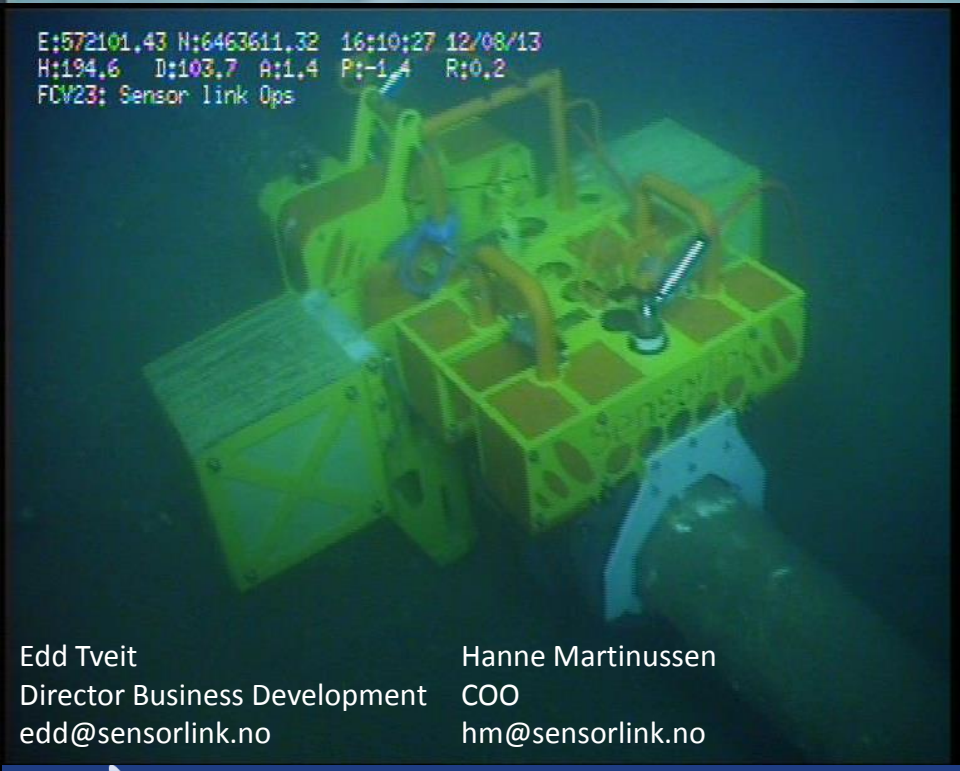
Subsea Controls Down Under 2016
Enhancing Value Through Technology

Online and Real-Time Corrosion and Erosion Monitoring of Subsea Pipework and Pipelines using Permanently Installed or Retrofitted Ultrasonic Sensor Arrays

SUT
Society for Underwater Technology



Edd Tveit
Director Business Development
edd@sensorlink.no

Hanne Martinussen
COO
hm@sensorlink.no

Outline

- ✓ Motivations and Applications
- ✓ Pulse/Echo Ultrasonic Measurements
- ✓ UT versus ring pair probe spools
- ✓ Subsea configurations and communication options
- ✓ Executed subsea projects
- ✓ Future UT arrays

Online subsea corrosion monitoring - motivation and applications

Reduced capex:

- ✓Eliminate requirements for intelligent pigging
- ✓Select less expensive materials through increased monitoring

Reduced opex:

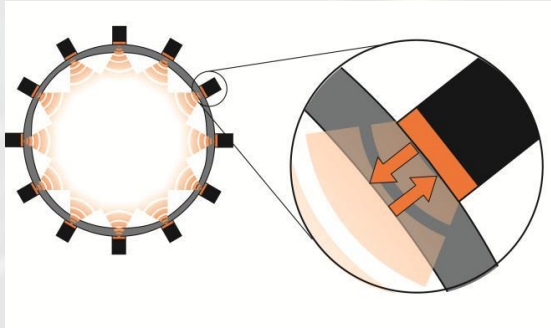
- ✓Avoid or reduce cost for intelligent pig runs
- ✓Optimise chemical injection programs

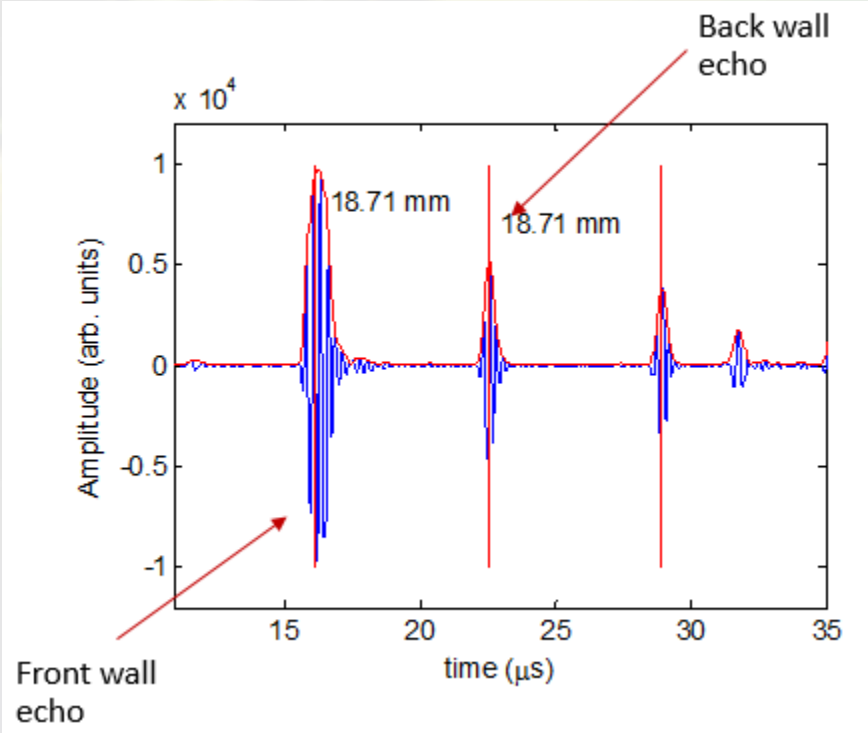
Improved Integrity Management

- ✓Real time knowledge of exact wall thickness and wall thickness changes

Monitoring using Single Element Pulse/Echo Transducers

- ✓ Non-Intrusive
- ✓ Direct wall thickness measurement of pipe wall, weld, HAZ zone, elbow, t-piece
- ✓ Not sensitive to pipe wall thickness
- ✓ Works through solid coatings (FBE, 3LPP, PE, etc.)
- ✓ Possible to separate pipe wall front and back wall echo's when used on coating.
- ✓ Does not discriminate between erosion and corrosion





Monitoring using Single Element Pulse/Echo Transducers

- ✓ No need for calibration:
  - speed of sound in steel is known
  - time of flight is measured using a crystal
- ✓ Works with a “stand off” between the transducer and the pipe wall - not sensitive for installation on “out of roundness” pipelines
- ✓ Fixed sensors combined with advanced signal processing detects wall loss of less than .1 mills (2.5 micrometres)
- ✓ Free forming sensor matrix to suit corrosion/erosion phenomena

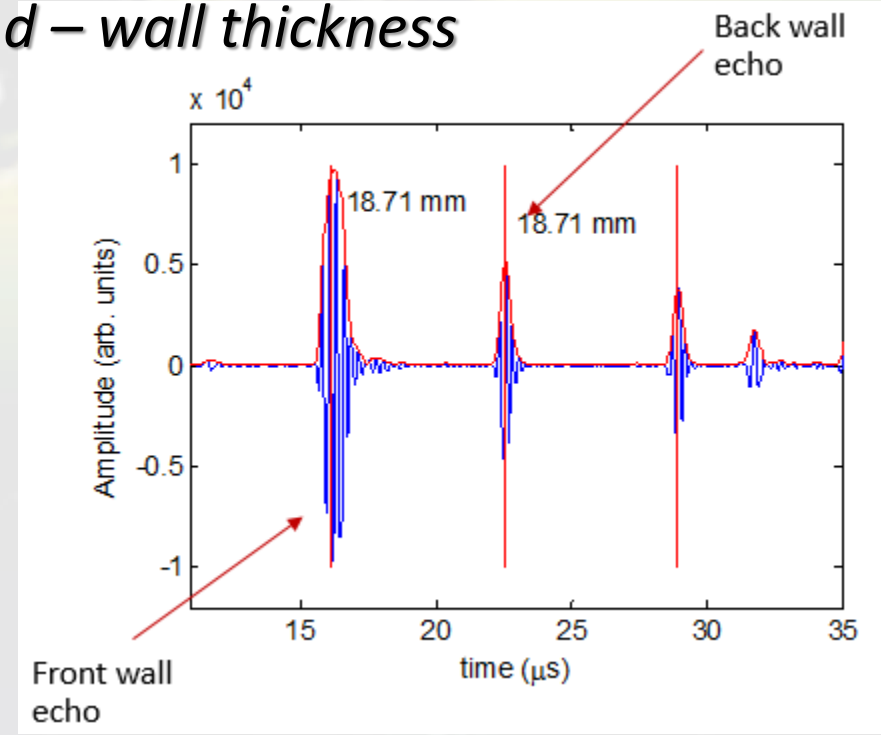
Pulse-echo:

