Developments in Corrosion Monitoring

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Content

- Early Corrosion Monitoring developments
- Permasense: what contributed to such a success
- Techniques for monitoring local corrosion defects
- Opportunities for monitoring with permanent sensors & gaps

Scope of the subject:

- Wall loss damage
- Internal damage

Corrosion Monitoring has a long history

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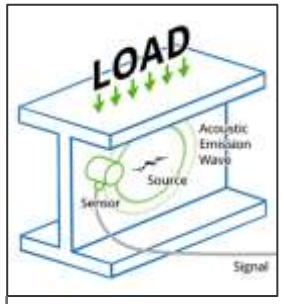
Some of the early corrosion damage monitoring techniques



Acoustic Emission Monitoring
(courtesy Physical Acoustics)

TOFD Monitoring
(courtesy Sonovation)

FSM (subsea/topsides)
(courtesy iicor/ROXAR)

Rightrax & Fleximat

PEC Monitoring

High-temperature UT probe
(courtesy GE/iicor)

1980 1990 2000 2010 2020 2030

Structured attempts to boost monitoring in O&G

- 1999 brainstorm in HOIS jip*: remote monitoring of plant condition most popular
- Result, program to develop capability of Permanently Installed Monitoring Sensors (PIMS), 2000-06)
  - It showed no commercial uptake
- Post-implementation review: why no uptake?
  - Technology: limited area coverage (CEM; Rightrax strips)
  - Wireless: early days (in hindsight)
  - Technology focus but no sensitivity for market forces
  - Corrosion rates incorporated in RBI only since 2010'ish (optimize inspection intervals; set Integrity Operating Windows)

HOIS field trial with ClampOn CEM system at Shell UK gas plant

** HOIS, (acronym has no meaning anymore); a jip led by ESR technology: link [ESR Technology – HOIS]*

Characteristics of early corrosion monitoring approaches

- Focus on existing defects
- Cumbersome to install
  - (gluing; welding; pre-installation; wiring for power and data)

- Structured review of the design of a Corrosion Monitoring (2003, see abstract);
  - One major gap sticks out: Poor knowledge of damage location
    - More area coverage needed beyond what systems could provide us in 2003

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03431

CORROSION 2003

CORROSION MONITORING IN OIL AND GAS PRODUCTION

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ABSTRACT

The design of corrosion monitoring systems for oil and gas production is discussed. A whole system approach has been taken: the user should carefully consider the monitoring objective, such as support corrosion control, monitor wall thickness, or determine the fluid corrosivity. This leads to selection of the relevant parameters to be monitored, logical monitoring locations, the required sensitivity and response time, data communication and analysis, and reliability requirements commensurate with the operating philosophy. In a parallel exercise the corrosion mechanism, taking into account potentially changing operating conditions, has to be analyzed to define the required coverage. Once these steps are taken, suitable techniques can be selected. The final choice will depend on availability and cost. Examples of corrosion monitoring systems and key performance indicators for common systems are given.

