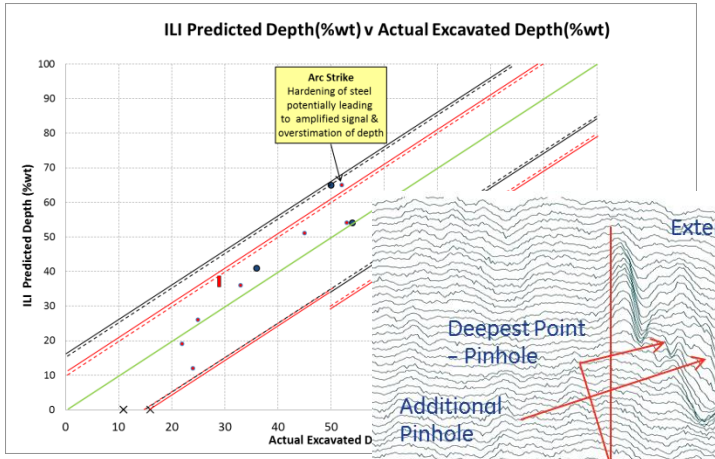
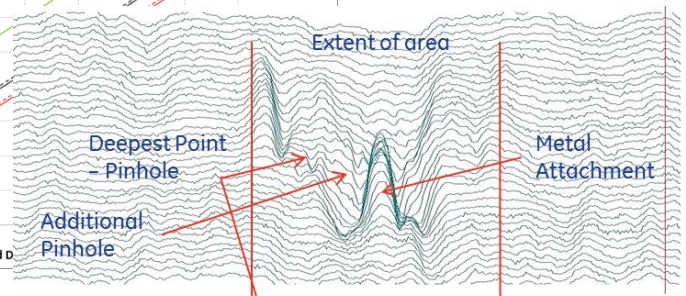
# Verification -> Improvement

## MagneScan ILI data vs Dig data

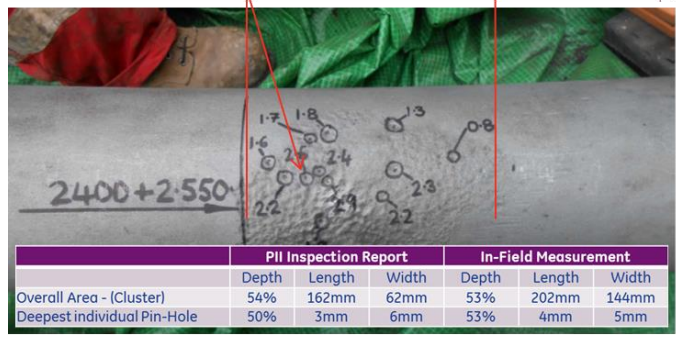



## Super High Resolution 'Plus'




Specifications for **pinholes** & **Grooves** introduced




| | PII Inspection Report | | | In-Field Measurement | | |
|---|---|---|---|---|---|---|
| | Depth | Length | Width | Depth | Length | Width |
| Overall Area - (Cluster) | 54% | 162mm | 62mm | 53% | 202mm | 144mm |
| Deepest individual Pin-Hole | 50% | 3mm | 6mm | 53% | 4mm | 5mm |

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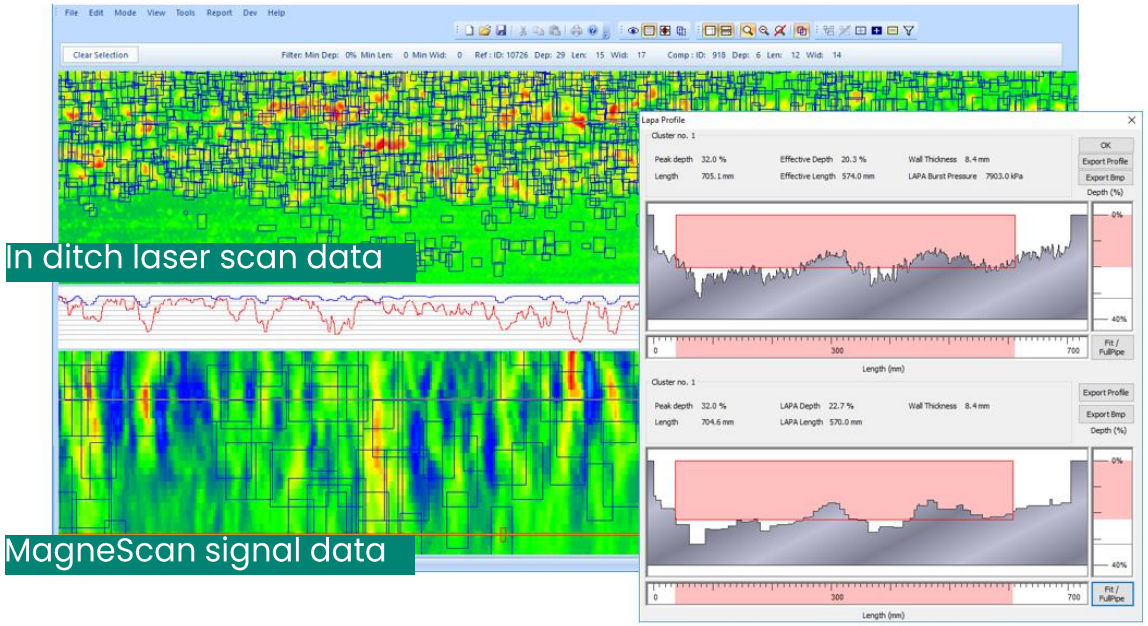
# Continuous Improvement