$$d = \frac{t \cdot c}{2}$$

c – speed of sound in steel

t – time

d – wall thickness



Pulse Echo UT array versus Ring Pair Probe Spools

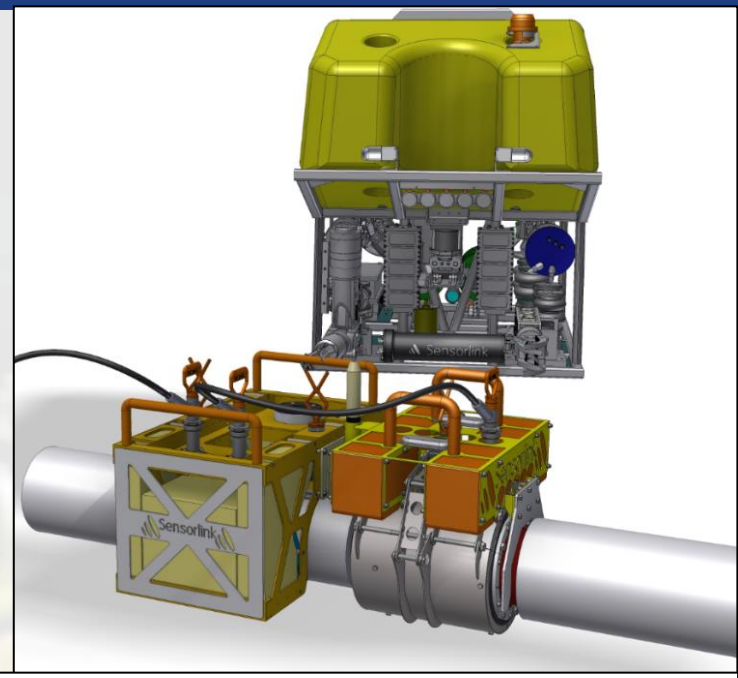
Parameter	UT Array	Ring pair probes
Type of measurement	Directly measurement of the pipe wall using pulse/echo UT	Indirect Electiral Restiance (Same as FSM) measurement on sample rings in the ring pair probe spool
Installation on new pipelines	Preinstalled on standard pipe joint on top of a field weld. Truly none intrusive with no pipe wall penetration	Special pipejoint made sensing instrumentatioin inside pressure barrier with wall penetration to external electronics
Installation on existing pipework and pipelines	ROV or Diver deployable. Truly none intrusive with no pipe wall penetration	Not possible
Temperature sensitivy	Moderate	High
Concept for obtaining high resolution	High quality electronics and transducers and advanced signal processing	Use of thin ring-coupons (life time limits on coupons?)
Erosion versus corrsosion	Does not descrimitate between erosion and corrsosion. Measures erosion on the pipeline itselves	Measures erosion in the ring pair probe spool

Parameter	UT Array	Ring pair probes
Type of measurement	Directly measurement of pipewall using pulse/echo UT	Indirect Electiral Restiance (Same as FSM) measurement on sample rings
Measurement results verifyable by reviewing of raw data	Yes. Well known and understood measurement concept. Result my be reprocced by others	No. Proporeitary processing, indempent verifcation not possible
Resolution	<0.1 mills/2.5µm measured directly on the pipe wall	0,005% of WT measured on ring pair probe spool
Direct measurementn on weld and heated weld zone	Yes	No
Detection speed (0.2 mm/year)	<5 days	2 days
Measruement method	Direct measurements	Indirect estimates
Design life	30 years	25 years
Replacale during operaiton	Yes (Retrofittable version)	No

Subsea Configurations

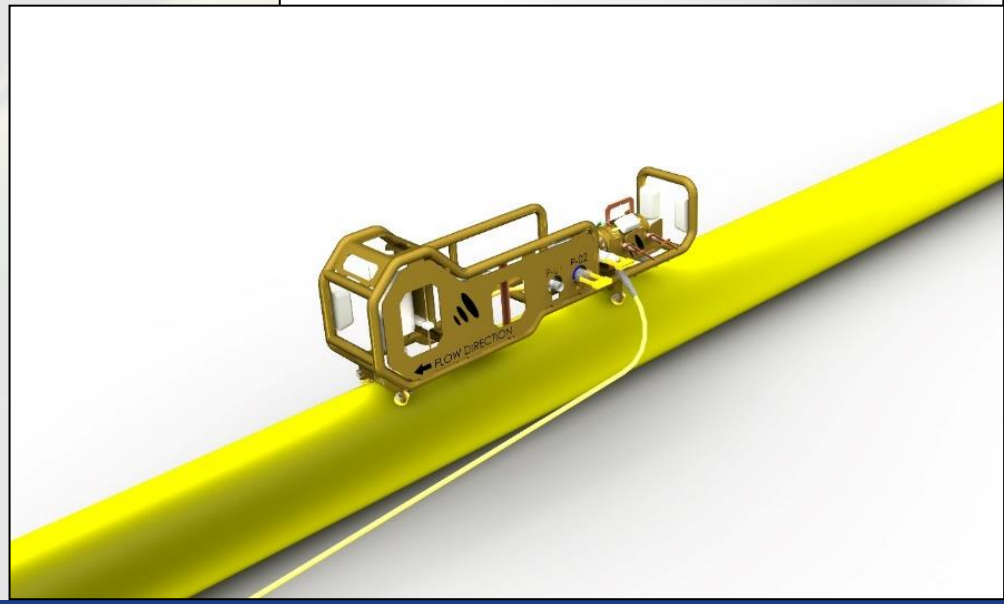
Retrofittable installations:

- Installed on existing subsea pipelines without production interference
- Fully ROV or diver installable, removable and movable



Fixes installations:

- Preinstalled
- 30 year life time
- Sensors installed inside insulation
- Can be installed to monitor a weld

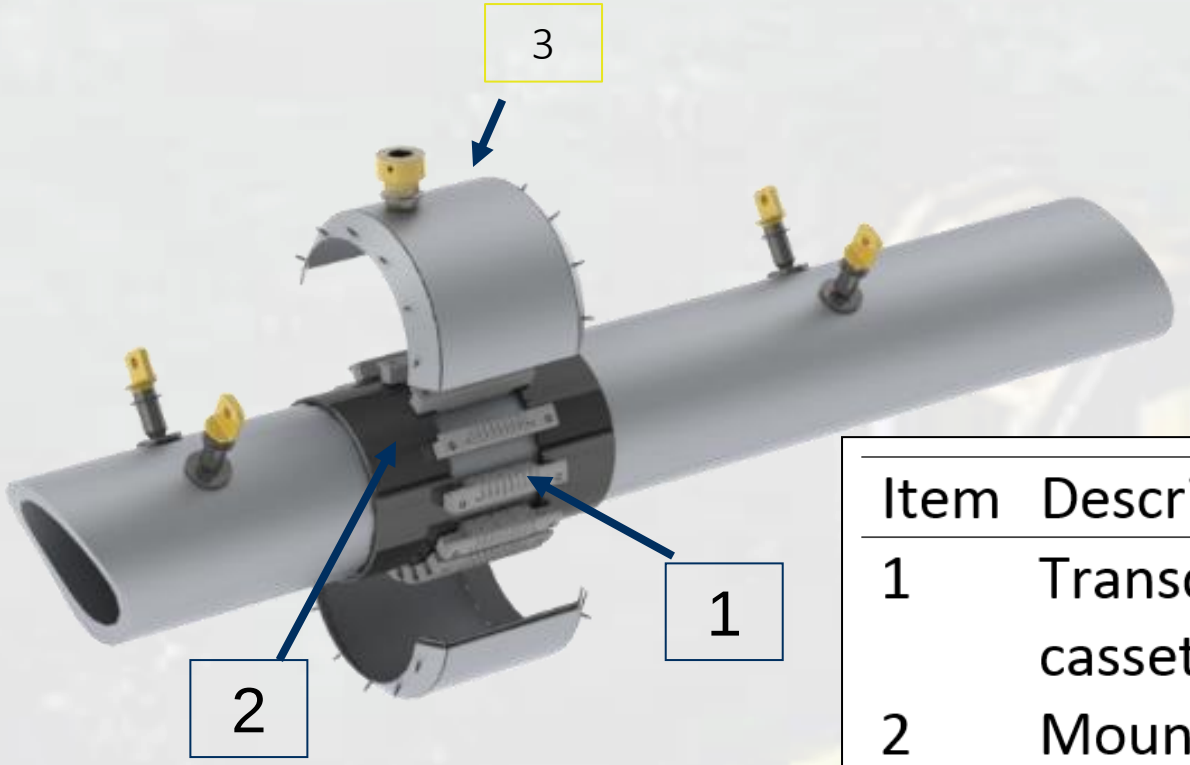


Specifications of Permanent Installed and retrofit subsea UT Arrays:

- Design temperature: -20 to 150°C
- Design pressure exposed electronics: 300 bar (10000 feet)
- Design pressure canister datalogger: 300 bar (10000 feet)
- Design life permanent installations: 30 years
- Design life retrofit installations: 15 years
- Transducer density >30%
- Resolution: <2.5 µm
- Wall thickness: <200 mm

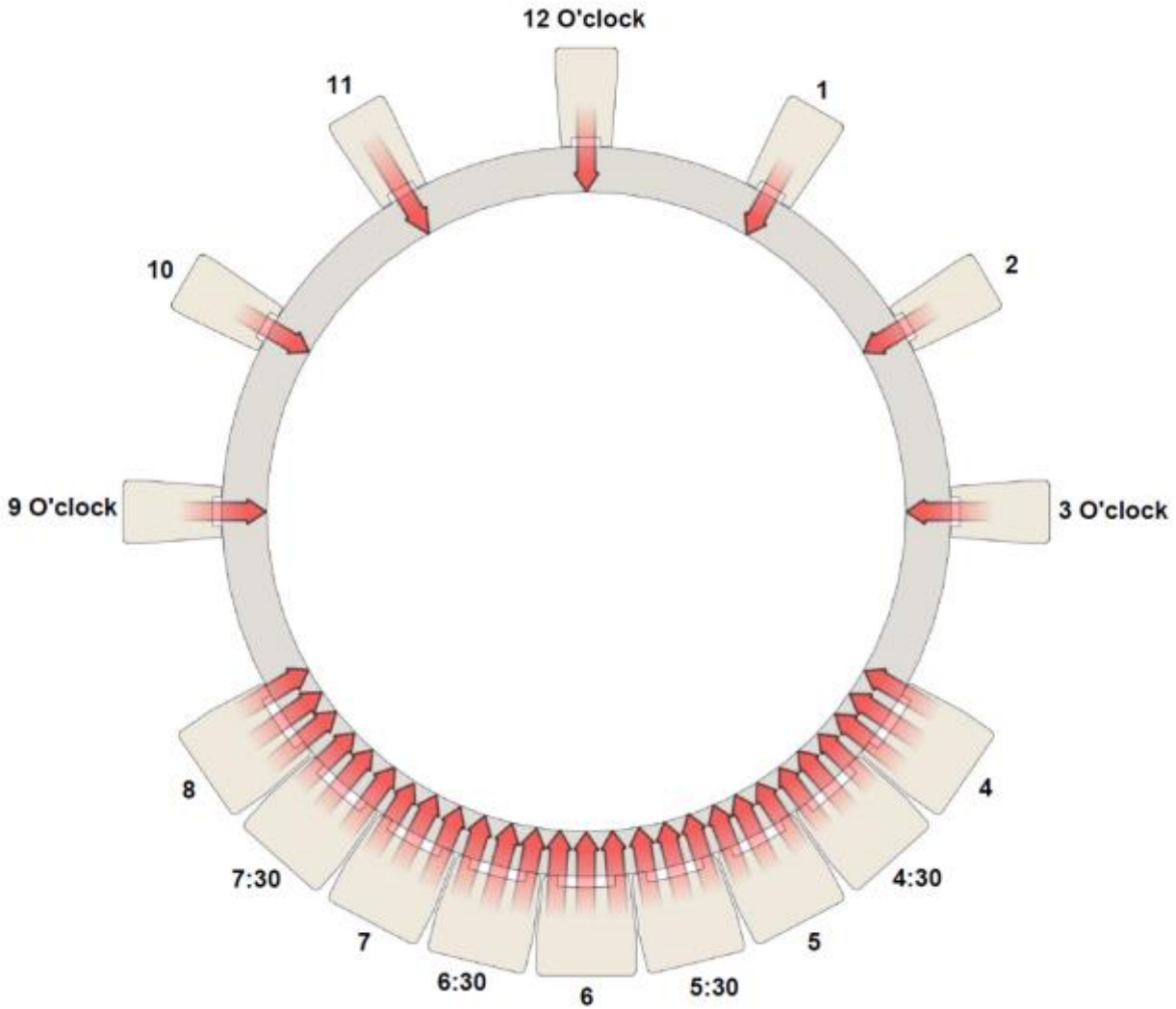
Permanently Installed Subsea UT Sensor Array