Keywords: corrosion monitoring, monitoring techniques, availability, reliability

Permasense: continuous data make a difference

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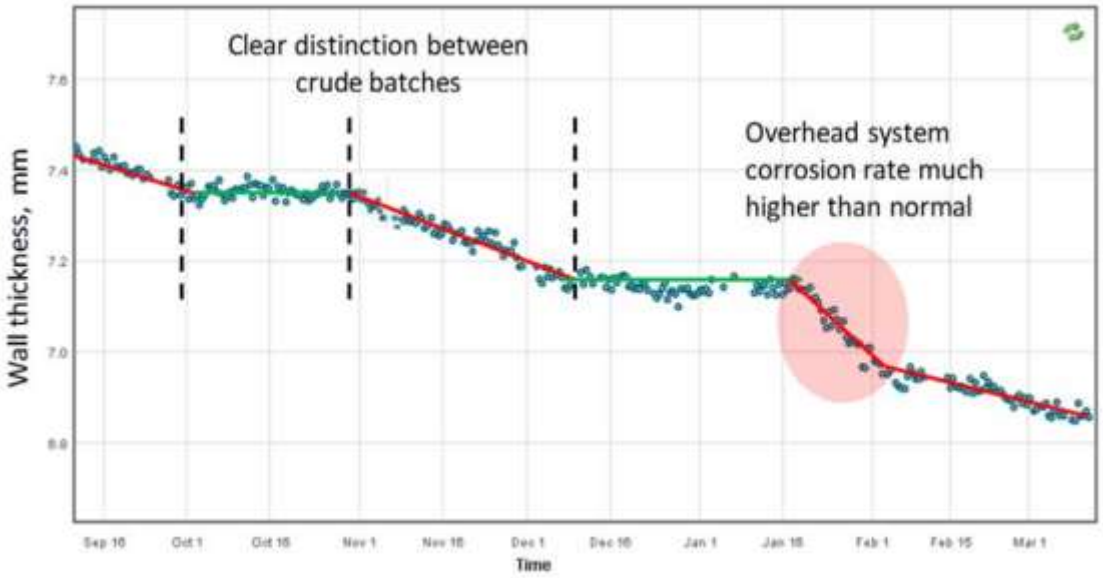
In 2010 a success story started: Permasense

- Developed at Imperial College, support from BP, rolled out via spin-out company Permasense
- First wireless sensor; up to 600 C
- High sensitivity: detecting small changes in wall loss in a meaningful time interval

EMAT version, strapped on pipe, to avoid welding
(courtesy Permasense)

Permasense sensors clamped, to avoid welding
(Courtesy NAM)

Permasense WT100/WT210 sensor, attached with stud-welded bolts (courtesy Permasense)



Example field data: sensitivity as high as 25-50 micron (after temperature compensation (courtesy Permasense)

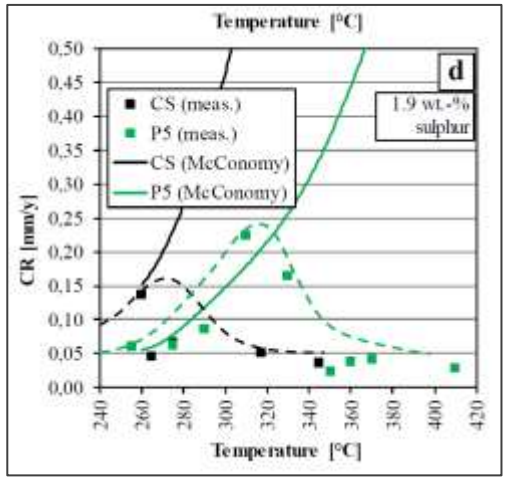
What contributed to Permasense become such a success?

- Sweet spot: high-temperature sulphidation in crude distillers in refineries
  - Mechanism produces highly uniform wall thinning
  - Hence, placement of the UT point sensors is not very location-critical

- 8" 150# CS elbow in 5Cr piping system in HVU (leak after 24 years) due to HT-sulphidation.
- Elbow original weight ~40 kg, remaining weight 6 kg.

What else did Permasense bring us?

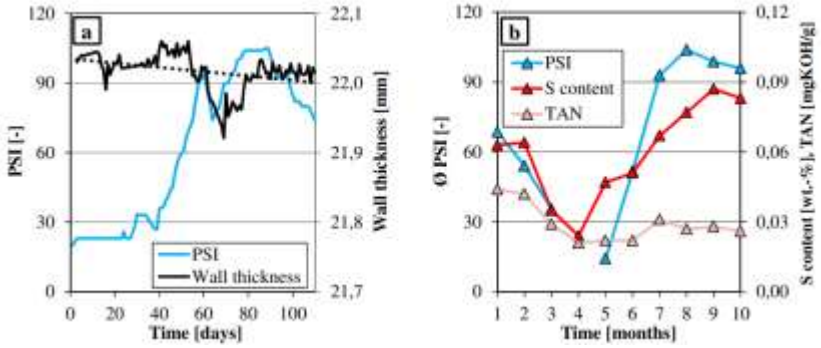
- Correlation Permasense thickness data with process data
  - This allowed correction of corrosion prediction models
- Correlation "pulse shape indicator" (PSI) with process data
  - Despite the qualitative nature, this correlated fairly well



