TETHERED INTERNAL CRAWLER-UNLOCKING NEW POSSIBILITIES FOR UNPIGGABLE PIPELINES

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Abstract

This paper presents two internal inspection campaigns involving a tethered robotic crawler system, one for continuous full-length inspection using Acoustic Resonance Technology (ART) and another for targeted localised inspection using Alternating Current Field Measurement (ACFM) and Phased Array Ultrasonic Testing (PAUT). The primary case study focuses on two subsea crude oil pipelines. Each pipeline exceeded 1.2 km in length, featured complex geometry including a near-vertical 24 m riser, and had no pigging infrastructure, only a single entry and exit point. Internal conditions included residual sludge and crude oil.

A bi-directional inspection approach was used to capture complete 360° wall thickness data. ART enabled wall loss measurements through contaminated internal surfaces, eliminating the need for prior cleaning. The crawler system maintained traction throughout bends and high-friction vertical sections, completing both inspections within four days.

A second case involved the inspection of a 110 m vertical offshore riser with recessed welds and multiple 3D bends. ACFM and PAUT modules were used for targeted weld and corrosion assessment. These examples demonstrate the applicability of internal crawler-based inspection in situations with limited access or geometric complexity where conventional ILI or external NDT methods are not feasible.

1 CASE STUDY 1: End-to-end inspection of unpiggable offshore crude oil loading lines

1.1 Introduction

Client engaged TSC Subsea to inspect two critical crude oil pipelines, 20-inch and 30-inch in diameter, running between their offshore infrastructure and their onshore storage terminal.

Pipelines labelled as "unpiggable" often remain uninspected due to geometry constraints, access limitations, or internal contamination. At the client’s terminal, two offshore crude oil loading lines fell into this category. These pipelines lacked pig launch and receive facilities, featured multiple bends, and terminated following a riser with an 87-degree vertical ascent at an offshore platform.

Figure 1 aerial view showing the onshore and offshore facilities

The client required an internal inspection solution capable of:

- Complete 360° wall thickness scanning
- Accurate detection and sizing of wall loss anomalies
- Navigating complex pipeline geometries
- Operating in sludge-contaminated conditions
- Entering and exiting from a single access point

This paper documents the engineering, integration, deployment, and outcomes of the project that addressed these challenges.

1.2 Technical Challenges

1.2.1 Geometry and Access Constraints

Each pipeline exceeded 1.2 km and included a 24-meter near-vertical riser after a 3D bend. No pig launch or receive infrastructure existed. Only a single point of entry and retrieval was available, necessitating a bidirectional system.

1.2.2 Internal Conditions

The pipelines were filled with crude oil residue and sludge, especially concentrated at the 6 o'clock position, rendering many conventional NDT methods ineffective due to signal attenuation.

1.2.3 Inspection Requirements

The clients mandated high-resolution, full-coverage data of the wall thickness across the entire pipeline and riser with no clearing, minimal pipeline modifications and disruption to operations.

1.3 Inspection Methodology

1.3.1 System Design and Integration

TSC Subsea led system engineering, adapting its TRITON tethered robotic crawler to integrate with NDT Global's ART Scan module.

Key components included:

- Two Triton crawlers will be used in the system to enable vertical movement while propelling the ART Scan Module. These crawlers are track-based inspection robots designed specifically for pipeline assessments. They are equipped with high-torque motors and tracks to ensure stable movement through complex pipeline geometries.