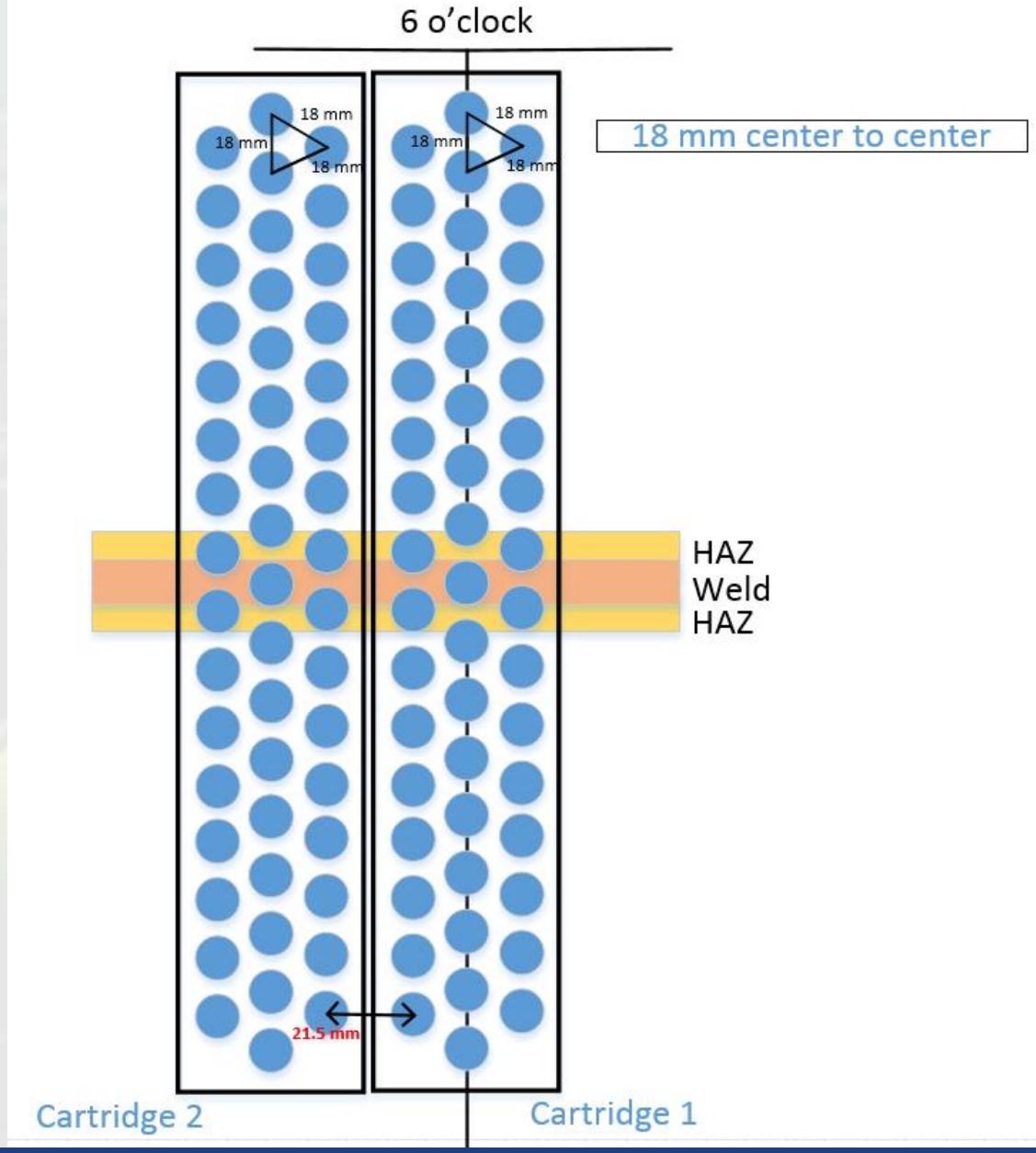
Layout of permanent UT Array



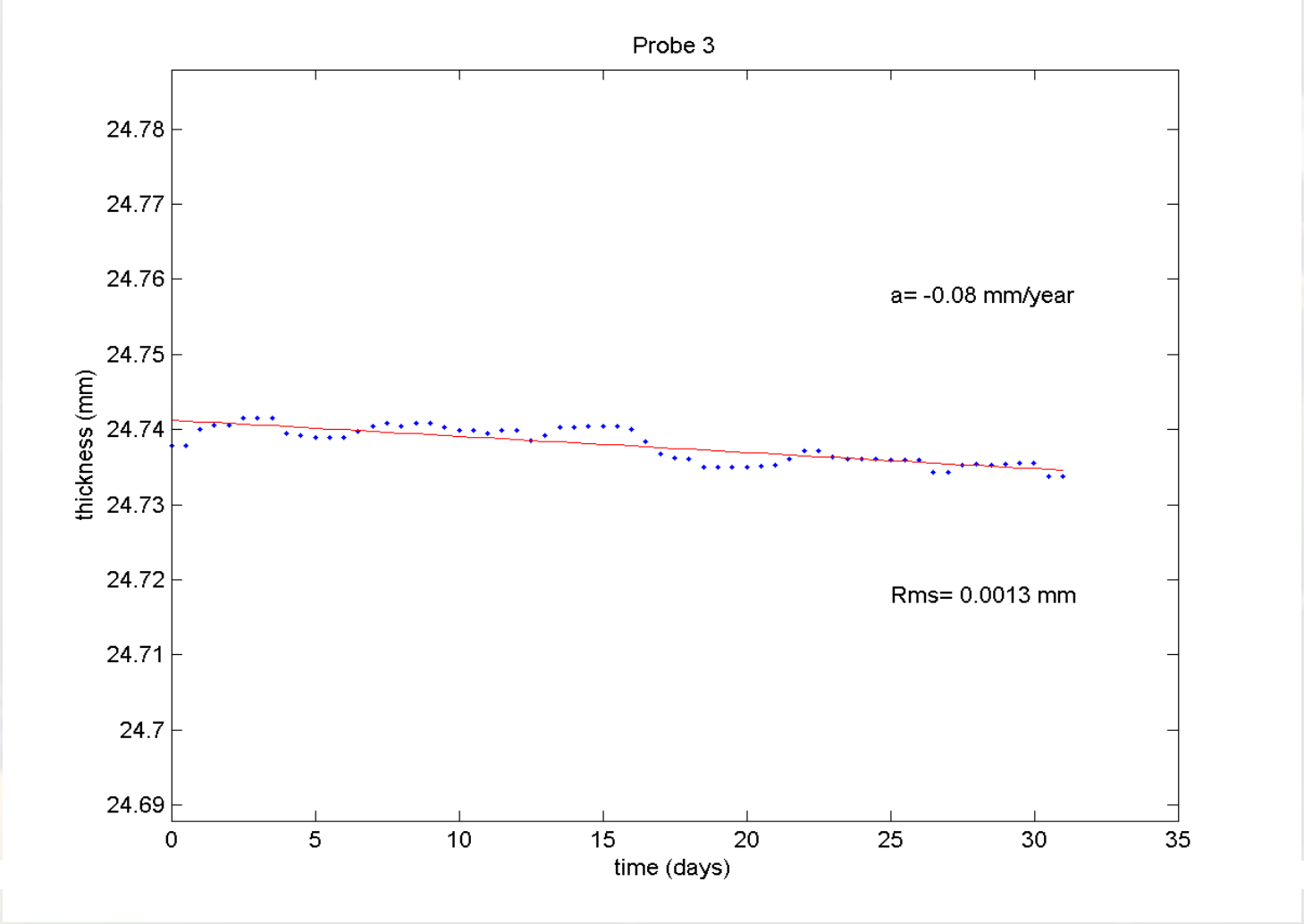
Item	Description
1	Transducer cassettes
2	Mounting plates
3	Transducer (T) Housing

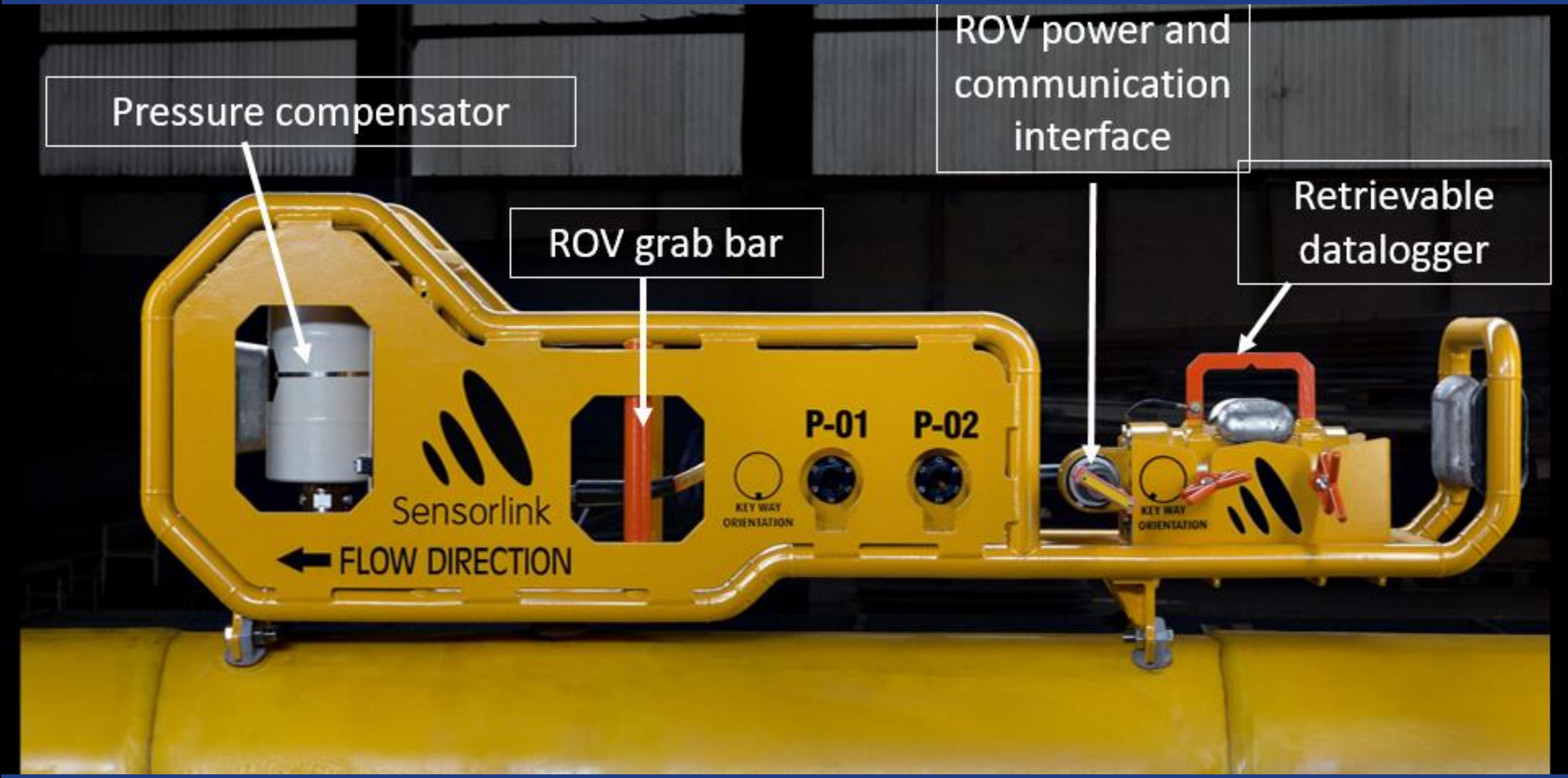
Transducer configuration





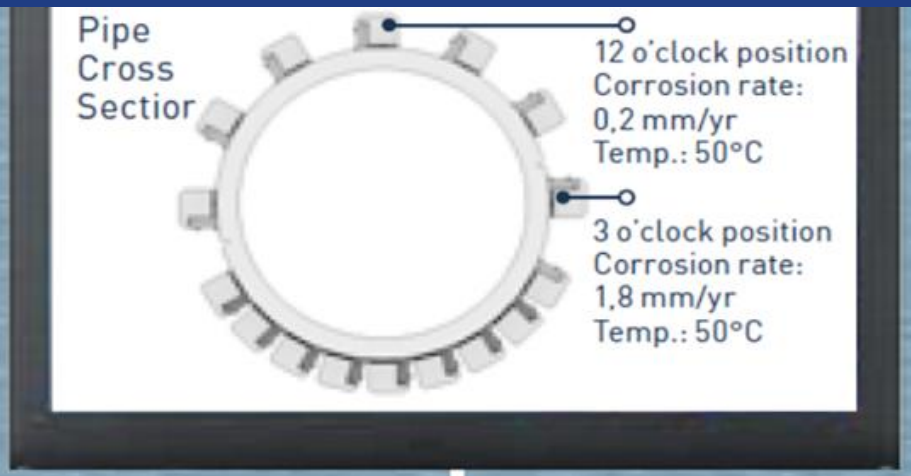
Wall thickness plot from one sensor




Pressure compensator
ROV grab bar
ROV power and communication interface
Retrievable datalogger
P-01
P-02
KEY WAY ORIENTATION
KEY WAY ORIENTATION
Sensorlink
FLOW DIRECTION