Example of comparison plant corrosion rate data with prediction model;
Ref. Schempp e.a., New approach for sulphidation prediction in crude oil refineries- Eurocorr 2019-paper 233938

Learnings:

- Correlation with process conditions opens new window on corrosion behavior
- Value from highly sensitive sensors; no need to be quantitative, monotonous response is good enough



Correlation of PSI factor with process conditions;
Ref. Schempp e.a., Prediction, monitoring and inspection of high temperature sulphidation, Eurocorr 2016, paper #68895

Monitoring for local defects

Are techniques up for the challenges?

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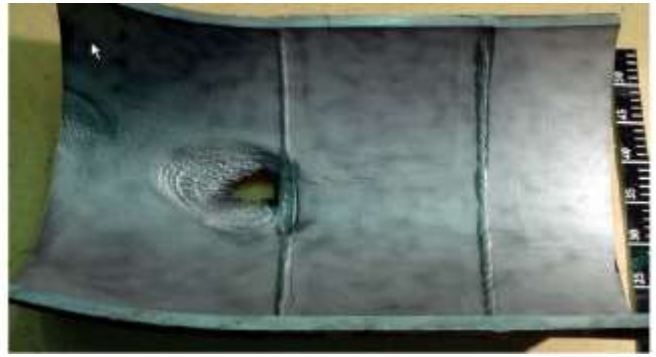
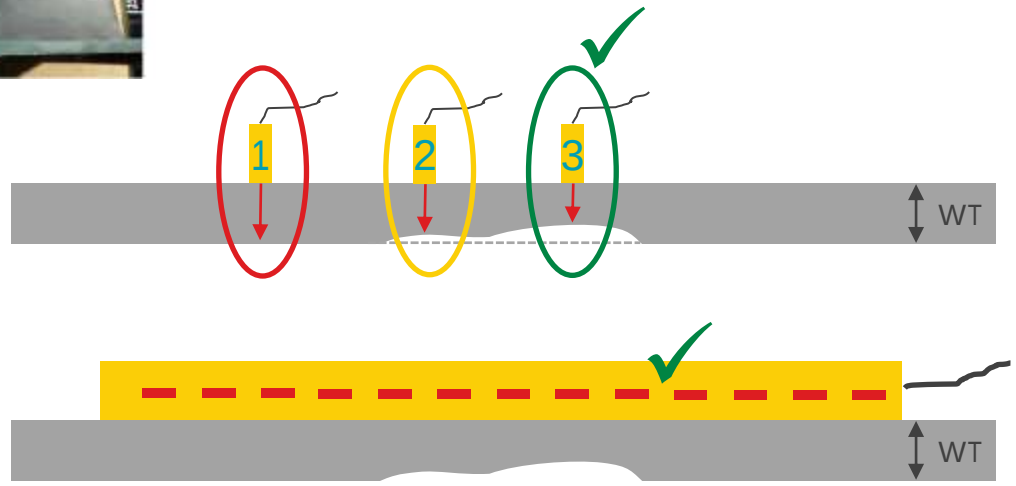
Characteristics of local corrosion damage

- Local corrosion damage is distinguished from uniform, or general, wall loss
  - (there is not a consistent definition of what is local)



- Amomium-bisulphide, ~2mm/y
- @ change of flow direction



- Monitoring with point sensors becomes challenging
  - For a reliable depth reading a probe need to be on top of the deepest section of the defect
- For reliable detection, the sensor area needs to include the location of the (future) defect

Techniques for monitoring local corrosion damage

Techniques suitable for monitoring of (yet unknown) local corrosion damage:

- Ultrasonic array
- FSM
- PEC
- Magnetometry
- Guided Wave Monitoring (pulse-echo)
- Guided Wave Tomography

- Common property: depth is not measured directly, rather volume or cross-section (see next slides)

How to compare these apples and pears?

