Sensorlink

Corrosion and Erosion Monitoring Using High Accuracy UT – Subsea, Topside and Underground

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Sensorlink

ISO 9001:2015 certified | IECEx certified | Achilles JQS qualified

Company Facts

Sensorlink specializes in innovative solutions for pipeline integrity management based on ultrasound technology

- Established in 1997
- Spinoff from NTNU/SINTEF *(one of Europe's largest technology and R&D centers)*
- Head office in Trondheim, Norway

Reference List - Recent Highlights (Apr 2023)

PipeMonit® and PipeMonit® Swarm (Dry)

More than 200 deliveries (<5500 sensors) delivered since 2011

- **Middle East – buried and open pipelines – 20 stations - 16 sensors each**
- **SEA – offshore erosion monitoring – 10 platforms, > 400 sensors**
- **Oceania – pipeline – 8 locations – 8 sensors each**
- **Kazakhstan – pipelines/refining – 6 locations – 24 sensors each**
- **Canada – Oil Sands – 10 Swarm belts – 24 sensors each**

## UltraMonit® (Subsea)

38 subsea deliveries since 2008

- **Azerbaijan - 10 UltraMonit devices**
- **Australia – UltraMonit retrofit system to existing pipelines**
- **Australia – erosion monitoring – 10 + 7 units**
- **West Africa – diver installed retrofit system**
- **Middle East – 7 UltraMonit Systems**

Corrosion and Erosion Monitoring Made Easy

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Current Trends in Integrity and Corrosion/Erosion Management 1/2.

Inspection and monitoring both needed

- Inspection cover total asset according to plan
  - Periodic
  - Moderate/low sensitivity
  - Focus on safety – fit for service - repairs
- Monitoring cover selected locations
  - Continuous – on-line
  - High sensitivity – fast information
  - Proactive actions (mitigation, process control)
- Trend towards increased monitoring share of integrity program


Swarm® on T-junction
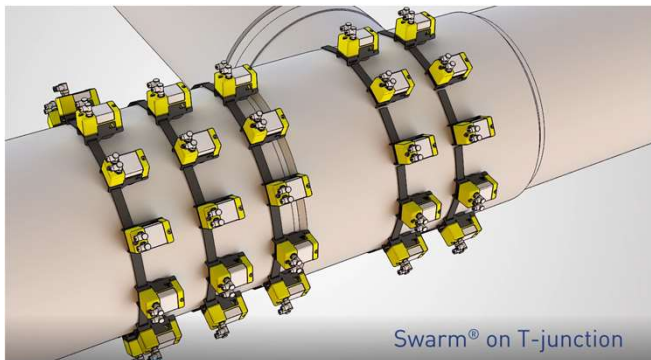
Non-intrusive replace intrusive monitoring

- Intrusive (probes): high sensitivity/fast response
  - UT closing sensitivity gap
- Non-intrusive benefits
  - Safety
    - Penetration of pipe not needed
    - High pressure retrievals not needed
      - Particularly important in sour service (safety)
  - Low long time cost (retrievals and replacement of equipment not needed).
  - More reliable measurements
    - Measure metal loss where it is
    - Not affected by patterns or deposits influencing measurements

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Current Trends in Integrity and Corrosion/Erosion Management 2/2.

Wired vs. wireless communication

- **Wireless makes on-line communication affordable – particularly brown fields**
- **Wireless standards established (ISA 100, WiHART)**
- **Wireless battery powered**
  - **Compromize on life/measurement frequency**
- **Wired solutions externally powered**
  - **Frequent measurements possible**
    - **Better trending, faster/more reliable information**
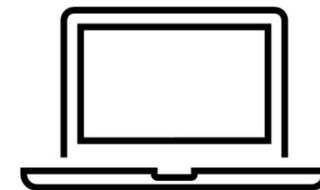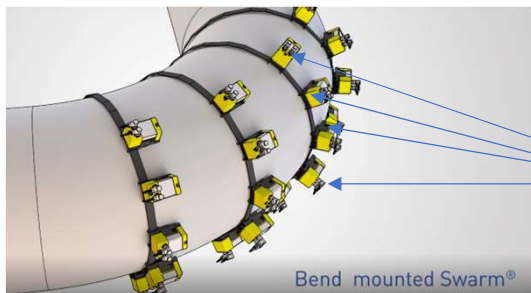
Focus on actionable information

- **Which decisions shall be made based on monitoring data?**
- **Type of data needed?**
- **Format of data preferred?**
- **Solutions to provide needed information?**
  - **Measurement technology?**
  - **Communication?**
  - **User interface (software)?**

Bend mounted Swarm®

High Accuracy UT Drives Transition Towards Non-Intrusive Monitoring

- **Accurate** Pulse Echo measurements and advanced processing provide easy to understand data – metal loss measured where it happens
- **High accuracy/repeatability** (down to 2,5 Um) ensures fast information allowing proactive actions and process optimization
- **Safe** and low maintenance/operational cost

Sensorlink UltraMonit®
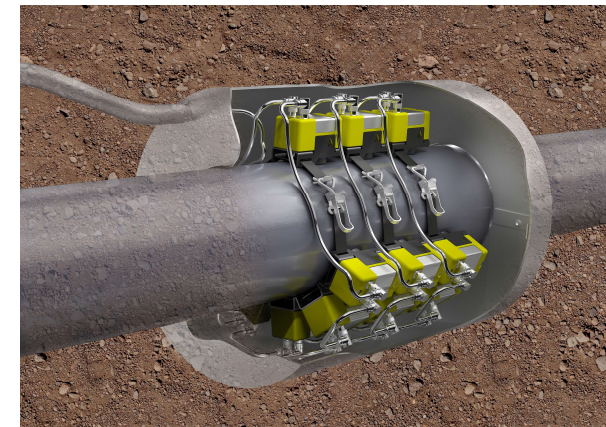
Subsea pipeline wall thickness monitoring (corrosion and erosion)

Sensorlink PipeMonit® Swarm

Topside/Landbased wall thickness monitoring

SensorlinkPipeMonit® Swarm

Cover for buried pipeline applications

Sensorlink Technology

Wall thickness monitoring using Single Element Pulse/Echo Transducers

- **Non-Intrusive**

- **Direct wall thickness measurement of pipe wall**

- **Not sensitive to pipe wall thickness**

- **Matrix driven to cover area of interest**

- **Temperature rating from -40 to 550°C (pipe wall temperature)**

- **Fixed sensors combined with advanced signal processing detects wall loss from less than .1 mills (2.5 micrometres) pending on product and installation location**

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Swarm

Corrosion and Erosion Monitoring Made Easy
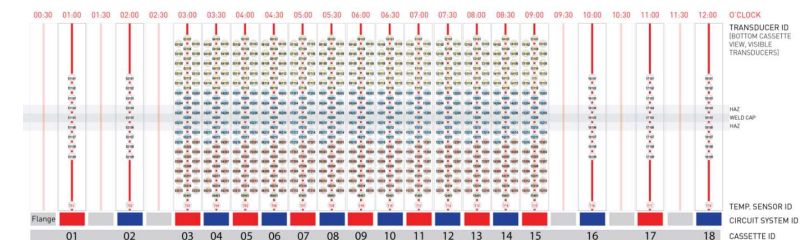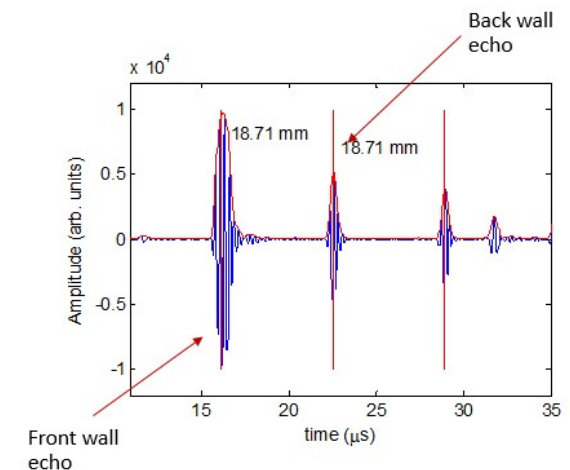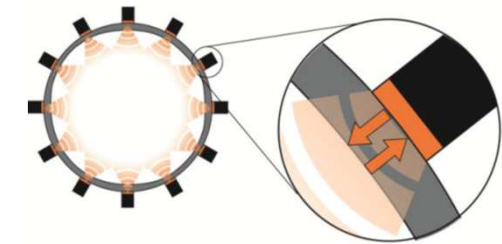
Swarm®/Ultramonit® Benefits

