IN-LINE INSPECTION, THE MISSING LINK IN FLEXIBLE PIPE INTEGRITY MANAGEMENT

Flexible Pipe ILI Solutions · Paul Birkinshaw & Tom Steinvoorte · © ROSEN Group · Nov-2022

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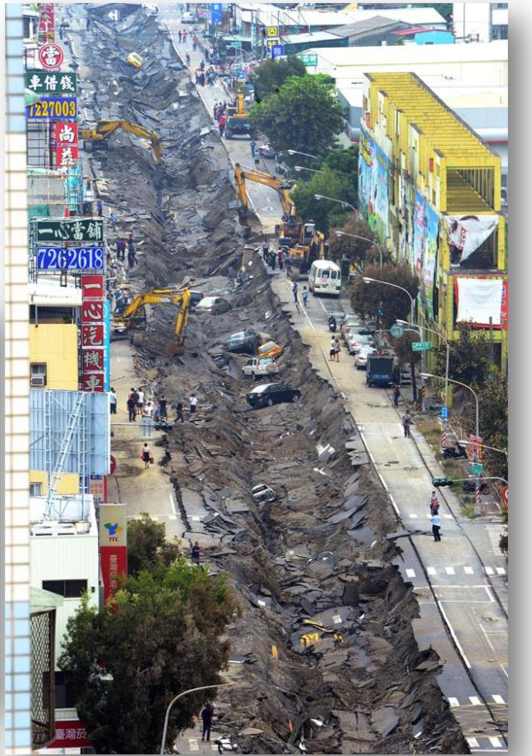
CONTENT

Background:
Rigid pipeline ILI & integrity management

RIGID PIPELINES – A LONG HISTORY

Threat Category	Threat
Internal corrosion	CO2 / O2 / H2S MIC / erosion
External corrosion	Galvanic / crevice / soil / AC / DC / atmospheric / under insulation / MIC
Environmentally assisted cracking	HIC / SCC
Mechanical damage	Third party impact / dropped objects / sabotage / unauthorised taps
Natural hazards	Earthquake / landslide / river crossing scour
Operational issues	Blockage (e.g. freezing) / incorrect operation
Design and materials	Pipe body defects / SW defects
Construction	Girth weld defects
Equipment failure	Valve / flange / pig trap

PD 8010



PIPELINE INTEGRITY MANAGEMENT (PIMS)

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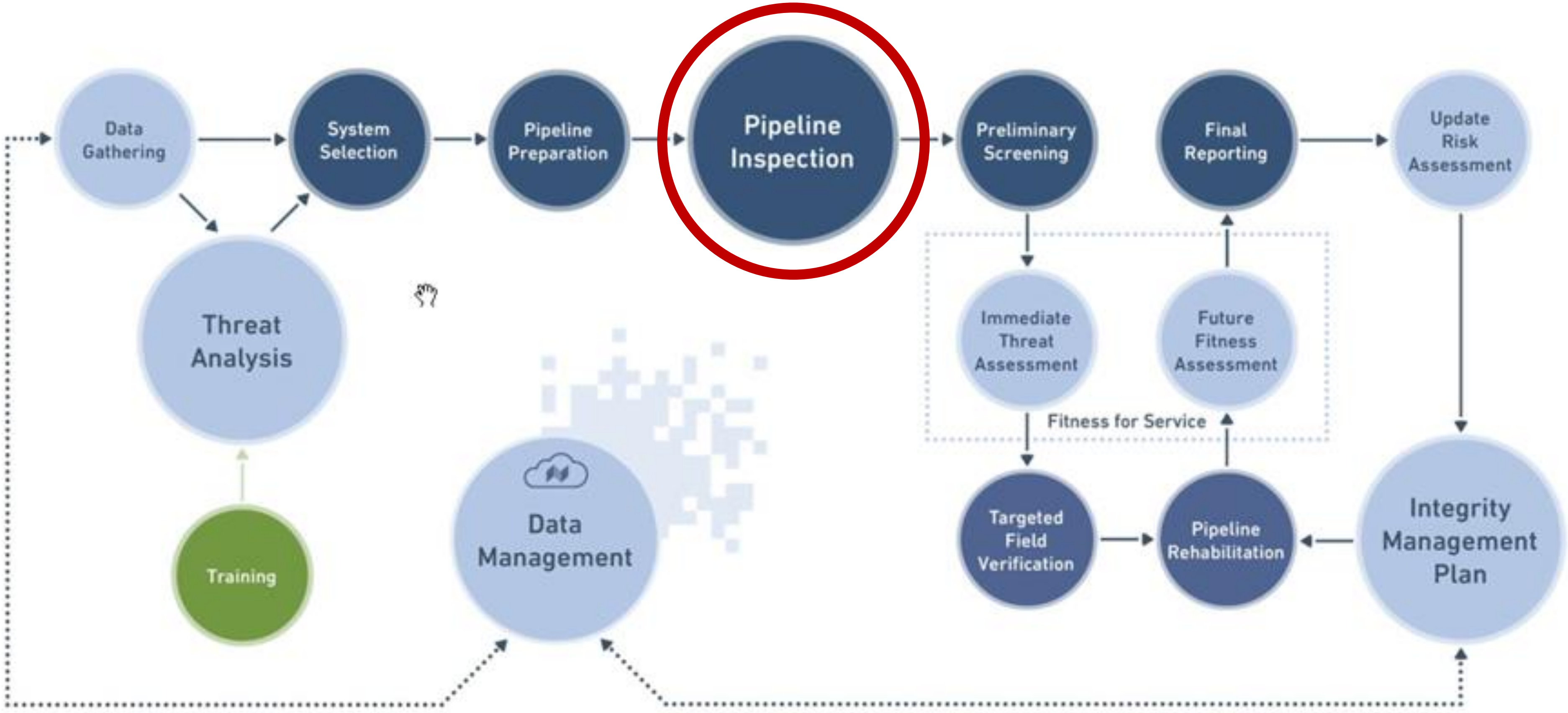

ROSEN's Pipeline Integrity Management Framework

PROLIFERATION OF ILI (& FFS)

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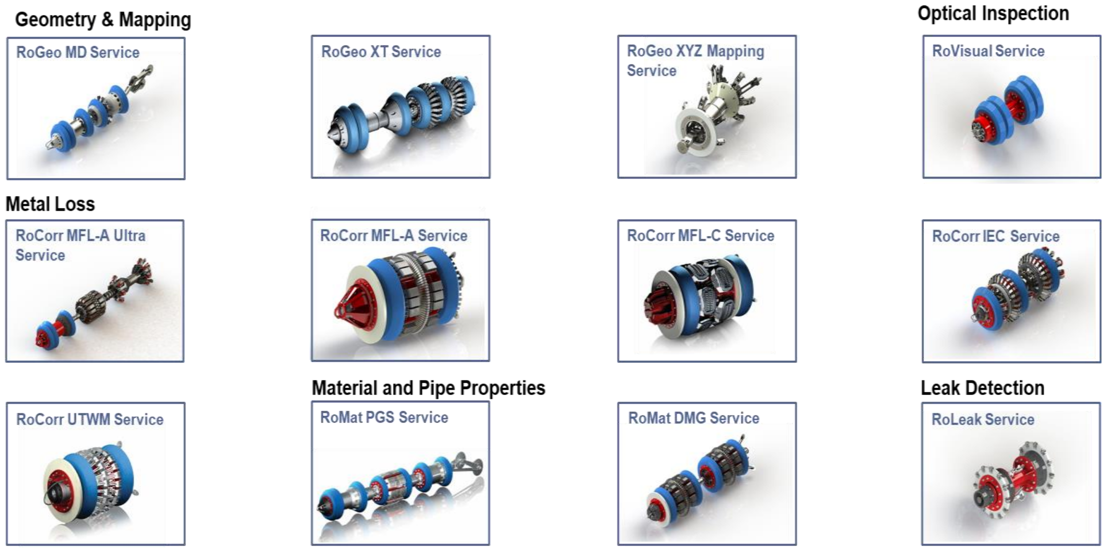
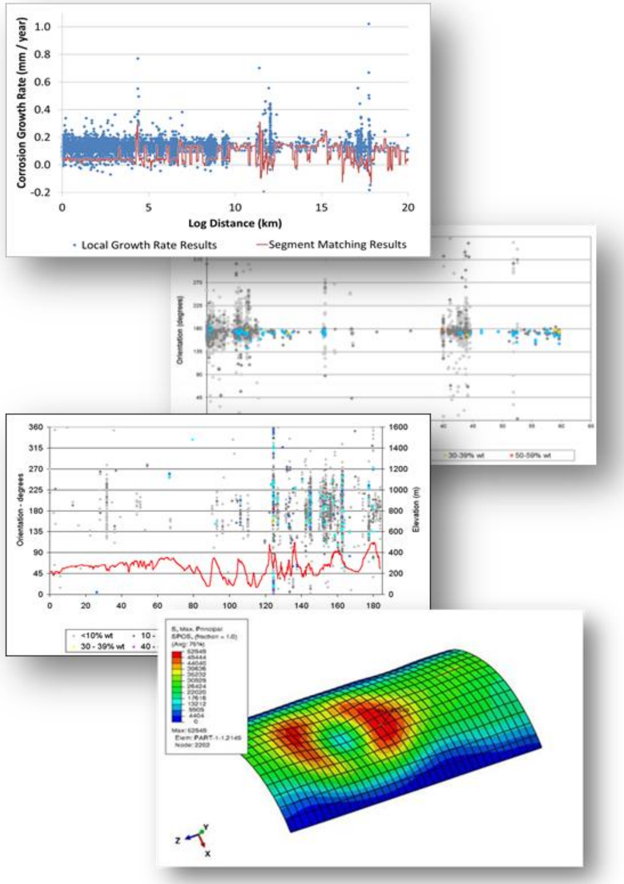


	GEOMETRY		METAL LOSS			CRACK DETECTION		MATERIAL PROPERTY DETERMINATION
	RoGeo MD	RoGeo XT	RoCorr MFL-A	RoCorr MFL-C	RoCorr UT	RoCD UT-C	RoCD EMAT-C	RoMat PGS
Corrosion Growth Assessment			●	●	●			●
Fitness for Purpose Assessment	●	●	●	●	●	●	●	●
Dent Strain / Stress		●						
Crack Assessment						●	●	
Bending Strain	●	●	●	●	●	●	●	●
MAOP Validation / PipeGrade Detection								●



High level of 'Decision Support'

Flexibles Perspective:

Inspection & integrity management

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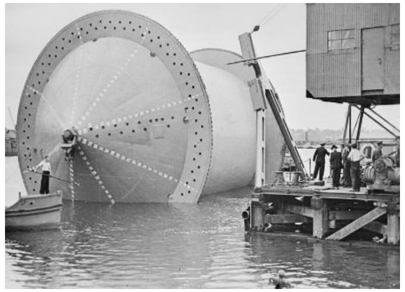
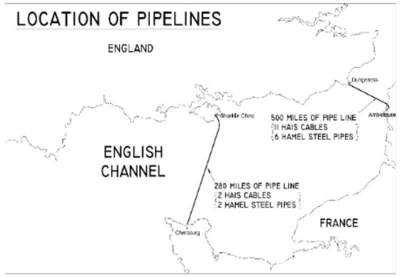
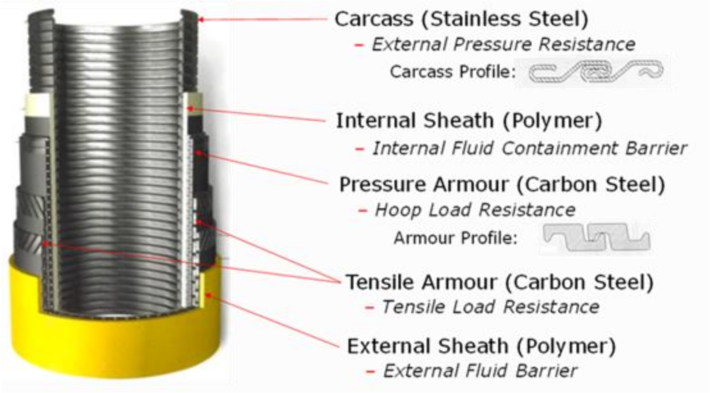
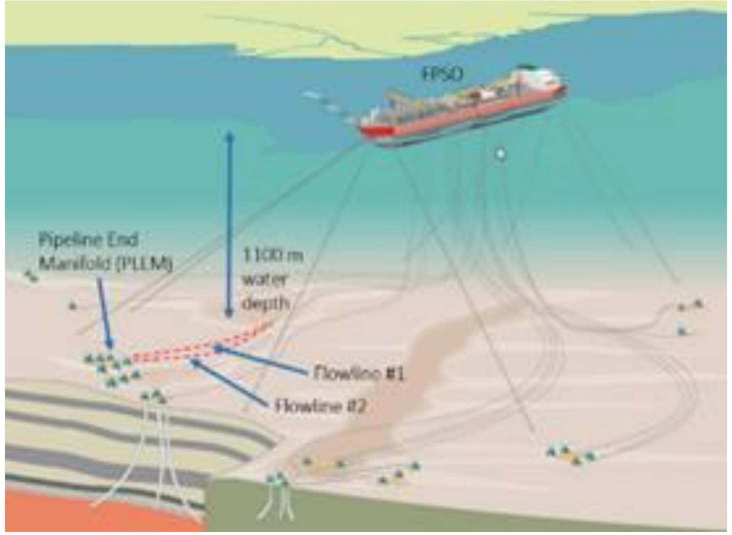
UNBONDED FLEXIBLE PIPE

