INSTITUTE OF CORROSION

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Effective pipework analysis and inspection planning using digital twins

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Sonomatic and CWL Group

CWL GROUP

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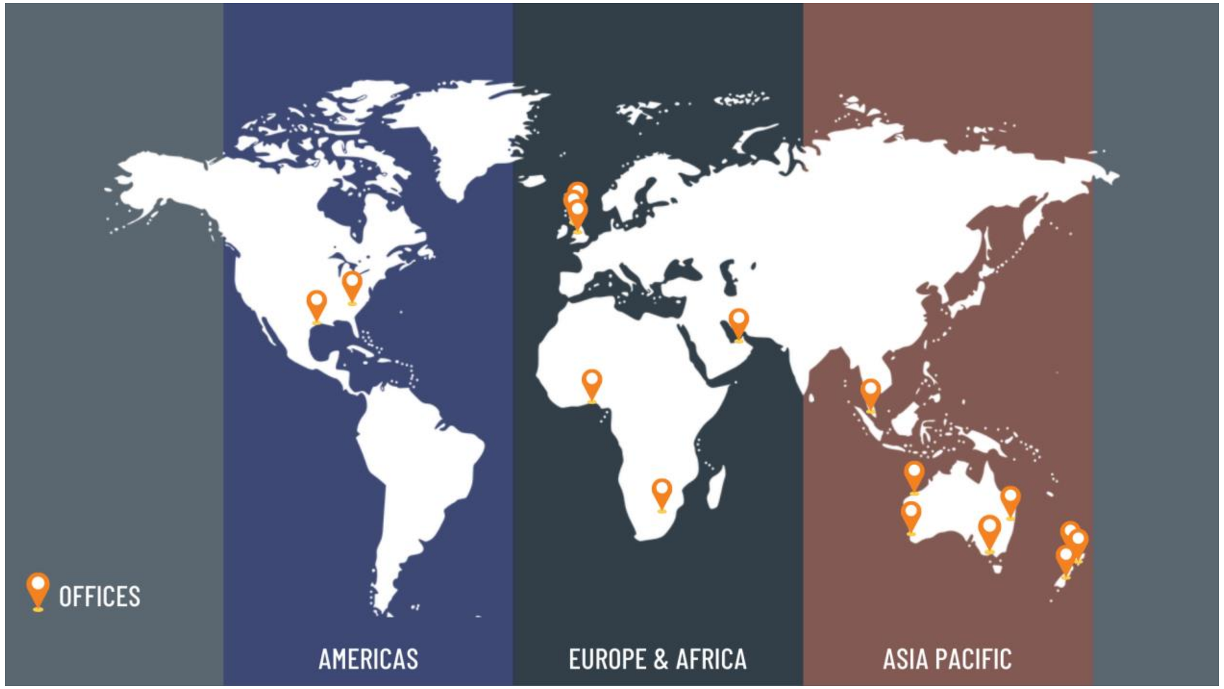
- GEO OCEANS
- SONOMATIC
- AUAV
- BLUE OCEAN MARINE SERVICES
- ABSEIL ACCESS
- aps



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Sonomatic Integrity Services

- Integrity Services
  - Integrity
  - Software
  - R&D
- Integrity to complement inspections
  - Inspection Planning
  - Advanced Data Analysis
  - Statistical Evaluation

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Overview

- Brief summary of traditional pipework inspection and analysis
- Impact of measurement error
- Sonomatic approach to pipework analysis and planning
- Case study
- Underpinned by software
- Links to digital twin

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Pipework Inspection – Traditional

- Extensive use of manual UT and radiography
  - Spot readings
  - Recorded in database
  - Limited analysis performed
- Low coverage (~1%)
- Acceptable strategy for predictable or extensive corrosion
- Random or localized corrosion unlikely to be found
- Action generally initiated per location basis
- Only ‘panic’ readings are actively acted upon

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Pipework Inspection – Traditional

- Strategy, in essence, sampling
  - Sampling from a distribution of wall thicknesses to predict overall behaviour
  - Evaluation and feedback loop needs to consider the inspection
  - Use to what you know as an input to future campaigns

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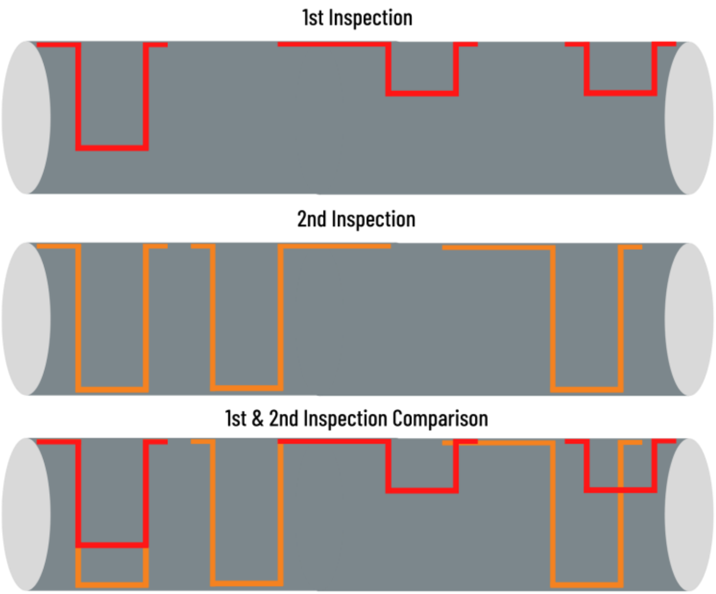
Measurement Error

- Analysis generally amounts to corrosion rate calculations
  - x-y/(time between x and y)
- Heavily influence by measurement error
- Location (example opposite)
- Technique
  - Probability of Detection (POD), applicability
- Data entry
  - Transposition (2.23 mm should be 22.3 mm)
  - Fat fingers (55.6 mm should be 45.6 mm)



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Pipework Inspection – Sonomatic

- Analysis based on delivering understanding of corrosion behaviour
- Starts with overview of whole inspection history and then drills down
- Differentiators
  - Recognition of sampling from a distribution
  - Response to measurement error
  - Utilisation of integrity group-based corrosion rate
  - Utilisation of corrosion coverage information
- Improvements in efficiency and effectiveness of whole inspection cycle

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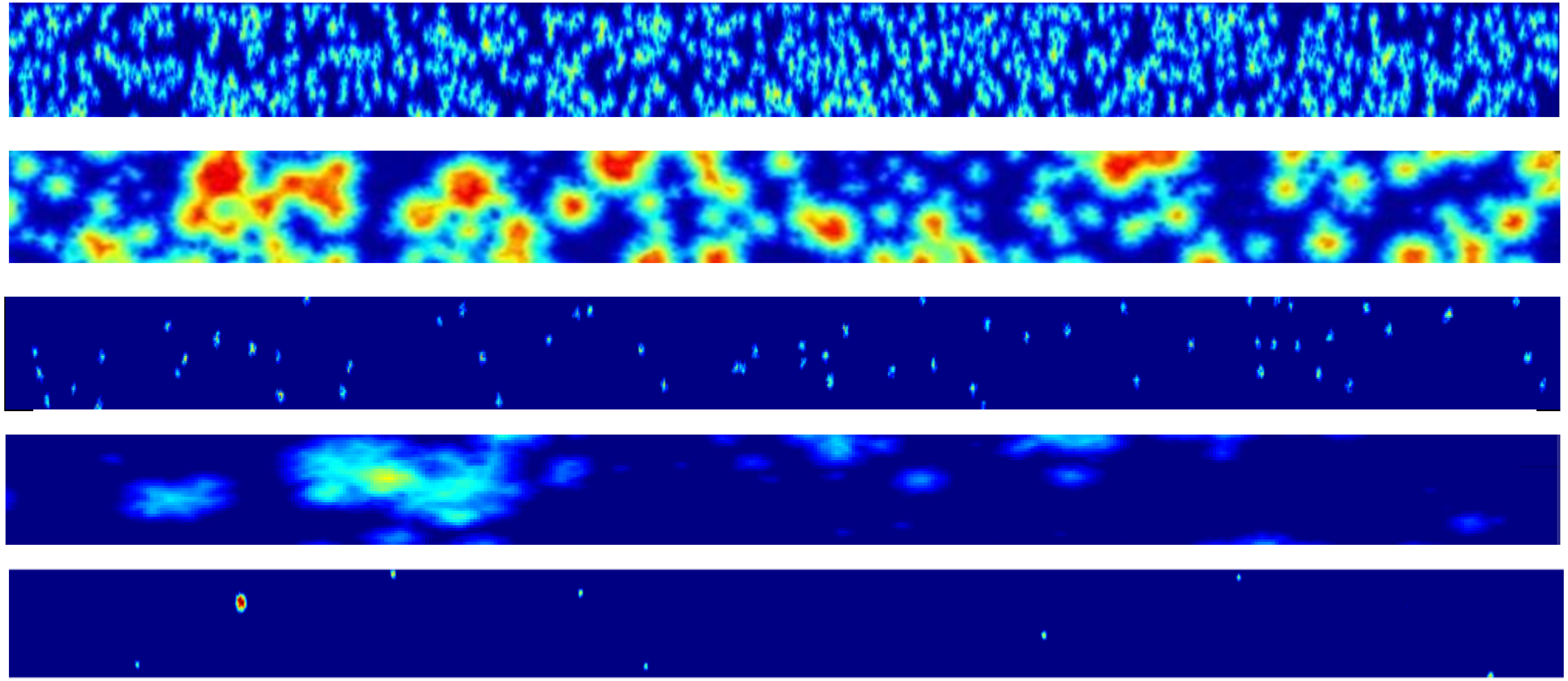
Consider Corrosion Spatially