- **Consistent over time – independent of operator**

- **Data processed and digitalized on location**
  - **Direct use of data by user**
  - **Application software for data analysis not needed**

- **Straight forward data interpretation**
  - **Trusted information**
  - **Informed actions**

- **"Best in class" data accuracy and repeatability**
  - **Early actions – before damage**
  - **Efficient corrosion and erosion management**
  - **Optimized process and operation**
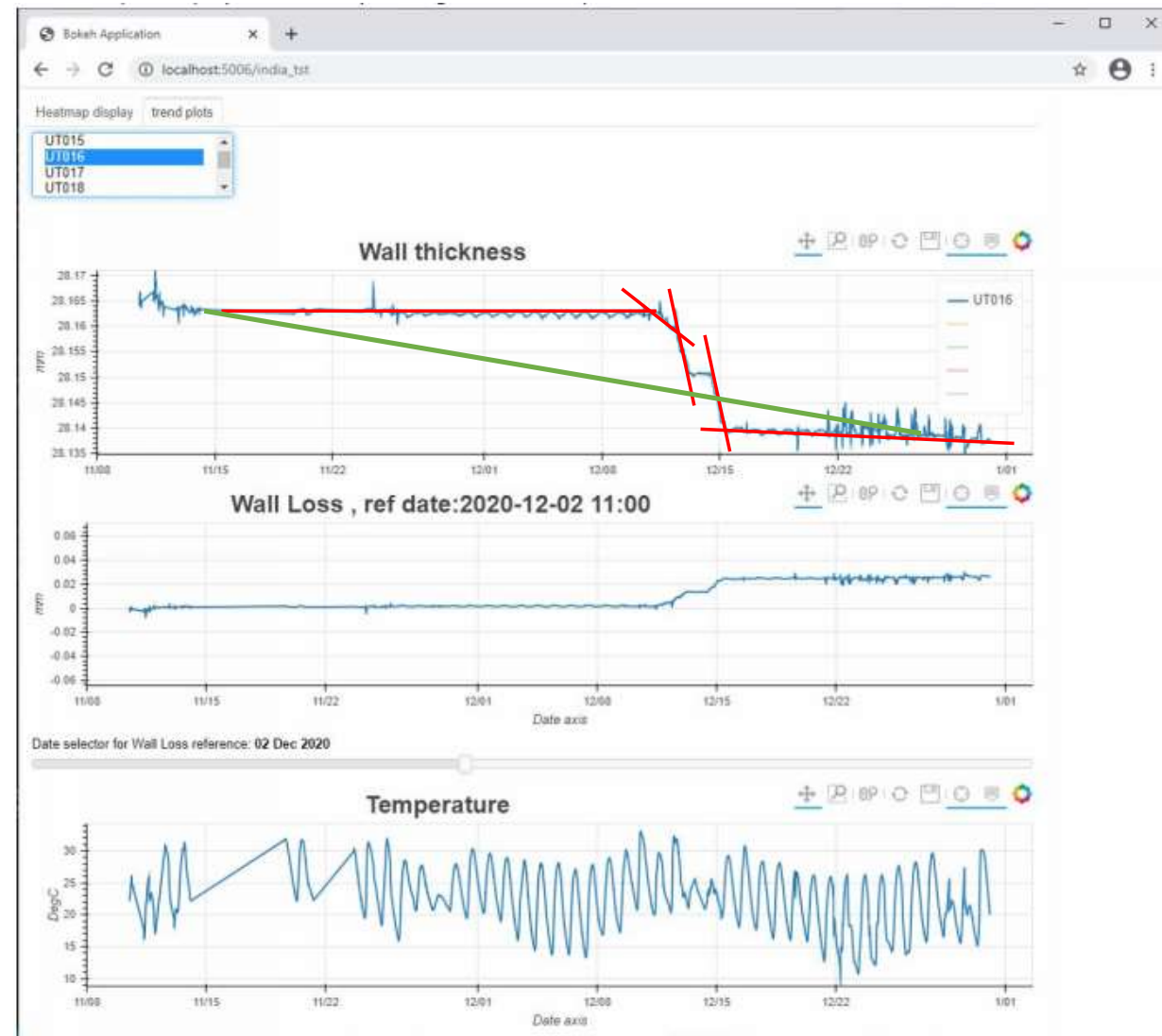
Sensors Optimized for Different Applications

SWARM S1

- Temp -40 to 125
- IP 67
- Repeatability 0,0025mm
- daisy chained for maximum of 250 S1 sensors per datalogger
- Communicates through SDL or FDL Dataloggers
- Certification:
  - EX ib IIB T4 Gb

SWARM LT

- Temp -40 p to 150
- IP 66
- Repeatability 0,01mm
- Single channel sensor with a maximum of 4 sensors per datalogger (option 4 x 4 with Multiplexer wired solutions)
- Commucates through Swarm S2 Datalogger
- Certification:
 - Ex II 2G Ex ib IIB T4 Gb

SWARM HT

- Temp 150 to 350
- IP 66 and 68
- Repeatability 0,01mm
- Single channel sensor with a maximum of 4 sensors per datalogger
- Communicates through Swarm S2 Datalogger
- Certification:
  - II 1 GD Ex ia IIC T* Ga

SWARM UHT

- Temp 350 to 500
- IP 66 and 68
- Repeatability 0,01mm
- Single channel sensor with a maximum of 4 sensors per datalogger
- Communicates through Swarm S2 Datalogger
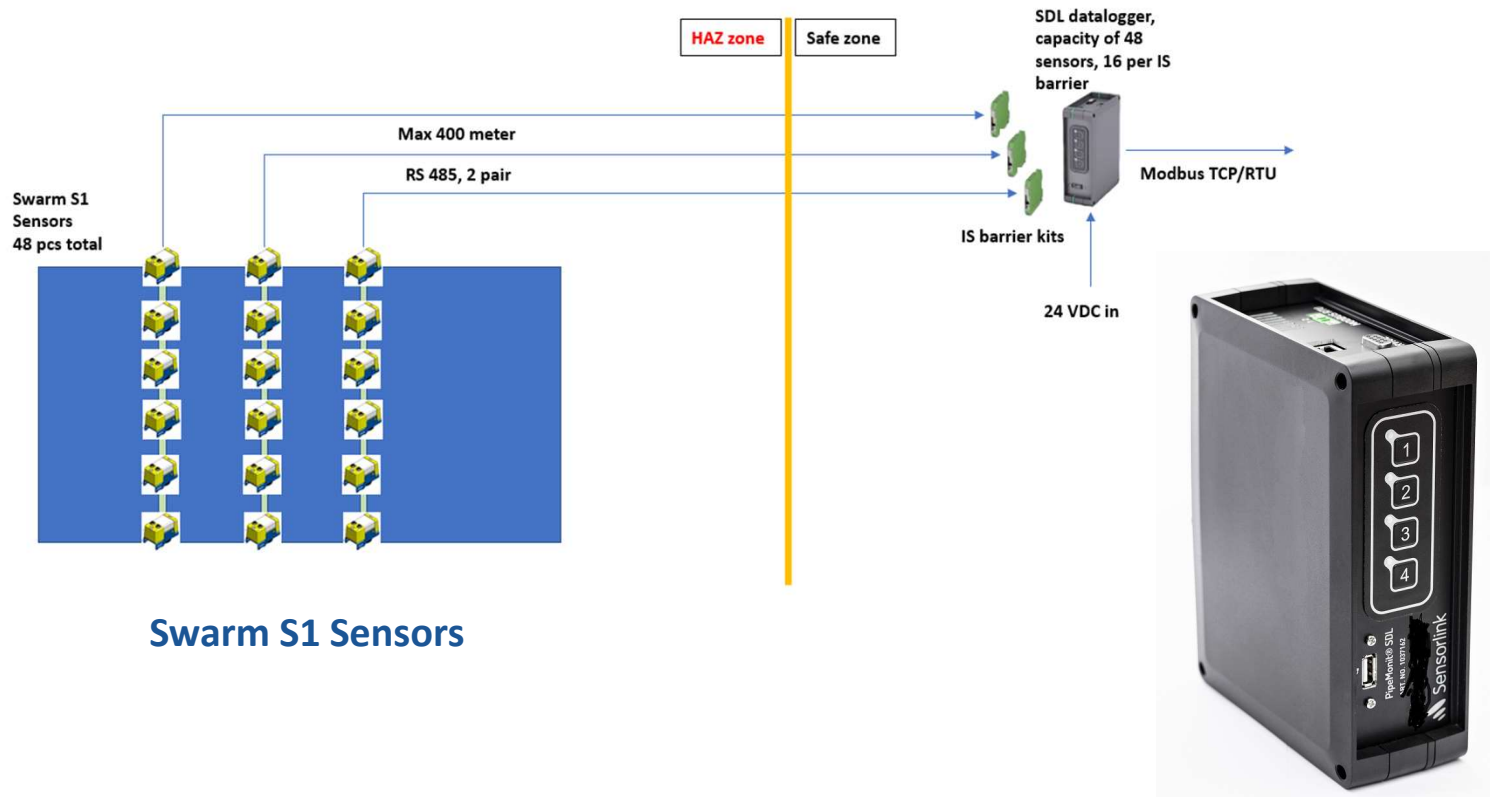- Certification:
  - II 1 GD Ex ia IIC T* Ga

