WiSense Project – Localised Corrosion Monitoring

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Introduction to WiSense project

- WiSense project is a collaboration project between Shell, Yokogawa Electric Company, and Charles Stark Draper Laboratory.
- WiSense is the name of an internal project between the three parties. WiSense is not a trademark or a product name.
- The word WiSense is being used in this presentation to describe the R&D system developed in Shell and with the collaboration parties.

Acknowledgements

We want to make the following acknowledgements:

- Charles Stark Draper Laboratory: Fran Schlosser, Neil Patel, Cort N. Johnson
- Yokogawa Electric Company: Yoshino Hiroki, Miyazawa Kazunori, and their teams
- Shell WiSense team: Chetan Laddha, Sieger Terpstra, Brian de Vuijst (retired); Many staff at Shell Operating Units supporting the field trials

Nondestructive testing technology gap

A gap exists in real-time corrosion monitoring

No existing system simultaneously:

- Provides area coverage
- Operates over coating / without surface contact
- Functions wirelessly (power and communications)
- Maintains long lifetime with minimal maintenance
- Is affordable

Photographs courtesy Draper

Need for Corrosion Monitoring

NDT Method	Concept	Advantages	Challenges
Eddy Current	Apply AC magnetic field; measure induced current	No surface contact needed Sensitive to cracks	Active measurement requires power: long-term, wireless operation is limited
Ultrasonic	Couple acoustic energy into material; measure reflected power	Direct, accurate depth measurement	Acoustic coupling required: no over-insulation mode Area coverage: requires many active probes; each requires power
Magnetic Flux Leakage	Magnetize material, detect field patterns caused by wall loss	Finds defects on inside/ outside surface No surface contact needed	Active measurement: requires power or large permanent magnets; long-term operation is limited, difficult to miniaturize

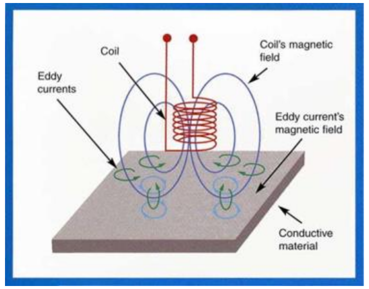
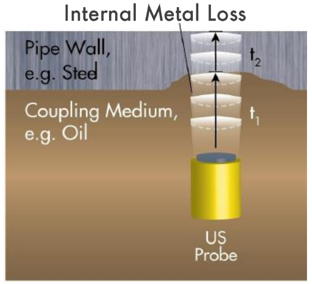
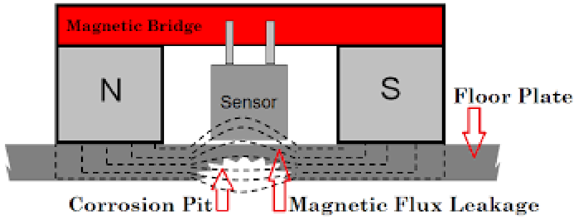


Figure from NDT Resource Center: www.nde-ed.org



Adapted from M. Beller "Pipeline inspection utilizing ultrasound technology: on the issue of resolution", Pigging Products and Services Association

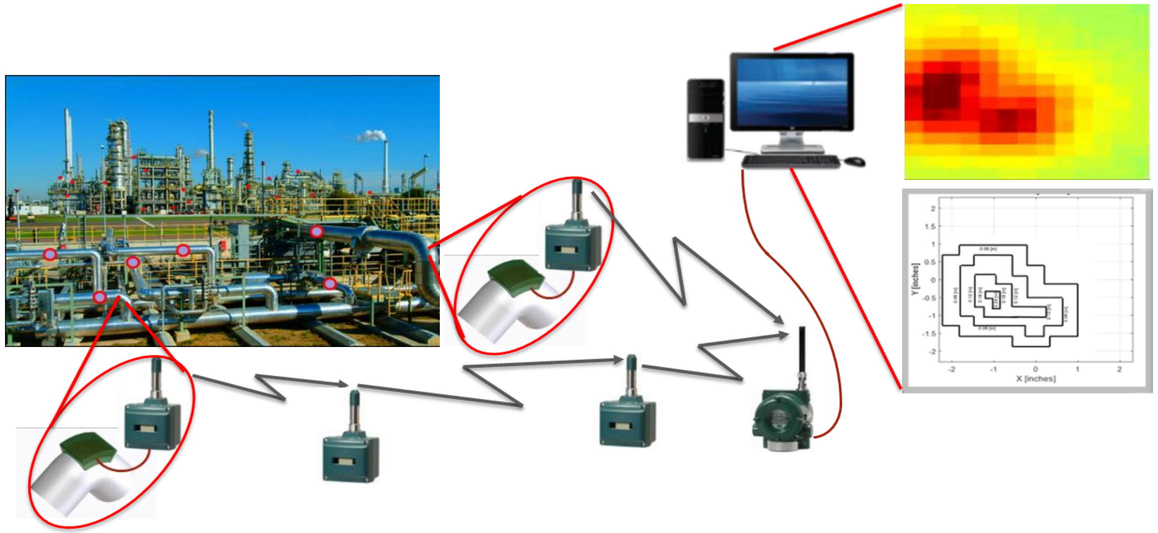


From MFE Enterprises Inc.: www.mfeenterprises.com

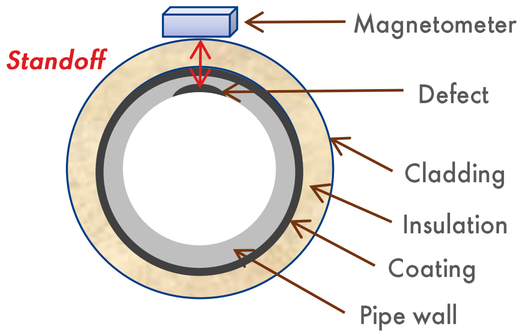
WiSense – Application of passive magnetometry

Magnetometry-based corrosion/erosion detection system

- "Permanent" system provides frequent, repeatable, measurements for trending
- Does not require pipe contact; can be on top of coating or a thin layer of stiff insulation
- Eliminate need for routine access to facility, benefit for hazardous areas (Zone 1, IIC)
- Low maintenance (5 year battery life expected; incidental calibration if defects grow)
- No external wiring, strap attachment for simple installation