- Corrosion with same minima and rate can be spatially different
- Should be reflected in inspection strategy

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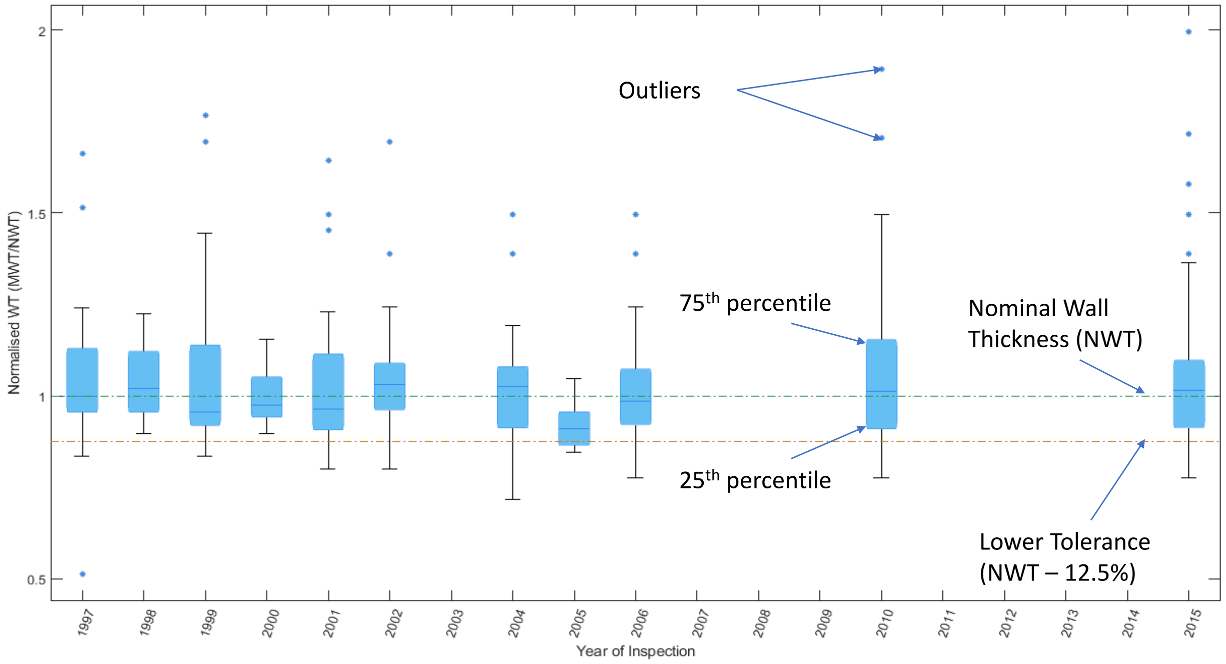
Sonomatic Implementation

- Boxplot – whole inspection history in one view
- Normalised view (minimum/nominal) allows all schedules of pipe to be compared initially



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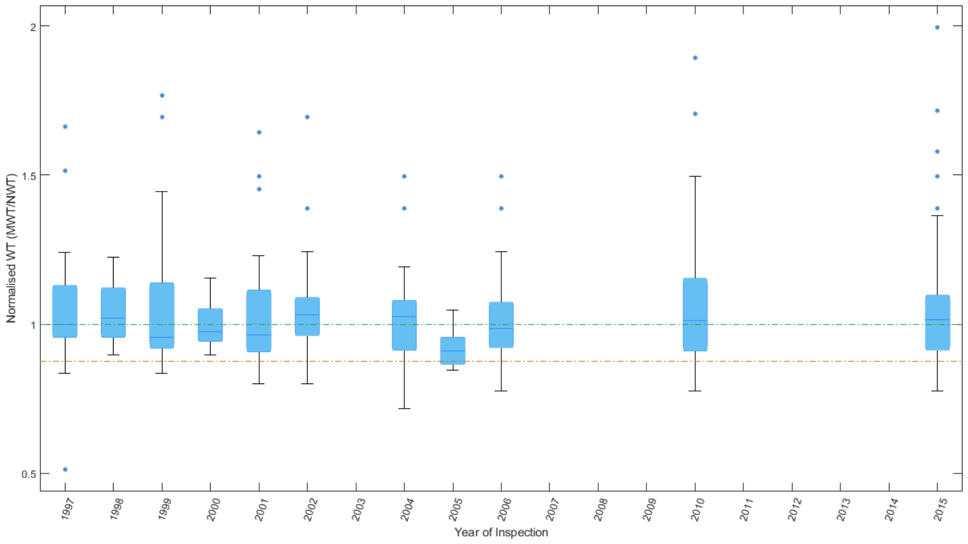
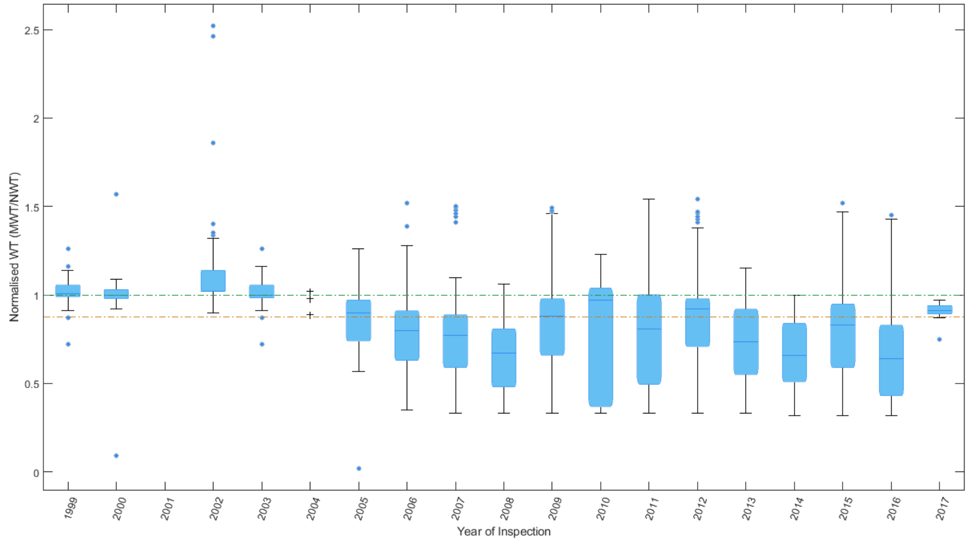
Long-term Trending

- Boxplots provide quick overview of long-term trends
- Image on the right shows a circuit where inspections have been largely stable for several years.



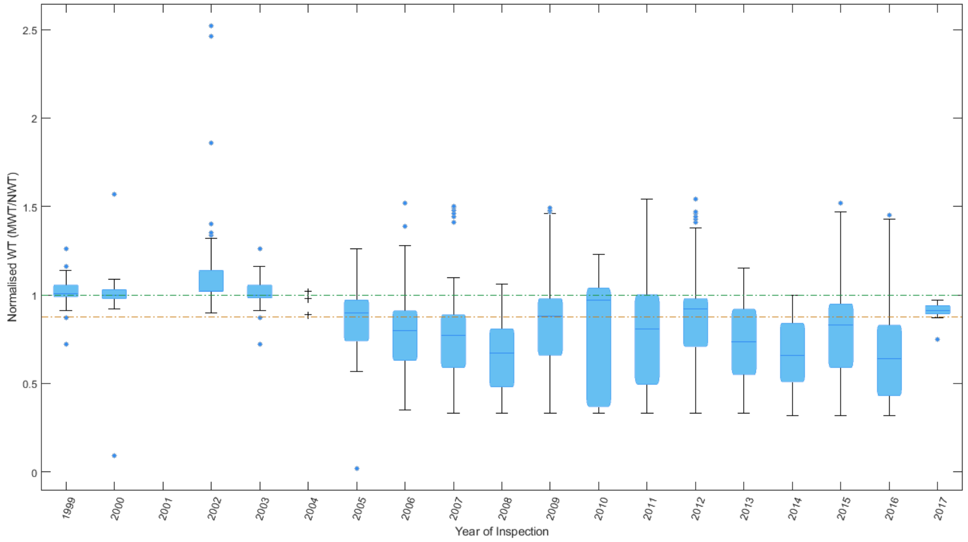
Long-term Trending

- This images shows a downward long-term trend.
- Indicative of increased corrosion activity.
- Provides context.
- Final result clear jump in thickness readings.
- Possible replacement.