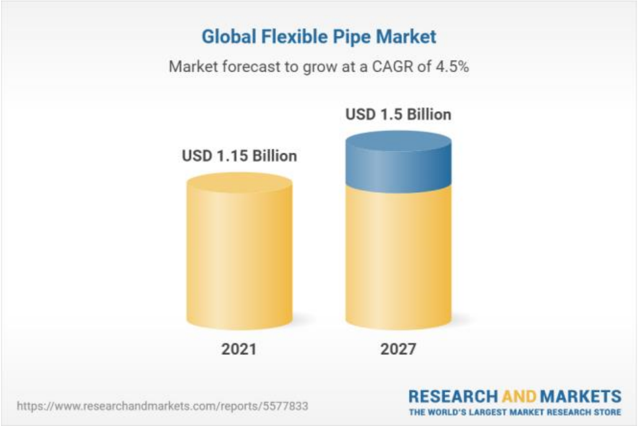




Pluto Pipeline (1944)

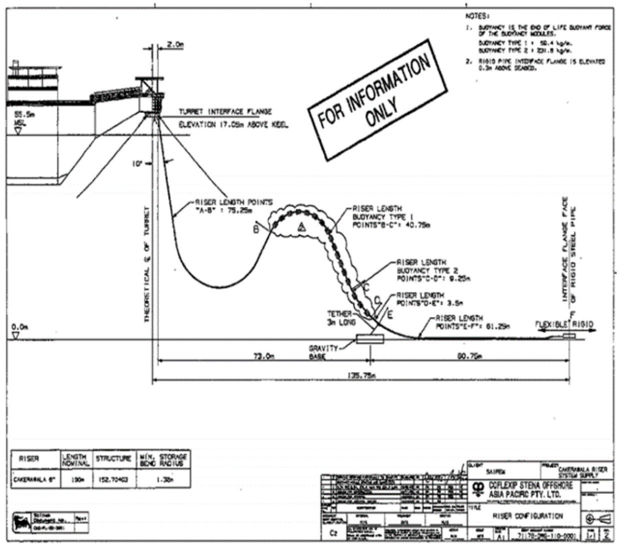






INSPECTION & INTEGRITY MANAGEMENT OF FLEXIBLES

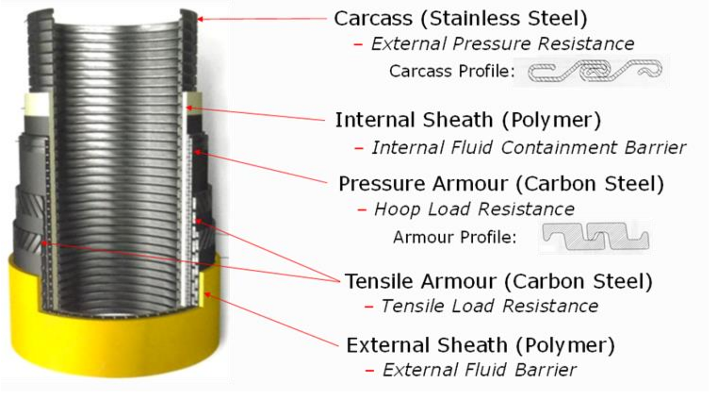
Good Practice Guidance:
- API 17B Third Edition March 2002: Recommended Practice for Flexible Pipe
- API 17J Second Edition Addendum 1 December 2002: Specification for Unbonded Flexible Pipe
- 2001 UKOOA State of the Art Flexible Riser Integrity Issues
- 2002 UKOOA Monitoring Methods and Integrity Assurance for Unbonded Flexible Pipelines



- Common inspection / monitoring methods:
  - External visual inspection
  - External NDT
  - Annulus Testing
  - Position monitoring
  - Production Monitoring

These only provide part of the data often needed to demonstrate integrity

- From a **pigging perspective**, the complexity of unbonded flexible pipe structure makes in-line inspection (and interpretation of results) difficult
- Installation **configuration** often restricts access for internal inspection options



A 'challenging' ILI & pigging application

INSPECTION & INTEGRITY MANAGEMENT OF FLEXIBLES

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Legislation:
- Pipelines Safety Regulations 1996 (PSR)
- Offshore Installations (Safety Case) Regulations 2005 (OSCR)

- An inability to unambiguously demonstrate the integrity of critical flexible pipelines or risers can lead to operational challenges

- Potential consequences:
  - Reduction in operating pressure
  - Production deferment
  - Restricted vessel movement
  - Unplanned intervention
  - Premature replacement
  - Premature decommissioning

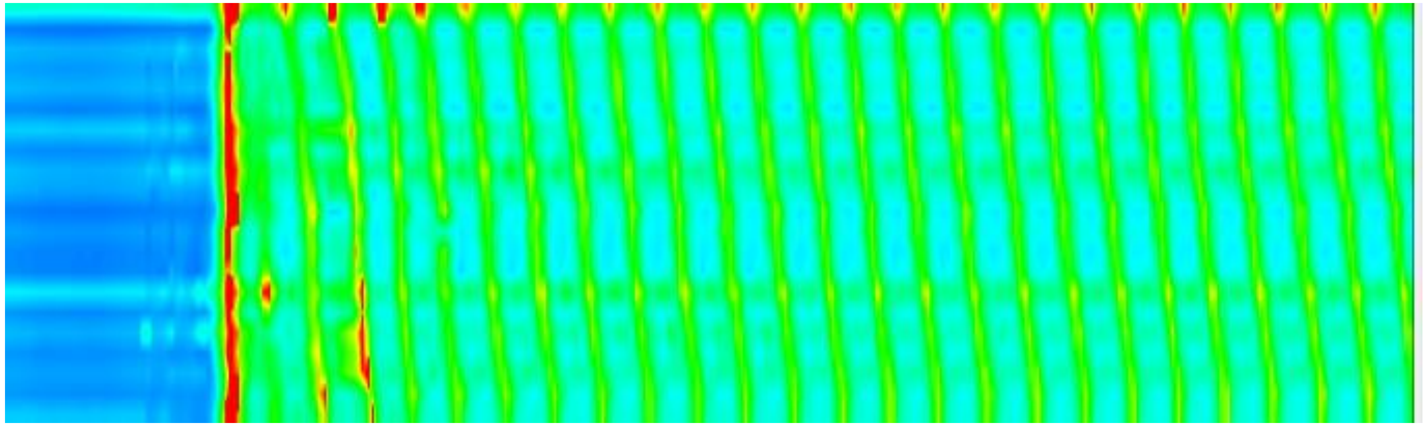
It is often uncertainty that drives these actions!

HSE Health and Safety Executive

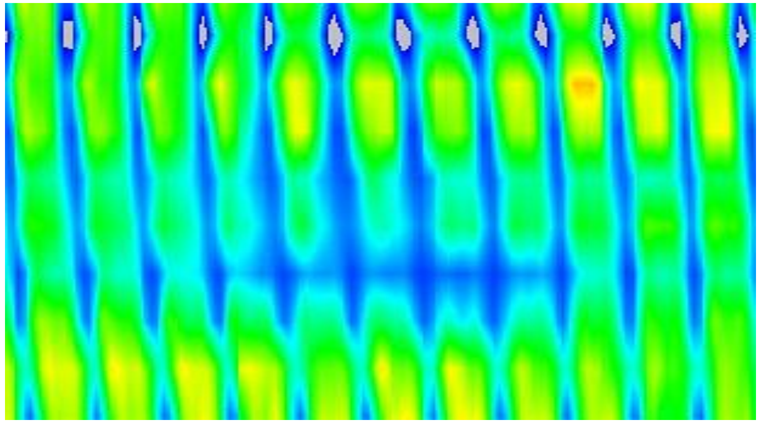
Pipeline operators should implement good practice guidance or equivalent arrangements including:
- *establishing an integrity and condition monitoring programme based on:*
  - *evaluation of relevant failure modes,*
  - *assessment of risk attributed to each failure mode,*
  - *a range of complementary inspection/monitoring/testing techniques,*
- *taking a whole lifecycle approach which should be established and implemented at design.*
- *providing systems which detect any degradation at an early stage,*
- *formally documenting and demonstrating best practice.*

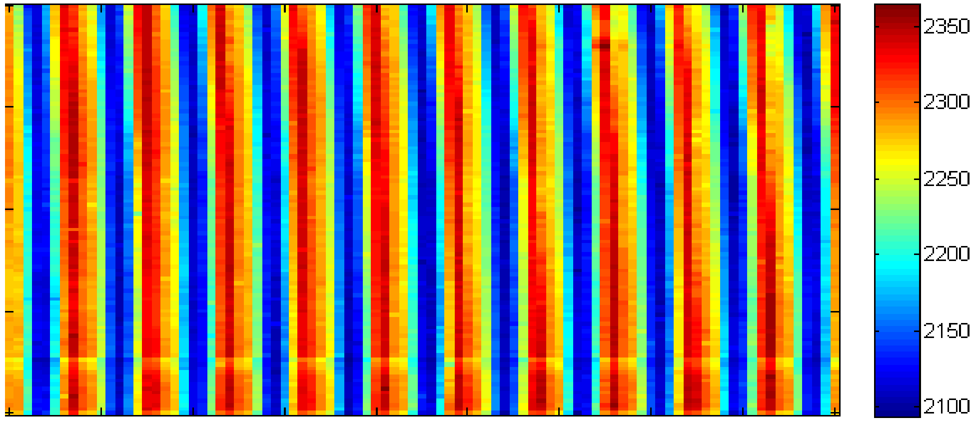
EARLY TESTING AND ILI TECHNOLOGY REVIEW

Mid 2016 In Service Pipe

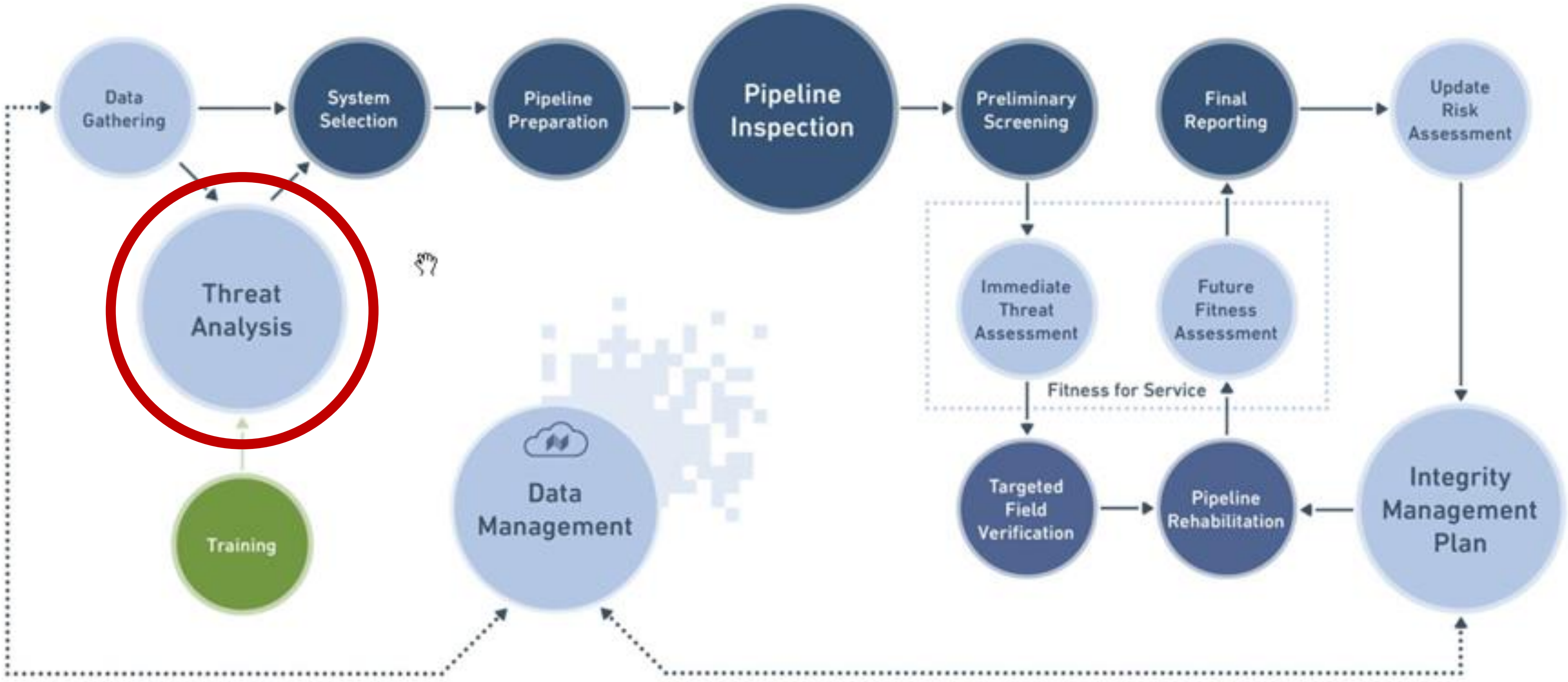


Early 2017 Lab Tests





WHAT ARE THE MAIN ISSUES?