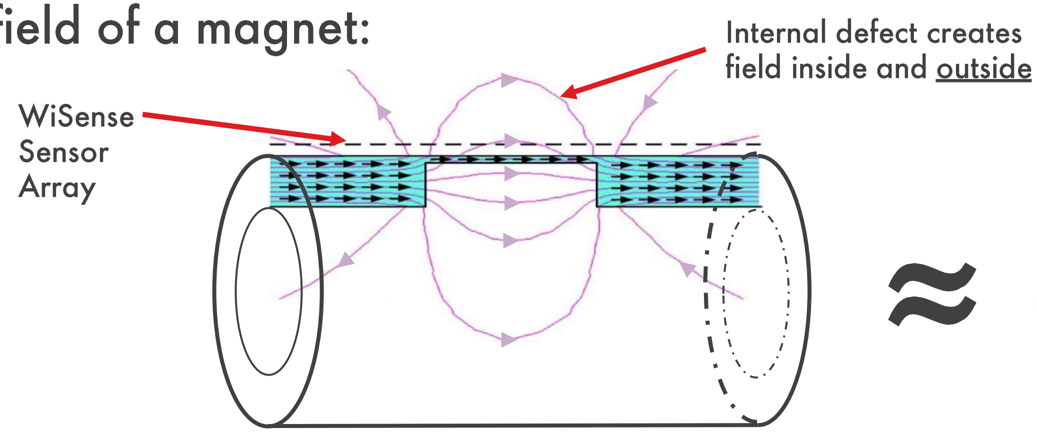
A 16cm x 16cm array of 3-axis magnetometers; 1 cm spacing



Principle of WiSense technology based on self-magnetic flux exclusion

- WiSense uses passive magnetometry
  - Pipes are magnetized during manufacturing
  - Residual magnetization is used for detection
- Defects (missing metal) with well-defined geometry have magnetic fields that can be approximated by the field of a magnet:

WiSense looks for patterns like those produced by an ideal magnet, called a <u>dipole</u>



Field Generated From Defect

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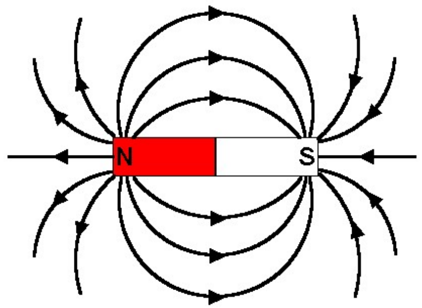
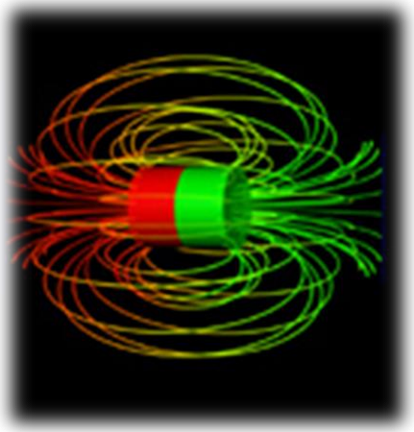


Field From Magnet



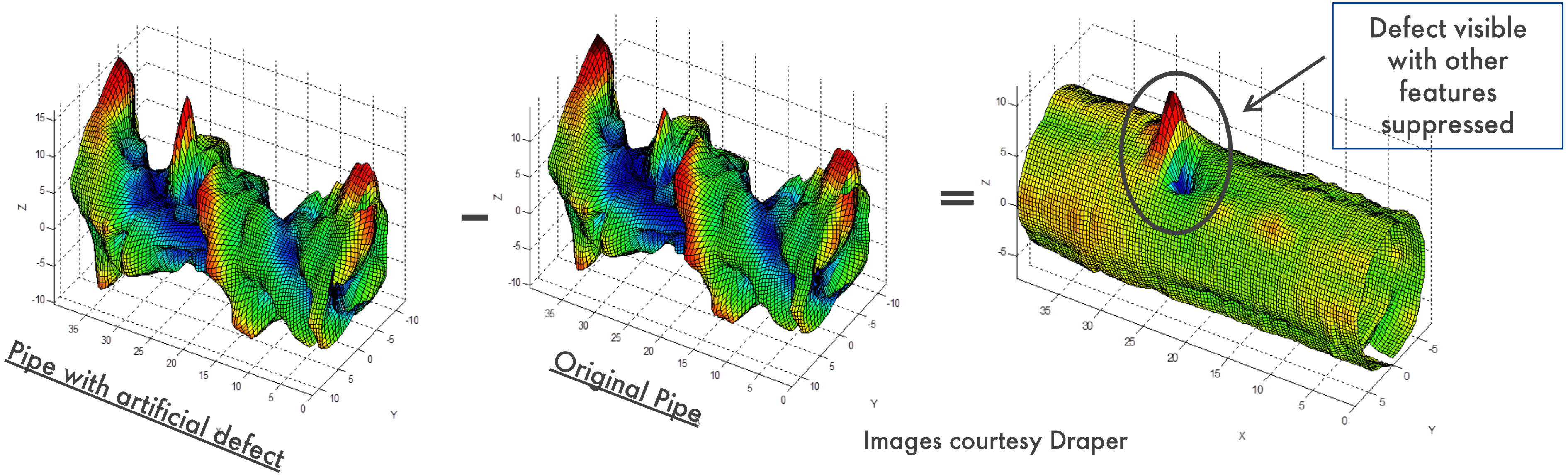
3D Field From Magnet

Reference: C N Johnson, e.a., The WiSense Technique: Passive Magnetometry of Pipes for Detection, Inspection, and Monitoring of Corrosion, 56th Annual British Conference of Non-Destructive Testing, Sept. 2017

Principle of WiSense technology – Baseline subtraction

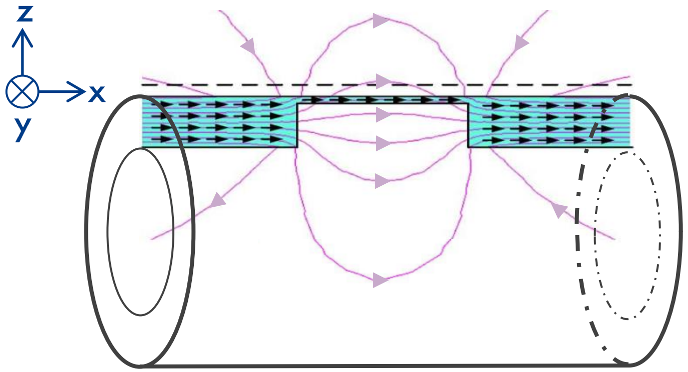
- Magnetometer array senses pipe's remnant magnetic field
  - Time-series subtraction of magnetic fields results on picking out defect from complex pipe magnetic field