Network interface - Display Data

Control Room



Main control system

Subsea Signal Processing

Ethernet
Modbus TCP/IP
Modbus RTU
Canbus

UltraMonit®

Transfer of display data
~20 per unit, 1-6 times per day

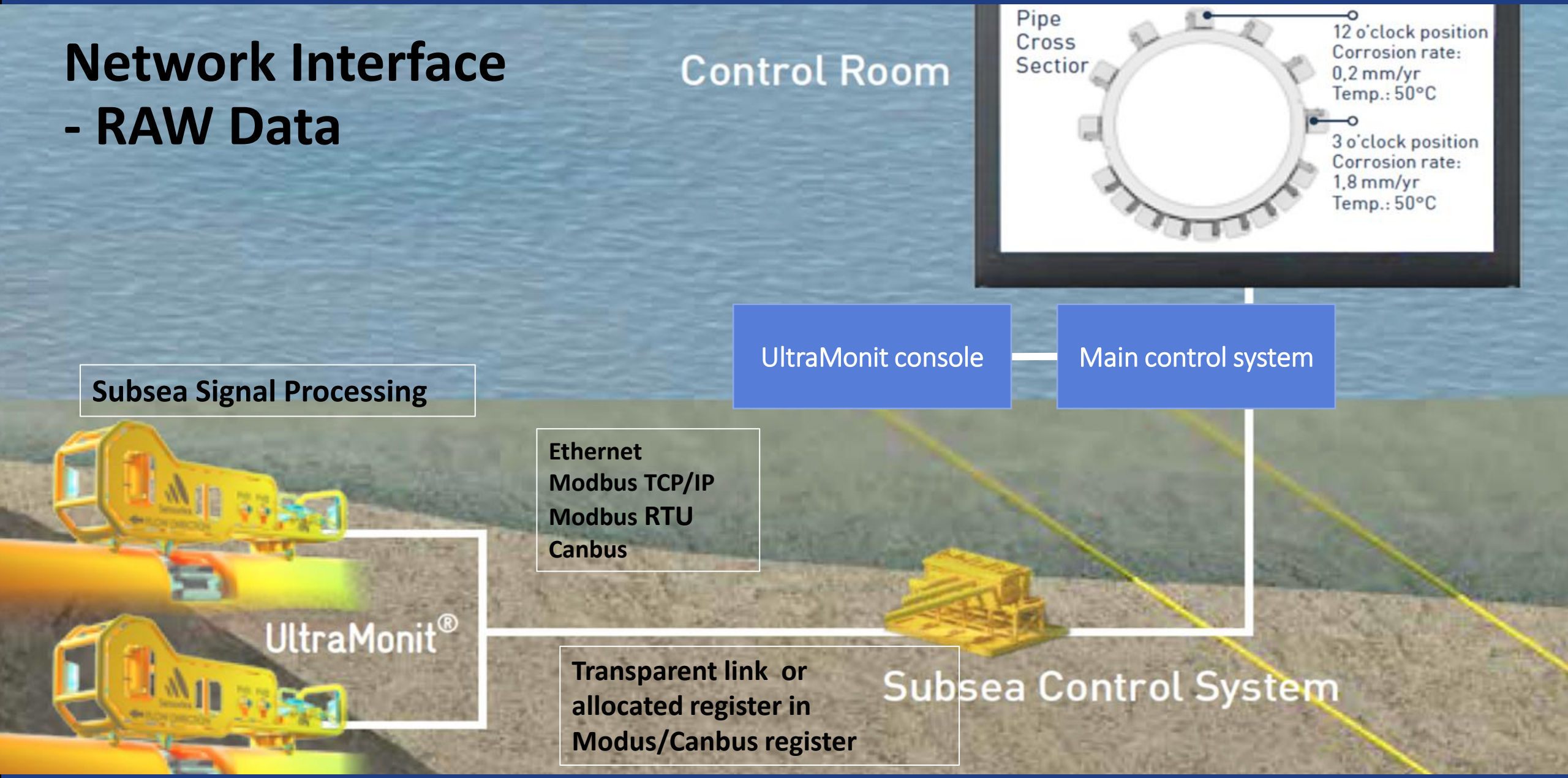
Subsea Control System

Amount of dispaly/engineering data for communication

- 6 readings per day on a tool with 500 sensors
- Local Data logger processess raw data and converts to wall thickness and communicates results, inclusive one temperature reading per cassette and housekeeping data; ~ 24 kB per day, og 4 kB every 4 hours.

- Power consumption
  - ✓ active < 10 W
  - ✓ idle/sleep: <0.001w

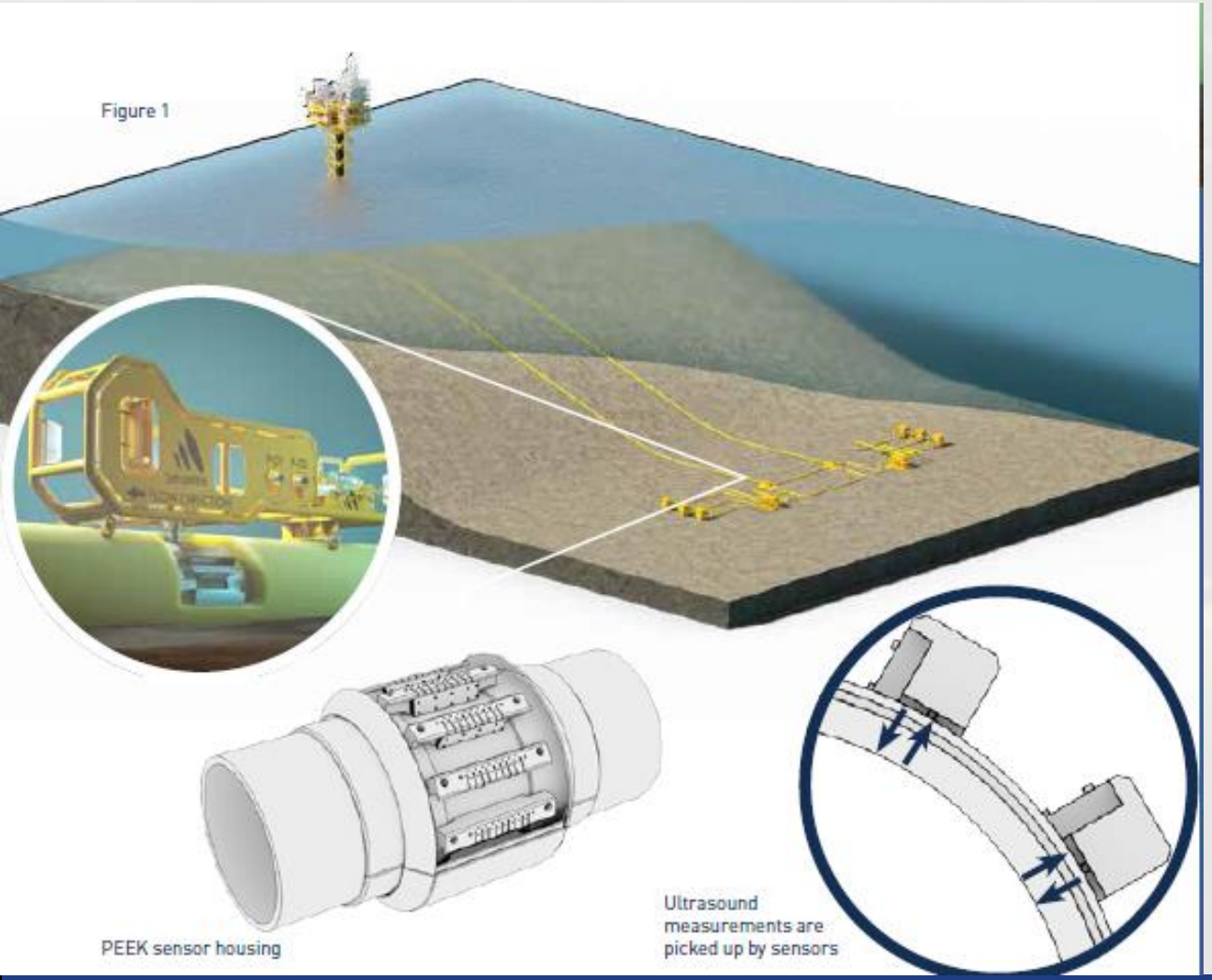
Network Interface - RAW Data



Amount of data communicated collecting raw data

- Raw data for 52 weekly readings for one cassette having 17 sensors equals about 3500 kB of data.
- Raw data is relevant for
  - ✓ commissioning
  - ✓ post processing for detailed corrosion analyzis