ROSEN's Pipeline Integrity Management Framework

FLEXIBLE PIPE OPERATIONAL EXPERIENCE

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SUREFLEX JIP (2017)

- Documents the industry challenges – damage / failure causes

Damage / Failure Cause	Number of cases, by Status								Total No.	%
	Installed (not operating)	Operating (minor defect / damage)	Shut-down (integrity concern)	Damaged (failure initiator)	Failed - Leak	Failed - Rupture	Failed - Connected System Failure	Recovered- Before Design Life		
Line Recovered Proactively - No significant damage / defect identified			23						23	3.9%
Carcass Failure - Fatigue					1				1	0.2%
Carcass Failure - Multilayer PVDF Collapse		1	7	24	4				36	6.2%
Carcass Failure - Tearing / Pullout		1		5	3				9	1.5%
Internal Damage - Pigging				2					2	0.3%
Internal Pressure Sheath - Ageing			13	1	17				31	5.3%
Internal Pressure Sheath - End Fitting Pull-out			11	3	19				33	5.7%
Internal Pressure Sheath - Fatigue / Fracture / Microleaks		2		2	9				13	2.2%
Internal Pressure Sheath - Smooth Bore Liner Collapse		1			5	3			9	1.5%
Tensile Armour Wire Breakage - in / close to end fitting					3				3	0.5%
Tensile Armour Wire Breakage - in main pipe section				2		1			3	0.5%
Tensile Armours - Birdcaging				4	14				18	3.1%
Corrosion of Armours - Major / Catastrophic				1	13	4			18	3.1%
Corrosion of Armours - Moderate		1	3	2				3	9	1.5%
Annulus Flooding - Cause Unknown		19	4	40				1	64	11.0%
Annulus Flooding - Defective Annulus Vent System	2	10		5					17	2.9%
Annulus Flooding - Outer Sheath Damage - Ageing / Fracture		1		4					5	0.9%
Annulus Flooding - Outer Sheath Damage - Mechanical / Impact / Wear	1	27	15	79				2	124	21.2%
Annulus Flooding - Permeated Liquids		2							2	0.3%

J000621-00-IM-GLN-001 - Flexible Pipe Integrity Management Guidance & Good Practice Rev 1 - September 2017

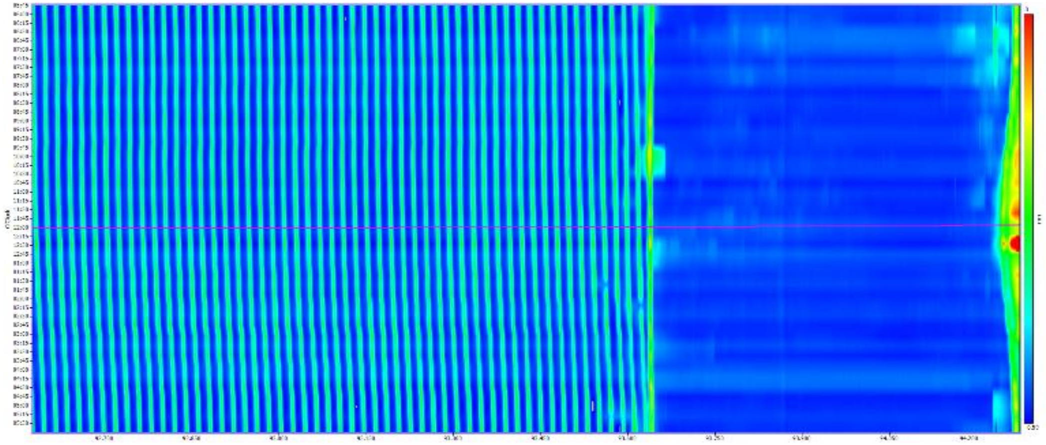
Four Areas of Interest:

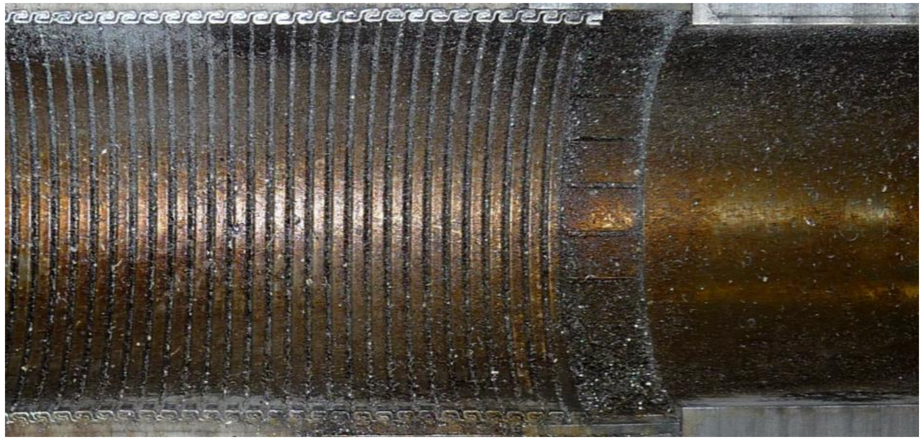
1. Carcass
2. Pressure Sheath
3. Tensile & Pressure Armour Wires
4. Annulus Flooding

ILI for Flexibles:

Technology solutions

TESTING SETUP IN LINGEN, GERMANY





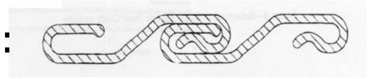
Flexible Pipe Sample

- 15m x 9” internal diameter
- Fully operational section
- No previous service construction

CARCASS MEASUREMENT

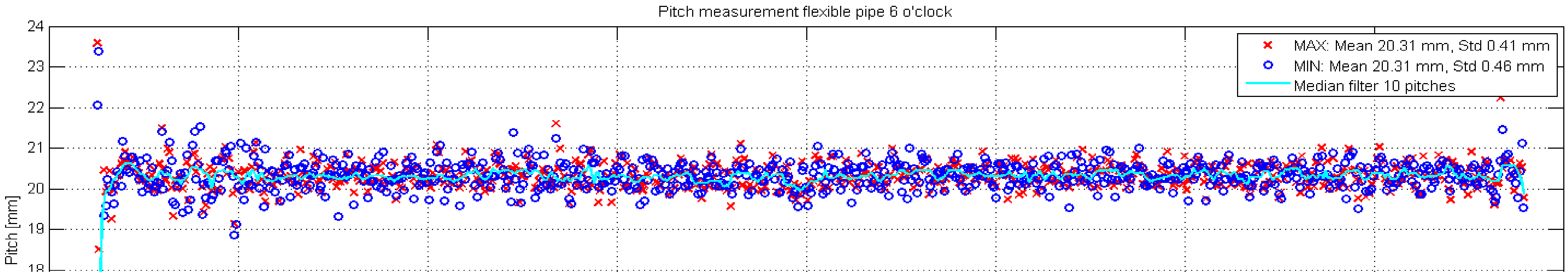
Carcass (Stainless Steel)

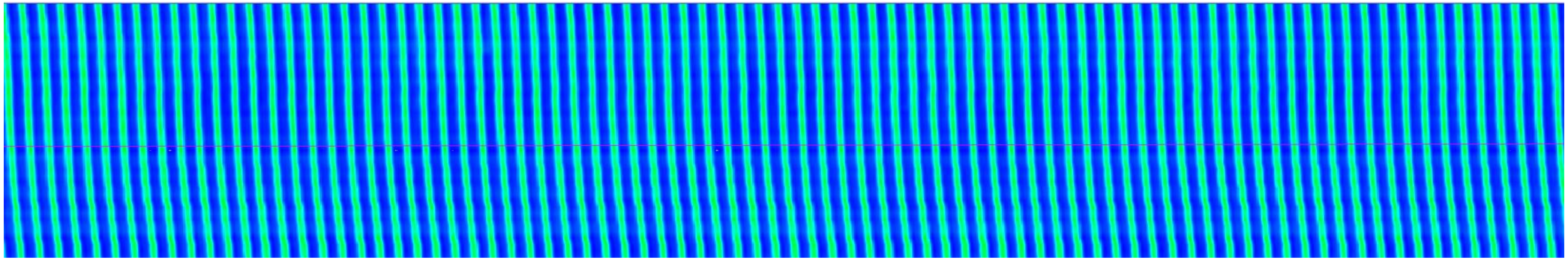
– *External Pressure Resistance*

Carcass Profile: 