- Non-intrusive patch
  - Flexible to suit different pipe geometry
  - Provides area coverage on top of pipe
  - Detects magnetic field due to both internal and external corrosion



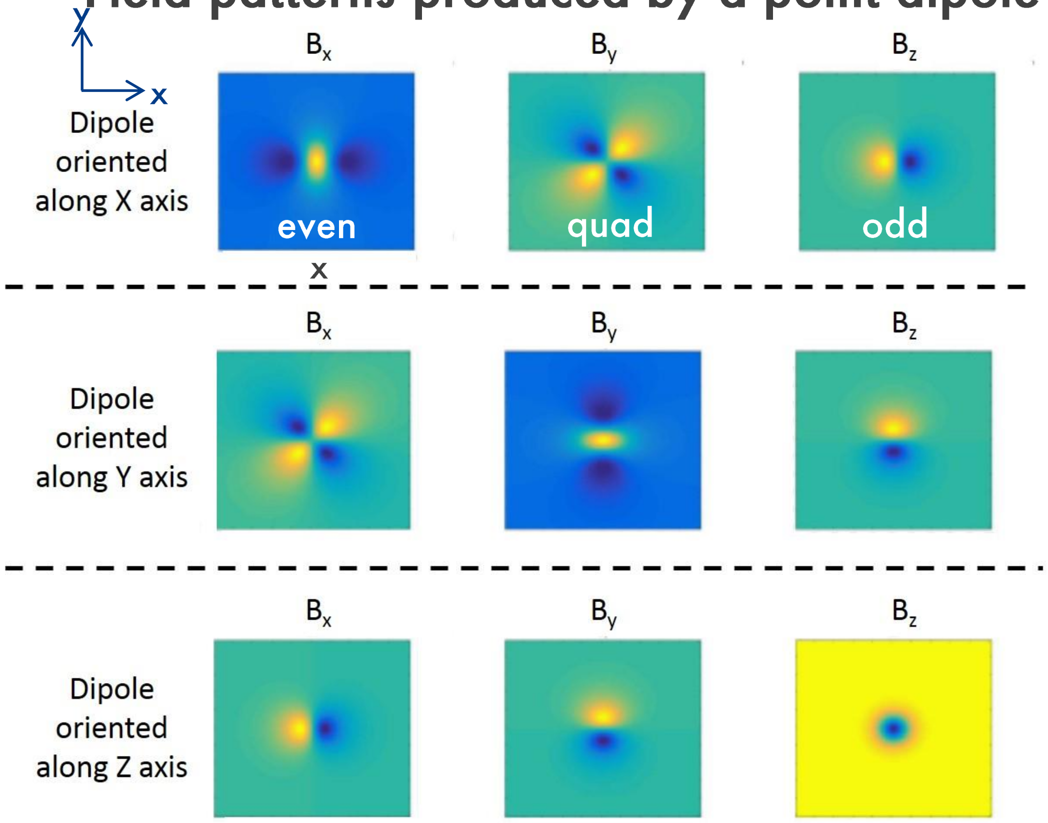
Images courtesy Draper

Magnetic dipole field patterns



- Sensor array: produces B-field “maps”
- Localized defects: magnetic “maps” resemble dipole field patterns
- Detection algorithm: find corroded regions by searching for dipole patterns
- Complex defects: search for patterns produced by a collection of dipoles
- Defect growth: monitored by tracking changes in signal size

Field patterns produced by a point dipole

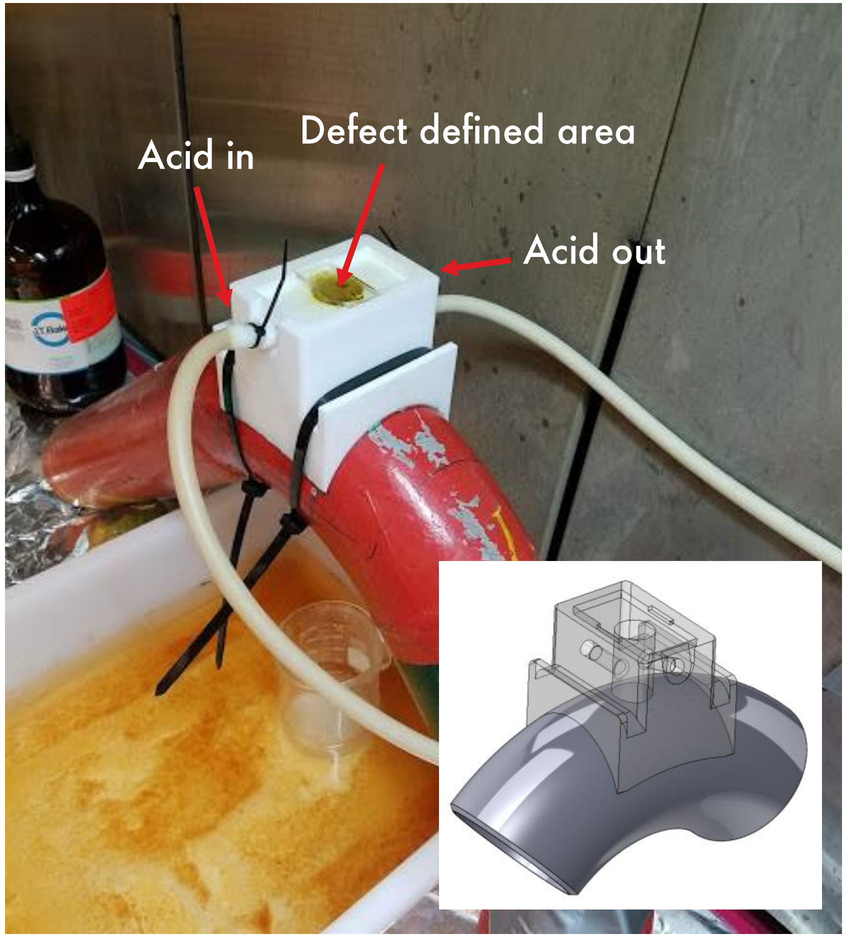


WiSense overview – localised corrosion monitoring

- WiSense initiative was started to fill the gaps in real-time corrosion/ erosion monitoring
- Key gaps that WiSense can cover:
  - Area coverage
  - Monitoring for local corrosion wall loss defects
  - No surface contact / Easy retrofit
  - Wireless for minimal infrastructure impact
  - Long lifetime with minimal maintenance
- Shell initiated development
  - Initial development by Shell and Charles Stark Draper Laboratory
  - Commercialization with Yokogawa Electric Corporation
  - Goal is to achieve step-change in capability to monitoring for local defects
  - Main drivers include cost reduction, asset integrity & life extension
- Current application target
  - Onshore and offshore topsides
  - Straight pipes, bends, tees, welds