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PipeMonit® Swarm S2 Datalogger (Ex)

Swarm LT Sensors
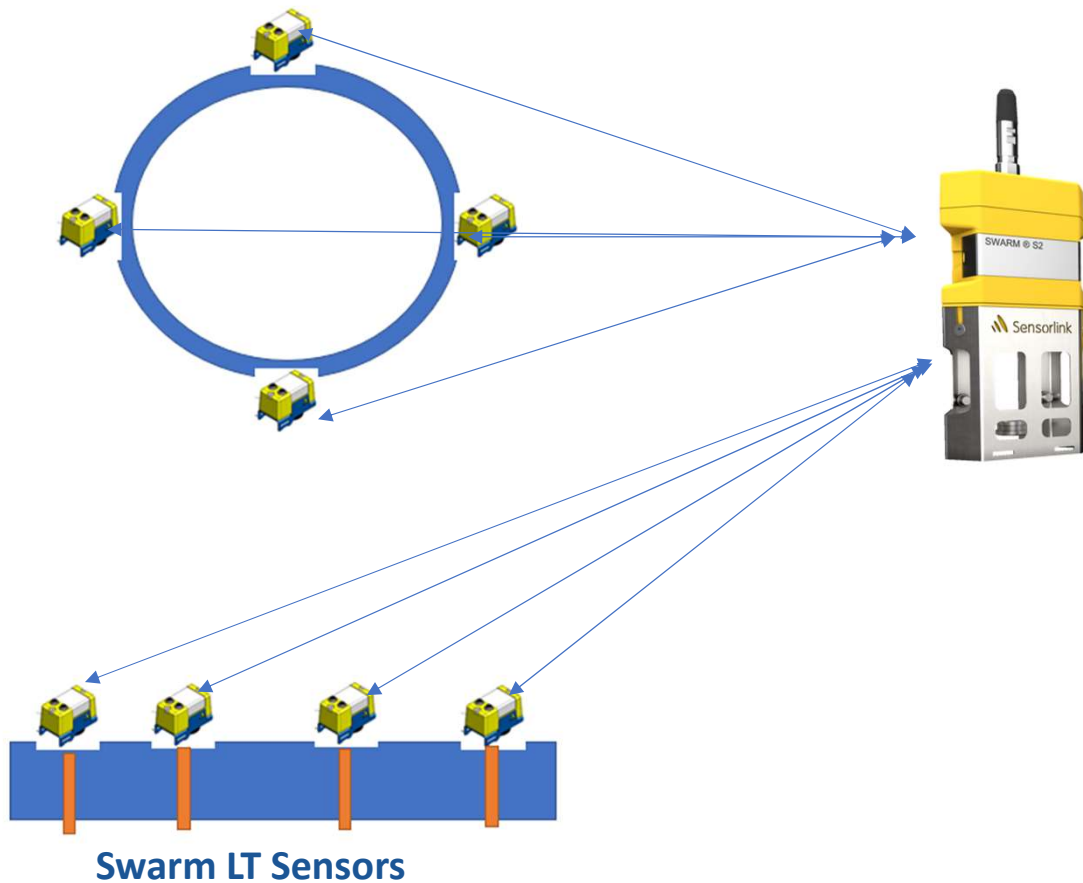
Main Specifications:

- **Ambient temp -40°C to 70°C**
- **Data output options:**
  - **Bluetooth**
  - **Wireless ISA 100 (WiHART Q3/2023 – LoRaWan Q1 2024)**
  - **GSM**
  - **Modbus TCP/RTU**
- **Data delivered**
  - **Wall thickness**
  - **Temperature on pipe**
  - **"Data Quality Stamp»**
- **Power options**
  - **Battery operated (industry standard batteries)**
   - **24 VDC/110-240VAC**
- **Ex rating**
  - **Ex II 2G Ex ib IIB T4 Gb**

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Pipemonit Swarm SDL Datalogger (safe zone)

Swarm S1 Sensors

Main Specifications:

- **Ambient temp -20°C to 50°C**
- **Data output options:**
  - **USB**
  - **Modbus TCP/RTU**
- **Data delivered**
  - **Wall thickness**
  - **Temperature on pipe**
  - **"Data Quality Stamp»**
  - **CSV format**
- **Power options**
  - **24 VDC/110-240VAC**
- **Ex rating**
  - **None, need ExD housing for ATEX zone**
  - **Barriers needed when installed in safe zone**

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Sensorlink Wireless Configuration Sketch
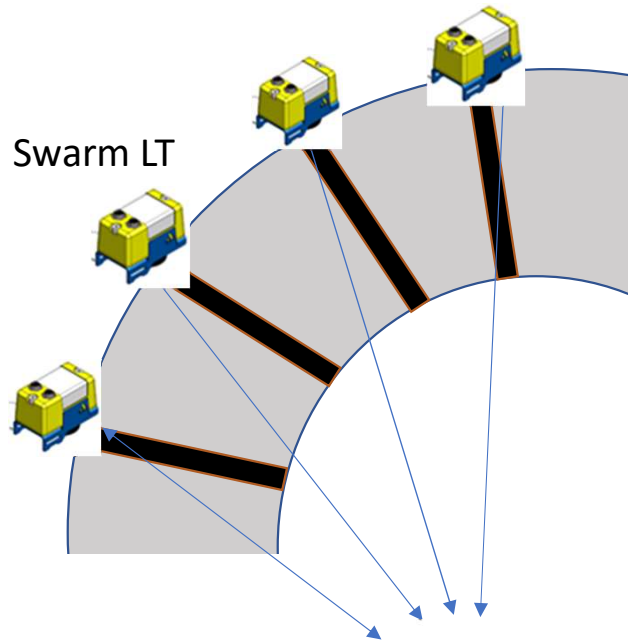
Swarm LT

Explanation:

- 4 Swarm LT sensors hooked up to Swarm S2 Datalogger (max 10 meter cable)
- Swarm S2 Datalogger hooked up to RadioHub
- RadioHub converts signal to ISA 100, WiHART for wireless Transmission
- Standard (or other) Wireless Gateway
- Wired connection to DCS or user data base

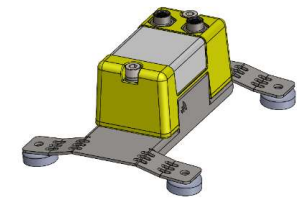1 – 4 LT sensor wired to Swarm S2 datalogger (max 10 meters)