Pitch of carcass

- Sections of compression
- Sections of extension
- Loss of Interlock





CARCASS MEASUREMENT

Overall accuracy

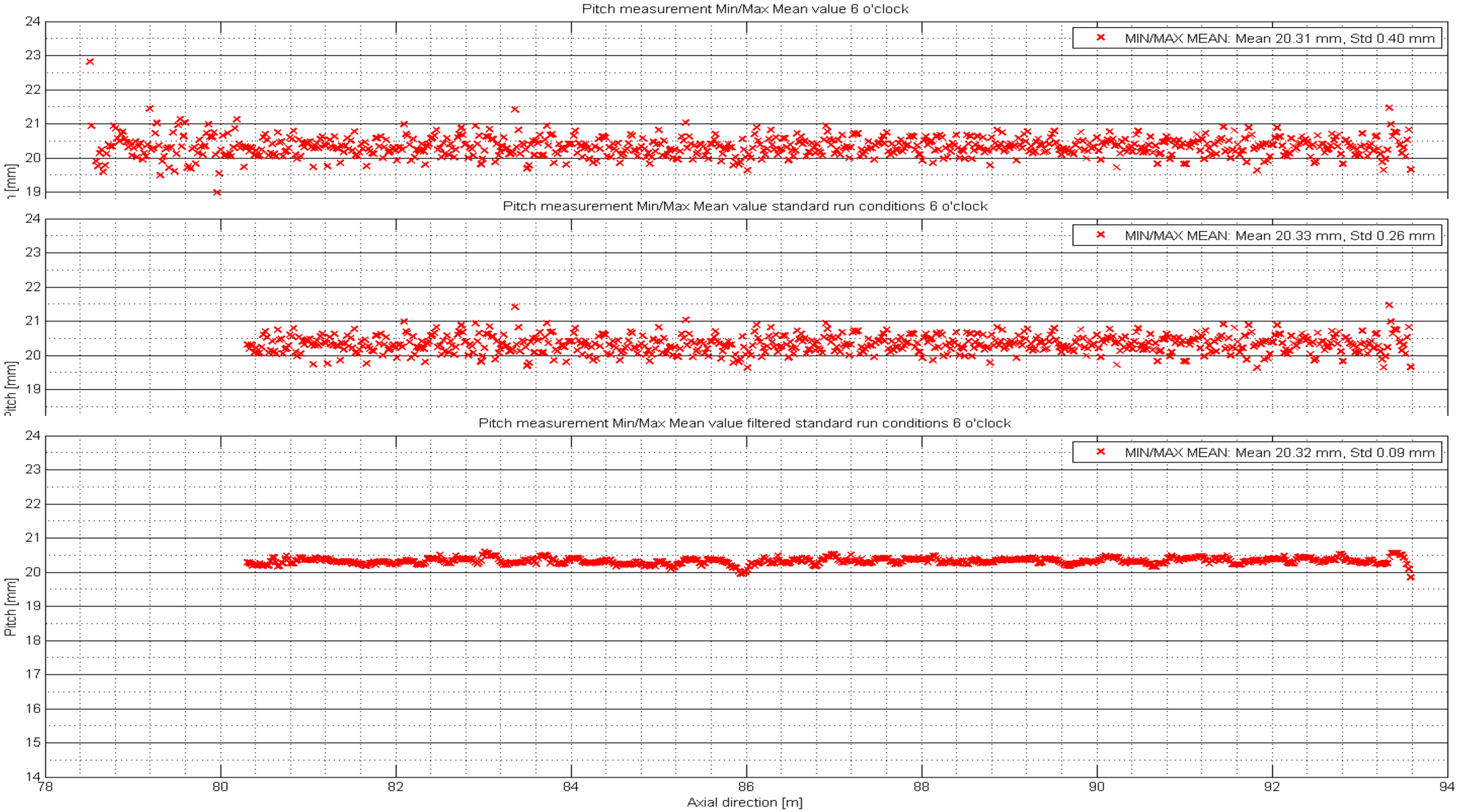
- Standard deviation is 0.4 mm

Without odometer slippage achieved accuracy

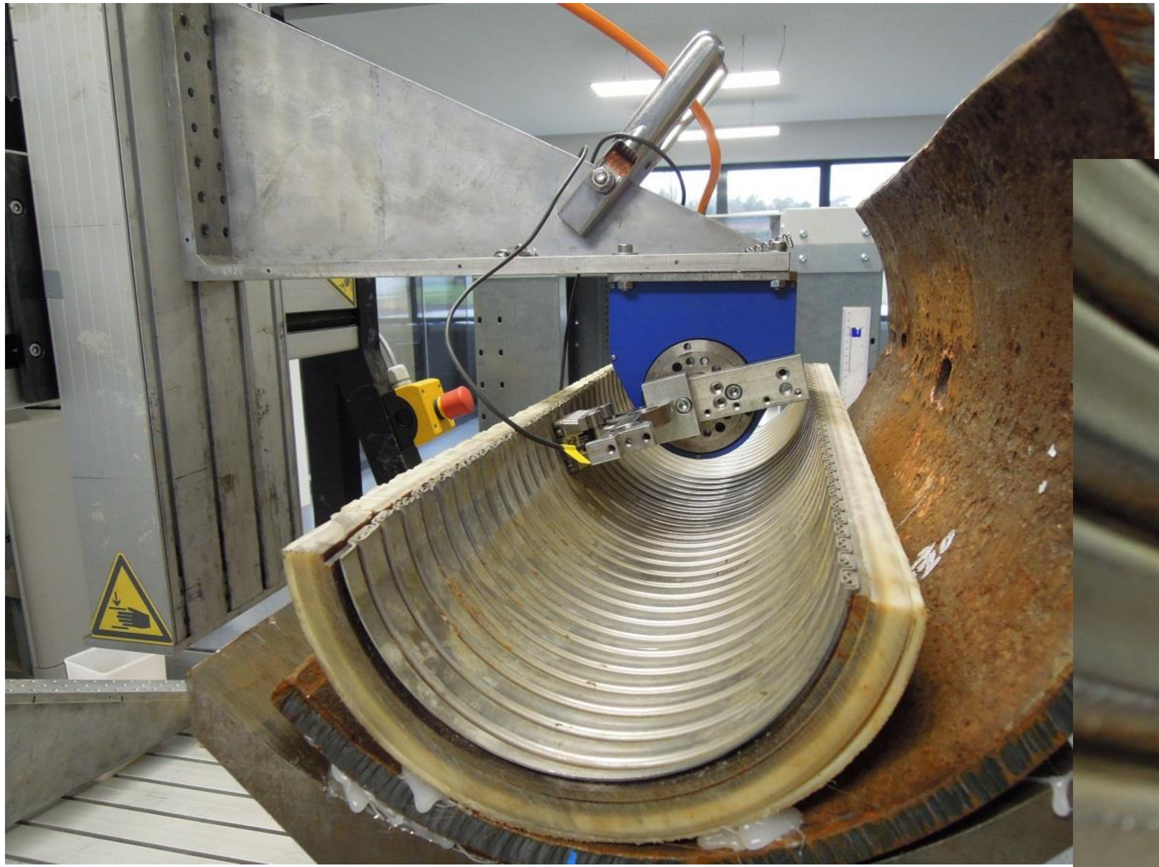
- Standard deviation is 0.26 mm

Without additional odometer slippage achieved accuracy

- Standard deviation is 0.09 mm

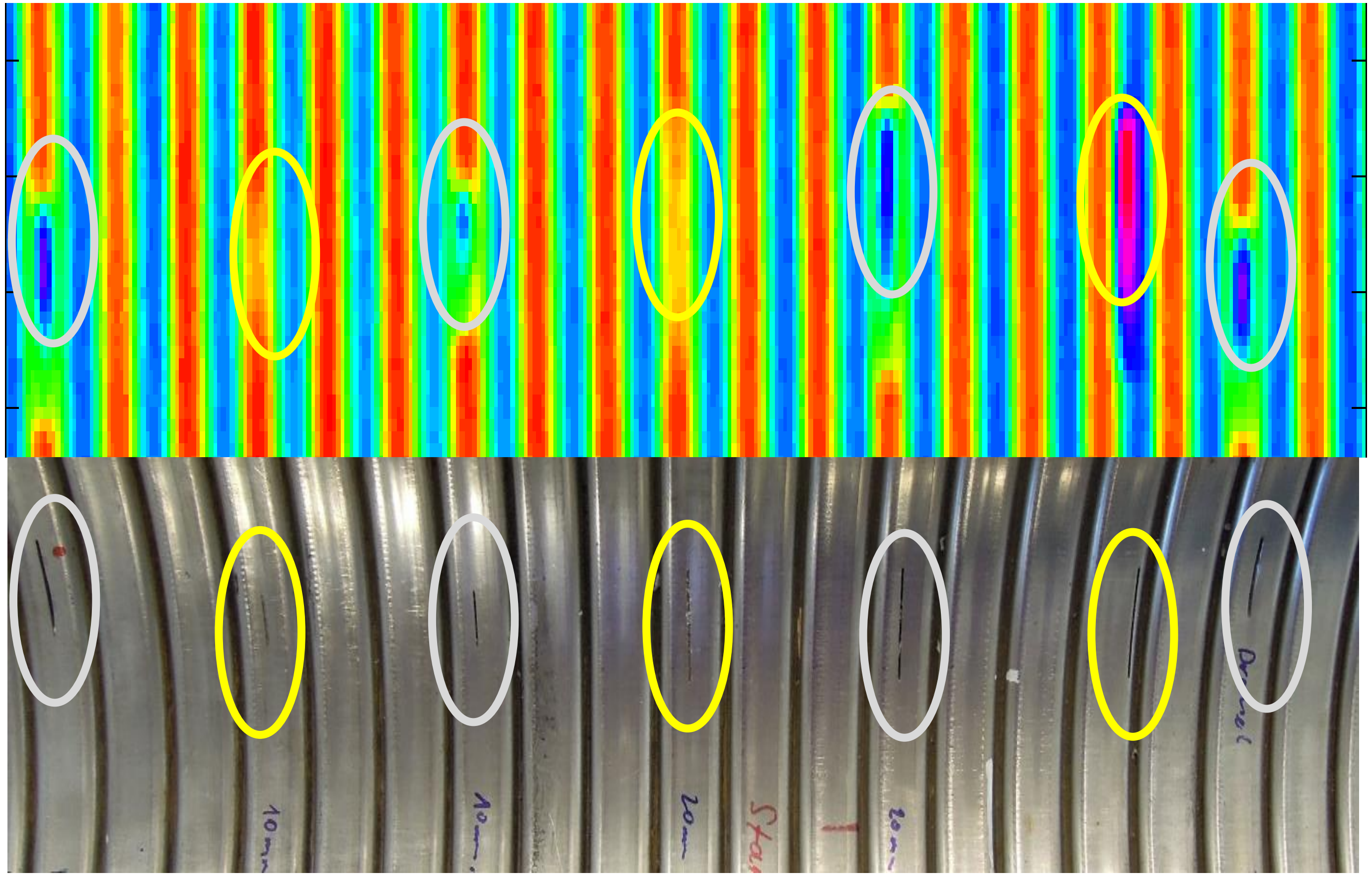


CARCASS DEFECTS

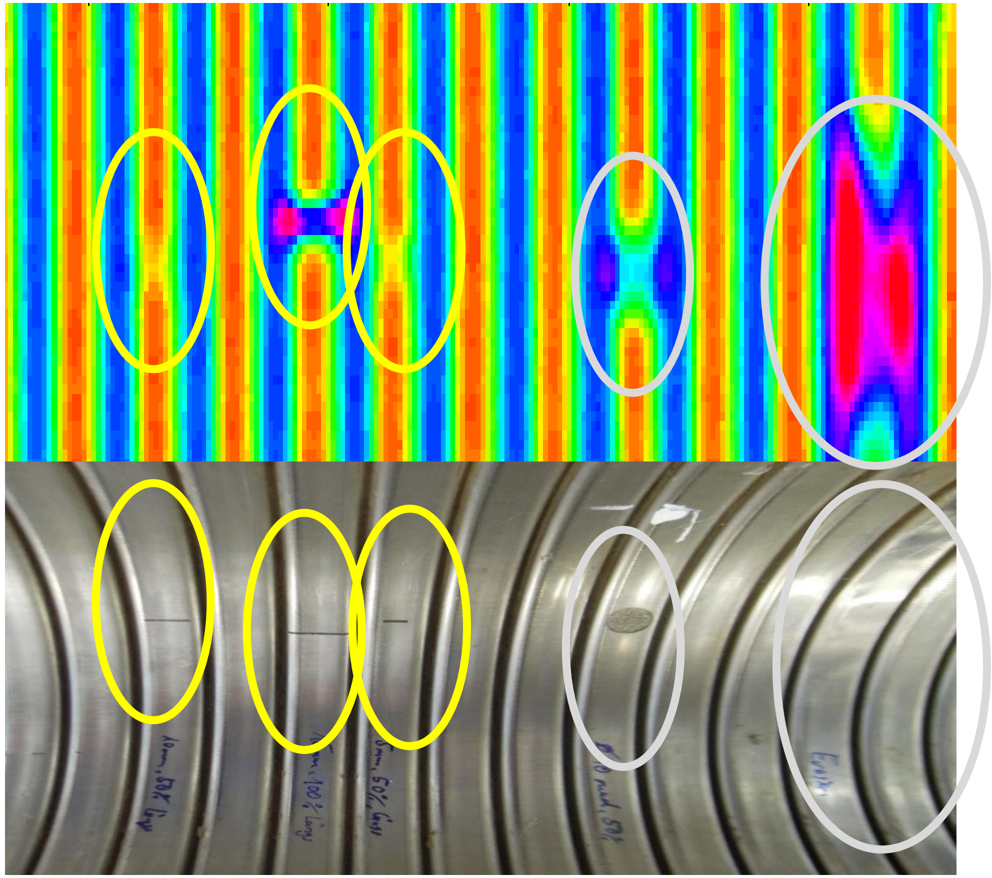


CARCASS DEFECTS

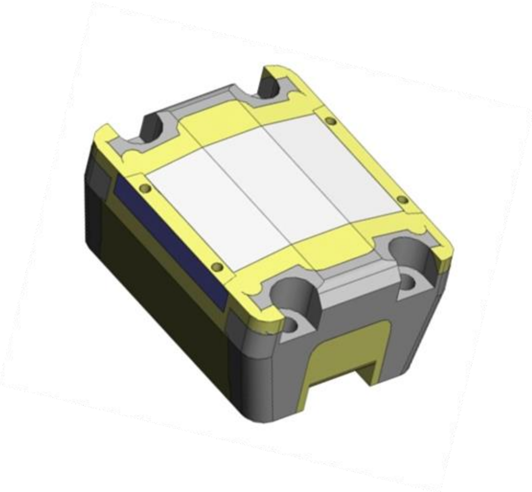
Circumferential Defects



Axial and Erosion Defects



CARCASS INSPECTION SUMMARY



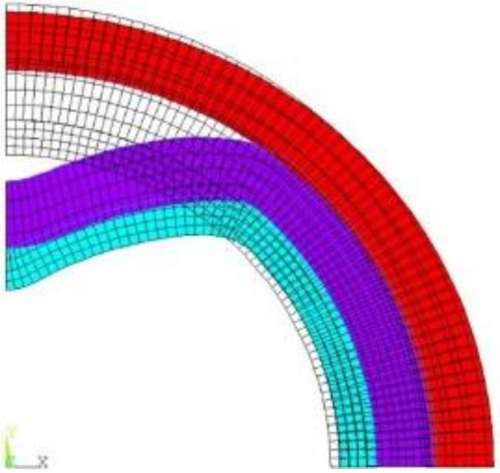
- New DRD sensor developed specifically for flexible pipe carcass inspection
  - Carcass Pitch
  - Circumferential damage
  - Axial damage
  - Erosion / Corrosion
- Pitch measurement with sub-mm accuracy
- Inferred results to identify possible damage to outer lying layers
- Targeting the findings from the SUREFLEX JIP
- Can be utilised on the inspection of rigid pipeline systems