Long-term Trending

- Entry point
- Raises questions based on knowledge of circuit
- Provide insight on behaviour of groupings
  - Materials parameters
  - Feature types
  - Process groupings



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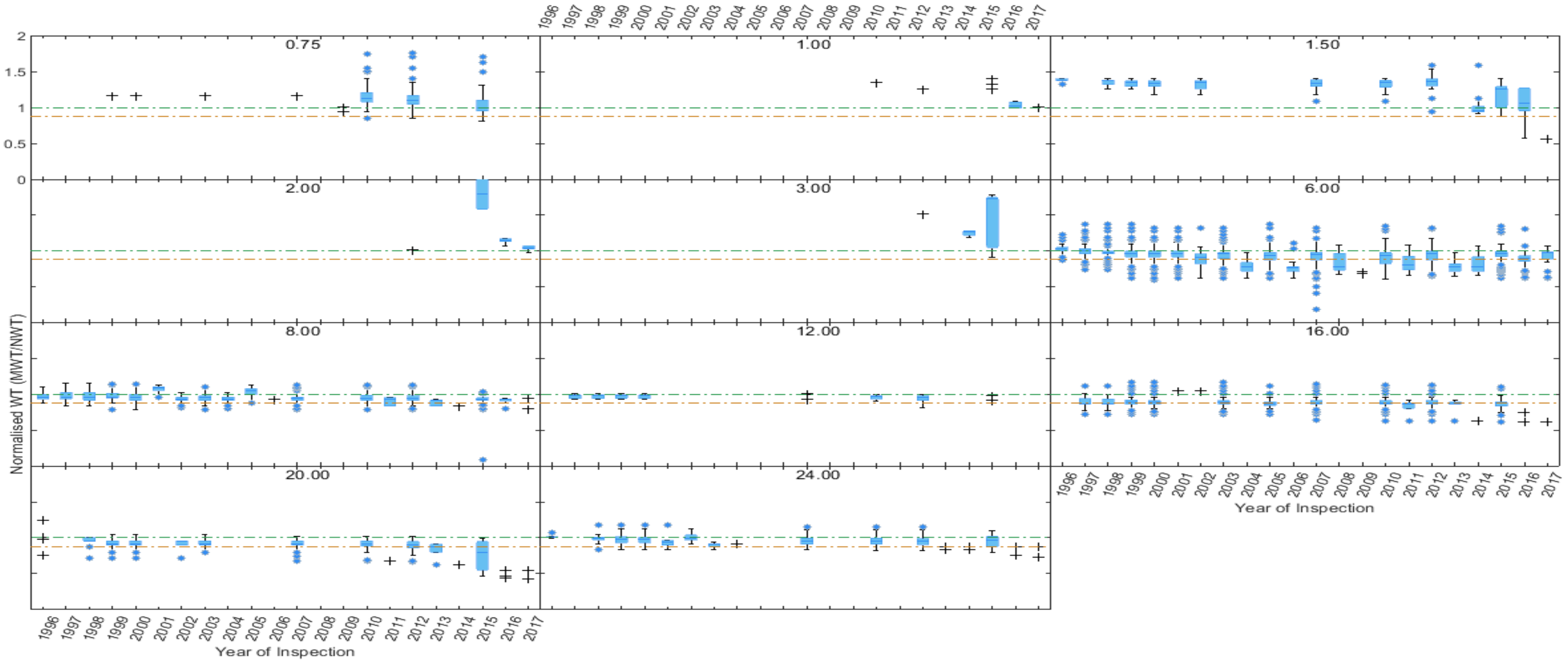
Example – Grouping by Diameter



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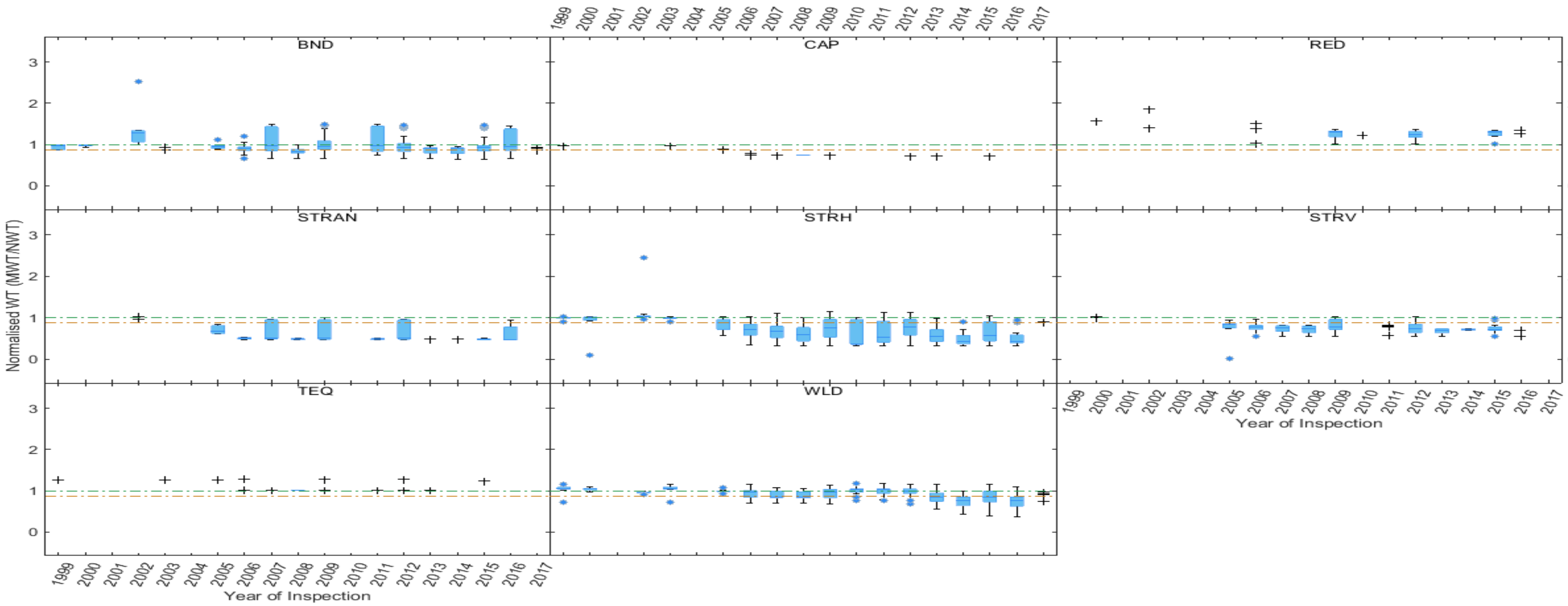
Example – Grouping by Feature Type



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Corrosion rates – Trending

- Take groupings from the analysis
- Trend on wall loss percentile values
- Looking at grouped trends mitigates measurement error
- More accurate short-term and long-term corrosion rate calculations
- Allows consideration of individual points
  - Any point showing concerning trend can be extrapolated to predict when alarm limit may be reached
- More targeted, more efficient inspections

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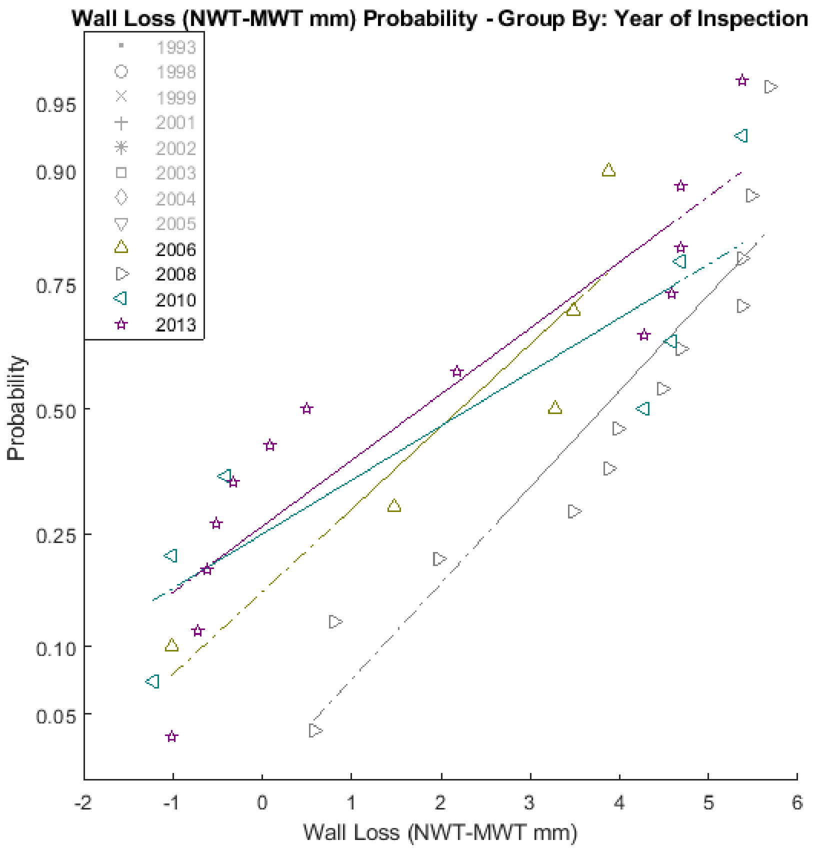
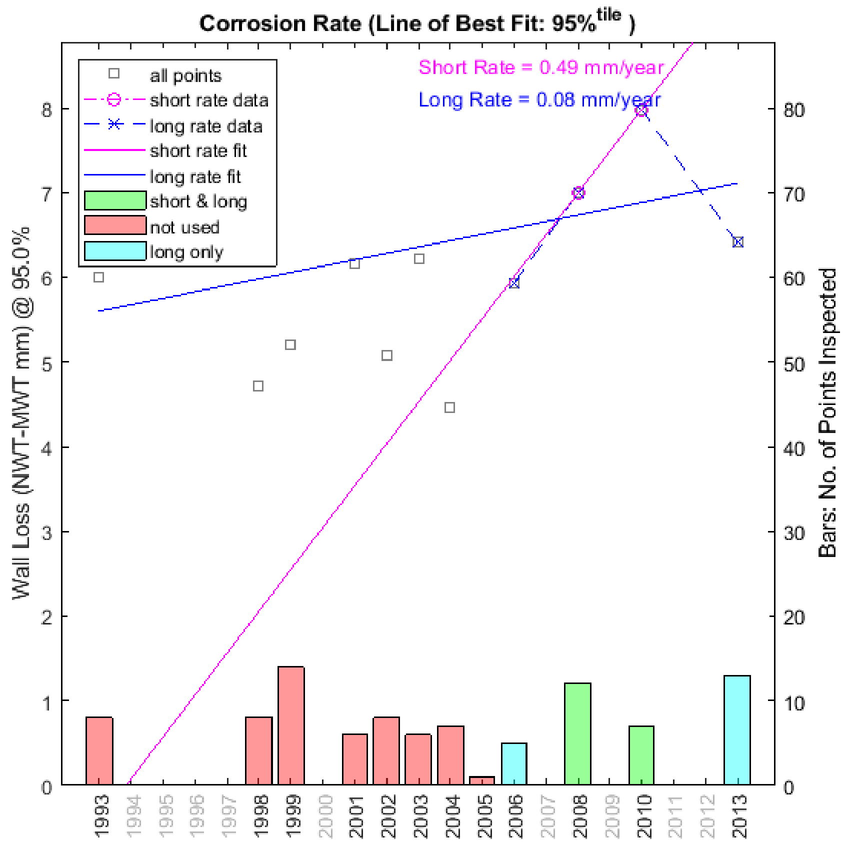
Corrosion rates – Trending Example