WirelessHART

DCS or Customer Data Base

Swarm S2   RadioHub

Standard WiHART Gateway

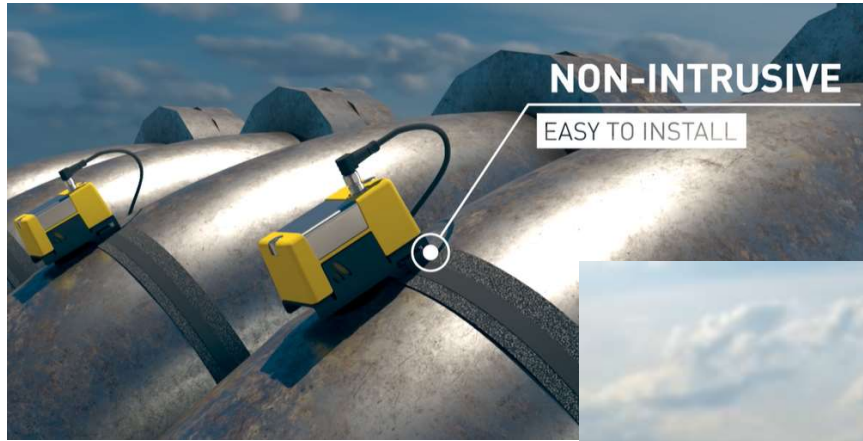Corrosion and Erosion Monitoring Made Easy

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PipeMonit® Swarm for Topside/Landbased Applications

Magnetic clamp for Sensor installation (welded installation optional)

Strap installation allow flexibility in installation and configuration

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PipeMonit® Swarm Platform Topsides/Plants

NON-INTRUSIVE
EASY TO INSTALL

- Strap, magnet or welded sensor attachment
- Multiple Swarm LT sensors per strap
- Multiple Swarm LT sensors per Swarm S2 Datalogger
- Wired or wireless communication
- Batteries or permanent power

- Typical applications:
  - Carbon steel flowlines and process piping
    - Tuning and verifying corrosion inhibitors
    - Process tuning and root cause identification
    - Integrity verification
  - Corrosion Resistant Alloys
    - Erosion monitoring and wall thickness verification
    - Sand detection
    - Flow rate optimization
- Value
  - Safer operations
  - Extended equipment life
  - Reduced OPEX (planned maintenance and repair)
  - Optimized production rates
  - Non-Intrusive => Low investment – low operating cost – no added operational risk!

PipeMonit® Swarm (Buried) Pipelines

- **Typical applications:**
  - **Unprocessed crude or gas pipelines**
    - **Bottom/Top of Line Corrosion**
  - **Predictive:**
    - **Investigate critical points – low spots, condensation points….**
  - **Reactive:**
    - **Monitor corroded areas identified through ILI or other inspection**

- **Value**
  - **Safety – reduce risk of unexpected incidents**
  - **Cost reduction –**
    - **Optimize ILI frequency**
      - **Reduce if low corrosion rates**
      - **Increase if high corrosion rates**
    - **Plan maintenance and repairs**
    - **Extend asset life**

Corrosion and Erosion Monitoring Made Easy

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Swarm Installation Buried Pipe

Corrosion and Erosion Monitoring Made Easy

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PipeMonit® Swarm on Riser Bend

Swarm S1 w/ protective cover

Swarm S1 with fire protection

Swarm Visualisation
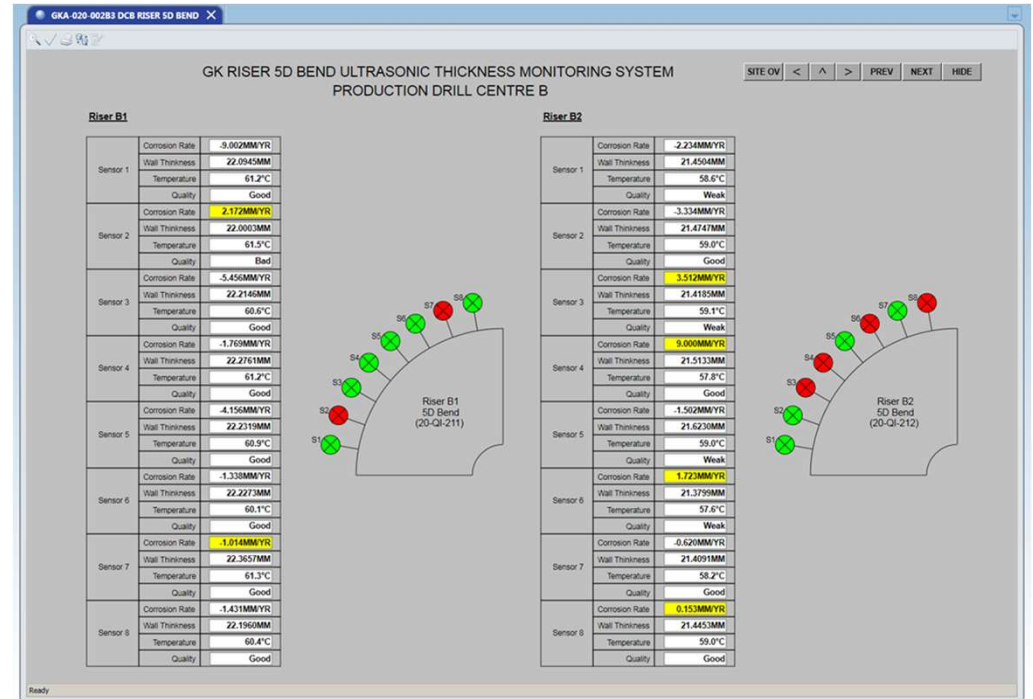
PipeMonit® Swarm UT Sensor Belt for Extended Pipe-Life

- **Typical applications:**
  - **Mining/Sand Oil Production**
  - **Monitor erosion/corrosion at critical clock positions**
  - **Rotate pipe to maximize pipe life based on erosion/corrosion measurements**

- **Value**
  - **Extended pipe life**
  - **Reduced risk for unexpected failure**

- **Key data**
  - **24 sensors per belt**
  - **Repeatability typically 25 micrometer**
  - **On-line and off-line options**
  - **Not certifed for hazardous areas**

Low-Cost Option for Field Applications!

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PipeMonit® Swarm in Refineries

- **Challenges:**
  - **Many locations**
  - **Difficult access**
  - **High Temperatures**
  - **Complex corrosion challenges**

- **PipeMonit® Swarm Benefits:**
  - **Sensors up to 500 ºC**
  - **Cost-effective**
    - **Up to 4 sensors per datalogger**
    - **Wireless communication**
    - **Commercially available batteries, easy replacement**
    - **Data processed on location - application software not needed**
  - **Best in class accuracy/repeatability**

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UltraMonit - Subsea systems

Fixed installations/ new pipelines
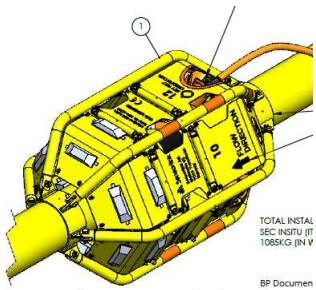
Retrofittable modular design
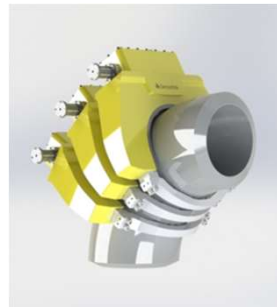
Retrofit installations