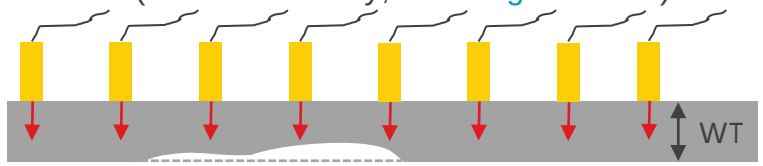
Desirable properties:

- High sensitivity
- Large monitoring area
- Retrofittable
  - Working on range of pipe geometries (straights, long or short; bends; reducers; etc.)
- Attractive Total Cost of Ownership
  - Incl. Hardware, installation, maintenance, analysis support, etc.

Measurement characteristics of some monitoring techniques

(applied to a 10" diam. pipe, 10 mm wall thickness)

(Ultrasonic array, Coverage 0.02m²)



PipeMonit-Swarm
(courtesy Sensorlink)

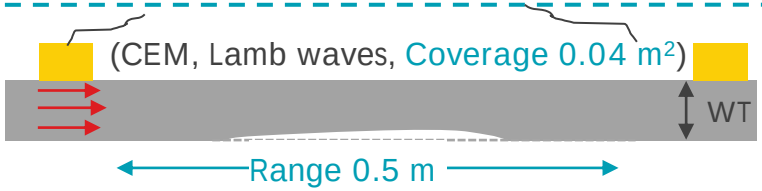
(Magnetometry patch, Coverage 0.15 m²)

Magnetometry
(Patch + Wireless unit)
(courtesy Shell/Yokogawa)

(PEC Array, Coverage 0.03 m²)

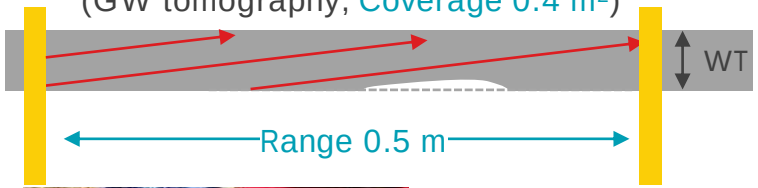
PEC Monitoring
(courtesy Shell)

(CEM, Lamb waves, Coverage 0.04 m²)



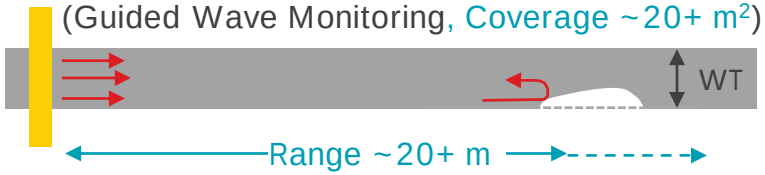
CEM
(courtesy ClampOn)

(GW tomography, Coverage 0.4 m²)



GWT
(courtesy ClampOn/PDO)

(Guided Wave Monitoring, Coverage ~20+ m²)

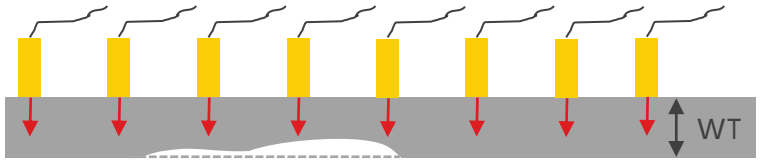


gPIMS
(courtesy GUL/HOIS)