Inspection Planning Methodology – 1

- Analysis Phase 1, inspection planning Phase 2
- Consider several factors:
  - General state at last inspection (stable, major downward trend etc)
  - Consider relevant groupings.
  - Applicable degradation threats from CRA
    - Predictability and severity of corrosion, if it were to become active.
    - How mechanism would develop spatially if active.

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Inspection Planning Methodology – 2

- Define corrosion state (what we expect to find)
- Define a corrosion coverage from previous results
  - Extent of corroded material
- Define thresholds of concern (based on historic results)
- Consider points flagged as over/under inspected
- Expected corrosion mechanisms has a bearing on technique
  - Detection threshold
  - POD

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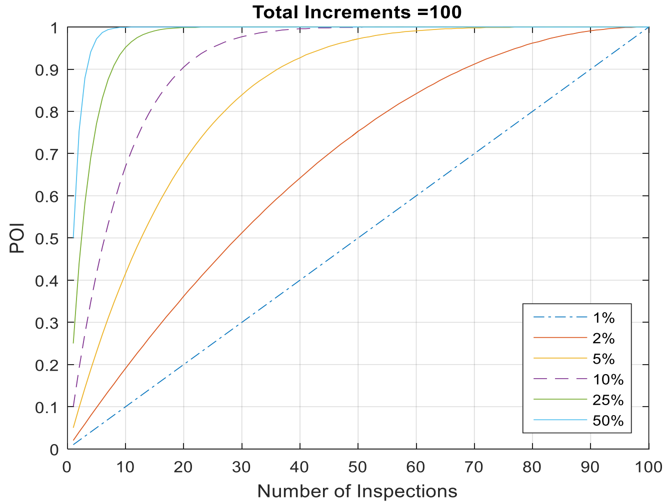
Inspection Planning Methodology – 3

- Take threshold and corrosion state
- Calculate proportion of historic results below this threshold
- $PET_H = \dfrac{points\ below\ threshold}{total\ points}$
- Sonomatic use advanced algorithms to calculate the minimum amount of inspection increments expected to find points below this threshold



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Inspection Evaluation

- Assess the level of points expected to exceed threshold vs. points that did exceed threshold.
- Use a ratio to determine if anticipated findings reflected reality.
- Fed back into analysis loop to refine additional/future inspections

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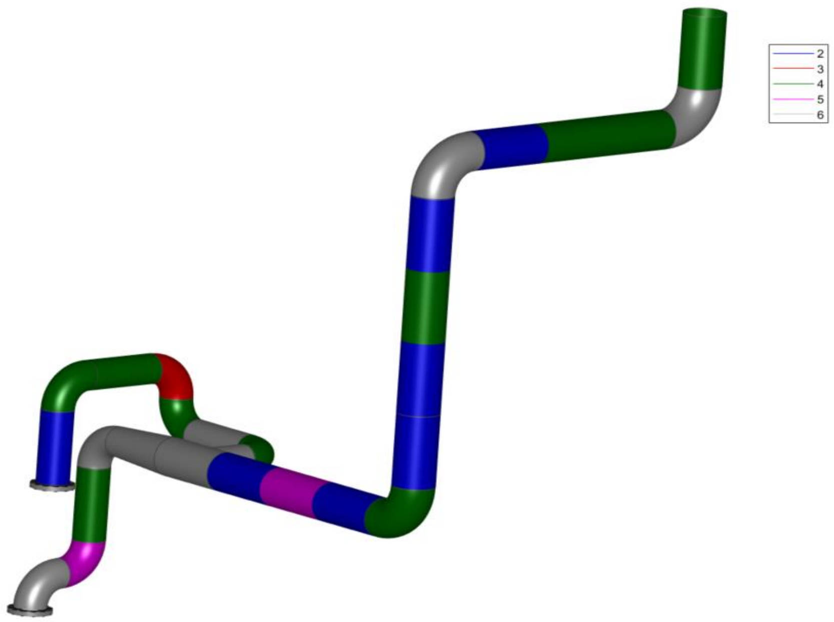
Software (SPiDARS)

- All earlier images come from Sonomatic SPiDARS software
- Accommodates many data formats
  - Screened on upload for spurious points
- Automated and electronic reporting
- Upload new inspection data
- Refine analysis
- Links to MiniTwin, more later



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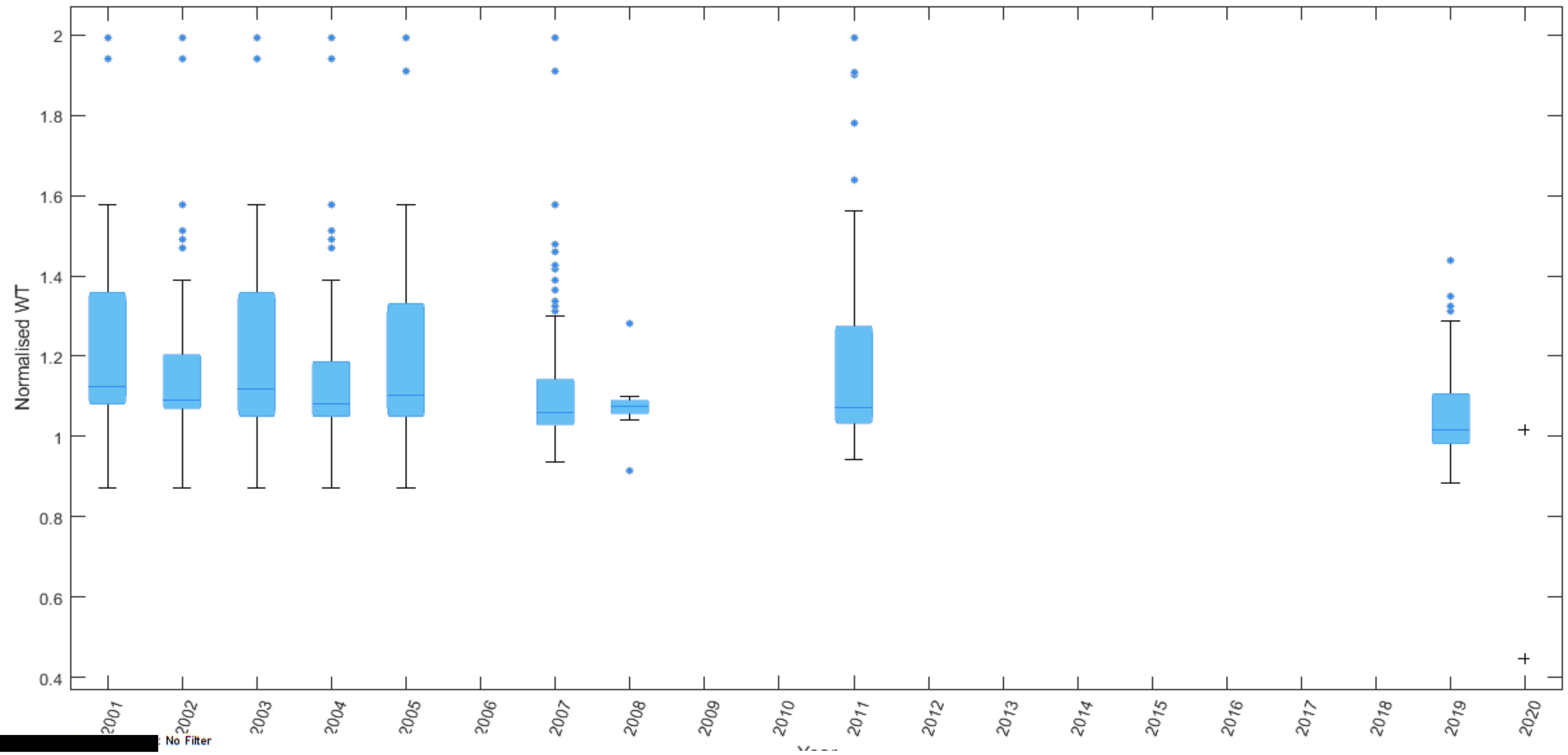
Methodology Case Study

- Client with vast amount of inspection data
- **6,349** excel workbooks containing historic thickness readings, **22,365** excel sheets
- Data mining of unstructured data
- Review data to make choices on optimal method
- Data in a similar formats but not identical

Methodology Case Study



Boxplot (all data)