Example from pilot deployments at difficult to access/ monitor locations (deployed since 2017)

Laboratory testing (external defects)



- Defects are acid-etched on outer surface of pipes
- A Teflon fixture defines the defect area
  - Mates tightly with pipe surface
  - Grease seal prevents acid leaks
- Defects etched in straight & elbow pipes

Photographs courtesy Draper

Independent Validation Testing

- Independent validation testing of WiSense sensor performance.
- Defects etched on inside of the pipe by dripping acid and sensor patch placed on the outside of the pipe.
- Acid etching preferred to make irregular defect shapes with clear/ sharp boundaries.

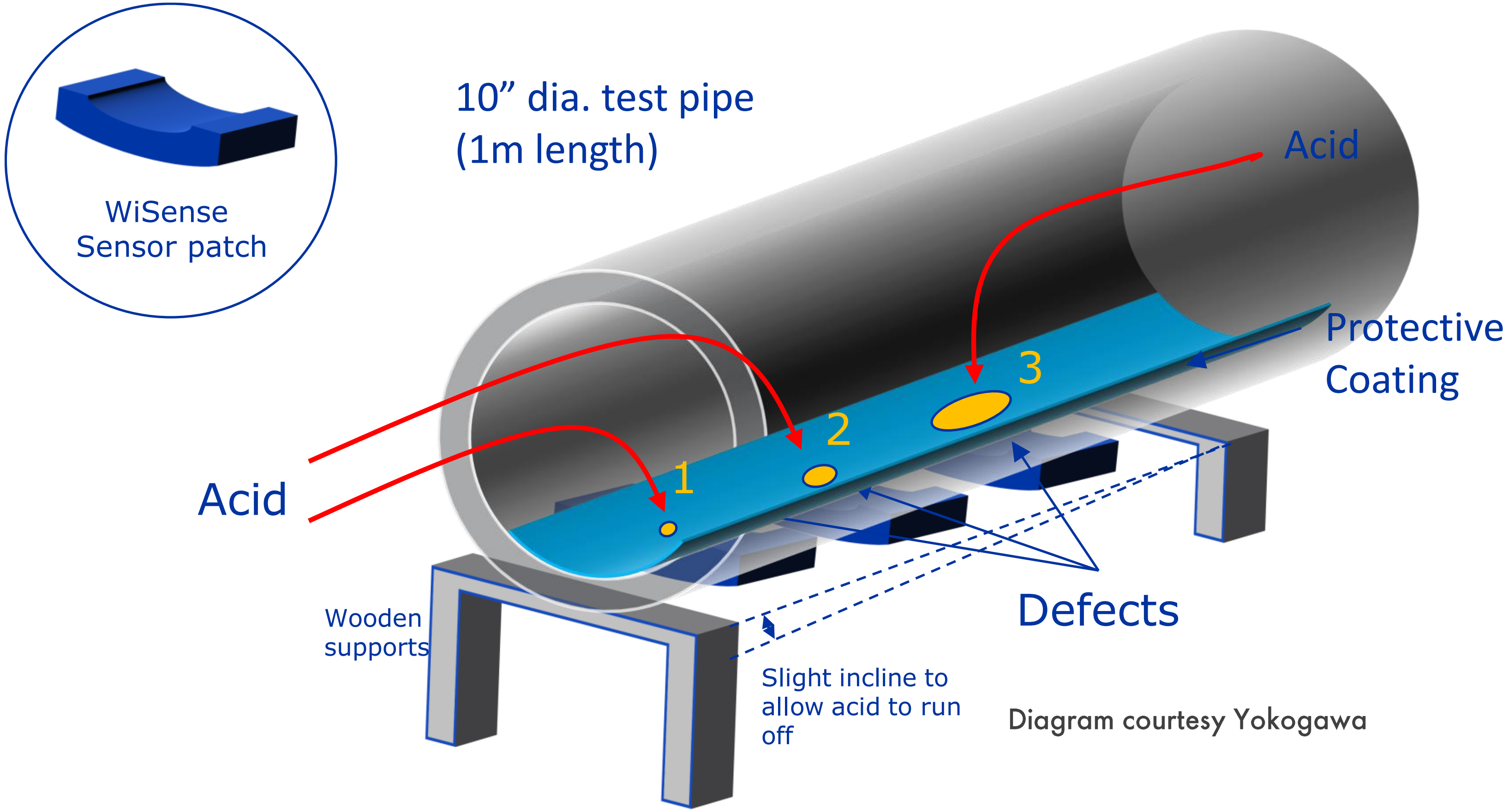


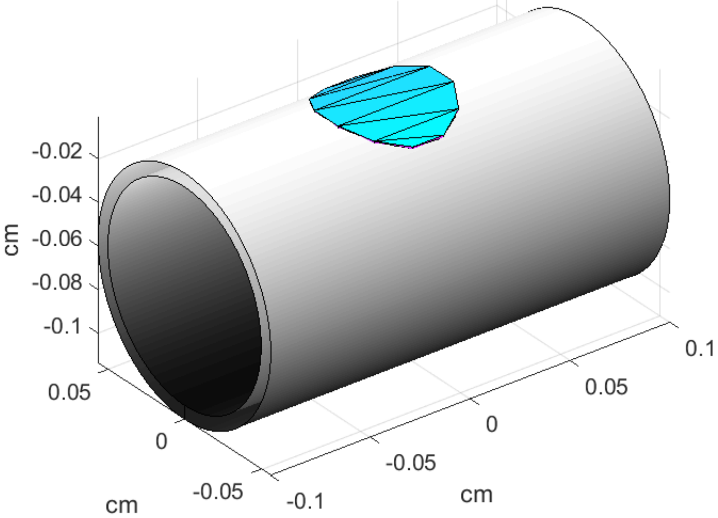
Diagram courtesy Yokogawa

Template Matching for Detection

- Real-world defects are not ideal dipoles
  - Ideal dipoles are point sources
  - Defects have lateral dimensions and depth
- Defects are detected via physics modeling
  - Data is compared with models of fields produced by parameterized "templates"
    - Magnetization amplitude/direction
    - Shape (circular/elliptical)
    - Diameter, semi-major/semi-minor axes
  - Including defect geometry in the models leads to a better match than a pure dipole
  - Template match provides not only detection but also sizing information
    - Corrosion expert can convert lateral dimensions to depth using past experience with defect aspect ratio