Salient properties of some monitoring techniques

(applied to a 10" diam. pipe, 10 mm wall thickness, and 20 mm dia disk)

(Ultrasonic array)



- High temperature
- Measurement reliability decreases when defect width ~< sensor spacing
- Installation tedious

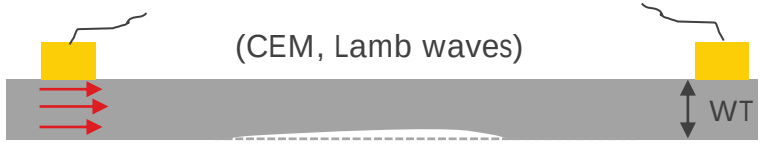
(Magnetometry patch)

- Easy retrofit
- Sensitive
- Low power; Wireless
- Uncalibrated response

(PEC Array)

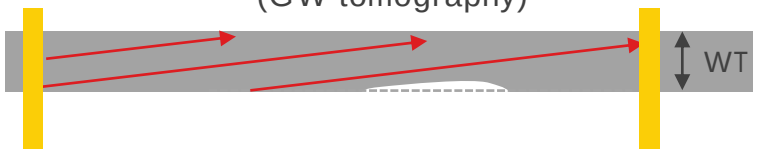
- Easy retrofit
- Can operate at high temperature
- Arrays-system to be developed

(CEM, Lamb waves)



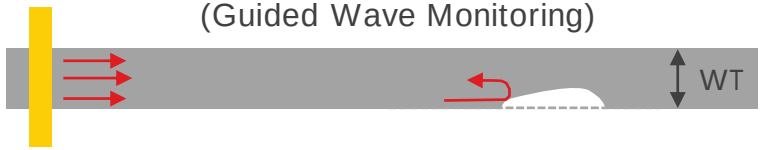
- Easy retrofit
- Fit to curved surfaces
- Medium sensitivity (screening)
- Small area

(GW tomography)



- Thickness map
- Medium sensitivity
- Complex analysis ; straights only
- Installation tedious

(Guided Wave Monitoring)