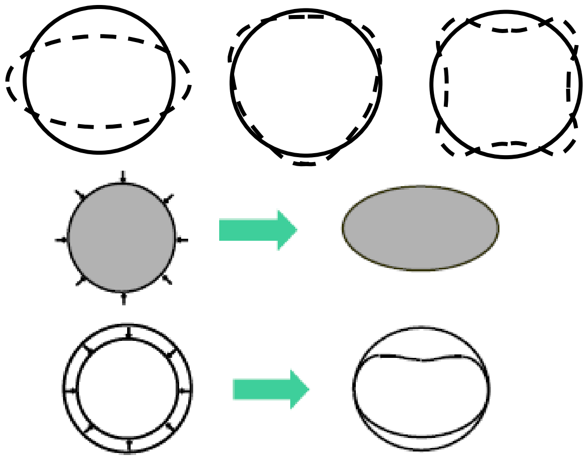
CARCASS ASSESSMENT

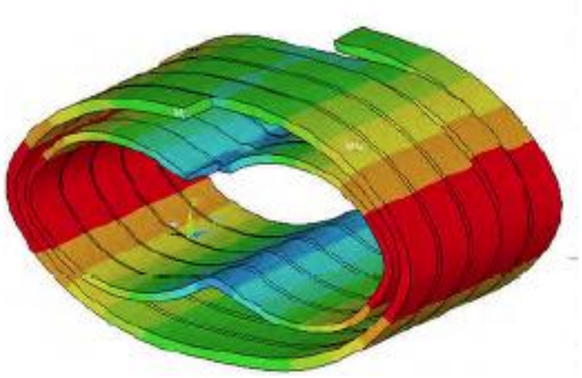
- Detect and Identify carcass pitch and gap
  - Calculate effects on collapse (bent collapse)
  - Regions of significant compression / extension / carcass pull out

- Detect and Identify cracks and erosion / corrosion in carcass
  - Calculate effects on collapse (bent collapse)

- Detect and Identify deformation
  - Root Cause Assessment for pipe deformation
  - Assess possible impact to the flexible pipe
  - Recommendation / targeting of other inspection







WHAT ELSE?
PRESSURE ARMOUR WIRE

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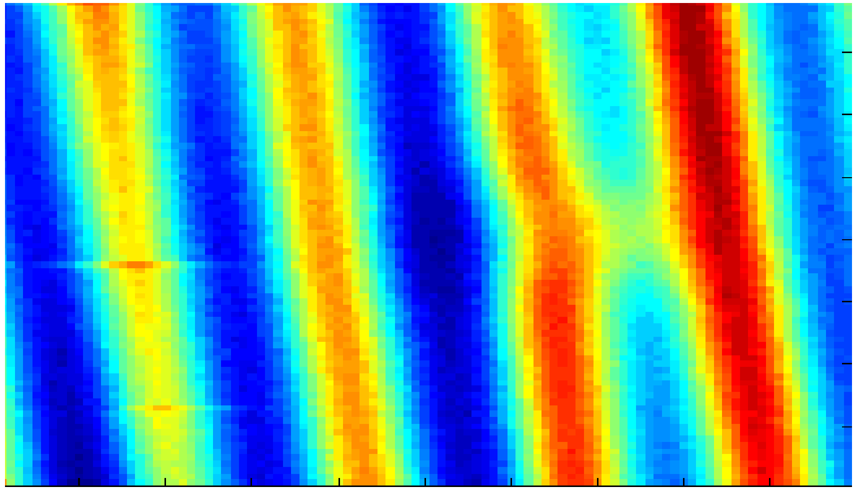
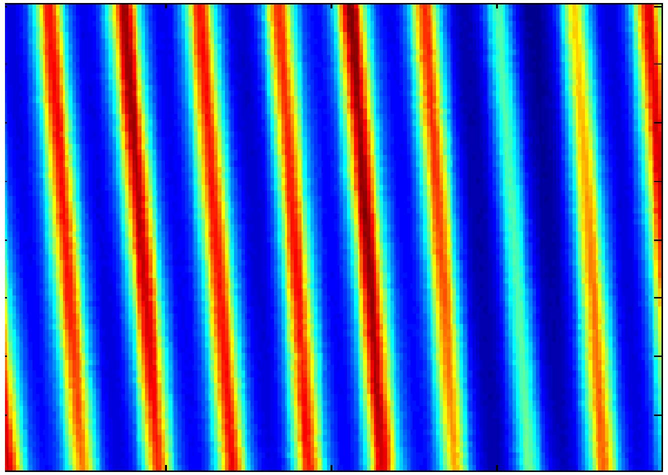


Channel 1



- 15mm sensor 'lift-off' to mimic pressure sheath and carcass thickness

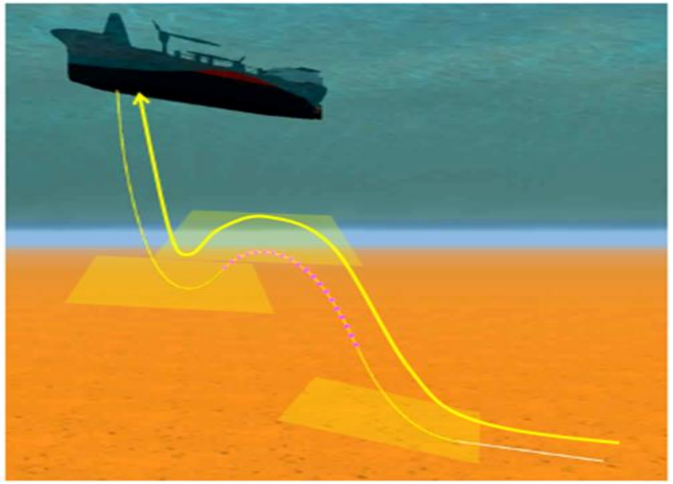
- Pitch and gap of pressure / tensile armour
- Loss of pressure armour interlock
- Areas of gross metal loss

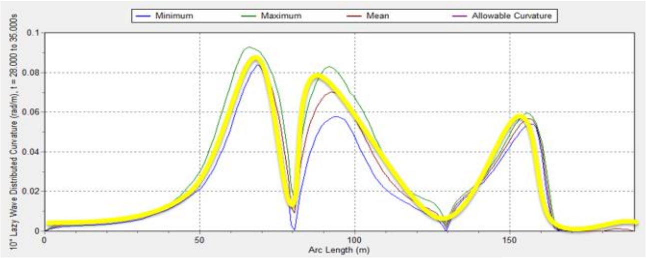
- Need to review magnetiser configuration to better address this layer (need representative use case)

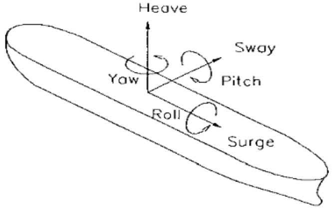
WHAT ELSE?
VERIFICATION OF RISER CONFIGURATION

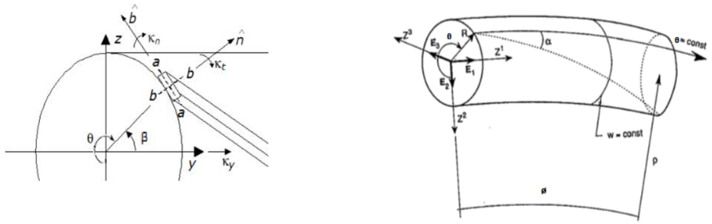
- Mapping flowline/riser 3D Profile using IMU
  - Riser X-Y curvature and angle
  - Riser X-Z curvature and angle
  - Measure bend radius and angle
  - Monitor change (multiple passes)

- Areas of interest
  - Hog Height and Radius
  - Sag Height and Radius
  - Touch Down Location

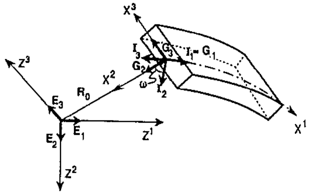








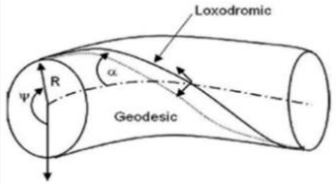
Centreline of tensile wire on the bent pipe surface



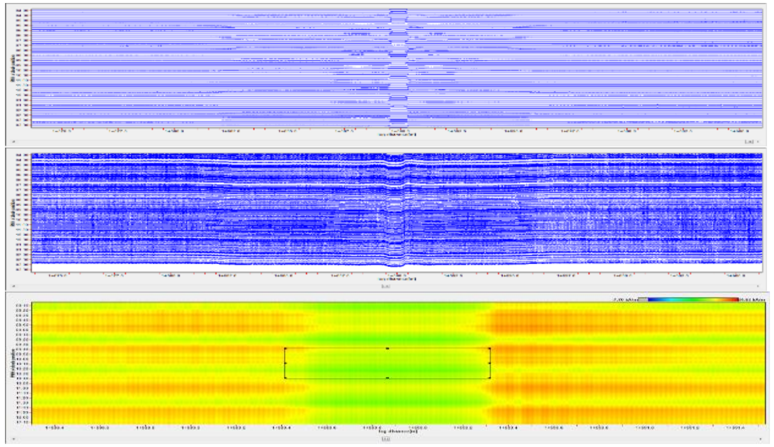
Local curve coordinate systems

Assessment:

- Determine if the riser configuration is as per design
  - Model configuration in Orcaflex
  - Identify as design range
  - Adjust flexible riser properties to align data (bending stiffness)
  - Calculate new Tension, Angle and Curvature
  - Calculate new fatigue life (Bflex)

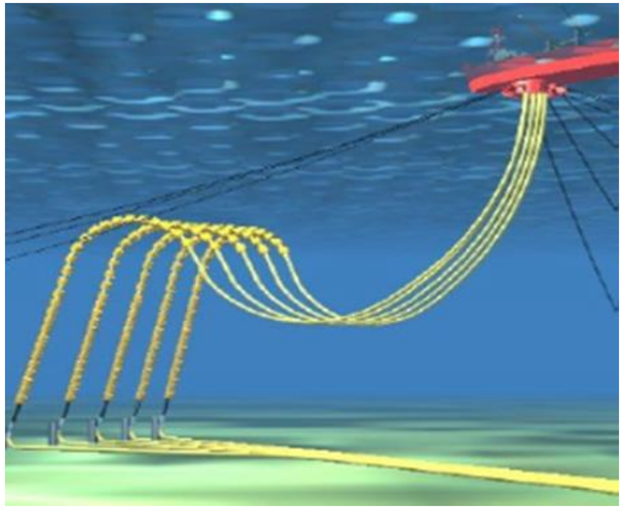


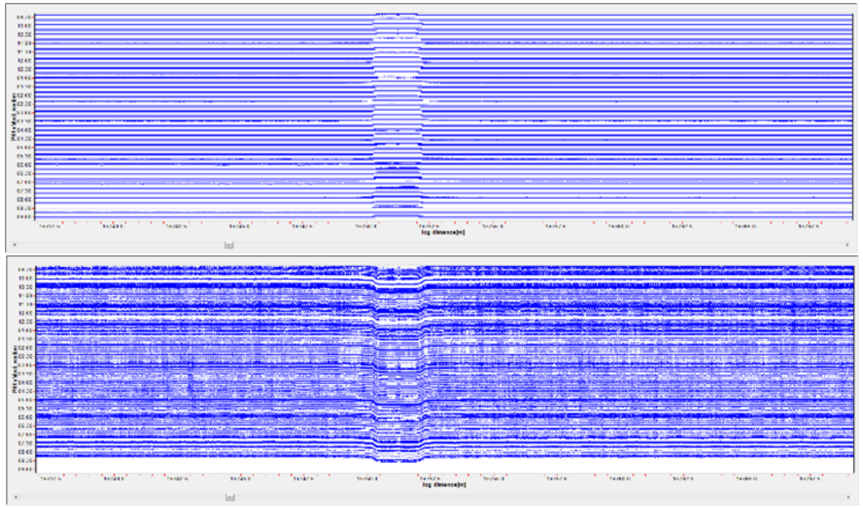
WHAT ELSE?
DETECTION OF ANCILLARY EQUIPMENT



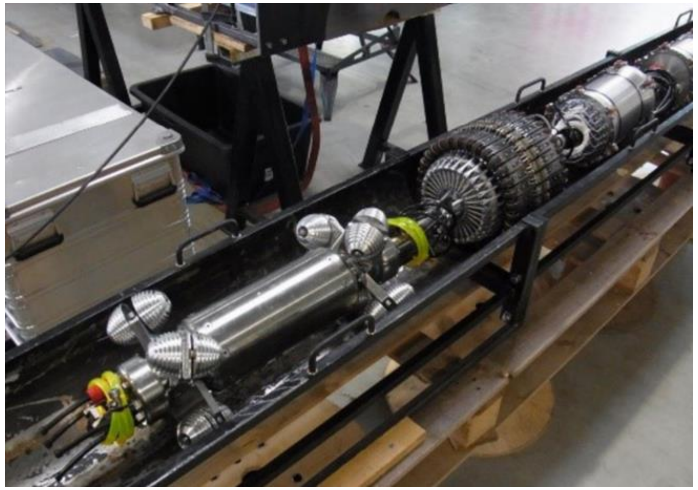
Mid Water Arch

Bend Stiffener





ILI TECHNOLOGY DEVELOPMENT SUMMARY



- ILI technology option ready for deployment (carcass inspection)
- Can be supplement by standard ILI options and other data sets to provide enhanced assessment
- Target areas identified for further development and performance improvement (pressure armour inspection)
  - Ideally need specific use case to give focus

But what about Tool Deployment??