Corrosion and Erosion Monitoring Made Easy

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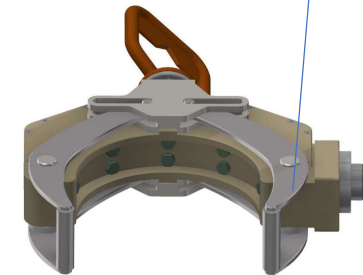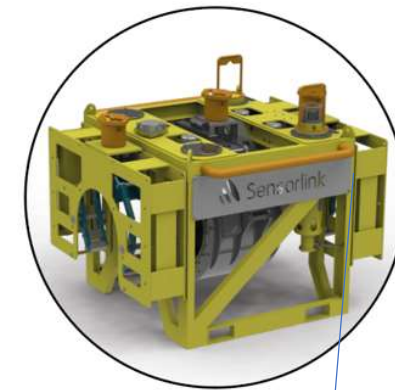
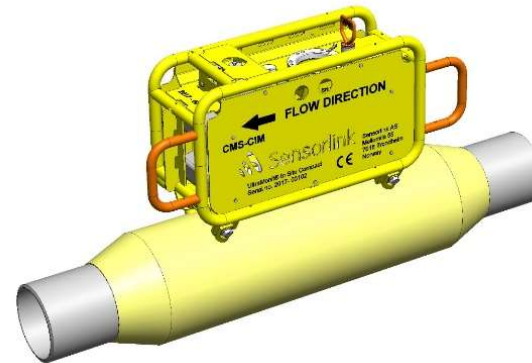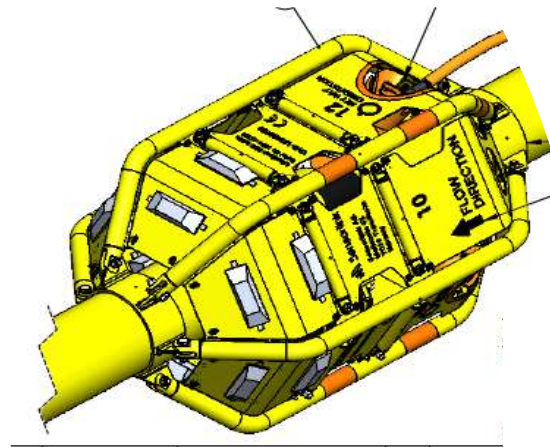# UltraMonit® - New Subsea Pipelines

Typical applications:

- **Carbon Steel Pipelines**
- **High content of corrosive media like CO2 or H2S**
- **Gas condensate wells**
- **Often installed close to well (highest potential for corrosion and condensation/temperature drop)**
- **Corrosion monitoring on weld/HAZ**

Value:

- **Safety – avoid unexpected corrosion damage and leaks**
- **Verify and tune corrosion inhibition**
- **Optimize use of inline inspection (ILI)**

Reference: AMPP Corrosion 2021 Paper No 16715

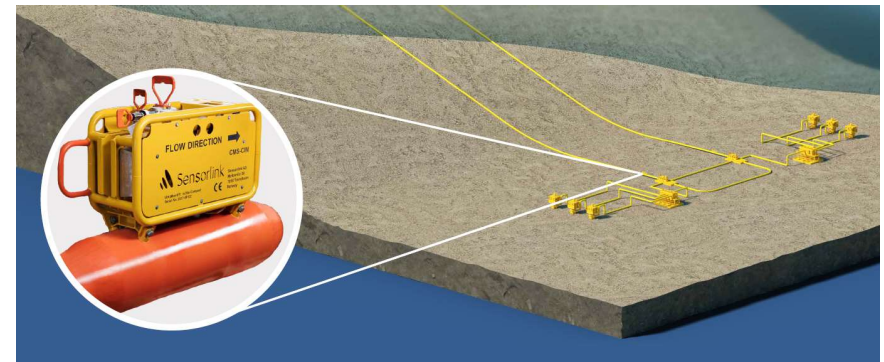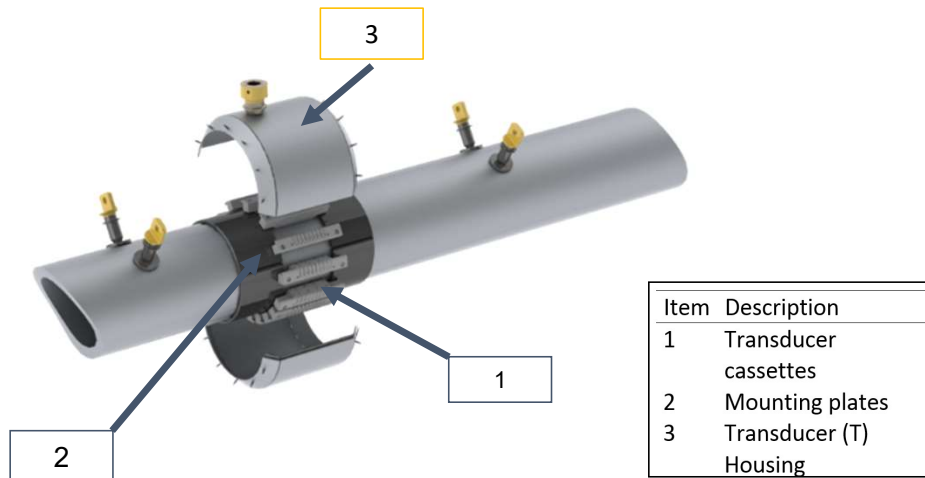Corrosion and Erosion Monitoring Made Easy

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Layout of UltraMonit® - New Subsea Pipelines

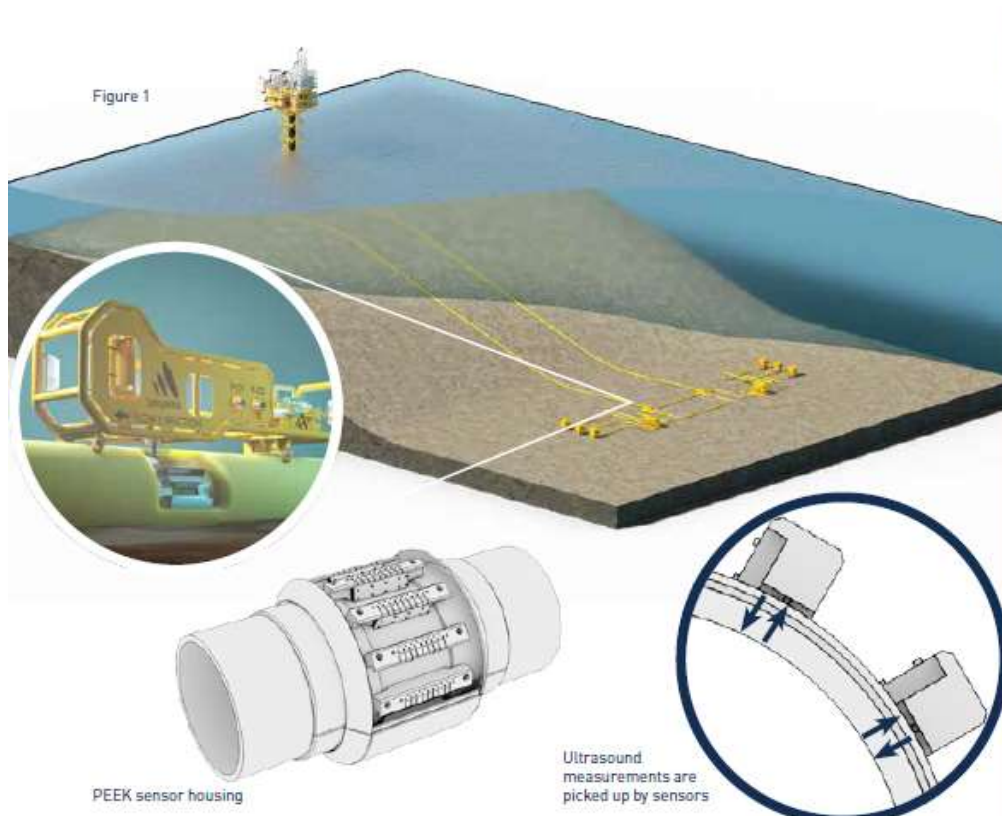**The UltraMonit® Unit is assembled by Sensorlink**

- **Client provide spool, with weld if corrosion monitoring on weld is important**
- **Sensorlink weld mounting plates and mount transducer cassettes and transducer housing**
- **Housing is pressure tested and filled with silicone oil**
- **Coating is applied**
- **Bumper frame with electronics is assembled to the spool**

Capacities

- **Wall Thickness Accuracy: <=0.1 mm (0,004 inches)**
- **Sensitivity:** **< 2,5um (0.1 mills)**
- **Temperature:** **150° C (302 F)**
- **Water depth :** **3000 meters (10 000ft)**
- **Design life:** **30 + years**
- **Qualified according to API 17F**

Item	Description
1	Transducer cassettes
2	Mounting plates
3	Transducer (T) Housing