- ‘DigCom’ Software introduced
- Getting more benefit from increased use of laser scanners
- Enabling match of pits & pinholes in areas of complex corrosion




**‘Truth Data’**
**–> driving change & optimising performance**

- ✓ Extensive performance database
- ✓ Over **60,000** MagneScan defects
- ✓ Regular customer performance reviews
- ✓ Outlier reduction & elimination
- ✓ Enhanced training & processes
- ✓ Additional & improved specifications

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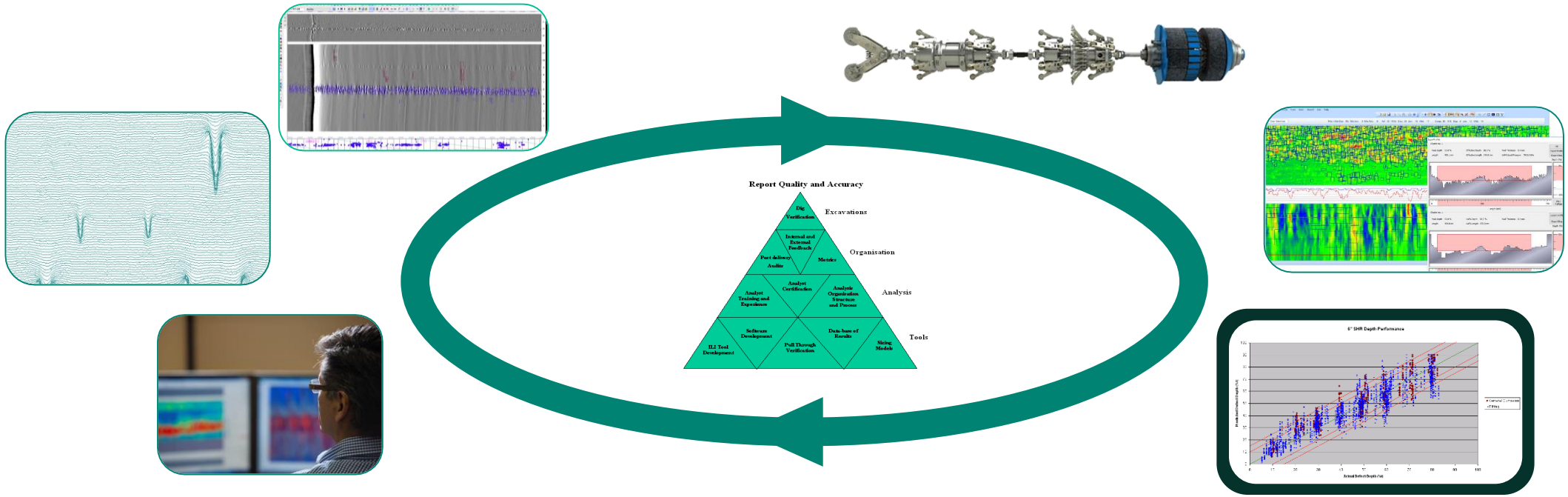
# Conclusions

## Reliable & accurate data … not just an MFL tool … It's a system




## … More to come from the data being gathered today




Baker Hughes

Baker Hughes

# Thank You ...

Baker Hughes