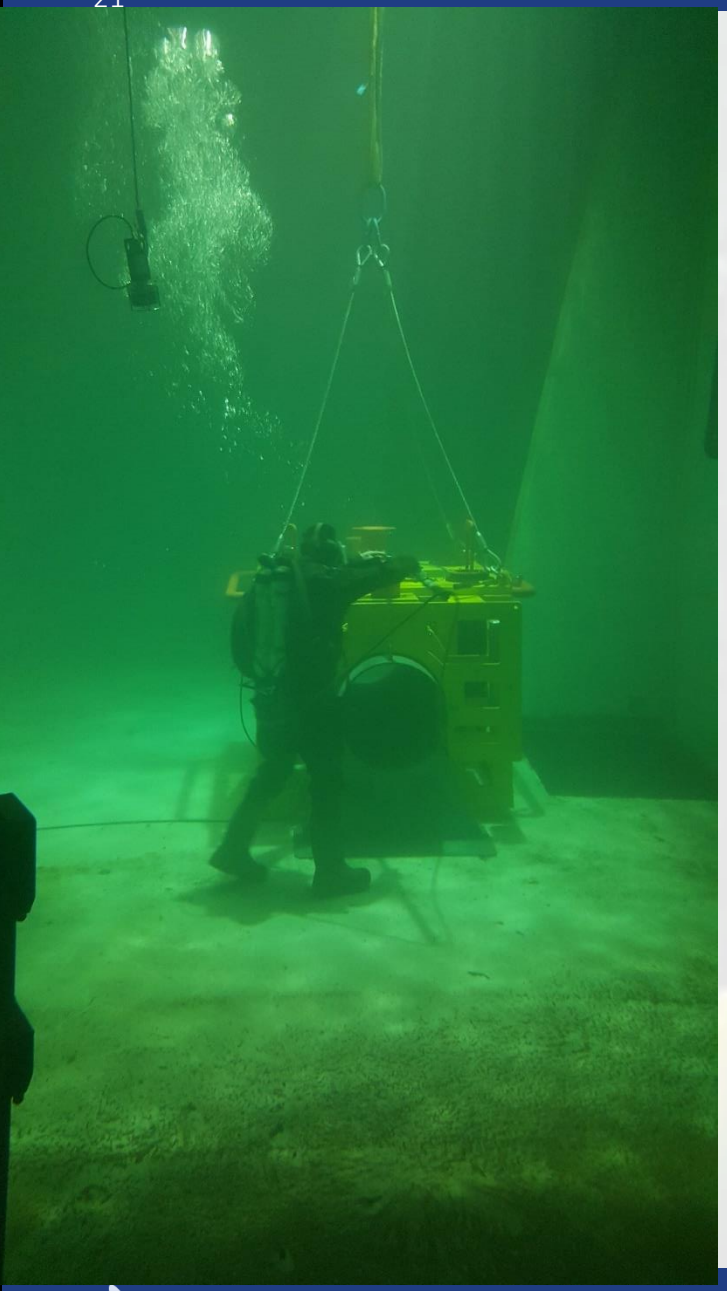
Permanent UT Array deployed on BP Shah Deniz 2



- 16 inch flow lines (10) feeds condensate from 30 deep water wells
- One fixed UT array installed on top of the weld on the first pipe joint after the FTA (Flowline Termination Assembly)
- Online and real-time feedback on corrosion inhibitor effectiveness

BP Shah Deniz In-Situ:

- Transducer array with 144 sensors covers straight pipe, field weld and HAZ zone.
- Real-time feed back on corrosion inhibitors effectiveness gives reduced opex cost
- The ability to rapidly detect corrosion rate changes enables the operator to plan and execute necessary actions to ensure that the corrosion rate do not exceed the maximum allowed rate (30 year design life time)

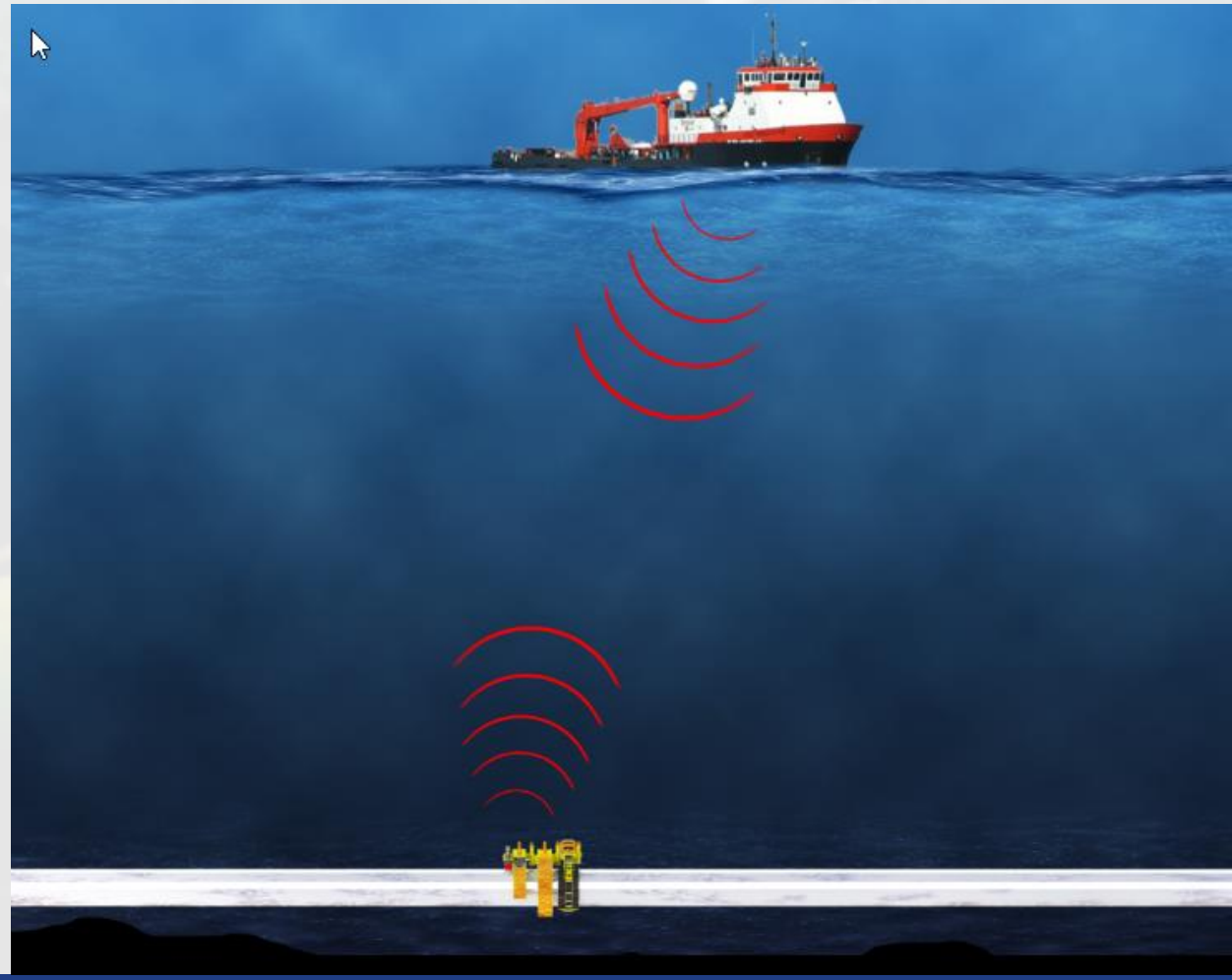


Retrofittable Subsea UT Array

- Non-intrusive ROV or Diver installation
- Works through solid coatings
- Autonomous operation with battery life time up to 10 years
- Wireless acoustic communication options

Data storage and collection – Battery Operation

- ✓ Local data processing and storage
- ✓ Wall thickness data transfer via acoustic link
- ✓ 10 year battery life (@ 4 measurements per day and 100 transducers)
- ✓ Consumption active: <10w, idle/sleep: <0.001w