Etched defect

Modeled template

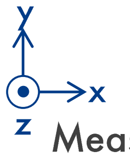


Figures courtesy Draper

Model Comparison

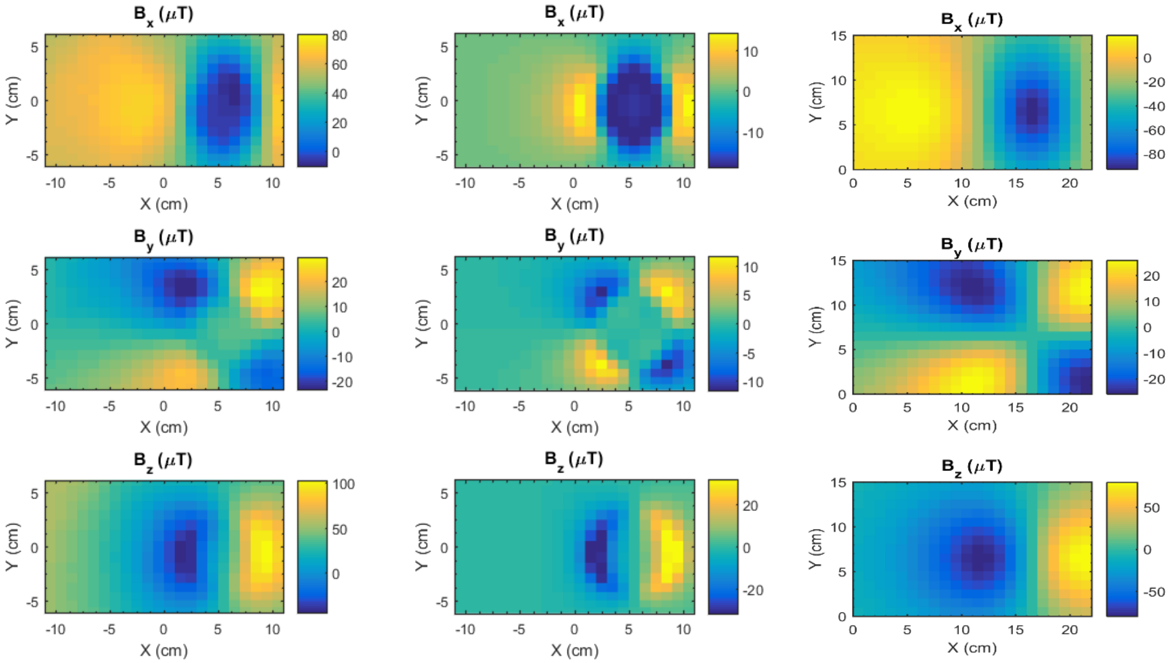
Template model captures features that dipole model cannot

- Region of constant field in the center of the defect
- Fine features (e.g. curvature)



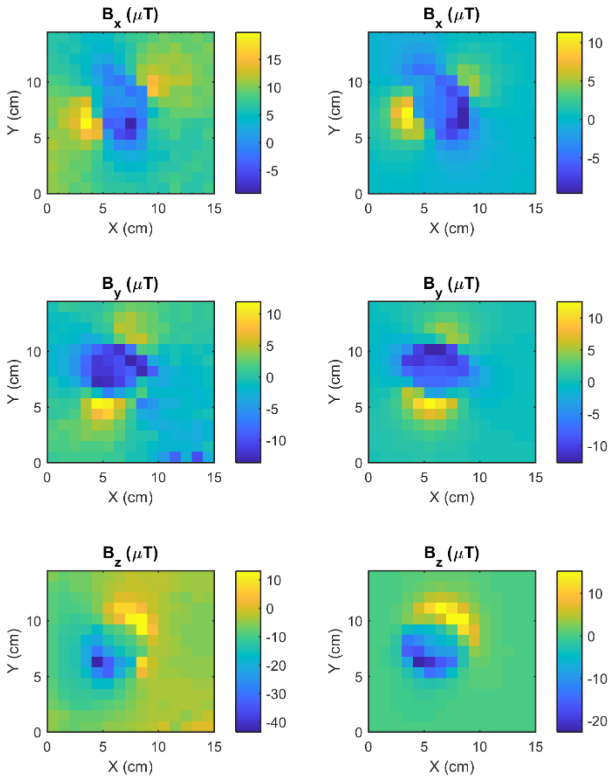
Defect magnetized along X direction

Measured field | Template model | Dipole model



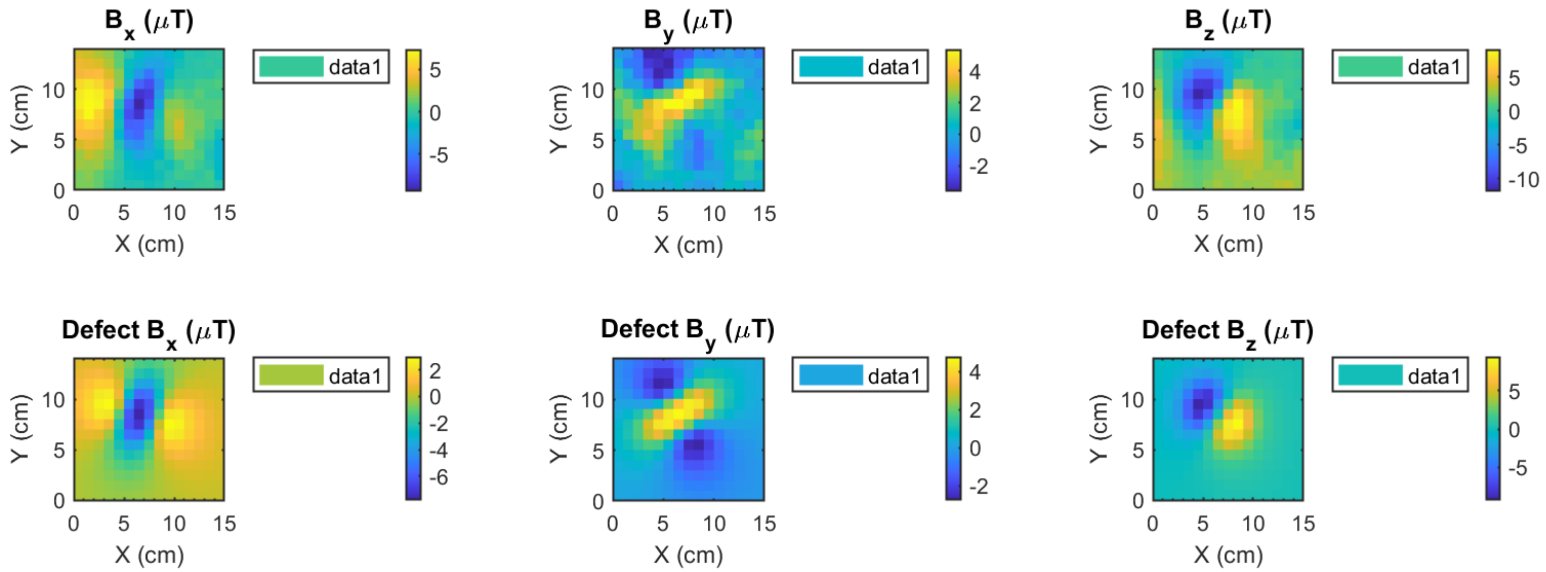
Defect with magnetization components along all three axes