Use Case, Caspian See

Figure 1

PEEK sensor housing

Ultrasound measurements are picked up by sensors
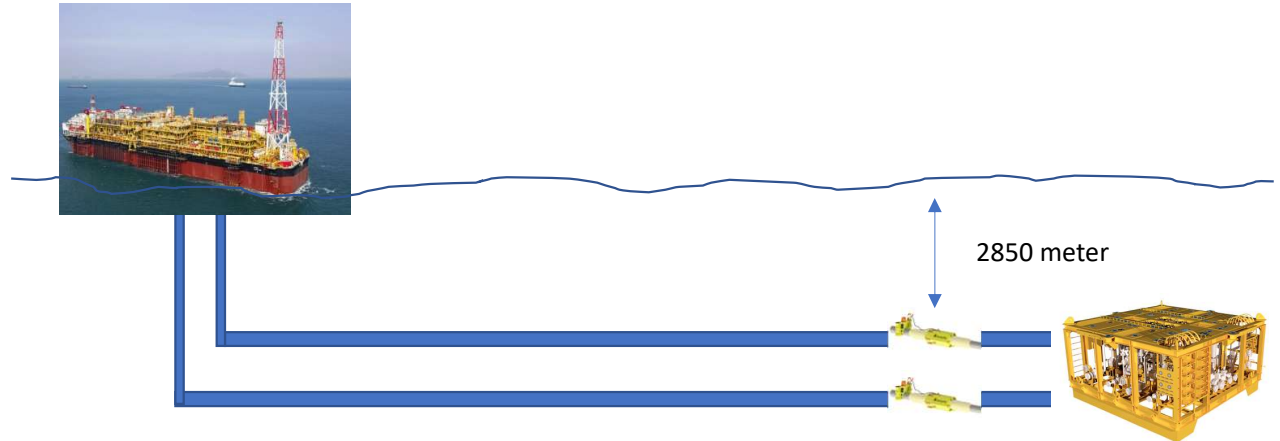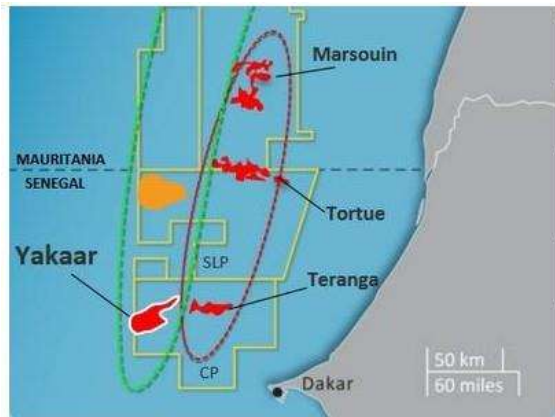
- 16 inch flowlines (10) feed condensate from 30 wells

- One UltraMonit In Situ installed on the first CS/CS weld after the FTA (Flowline Termination Assembly)

- Online and real-time feedback on corrosion rates used to evaluate inhibitor effectiveness

- 104 transducers per instrument

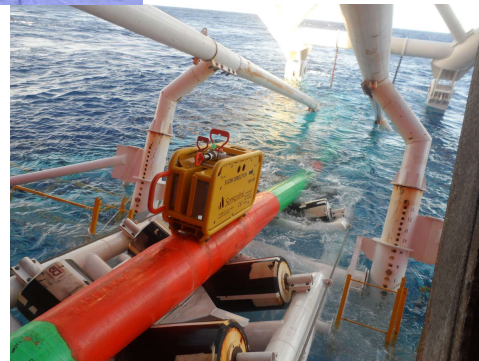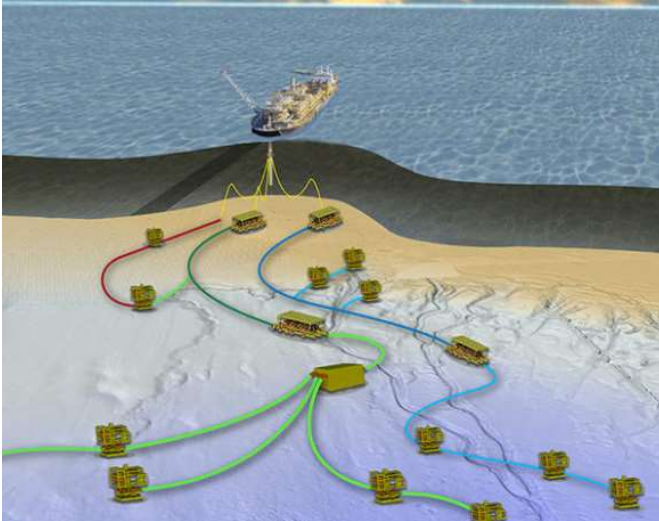**Reference: AMPP Corrosion 2021 Paper No 16715**

Use Case – Offshore West Africa

- 2850 meter

- **120 km offshore Senegal/Mauretania**

- **2850 meter water depth**

- **2 x production lines 16,75 inch**

- **Online and real-time feedback on corrosion rates used to evaluate inhibitor effectiveness**

- **700 transducers per instrument**

Use Case, Offshore Australia

- **Subsea tieback, 31 km**

- **2 x 24 inch pipelines from field to FPSO**

- **One UltraMonit In Situ installed close to PLET on each pipeline**

- **Online and real-time feedback on corrosion rates used to evaluate inhibitor effectiveness**

- **700 transducers per instrument**
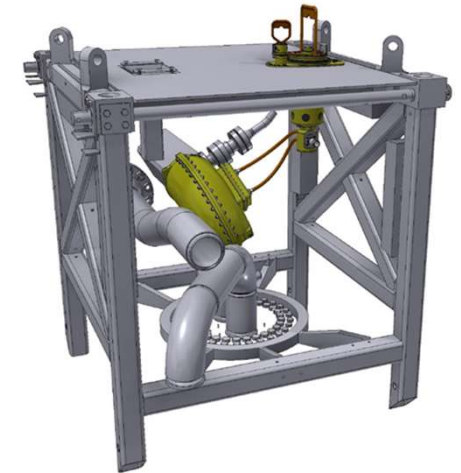
UltraMonit® Subsea Corrosion/Erosion Monitoring

Concept:

- **Installed on X-mas tree before installation or during dry maintenance**
- **Array of Ultrasound transducers**
- **Subsea clamp with sealing**
- **Pressure compensated**
- **Retrieveable datalogger**
- **Self contained unit with batteries or connected to subsea control system**
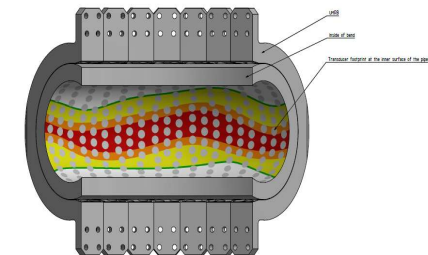
Value:

- **Safety: Avoid unexpected erosion damage and loss of containment**
- **Economics**
  - **Early warning if sand production/erosion increase – extended asset life**
  - **Optimize production rates versus sand production/erosion rates**

Retrieveable datalogger

Array of transducers

Subsea clamp with sealing

Erosion pattern example as per flow assurance analysis

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UltraMonit® Subsea Retrofit

**Tool for non-intrusive wall thickness monitoring.**

Provides pipe wall temperature, wall thickness, corrosion/erosion rate, and corrosion profile estimation.