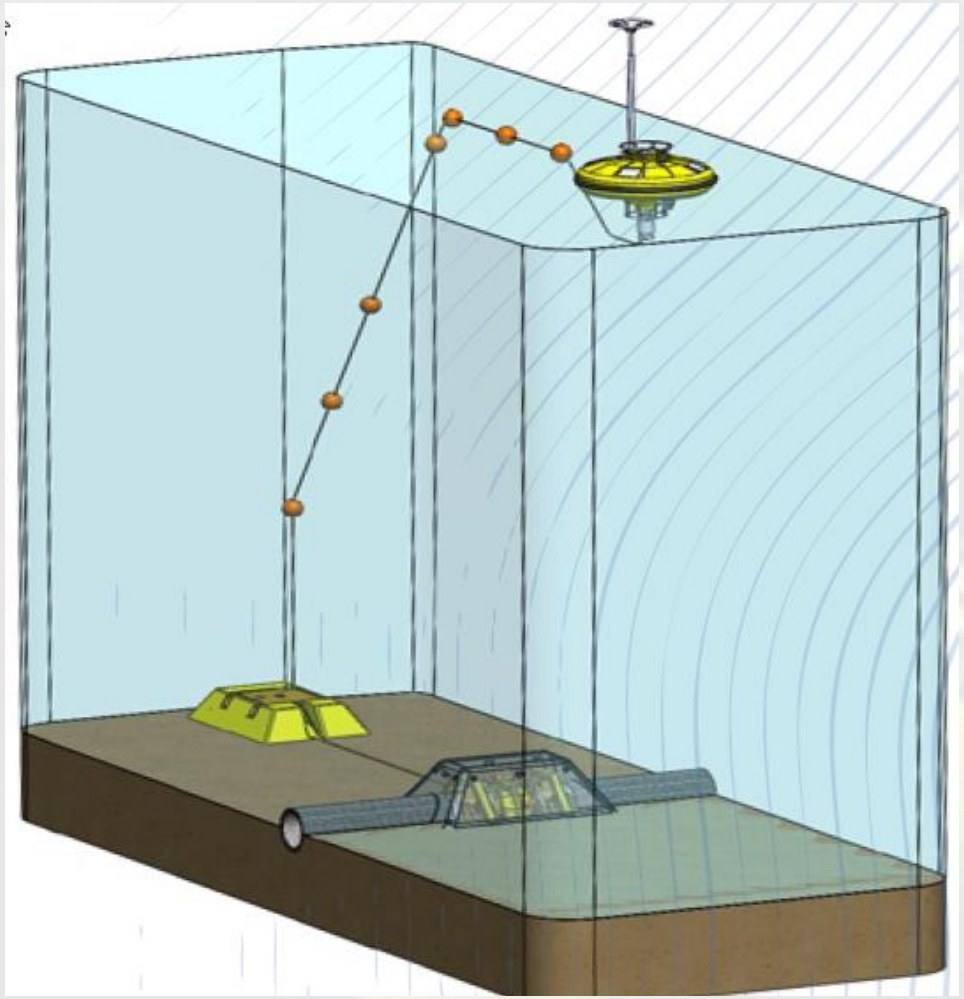
Data storage and collection using hard wire

- ✓ Local data processing and storage
- ✓ Consumption active: <10w, idle/sleep: <0.001w
- ✓ Communication interfaces: Ethernet, Modbus TCP/IP and RTU, Canbus (SIIS level 3 and SIIS level 2)
- ✓ Power: 24V DC

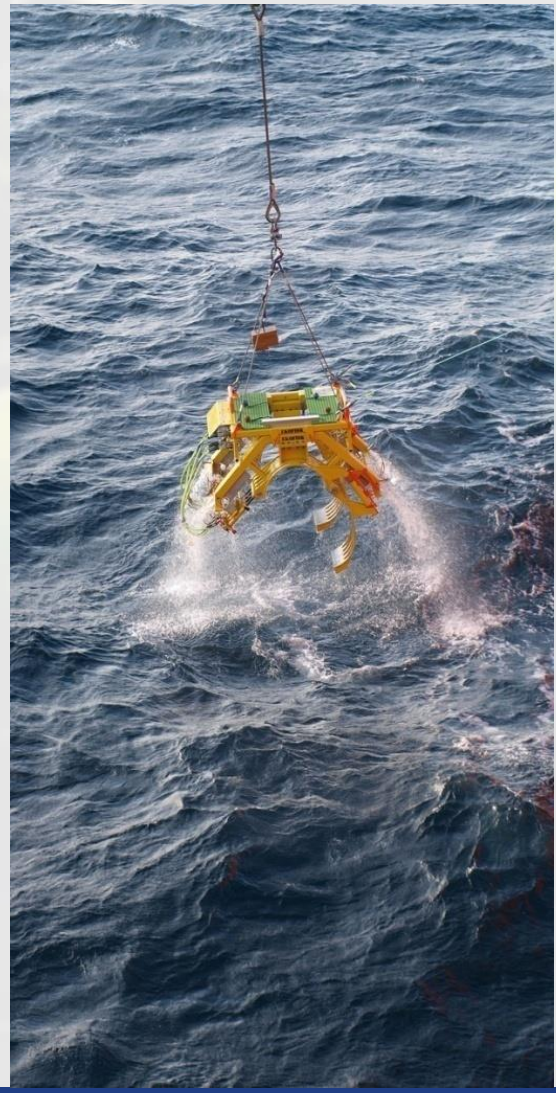
Retrofittable UT Array deployed on a 34 inch subsea crude oil pipeline

- Pigging showed local corrosion areas
- A 34” UltraMonit® subsea tool was installed to verify the chemical inhibition program
- Real time communication to the platform via radio link
- Data buoy with solar panels, batteries, data logger and radio link
- Anchor structure with subsea backup Data Logger
- Data showed little or no corrosion – inhibition successful

Retrofittable UT Array on a 34 inch subsea crude oil pipeline



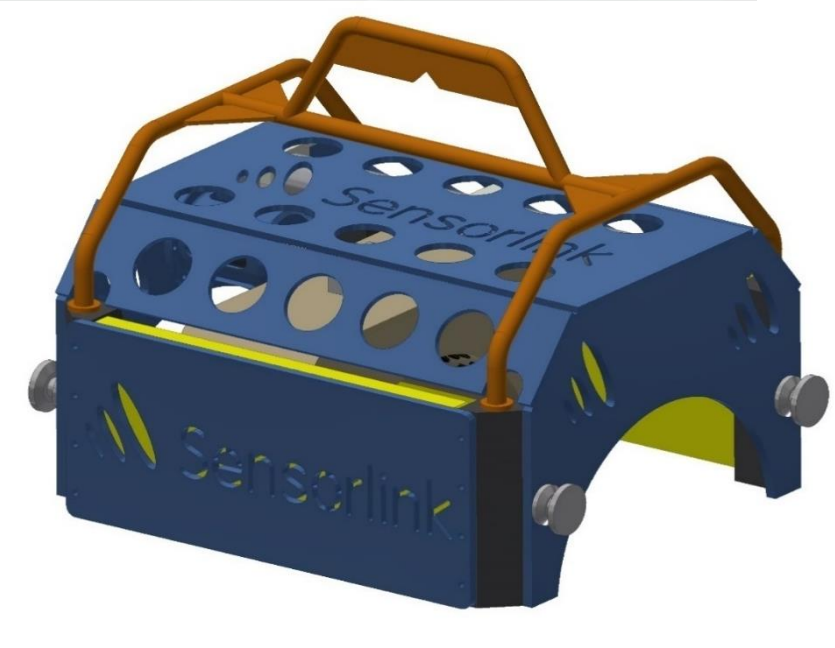
- 746 Transducers
- Installed by divers
- Maintained by ROV
- 18 months of monitoring enabled adjustment and verification of chemical inhibition program