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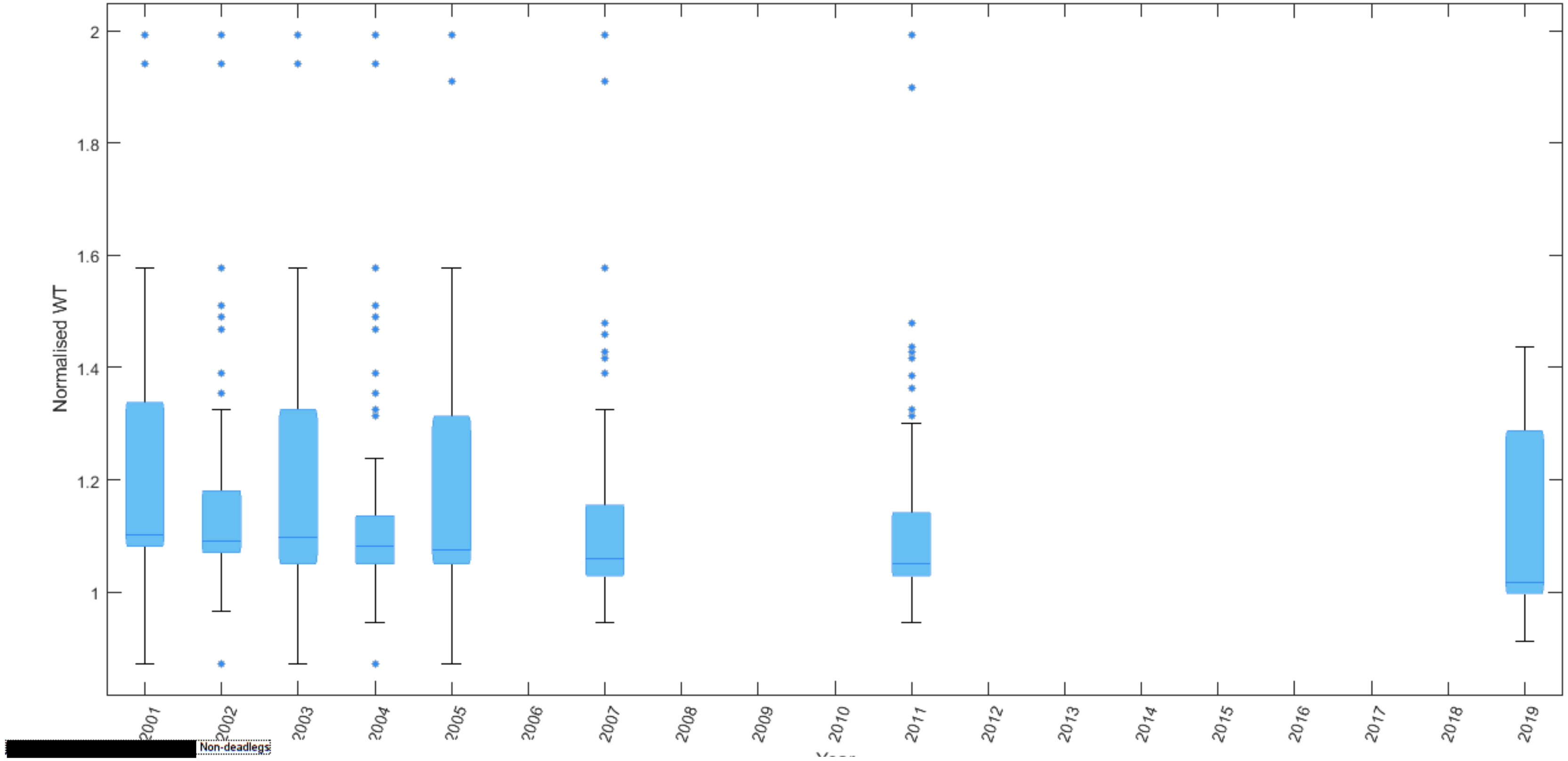
Methodology Case Study



Boxplot (non deadleg data)

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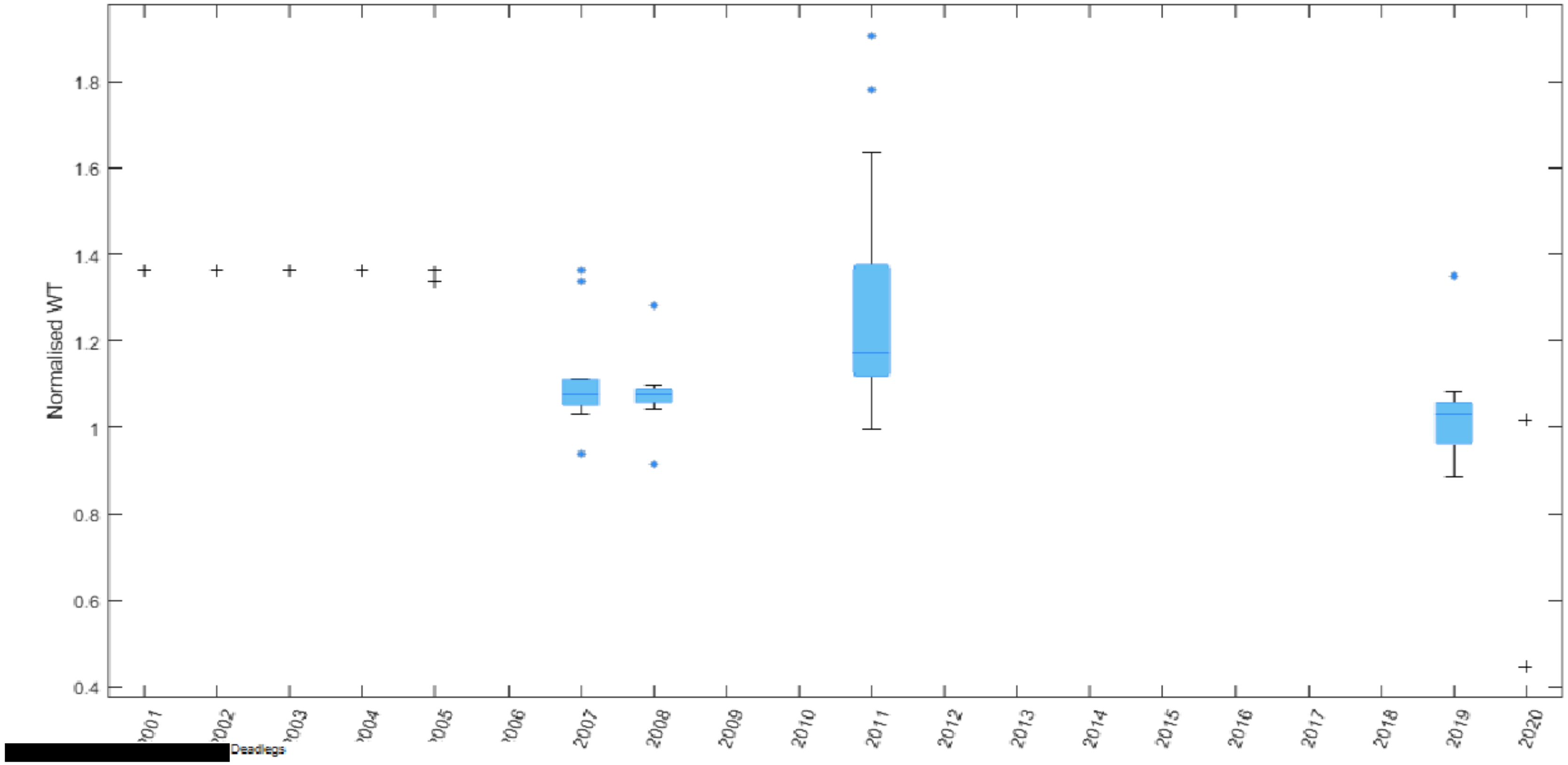
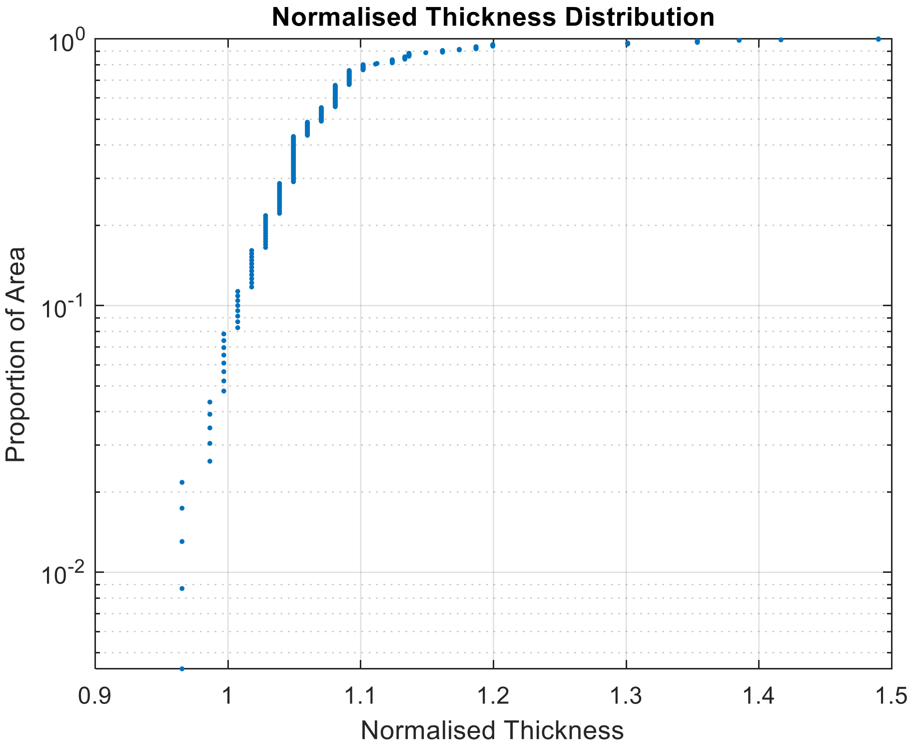
Methodology Case Study