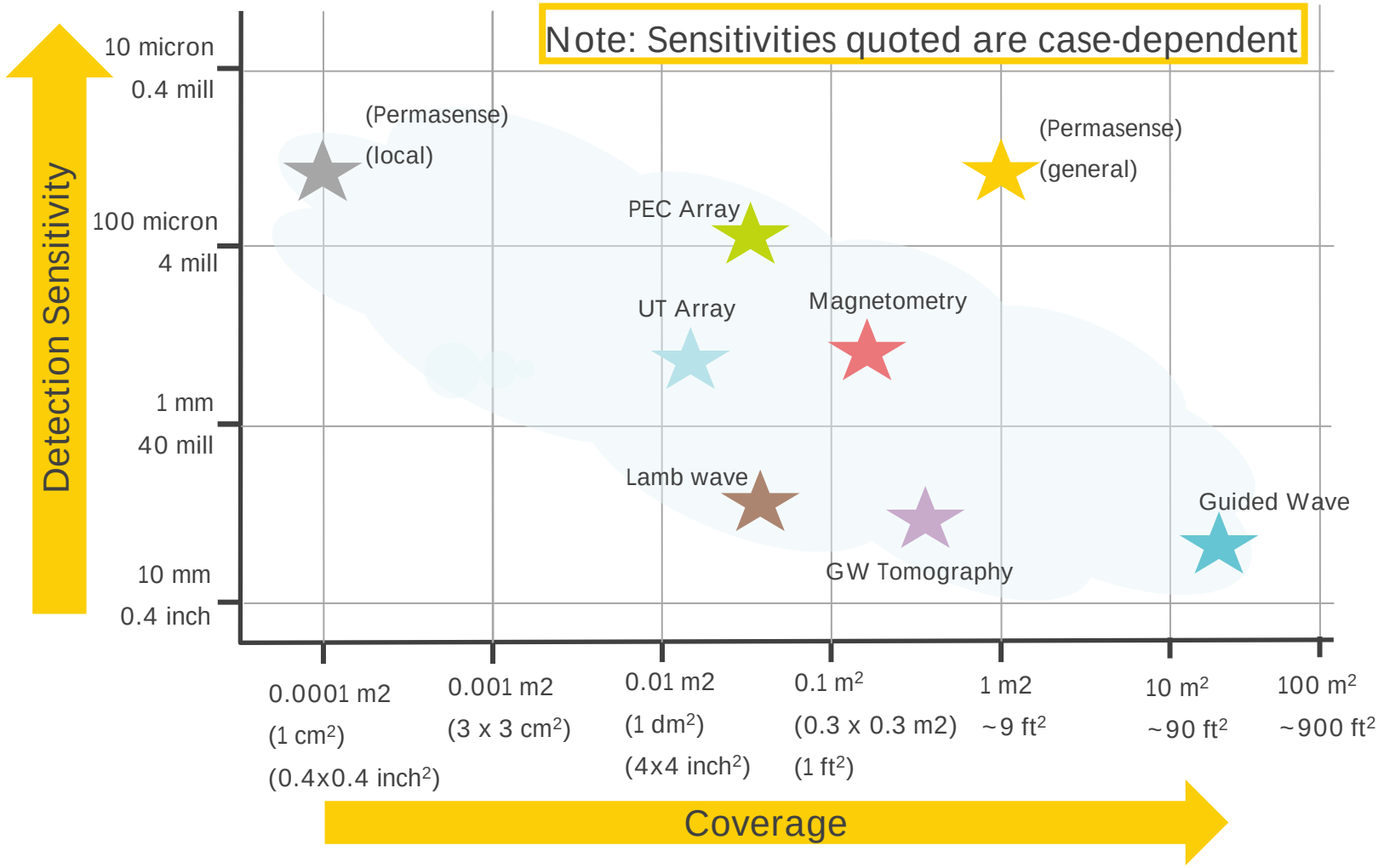
- Can cover straight+bend+welds
- Low sensitivity (screening)
- Not for complex/short pipe sections

Detection Sensitivity (depth, mm) versus area coverage (m^2)

(applied to a 10" diam. pipe, 10 mm wall thickness, and 20 mm dia disk)

(Data summary)

- UT thickness
  - (1 cm^2 OR 1 m^2) X 0.05 mm
- PEC Array
  - 0.03 m^2 X 0.09 mm
- Magnetometry
  - 0.15 m^2 X 0.45 mm
- UT Array
  - 0.02 m^2 X 0.4 mm
- CEM Lamb Wave (line)
  - 0.04 m^2 X 2.5 mm
- Guided Wave Tomo
  - 0.4 m^2 X 3.0 mm
- Guided Wave ring
  - 20 m^2 X 4 mm