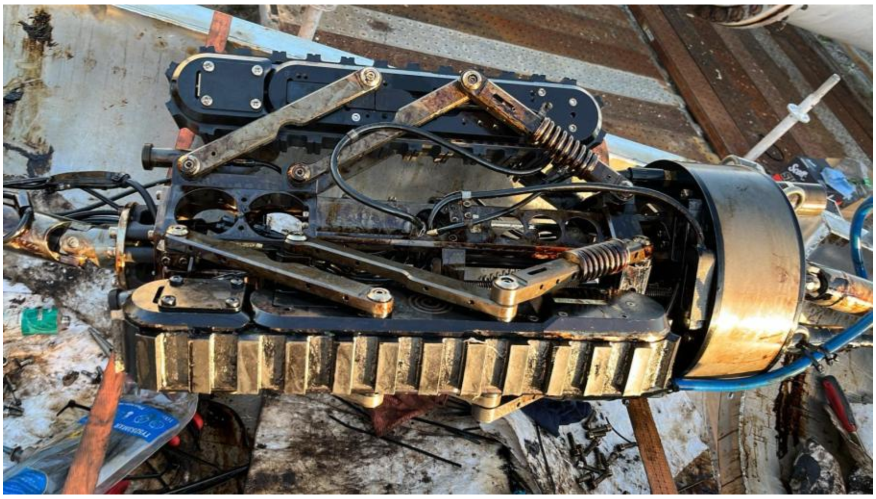

Figure 2 TRITON crawler

- The ART Scan Module (Acoustic Resonance Technology) is an ultrasonic testing (UT) tool used for pipeline inspections. It utilises ART to detect internal anomalies such as corrosion and other integrity issues by analysing resonance frequencies.
- The fibre cable winch is a motorised system that deploys and retrieves a hybrid cable containing both power and fibre optic lines. It ensures reliable power delivery to the subsea tool train and facilitates high-speed data communication with the topside system. With tension control to prevent cable damage, it is constructed from corrosion-resistant materials to withstand harsh environments and supports remote operation for real-time monitoring and control.

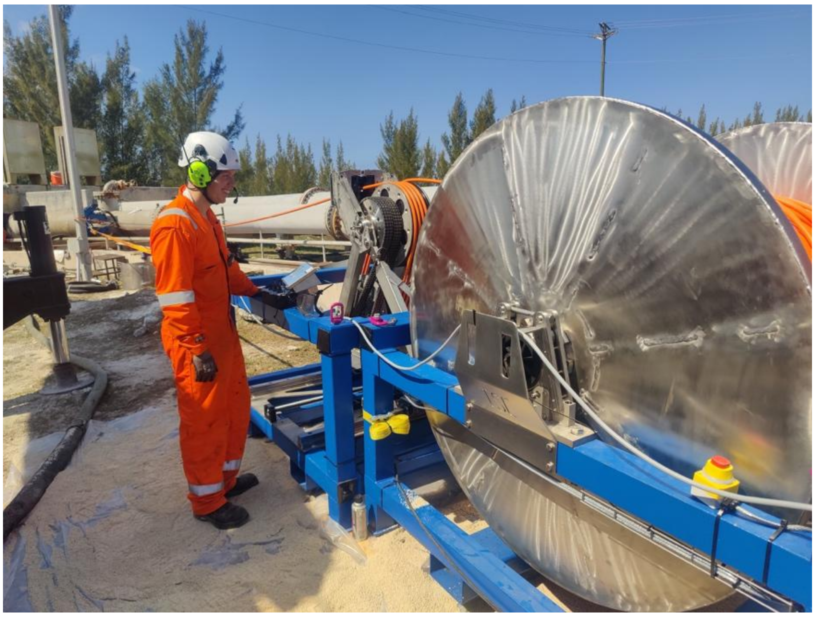

Figure 3 winch system

The integrated system was assembled and tested in TSC Subsea and NDT Global's shared facility in Bergen, Norway.

ART vs UT

Conventional ultrasonic testing (UT) relies on high-frequency sound waves transmitted through a couplant, typically a gel or liquid medium, to detect wall thickness and flaws in metallic structures. This method requires clean, debris-free surfaces to ensure effective signal transmission and accurate readings.

In contrast, Acoustic Resonance Technology (ART) operates on a fundamentally different principle: it induces acoustic resonance within the pipe wall and analyses the resulting frequency response to determine wall thickness. Because ART does not require direct contact or a clean surface, it can penetrate through sludge, wax, and other contaminants commonly found in unpiggable pipelines. This non-contact capability allows ART to deliver reliable, high-resolution data even in the most challenging internal environments, where traditional UT methods would fail or require extensive cleaning and preparation.

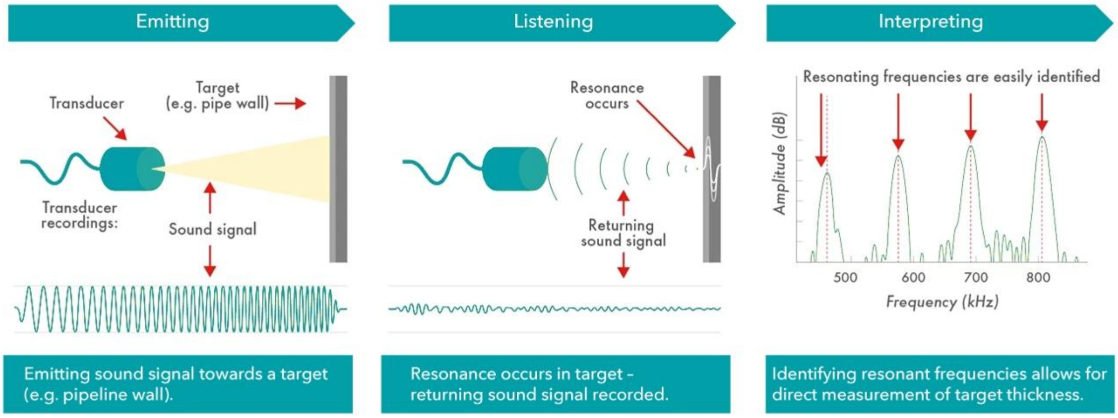

Figure 4 Acoustic Resonance Technology (ART)

1.4 Factory Acceptance Testing

FAT was conducted under simulated pipeline conditions to validate TRITON's mobility through bends and inclines

Testing of the Triton ART Scan tool is essential to ensure that all functional requirements are met prior to mobilisation to the operational site.