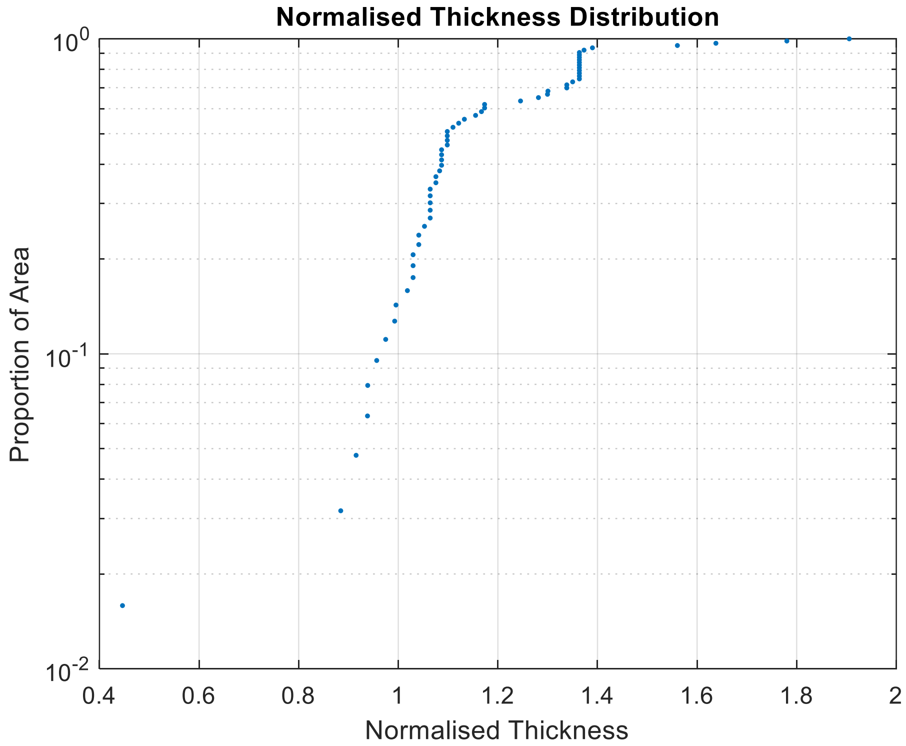
Boxplot (deadleg data)

Methodology Case Study

- Predicted corrosion coverage minimal



Non-deadleg Data



Deadleg Data

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Methodology Case Study

- For confirmation of absence, concern if significant increase to the proportion of points below nominal
  - Non-deadleg data all greater than 0.97 of nominal
- Morphology: localised if present, based on highest ranked corrosion threats
- Rate: low, approximately 0.03 mm/yr across the circuit but significantly higher rate on deadlegs.
- Inspection coverage 15%.
  - Recommendation to focus on a particular line as it accounted for 45% of locations but not seen ~5% of inspection.

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Digital Twin – Background

- Digital replica of a real-world component
- Can be used for multiple factors
  - Simulations
  - Testing
  - Aid access to and visualisation of information (Sonomatic)
- Oil and gas
  - Platform
  - Pipework
  - Pressure vessels
- Share with multiple stakeholders

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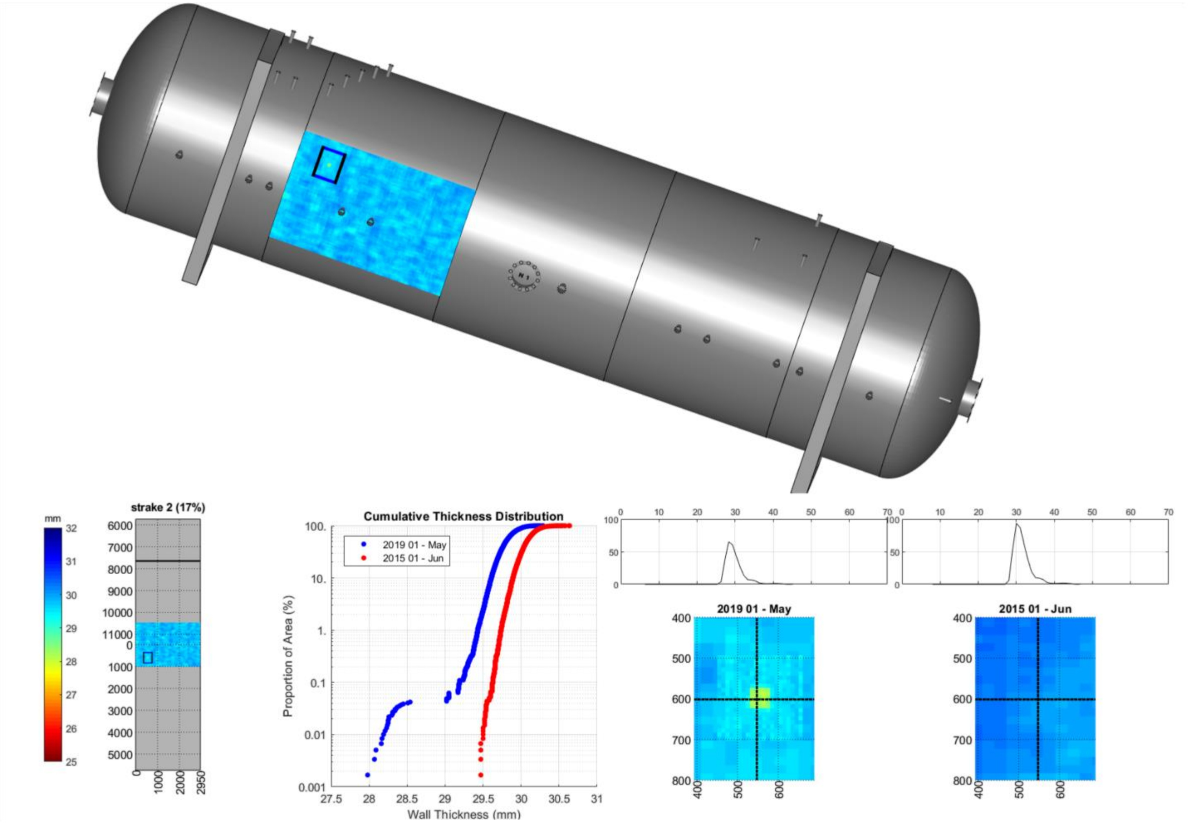
Digital Twin

- Disclaimer: screenshots
  - Can arrange demo
- Interactive access to:
  - Reports
  - Inspection scopes
  - Data
  - Photographs
  - Diagrams (GA/P&ID)
  - Much more
- Tree view to ease navigation
- Gif showing examples
- Cover some in more detail



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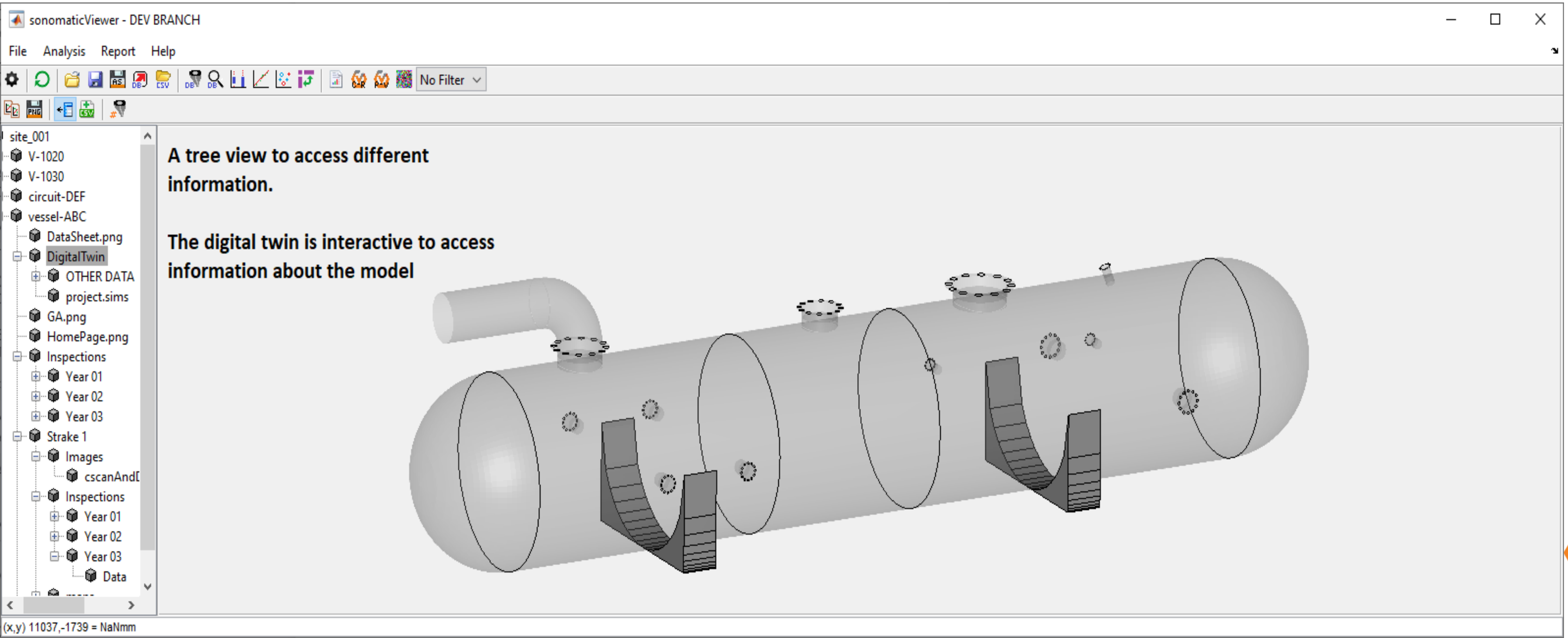
Digital Twin – Tree View