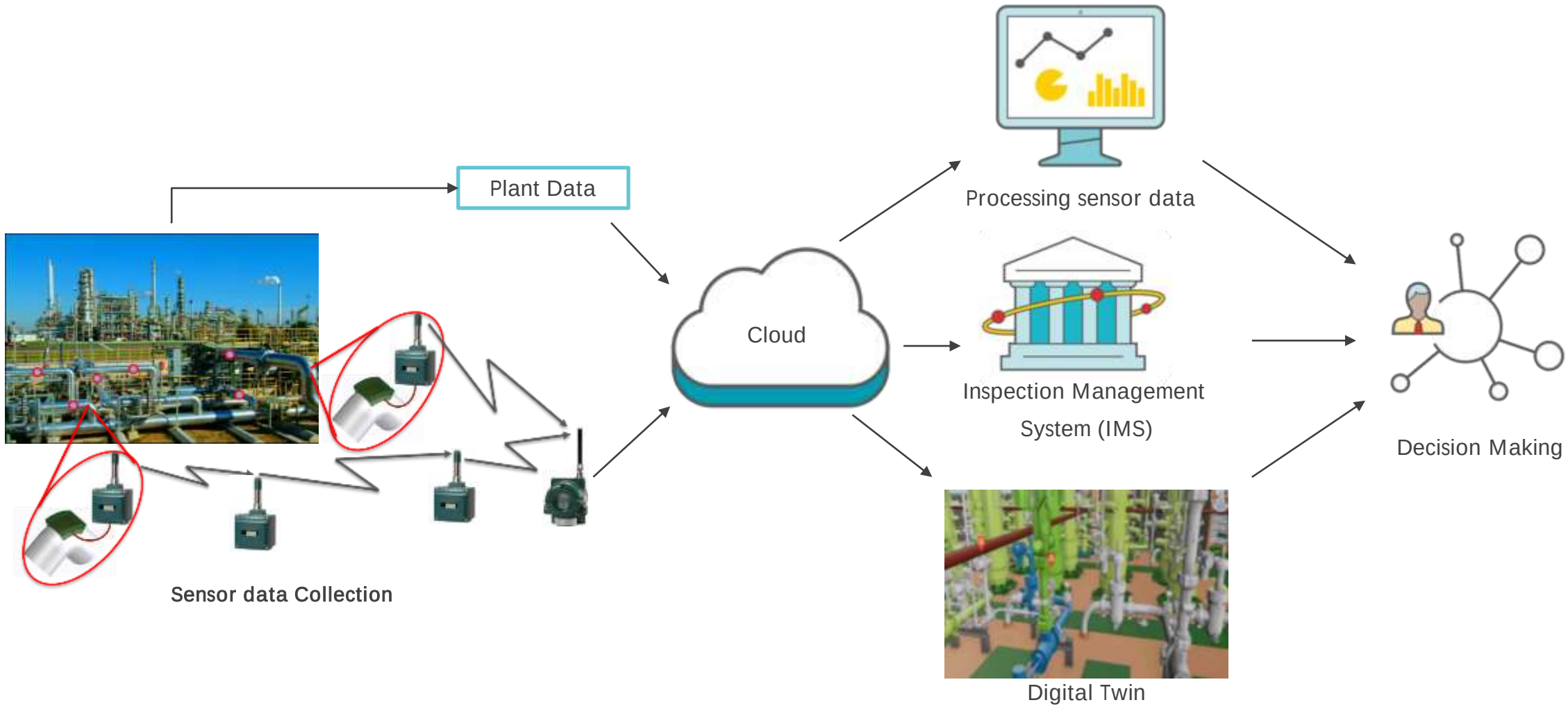


Monitoring for Local Corrosion

Success factors
Gaps

4

Drivers for success – a facilitating digital infrastructure



What are the new opportunities

- Sensors will increasingly play a role in monitoring the condition of process plant
  - "Fast Response" sensors enhancing corrosion prediction capability (correlation with Operating conditions)
  - "Fast Response" sensors verifying Corrosion Control an Integrity Operating Window management
  - "Fast-" and "Slow Response" sensors complementing and (partly) replacing periodic inspection.

- A personal observation: our digital environment is developing at a high rate; development of sensor capability seems to follow typical O&G pace of development.
  - Sensor capability could soon become the bottleneck

Gaps in monitoring capability for local corrosion damage

- Maturity: many systems still in development stage
- Significant gap in sensors operating at elevated temperature (150-450 degr C)
- Few monitoring techniques fit well on complex piping components (where corrosion is more abundant!)
- Pace of development of monitoring systems not on par with ambitions to increase remote plant operation
  - And likely not on par with pace with which Digitalisation will change our ways of working

Questions and Answers

Developments in Corrosion Monitoring