Measured field | Template model



WiSense uses two step analysis: detection and growth monitoring

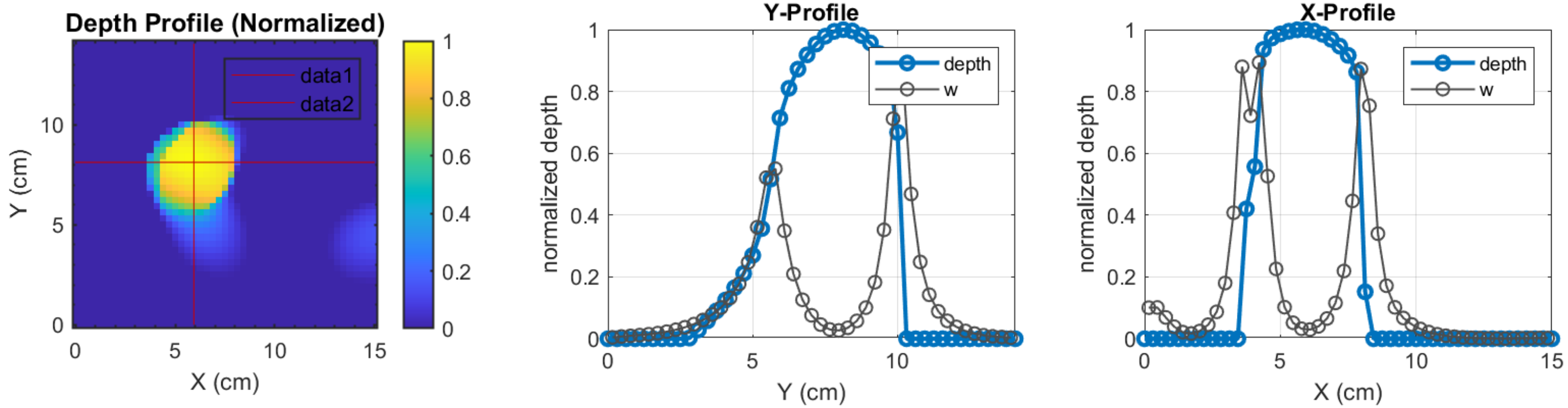
Detection:



Measured data

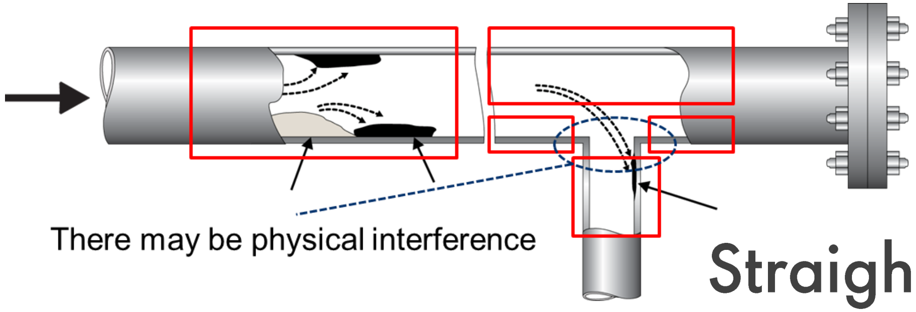
Analysed data

Growth monitoring:

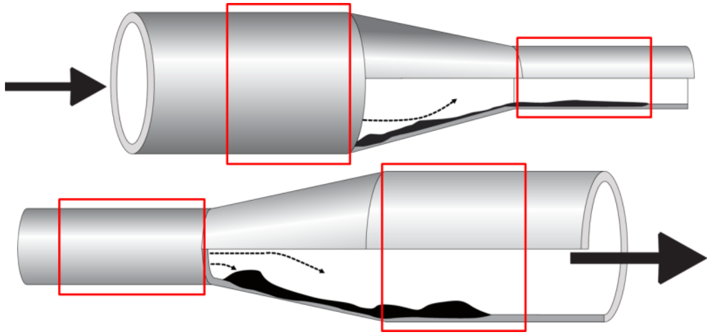


Examples of candidate deployments locations

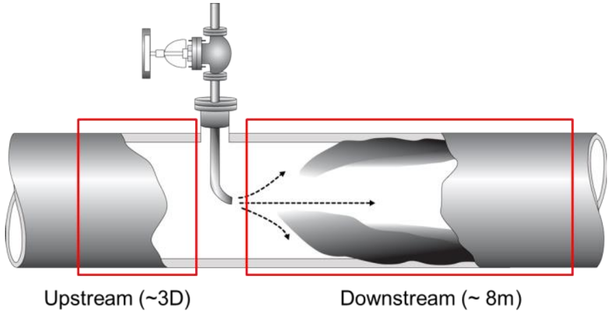
WiSense prototype



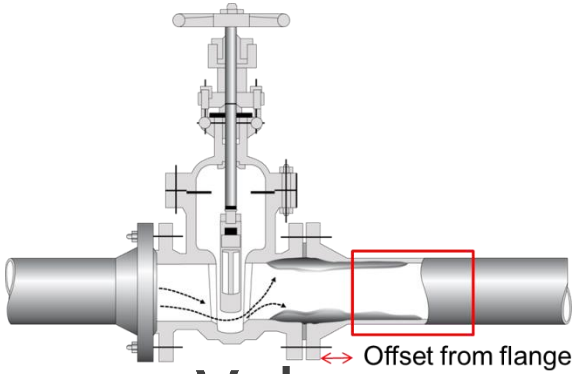
Straight & elbow



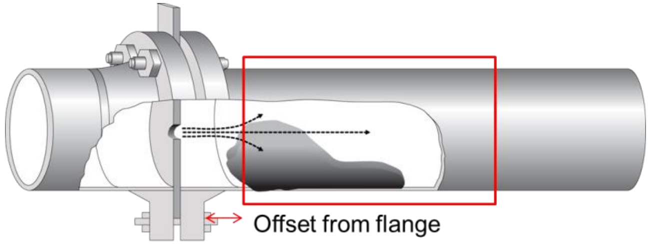
Reducer



Injection point



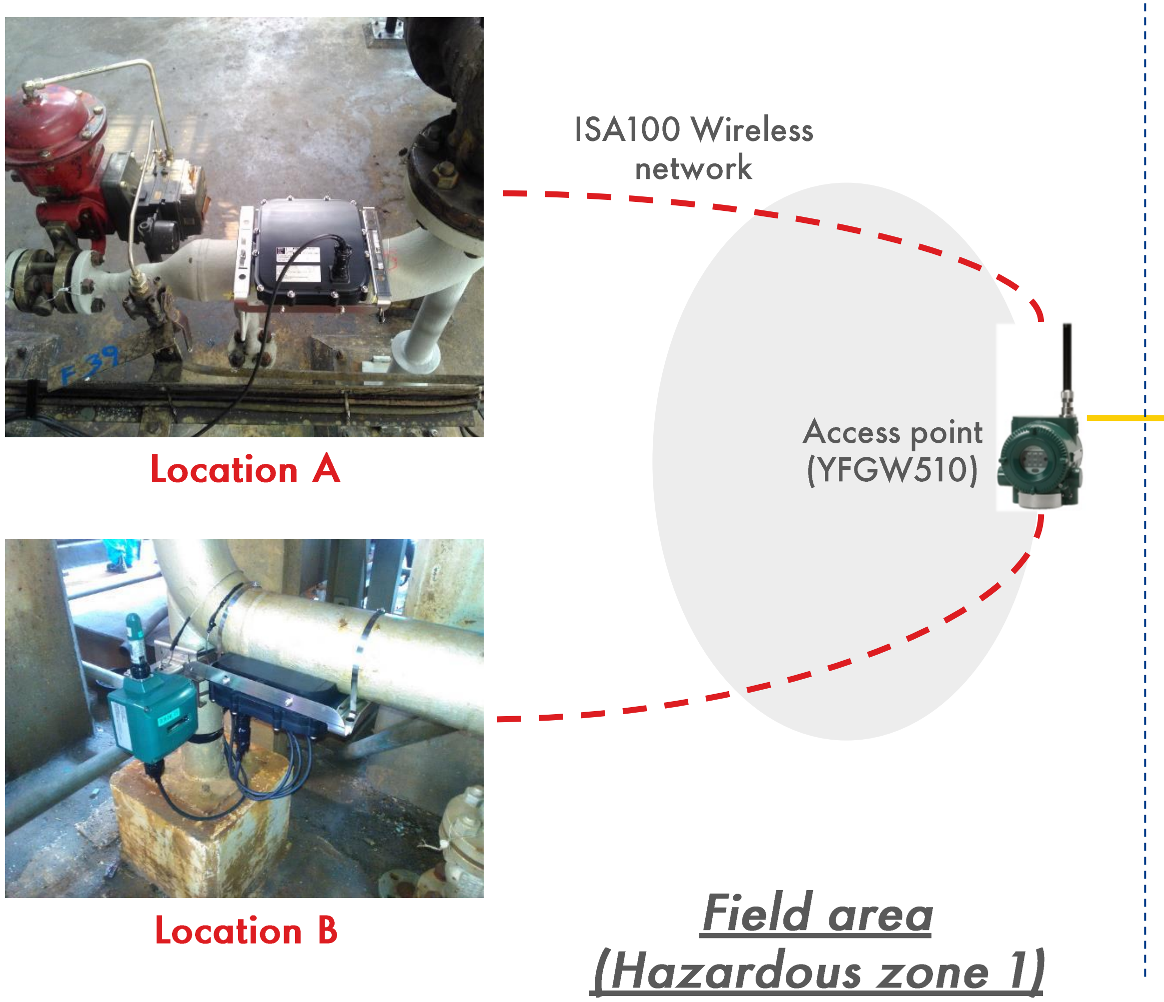
Valve



Orifice

Diagram courtesy Yokogawa

Installation and Deployment Overview

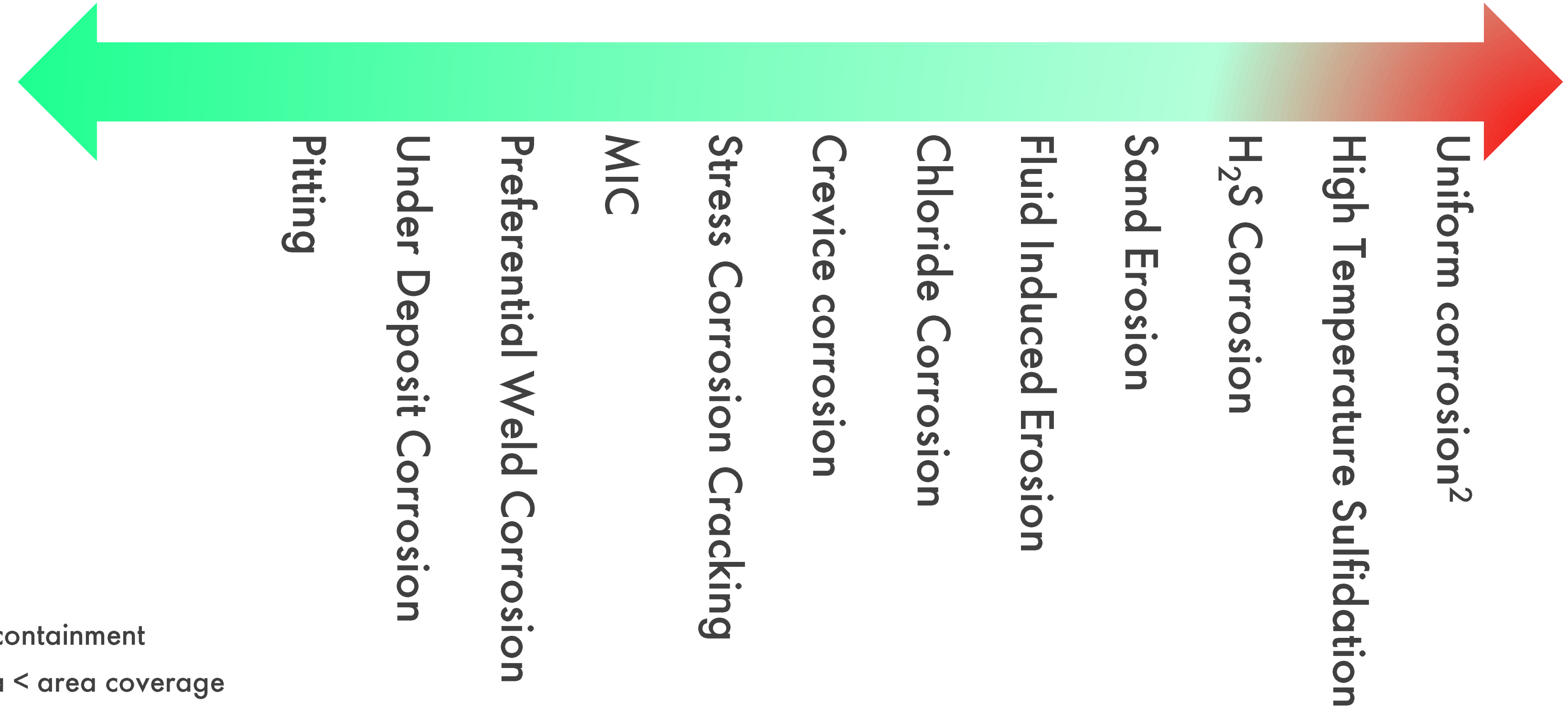


- Remote access to cloud solution
- Data stored at standalone workstation in control room (CCR) and uploaded on cloud via Azure IoT edge

Diagram courtesy Yokogawa

Unique positioning of WiSense for localised degradation mechanisms

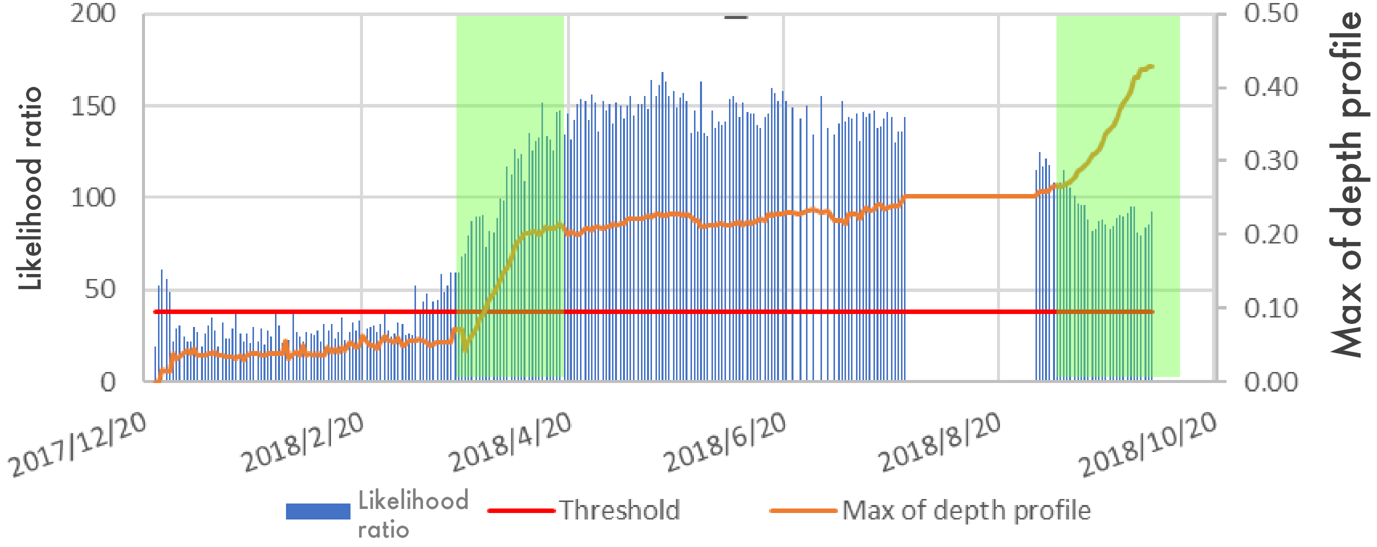
The root cause of majority of LoPC[1] incidents or accidents can be traced back to localised degradation mechanisms – a major gap in the industry. WiSense has strong competitive advantages and is uniquely placed for monitoring localised degradation regimes.



1. LoPC: Loss of primary containment
2. Uniform corrosion area < area coverage