Figure 5 FAT setup

1.4.1 Primary Objectives

- **Verify System Functionality**
  Ensure that the entire system operates as intended, in accordance with the technical specifications.
- **Test Compliance with Project Requirements**
  Confirm that the system meets the performance standards and functional requirements outlined in the project agreement.
- **Validate Integration of Components**
  Confirm that all components integrate and communicate correctly to function as a cohesive system.
- **Minimise Risk for On-Site Operations**
  By verifying functionality in a controlled environment, you can reduce the risk of operational failures once the system is deployed in the field.

1.4.2 Secondary Objectives

- **Confirm Redundancy and Fail-Safe Features**
  Test all backup systems, redundancy measures, and fail-safe mechanisms to ensure they operate correctly in the event of a malfunction or power failure.
- **Simulate Emergency Shutdown Procedures**
  Assess the system's ability to safely shut down during an emergency or fault, and confirm that restart procedures function smoothly.
- **Assess System Efficiency**
  Evaluate the system's operational efficiency, speed, and overall performance under standard working conditions.

1.4.3 Test Rig Layout

The test loop consists of two 6-metre sections of 20-inch diameter pipe. This setup is used for both dry and wet testing of the inspection equipment, including mechanical pull tests and full system evaluations. The actual pipeline to be inspected includes a 3D bend, which will be replicated during testing to assess the crawlers' ability to navigate the bend while maintaining stability and load-handling performance.

Figure 6 FAT Rig Setup

1.5 Site Preparation and Access Planning

A field team visited the site to assess pipeline access. A spool piece between flanged connections was identified for crawler entry, minimising intervention.

A 3D LIDAR scan of the site was conducted to:

- Verify fit-up for all hardware
- Confirm crawler clearances
- Minimise onsite risk and downtime

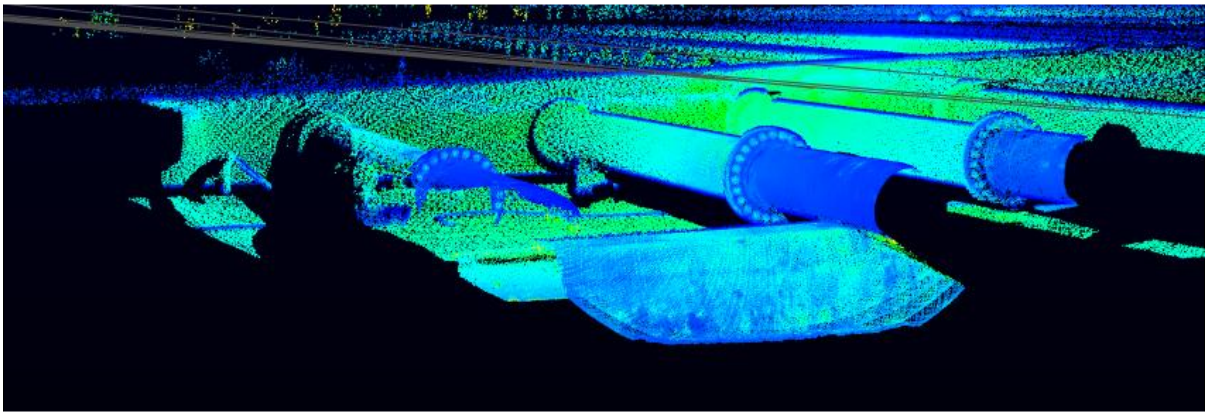

Figure 7 LIDAR site image

1.6 Deployment and Execution

1.6.1 Initial Pipeline Preparation

- Crude oil was drained below the entry point.
- A flanged spool piece was removed to allow entry to the pipe
- TRITON was first deployed without the ART scan module for a visual and laser scan inspection and to prove the crawler's navigation capabilities.
- From the visual and laser scan, it was clear that there was sludge and debris located at the six o'clock position, but the team were confident that the ART Scan could overcome the challenge without cleaning or flushing the pipeline.
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Figure 8 TRITON first run setup

1.6.2 ART Module Integration and Final Inspection

- The ART scan module was mounted on TRITON and then driven into the pipe to the start position.
- A custom flange plate, which allowed for the routing of the tether, was bolted to the pipe flange, sealing the pipe.
- Crude oil was refilled to the top of the riser.
- TRITON performed a full-length inspection, capturing 360° wall thickness data during both forward and return journeys, ensuring data validation.