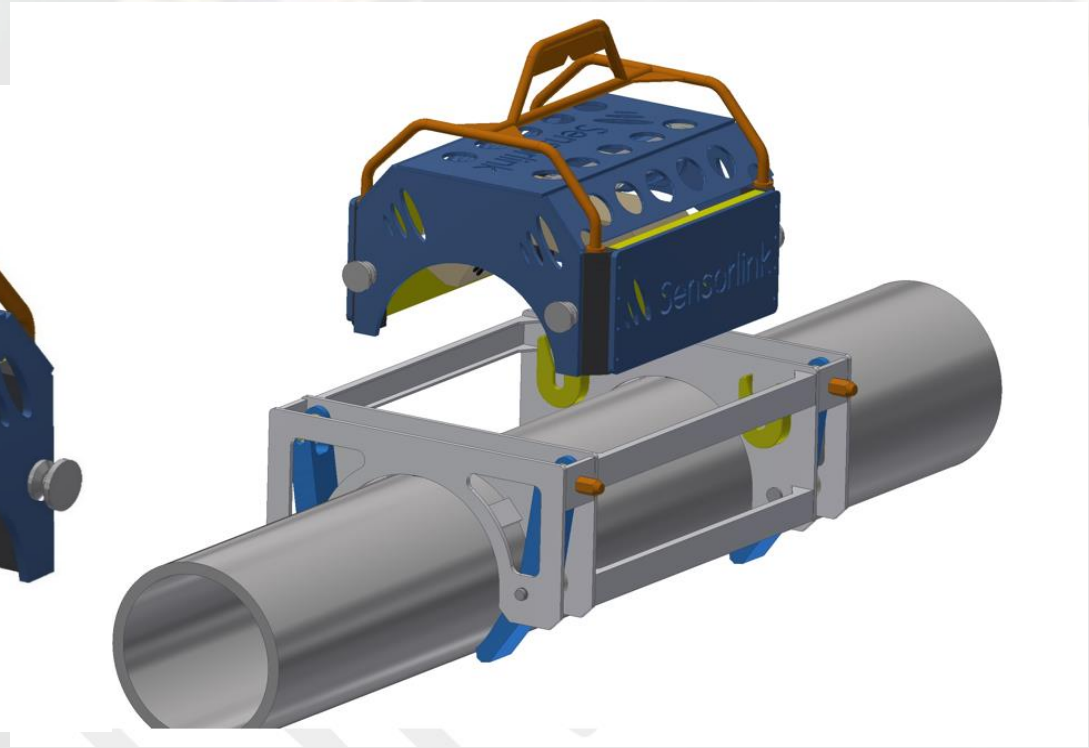


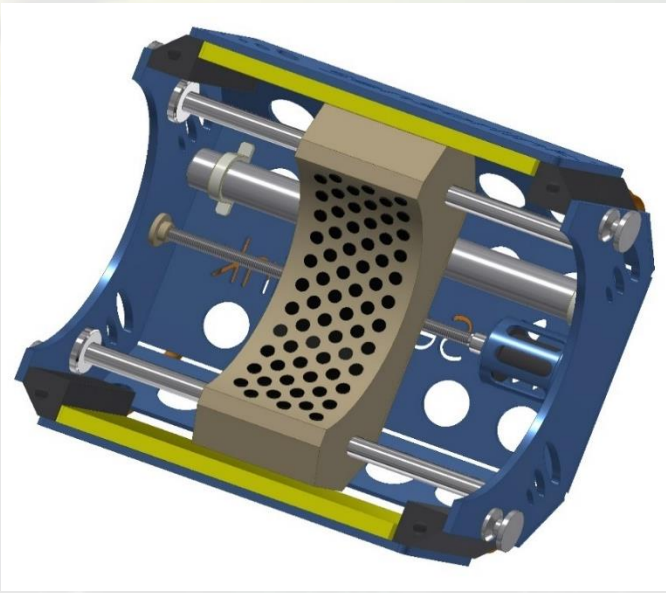
ROV Deployable UT Sensor Arrays for Inspection

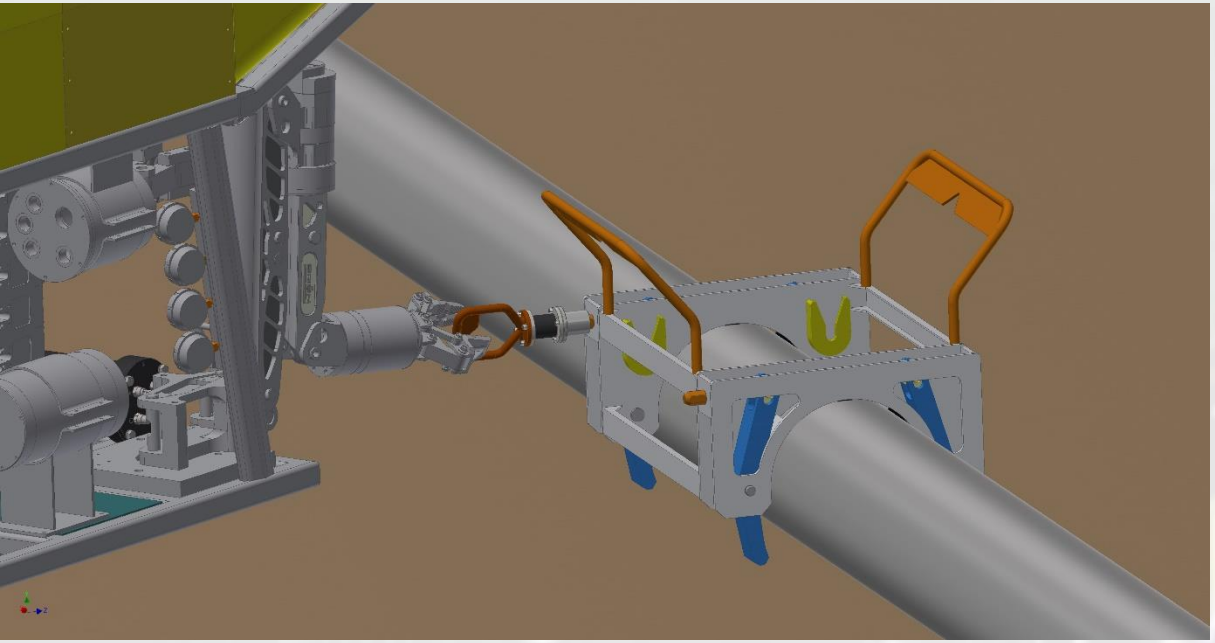
UT Arrays for Subsea Pipeline Inspection

- ✓ ROV deployable inspection tool providing autonomous scanning using an array of pulse/echo transducers operated by a battery driven data logger



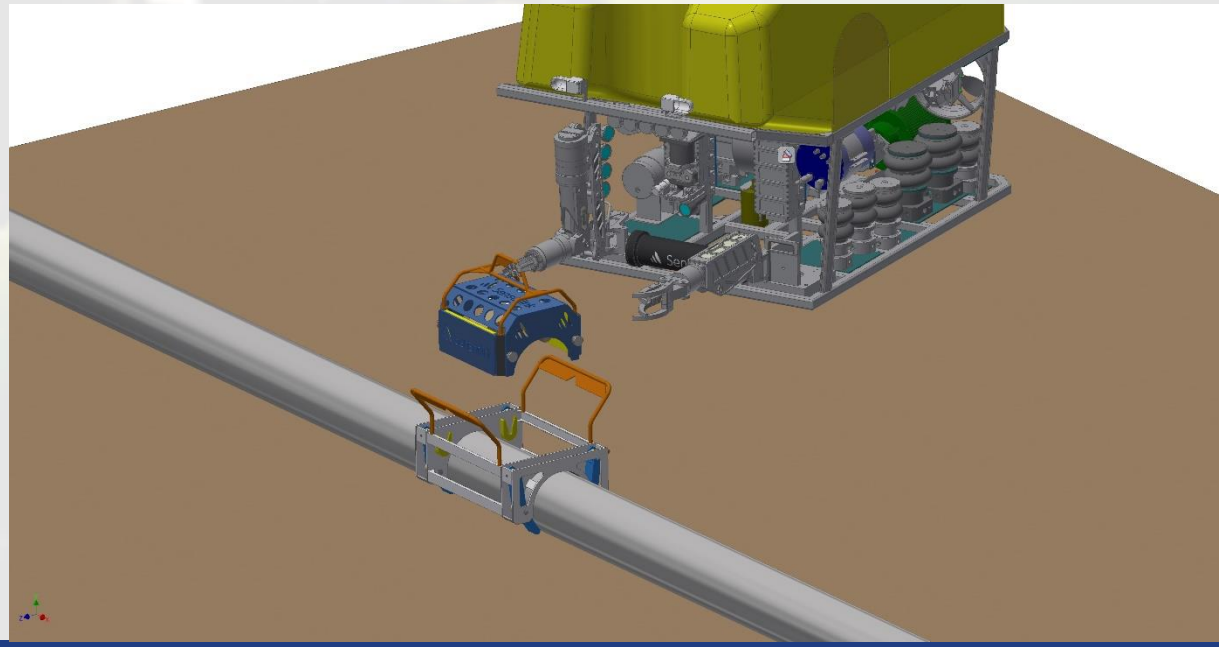






ROV flies in and mount an anchor frame. The anchor frame may be left in position to enable re-inspection of the same spot

ROV flies in the inspection unit. A green light will indicate completed inspection cycle



Any Questions, please?

Thank You!

Trondheim by night
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