Typical build-up of UltraMonit® retrofit
- **Bumper frame**
- **Clamp with transducer elements**
- **Datalogger**
- **Battery/batteries**

The transducers can be arranged according to client requirements, either in elements or in a matrix to cover more pipe wall

- **Capacities**
- **Accuracy:**   **<=0.1 mm (0,004 inches)**
- **Sensitivity:**   **< 10um (0.4 mills)**
- **Temperature:**   **150° C (302 F)**
- **Water depth :**   **3000 meters (10 000ft)**
- **Design life:**   **15 years**
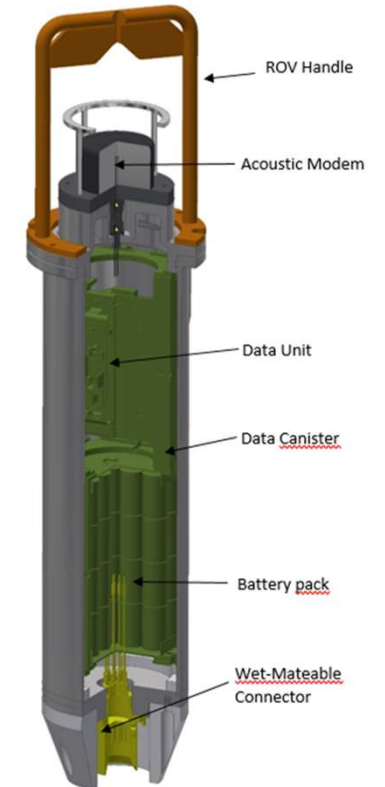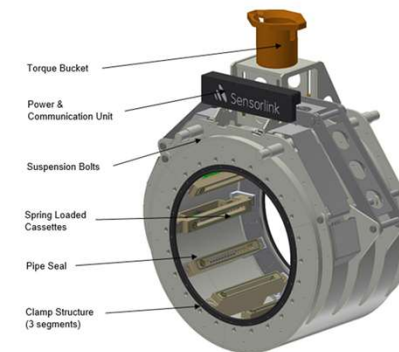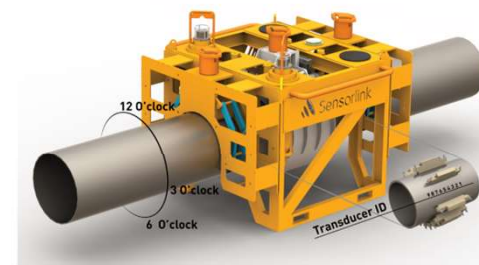
UltraMonit® Shallow Water Subsea

- **Actual application 50 meters**
- **40 High Accuracy UT sensors bottom of pipe**
- **Sensors in closed oil filled chamber**
- **Data logger installation/replacement by diver or ROV**
- **Upgrade to external power/online communication possible**
- **Installation 2023**

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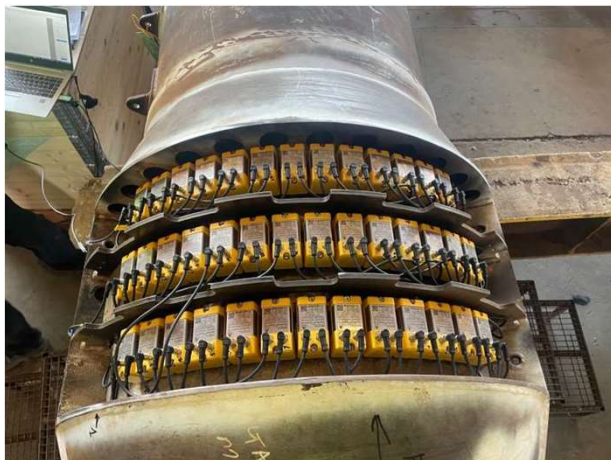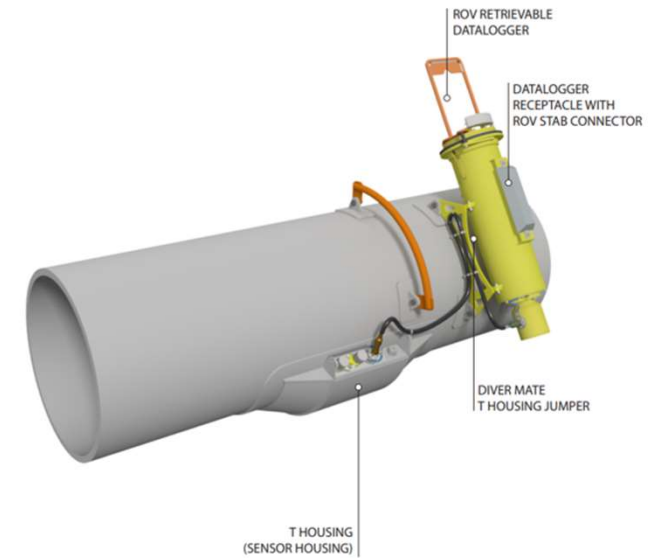
Proactive corrosion and erosion management

Ultramonit®/Swarm® measurements allow proactive use of corrosion/erosion monitoring data

- **Inhibitor tuning**
- **Optimized production rates**
- **Crude feed blending**
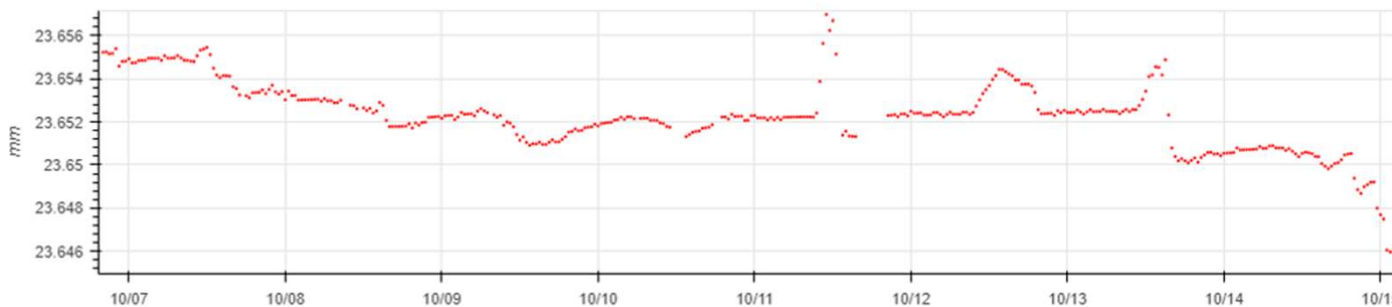
Metal loss versus time data (one sensor) from erosion test stainless steel pipe. Unfiltered, temperature compensated data. Observe random variations in +/- 2 micron range

Suggested approach:

Set flag when corrosion/erosion rates exceed random variations:
- **Warning:**
  - **1 day rate exceed 1 mm/y**
- **Managing**
  - **1 week rate exceed 0,2 mm/y**
- **Integrity**
  - **1 month rate exceed 0,05 mm/y**

**Flag settings tuned to actual measurement variations**

2,7 micron/day = 1 mm/y
2,7 micron/week = 0,14 mm/y
2,7 micron/month = 0,03 mm/Y

Accuracy/response time can be improved by more frequent measurements/filtering (wired systems)

Ultramonit®/PipeMonit® Swarm Data

Efficient tracking of corrosion/erosion distribution and growth

Data processed and digitalized on location – straight forward data interpretation and reporting
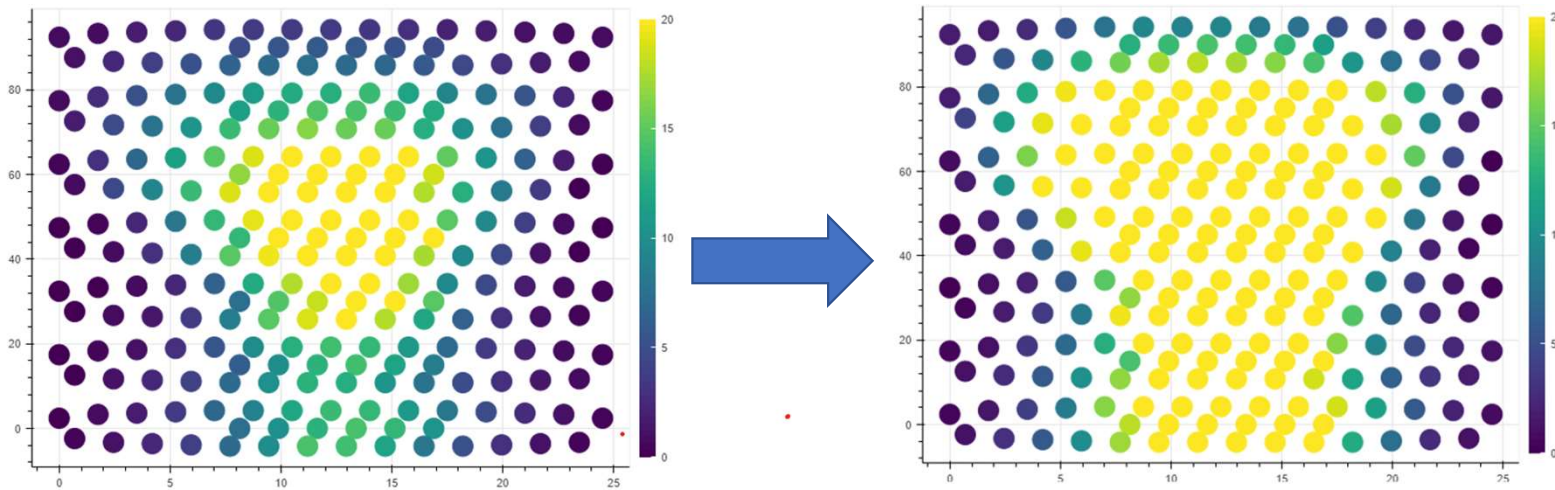
Format for metal loss mapping subject to change