ILI for Flexibles:
Deployment solutions

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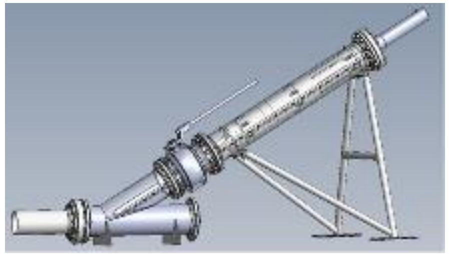
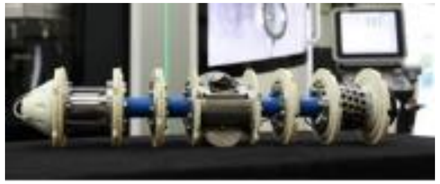
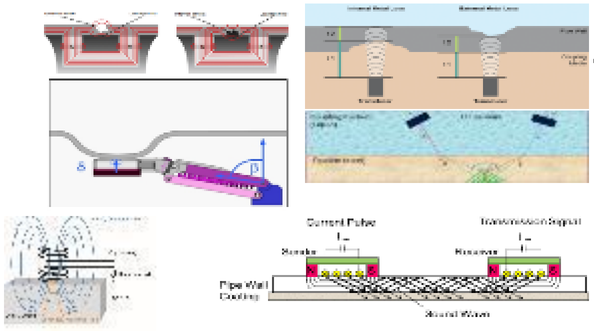
TOOL BOX APPROACH



ACCESS TECHNIQUES
- Hot tapping
- Tool launch valves
- Launchers / Receivers
- Spool piece
- Single Access

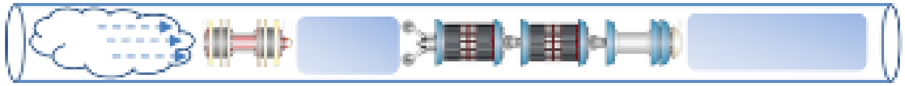
SENSOR CARRIER CONFIGURATIONS
- Unidirectional
- Bidirectional
- Low Friction
- Ultra Compact
- Multi-Diameter





SENSOR TECHNOLOGIES
- MFL-A / MFL-C
- Geometry / XYZ
- UTWM / UTCD
- IEC
- EMAT
- DRD

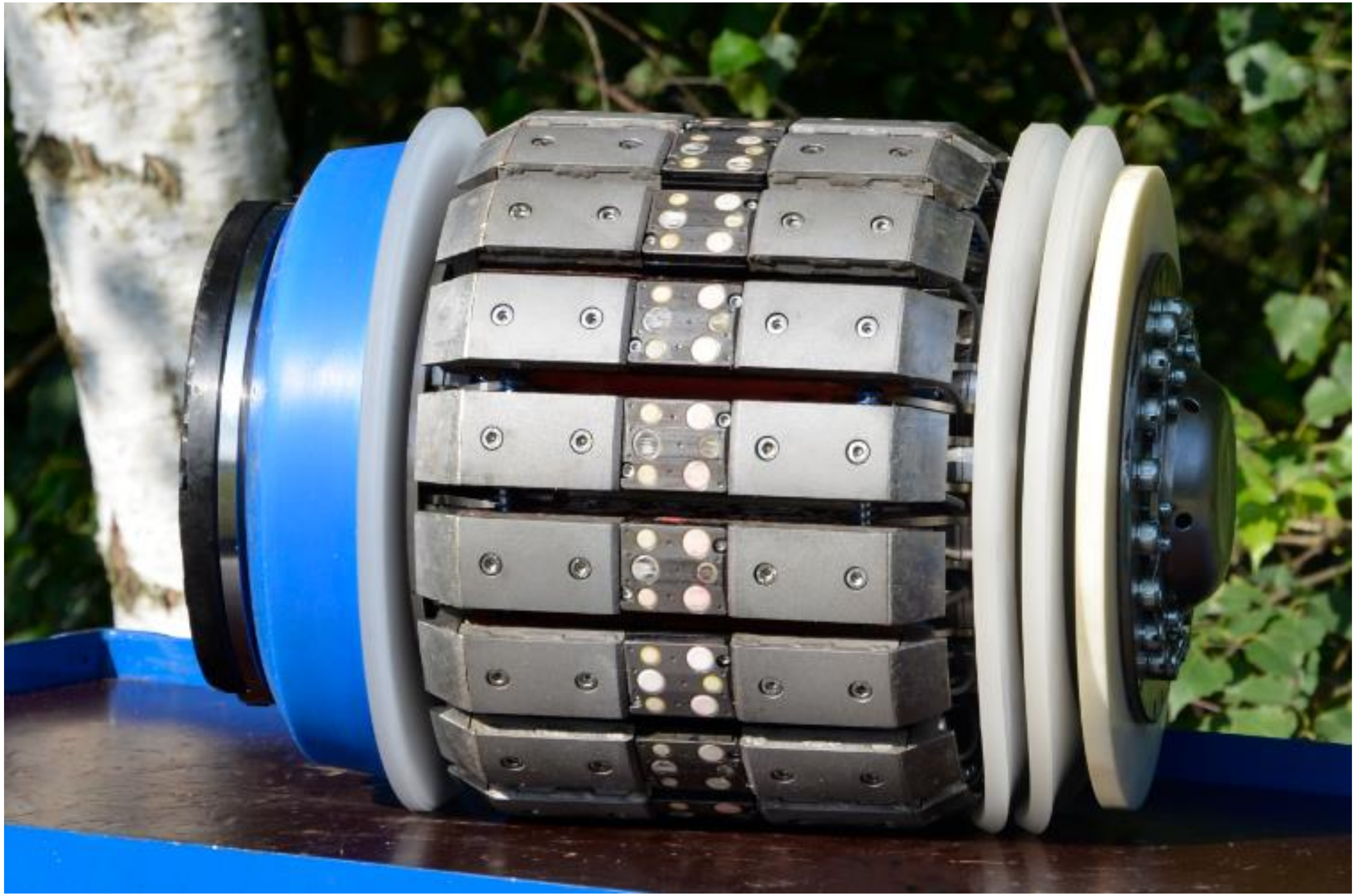
PROPULSION
- Nitrogen / Air
- Batching
- Robotic / Autonomous
- Tethered



CASE STUDY - FLOW LINES WITH PIG VALVES
WHEN SPACE IS RESTRICTED

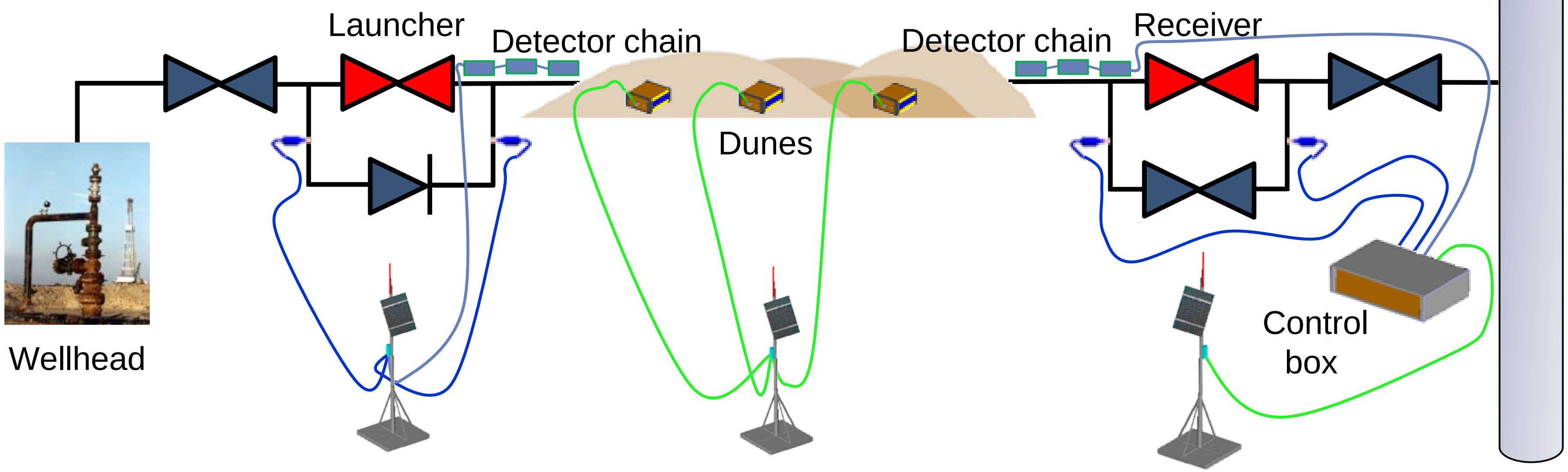
CASE STUDY - FLOW LINES WITH PIG VALVES

SOLUTION – 1ST GENERATION (2011)



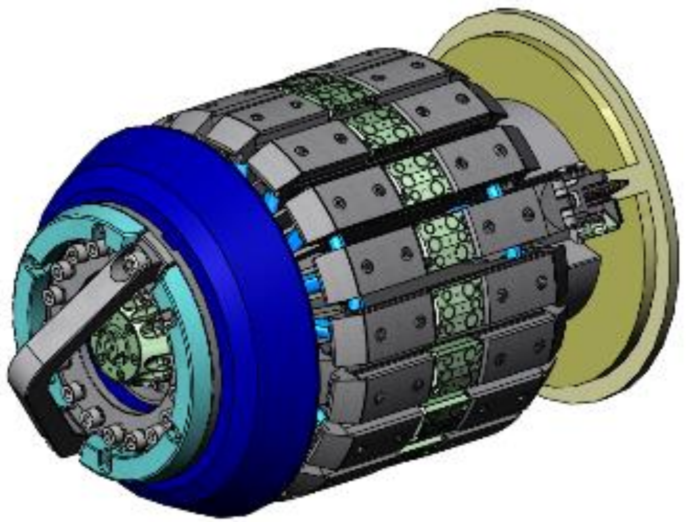
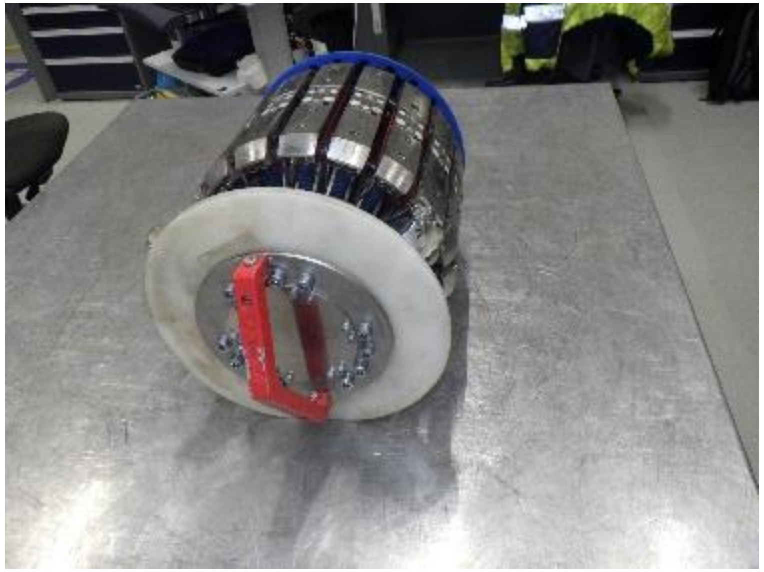
CASE STUDY - FLOW LINES WITH PIG VALVES

SOLUTION – 1ST GENERATION 2011)