- Start at site level
  - Move on a component or circuit basis
- Models created when needed



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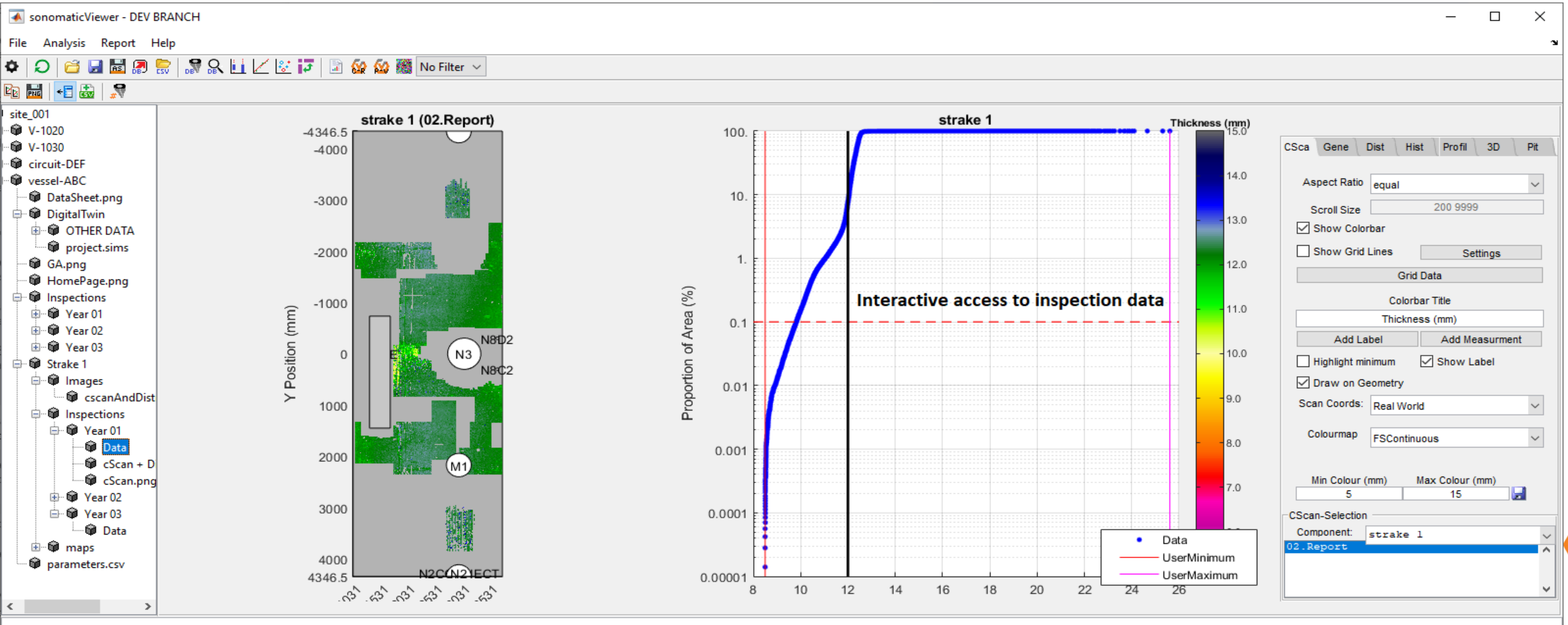
Digital Twin – Analysis

- Interactive access to inspection data
- Statistical distributions and evaluation
- Levels of access



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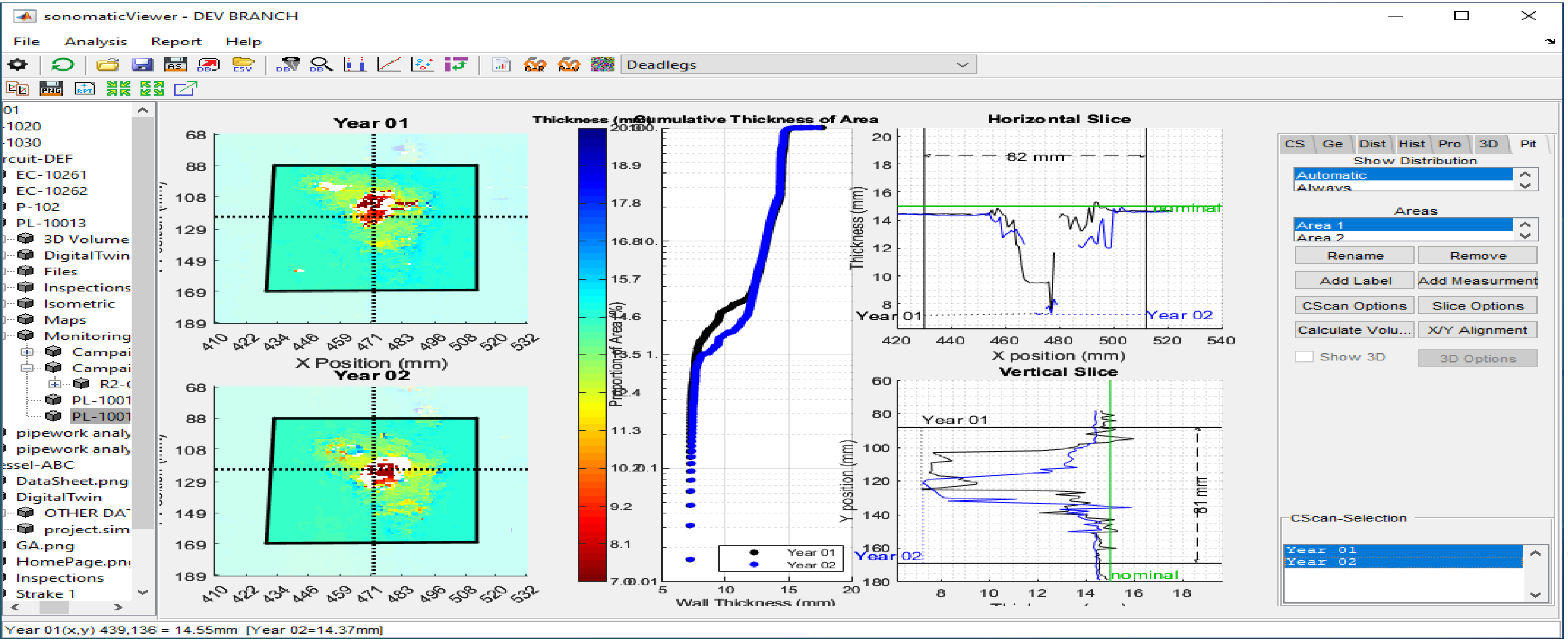
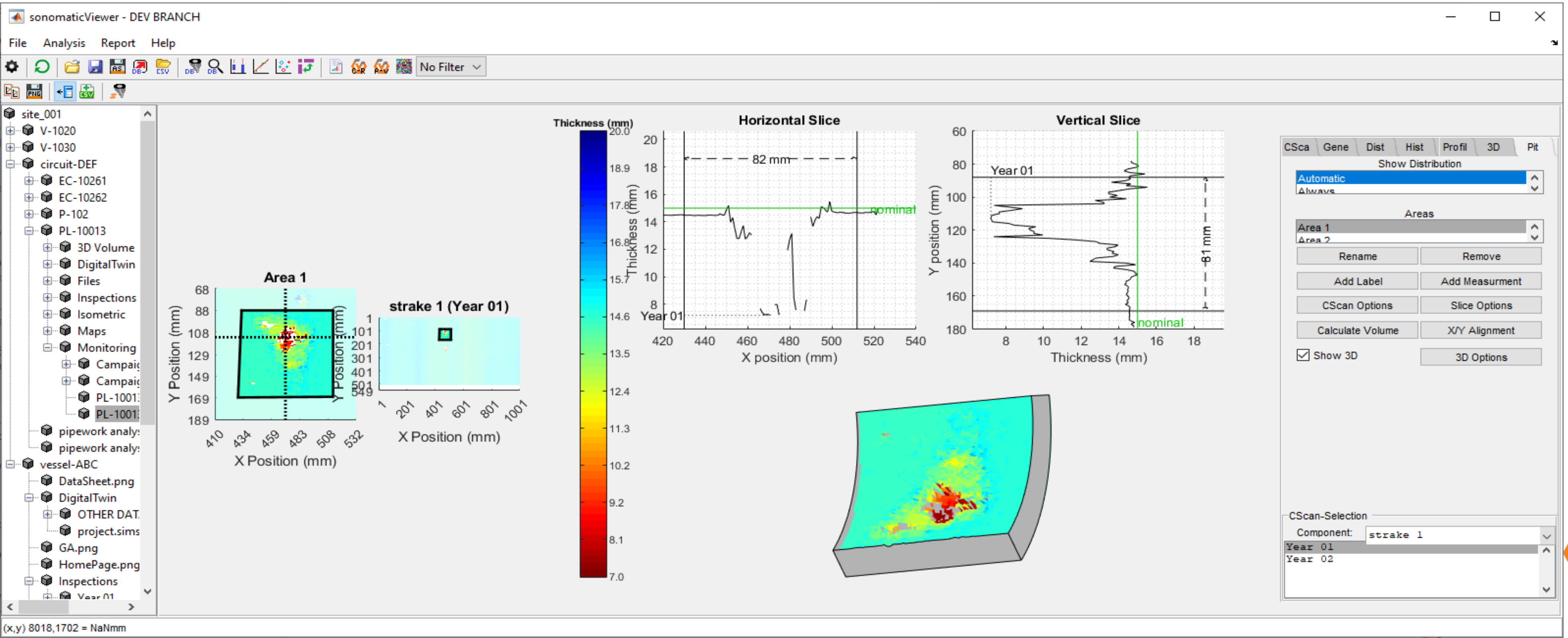
Digital Twin – Analysis (Pit Modelling)