Distribution of UT sensors at Subsea Bend

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Intrusive vs Non-Intrusive Sand/Erosion Monitoring (SL Swarm)

- **Both systems measure erosive effect of sand particles**

- **Intrusive system**
  - **+ Very high sensitivity 0,01 – 0,1 micrometer – very fast response to sand production**
  - **+ Multiple elements – increased probability for detecting sand**
  - **- Intrusive**
    - **Costly access systems, probe consumed, field retrievals, extra turbulence, wake frequency qualification**

- **Sensorlink Swarm**
  - **+/- High sensitivity (2,5 micrometer) – fast response**
  - **+ Erosion at pipe wall measured directly**
  - **+ Data processed on location – direct transfer to DCS**
  - **+ Non-intrusive**
    - **Safety not compromised, maintenance free, no additional erosion caused by intrusive probe**

NOTE:
Quantification of sand based on erosion rates is possible in theory, but highly dependent on flow rates and not recommended by Sensorlink

Corrosion and Erosion Monitoring Made Easy
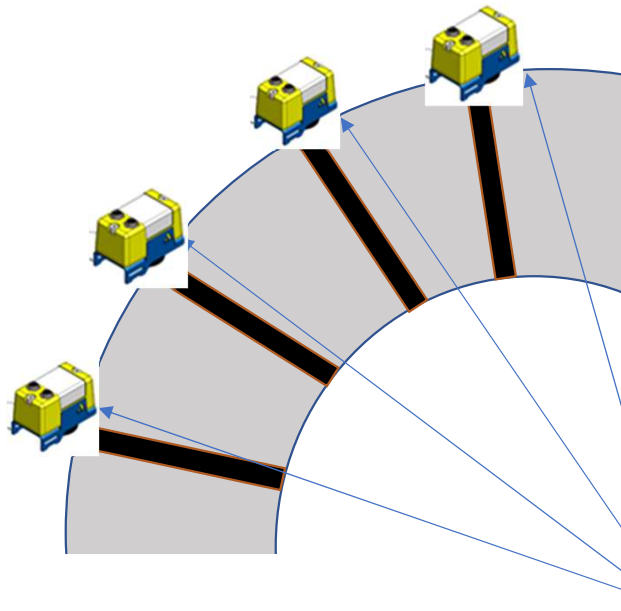
Sensorlink
Swarm

Summary

- Full range of topside and subsea solutions.

- Array of high accuracy pulse echo sensors provide:
    - High resolution/repeatability (2,5 micrometers)
    - Wall thickness measurements easy to understand and relate to
    - Heat maps for distribution of erosion/erosion rates
- Combined solutions with intrusive and non-intrusive corrosion and erosion monitoring available

- Sensitivity of high accuracy UT allows proactive corrosion/erosion/sand management

Try It!

Fast and reliable information that is easy to understand
=> better operational decisions

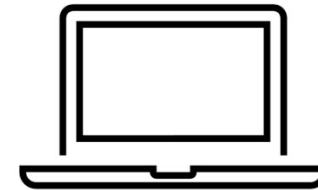# Suggested start-up solution with Swarm LT sensors in bend

1 – 4 LT sensor wired to Swarm S2 datalogger (max 10 meters)

Laptop PC – Pipeview Software

SWARM ® S2

Sensorlink

Bluetooth

Note: Antenna applicable for wireless communication only

Thank You for Listening

Kjell Wold

Business Development Director

Email: kjell.wold@sensorlink.no

ISO 9001:2015 certified | IECEx certified | Achilles JQS qualified
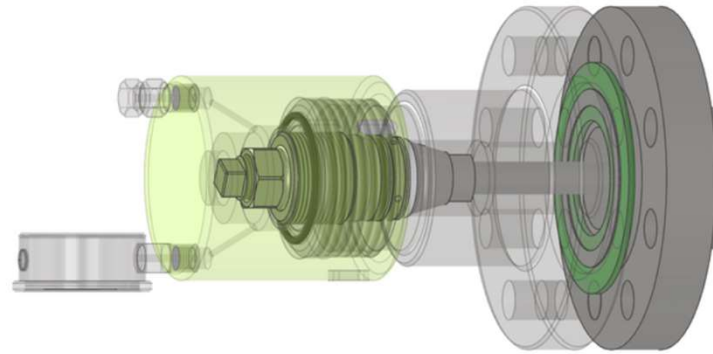
Sensorlink

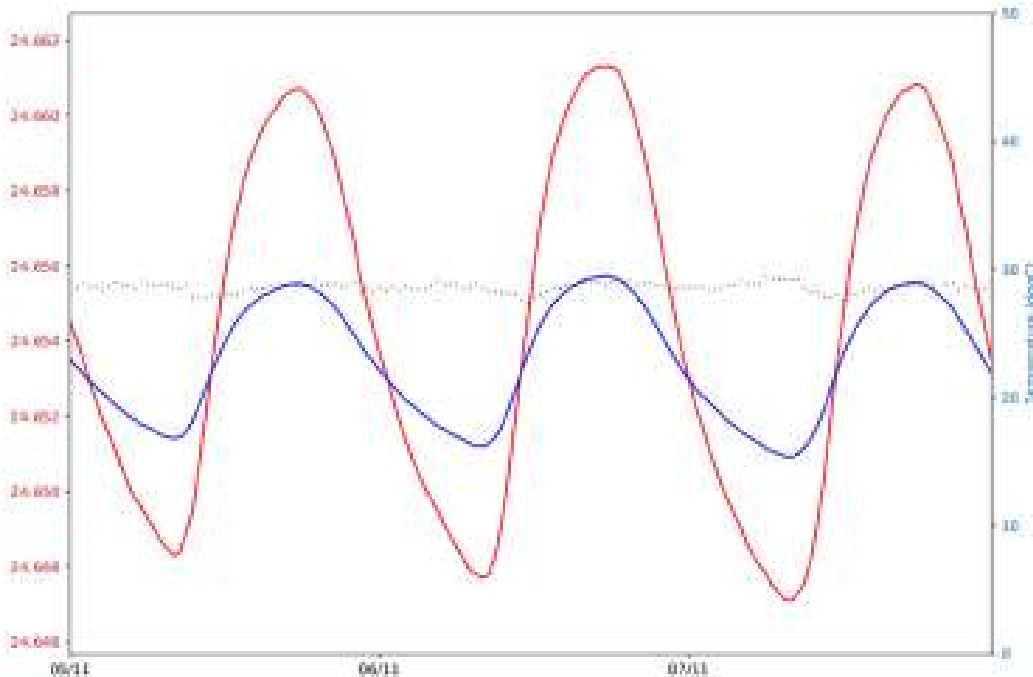# Combined Intrusive and Non-Intrusive Solutions

Axess-Corrosion:

Full range of intrusive corrosion and erosion monitoring

- Access Fitting Assemblies
- Corrosion and Erosion Probes
- Injection Systems
- Instruments - Transmitters

Innovation award at AMPP Corrosion 2023 – Axess Janus Guard System

Sensorlink

Potential for further enhanced measurement accuracy

Accuracy/sensitivity can be enhanced by:

- More frequent measurements and averaging to eliminate random variations (system power dependent)

- Select measurement times to avoid periodic fluctuations (e.g day/nigth)

- Tune temperature compensation to actual material and temperature coefficients

Example from sand/erosion trial:
Red: Wall thickness using Sensorlink default temperature compensation (CS)
Blue: Measured temperature
Black: Wall thickness, temperature compensated using improved temperature coefficient (SS)

Sensorlink
Swarm