CASE STUDY - FLOW LINES WITH PIG VALVES

SOLUTION – 2ND GENERATION (2021)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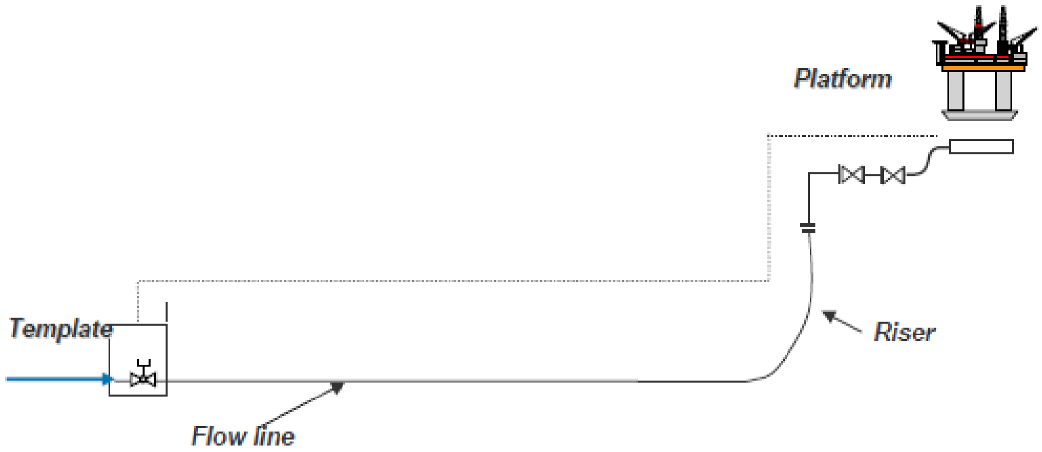
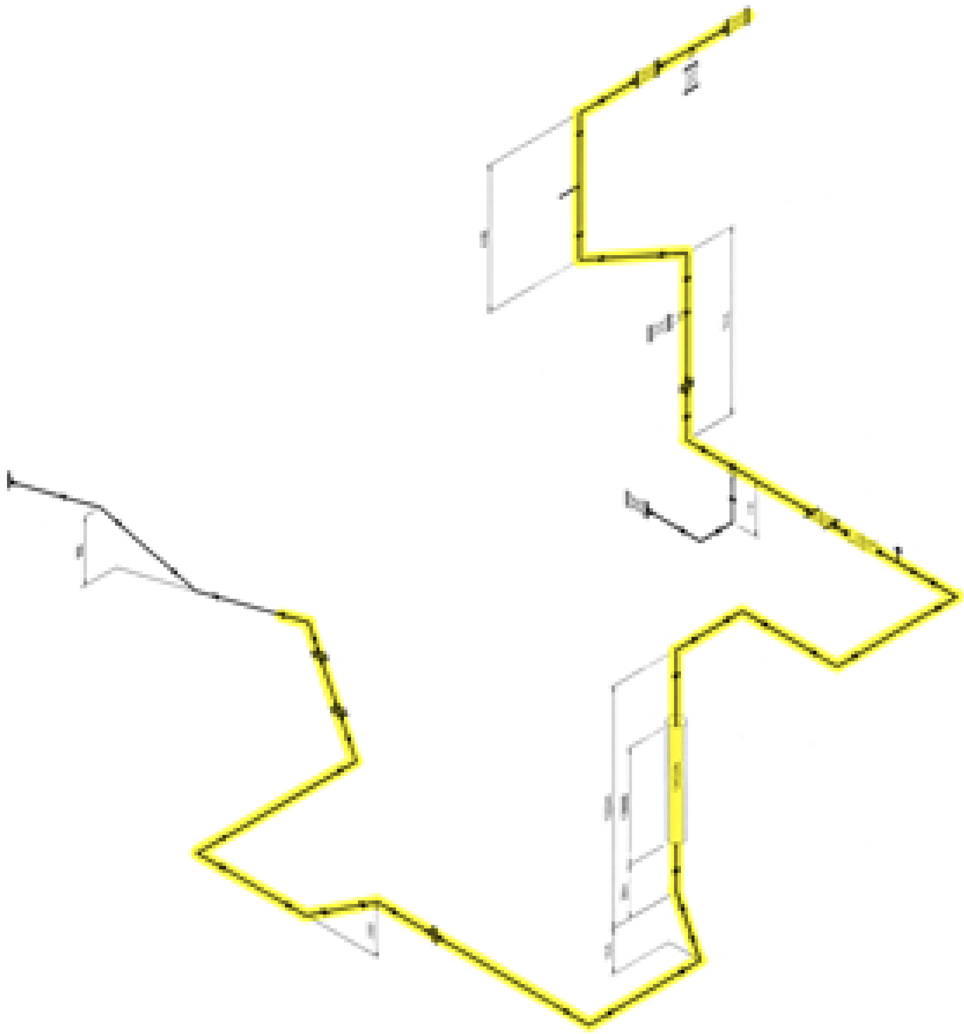
CASE STUDY – 10” OFFSHORE OIL RISER
SINGLE ACCESS AND COMPLEX GEOMETRY

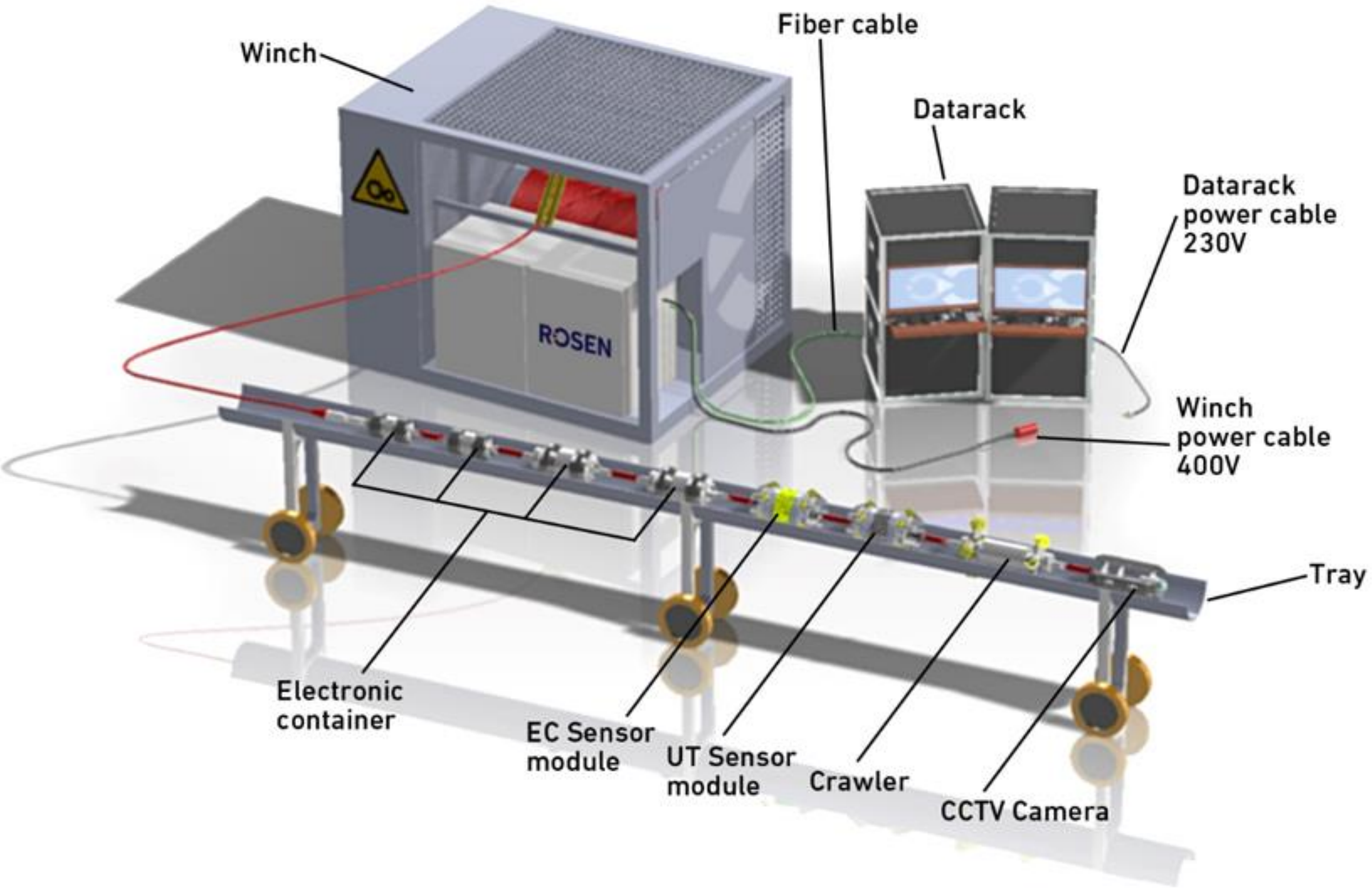
Pipeline details:
- Nom. OD 10.75", length ~17km
- Inspection length around 300m
- Max. depth ~150m
- Wall thickness 16-18 mm

Inspection task:
- Detection/sizing Internal and external Corrosion in riser.
- Detection/sizing Cracks in circumferential welds.

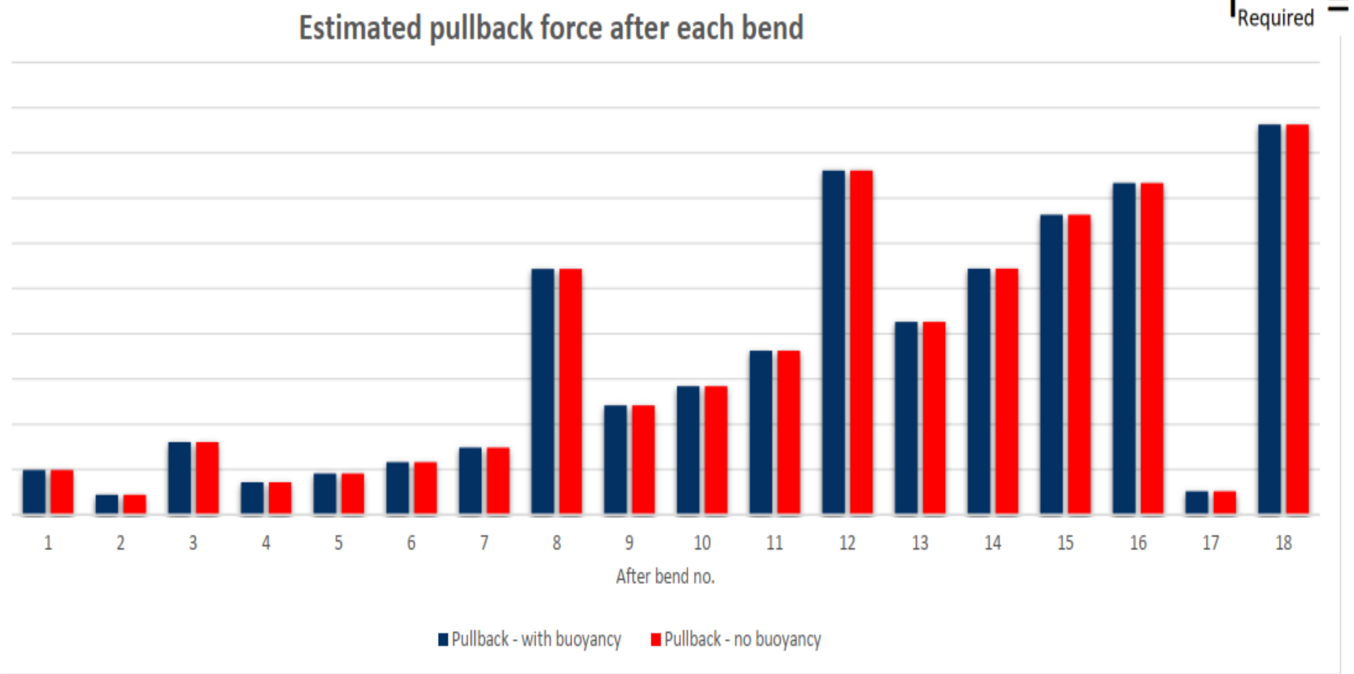




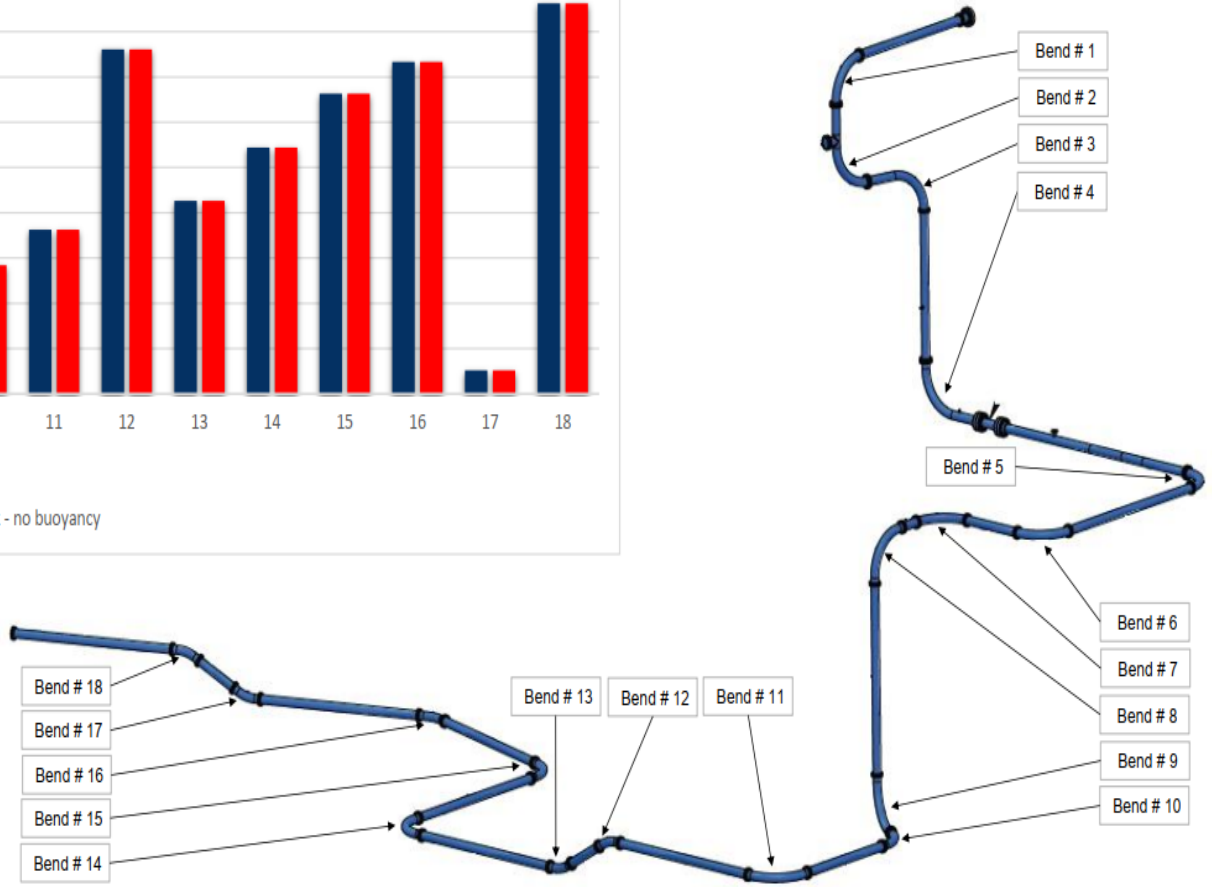
CASE STUDY – 10” OFFSHORE OIL RISER
SINGLE ACCESS AND COMPLEX GEOMETRY



CASE STUDY – 10" OFFSHORE OIL RISER
SINGLE ACCESS AND COMPLEX GEOMETRY



$$T_{Required} = (T_{Weight} + T_{0\,(Friction)}) \cdot e^{(\mu \cdot (\theta_1 + \theta_2 + \theta_3 \ldots\ldots \theta_n))}$$