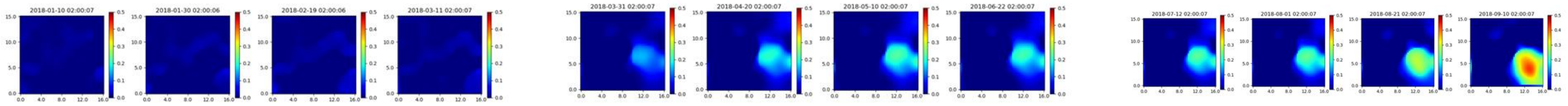
Field example two step analysis: detection and growth monitoring

Detection:



Area with green highlight represents the duration of defect growth

Growth monitoring:



WiSense Capabilities

- Defect detection (Y/N indication) – indicated by rise of likelihood ratio above the threshold
- Growth monitoring – indicated by lateral area of the defect and the rate of change of relative depth

Conclusions and Summary

- WiSense technology introduced localised defect monitoring capability and is an important inclusion in the NDT toolbox, alongside other inspection and monitoring techniques.
- WiSense technique has demonstrated robust performance over 3+ years of pilot testing at multiple assets with Shell (upstream as well as downstream).
- Highly sensitive technique for localised degradation mechanisms and allow proactive monitoring and prediction of pipe integrity, when used alongside simulation or prediction tool.
- Applicable on process piping as well as onshore/ subsea pipelines.

Questions and Answers

Q&A