- A tilt sensor mounted to Triton alerted the technicians to when the system reached the bottom of the riser section, and a magnetic tracker confirmed once the system had reached the top of the riser.
- The crawler then reversed through the pipe to the original entry point. Prior to extracting the system, a data validation test was performed to ensure the quality of the data.
- When all parties were satisfied, the spool was reinstalled, and a production system restoration was performed.

1.7 Results and Findings

1.7.1 Inspection Coverage and Performance

- Both pipelines and risers were successfully inspected over four days
- The system navigated all 3D bends and the 24-meter 87-degree near-vertical riser
- Data quality was validated on-site with no rescanning required

Figure 9 The team with TRITON

1.7.2 ART Performance in Sludge Conditions

ART delivered accurate measurements even through sludge and debris accumulation at the pipe's six o'clock position. This confirmed its ability to maintain signal fidelity where other NDT methods typically fail.

1.7.3 Visual and Laser Scanning

The initial run also enabled precise mapping of internal features, aiding in anomaly localisation and confirming that the inspection covered slightly more pipe length than originally scoped.

1.8 Key Outcomes

- No Cleaning Required: ART functioned effectively in heavily contaminated pipes.
- Full Vertical Access: TRITON climbed the 24 m riser with high reliability and no incidents.
- Complete Data Acquisition: High-resolution wall thickness data was captured along the entire pipeline length.
- Zero Incidents: The system operated without any unplanned downtime, and no rescanning was required at any stage of the operation.

2 CASE STUDY 2: Targeted Internal Inspection of Offshore Riser with Tethered Robotic Crawler

2.1 Introduction

bp approached TSC Subsea with a challenge: to inspect an unused 110-meter-long 14-inch-diameter duplex riser on a North Sea offshore platform. The riser, which had never been previously operational, required assessment before commissioning for a new development. Its complex geometry, including three 90-degree bends and a single entry/exit point, made conventional inspection methods unfeasible. The client was specifically interested in a targeted, localised inspection of 10 recessed welds, which were every 10 metres and areas of concern of possible corrosion that were detected during a previous visual inspection.

2.2 Technical Challenges

- Complex geometry and access constraints required a system capable of navigating bends and performing 360-degree scans.
- Internal conditions included anti-corrosion fluid at elevated temperatures, adding operational complexity.

Figure 10 Offshore riser entry/exit

2.3 Inspection Methodology

- TSC Subsea deployed a tethered TRITON robotic crawler, engineered for diameter adaptability and bend negotiation.
- The system enabled 360-degree probe rotation whilst applying constant probe pressure.
- Alternating Current Field Measurement (ACFM) was used for surface-breaking crack detection of the welds, and Subsea Phased Array (SPA) enabled volumetric weld inspection and corrosion mapping of the suspected areas.

Figure 11 TRITON with ACFM Probe

2.4 Factory Acceptance Testing

A full-scale riser mock-up validated crawler navigation and NDT performance. ACFM and SPA successfully detected all test defects within tolerances. System mobility was proven in both dry and flooded conditions.

Figure 12 FAT Setup

2.5 Deployment and Execution

Robotic engineers and NDT specialists mobilised offshore. The TRITON crawler inspected all 10 welds, with ACFM and SPA confirming no reportable defects.

Figure 13 TRITON entering the riser

2.6 Results and Findings

- All welds and critical areas were inspected with no significant anomalies.
- The successful inspection enabled bp to re-commission the riser and proceed with their development.

2.7 Conclusion

TSC Subsea's tethered solution overcame the challenges of inspecting a complex, unpiggable riser. The project demonstrated the effectiveness of advanced robotic inspection and NDT technologies in offshore environments.

3 Conclusion

The successful deployment of tethered robotic crawler systems and advanced NDT technologies has redefined what is possible for the internal inspection of pipelines and risers previously considered unpiggable. Both case studies demonstrate that complex geometries, challenging access constraints, and severe internal contamination can be overcome without the need for cleaning or major operational disruption. The integrated approach delivered reliable, high-resolution data, enabling confident integrity management and asset recommissioning. These pioneering projects set a new benchmark for offshore inspection, providing a replicable methodology for future campaigns and reinforcing the value of collaboration between TSC Subsea, NDT Global, and their clients.

Acknowledgements

The authors acknowledge the collaboration between TSC Subsea and NDT Global teams and thank our client for their cooperation and support during these pioneering campaigns.

Keywords

Unpiggable pipelines, Acoustic Resonance Technology, tethered crawler inspection, internal inspection, vertical riser, sludge contamination, ART, TRITON crawler, NDT Global, TSC Subsea