Total number of bends: 17
Total accumulated bend angle: 1188º

CASE STUDY – 10” OFFSHORE OIL RISER
SINGLE ACCESS AND COMPLEX GEOMETRY

CASE STUDY – 10” OFFSHORE OIL RISER
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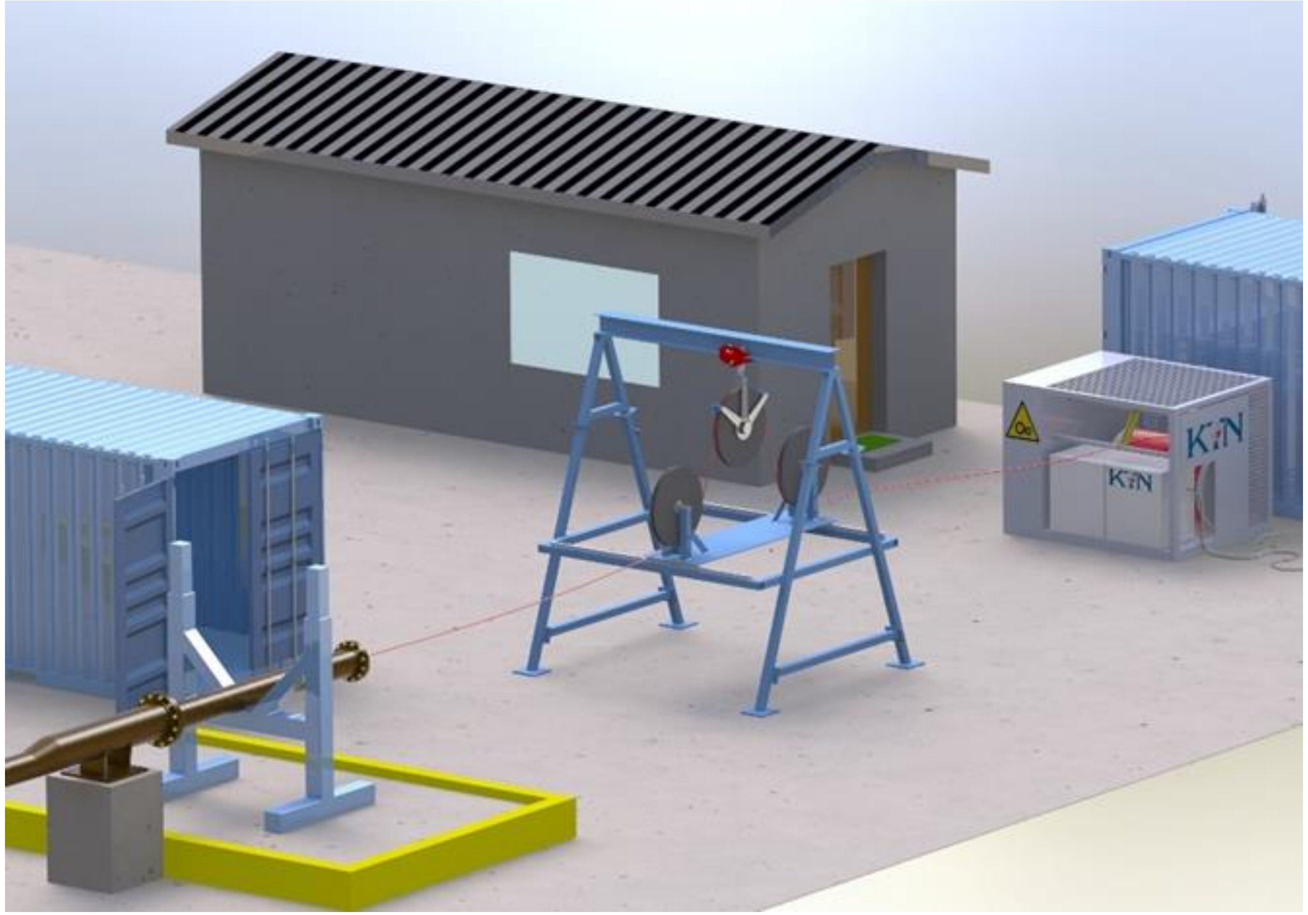
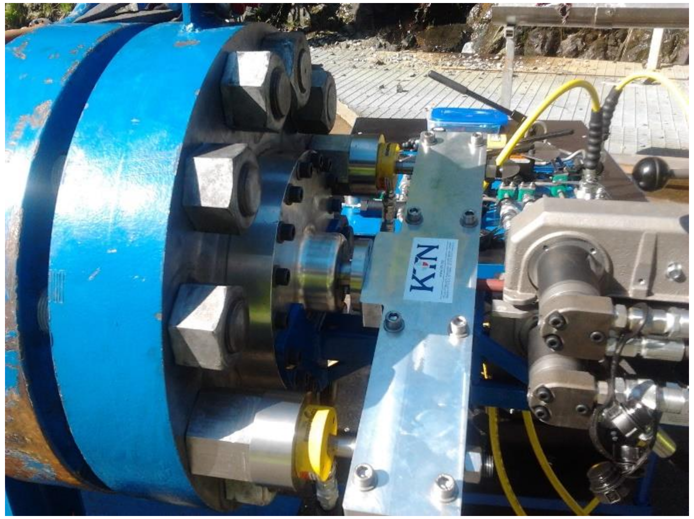
Typical example for site operation, umbilical winch arrangements

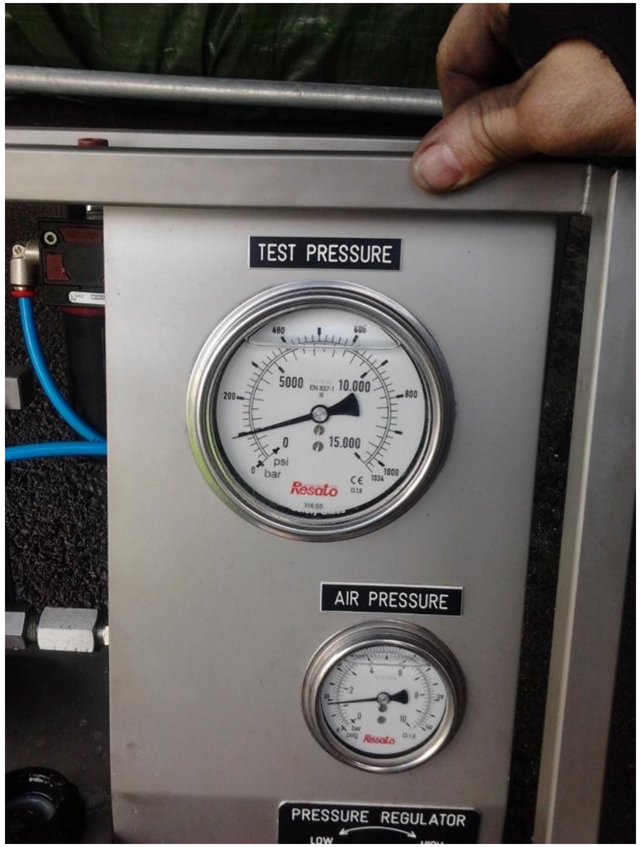
CASE STUDY – 10” OFFSHORE OIL RISER
SINGLE ACCESS AND COMPLEX GEOMETRY



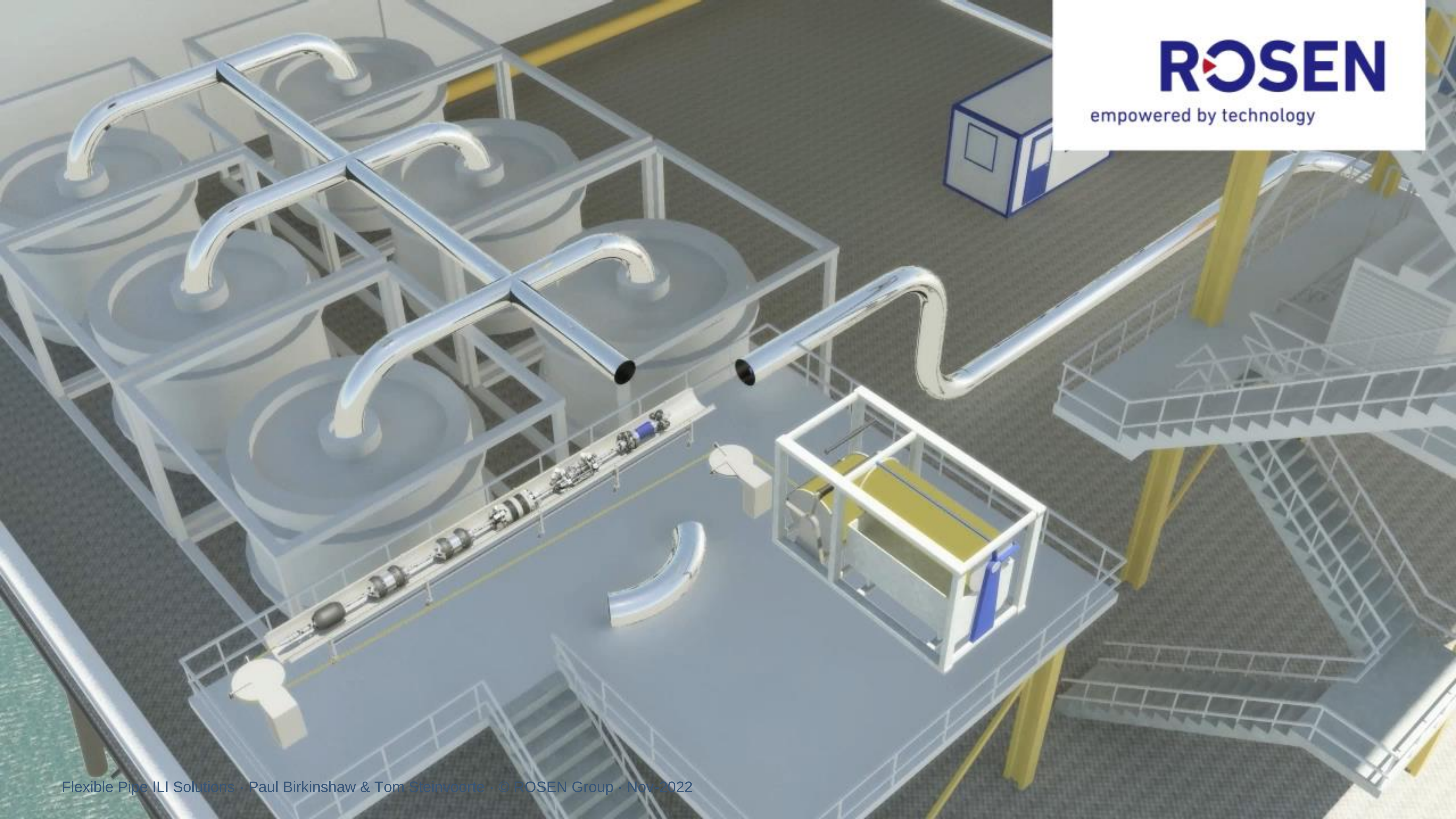
CASE STUDY – 10” OFFSHORE OIL RISER
SINGLE ACCESS AND COMPLEX GEOMETRY



Cable feeder to reduce cable friction at stuffing box



100 Bar



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CLOSING REMARKS & QUESTIONS

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