- Focus on an area of concern
  - View pit profile
- Compare to previous inspection



Digital Twin – Analysis

- Pit modeling
- Profile single pit and view 3D slice



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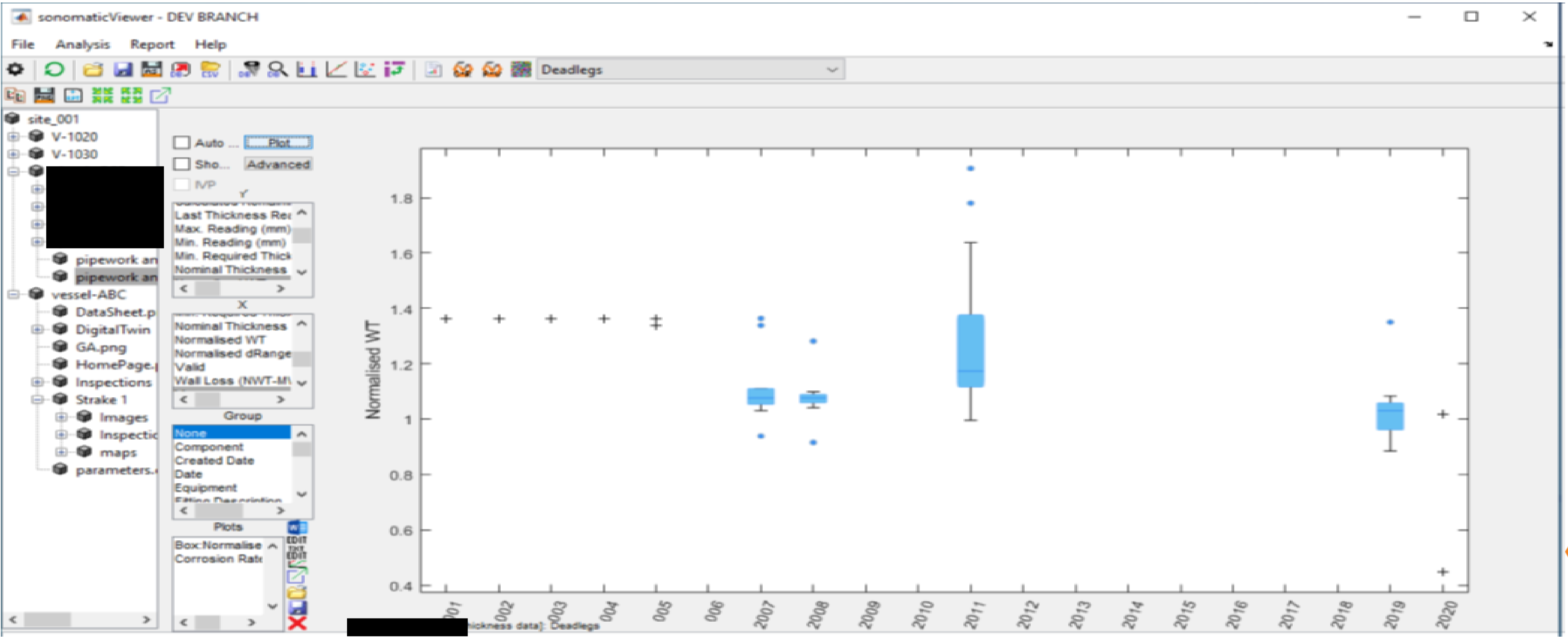
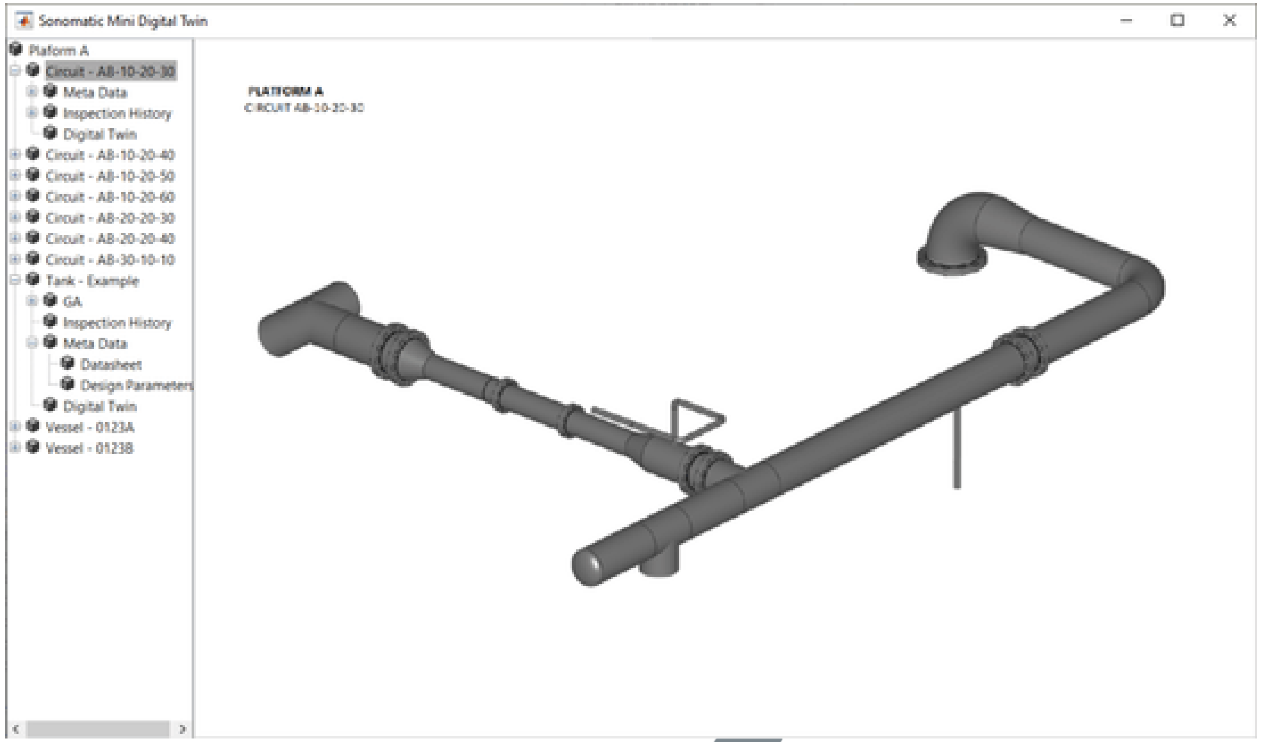
Digital Twin – Pipework

- Tree format links to SPiDARS analysis
- Aids data access and understanding



Digital Twin – Pipework

- Example of how we display information
- Multiple examples shown here:
  - Parameters
    - Diameter
    - Thickness
  - Time since last inspection
  - Number of times inspected
  - Minimum
  - Calculated corrosion rate
  - Normalised wall thickness
- Gridded data (if maps available)



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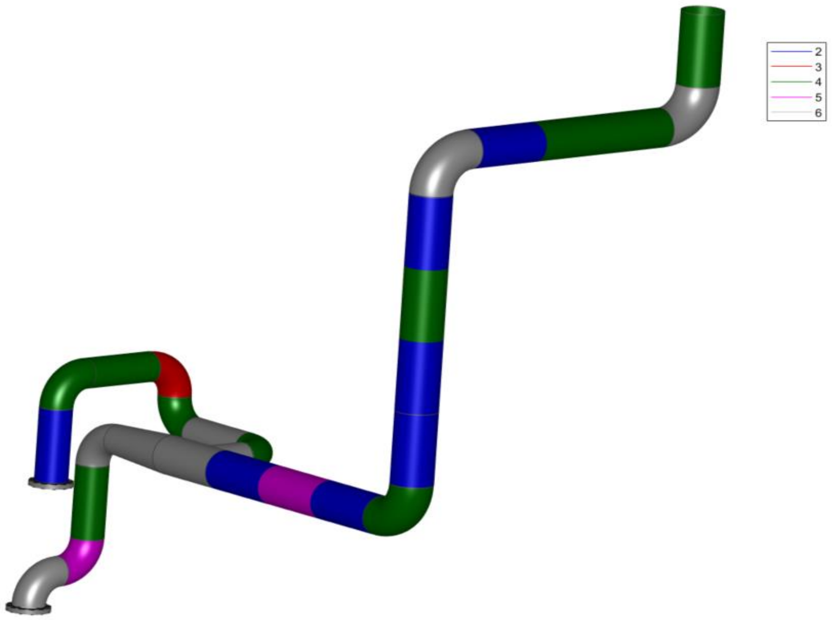
Digital Twin – Pipework

- Inspection recommendations from SPiDARS fed into twin
- Ease of issue
- Data Extrapolation
  - Flag when repair/maintenance required
- Aids in efficient inspection planning
- Optimised resource allocation
- Streamlined costs



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