These challenges underscore the urgent need for a more efficient, objective, and comprehensive approach to fabric maintenance of offshore assets.

4.2 AI-Based Corrosion Detection and Management: A Transformative Solution

AI-based systems offer a revolutionary solution to the shortcomings of traditional FM, fundamentally improving inspection coverage and overall efficiency:

- **Enhanced Inspection Coverage:** Unlike the limited scope of traditional visual inspections, automated AI-based systems can achieve over 95% inspection coverage of a facility. This near-total visibility ensures that anomalies, regardless of their location, are identified and tracked.
- **Significant Cost Reduction:** The dramatic increase in coverage translates to better prioritization of maintenance activities. This can lead to an estimated 86% reduction in maintenance costs over a 2-year period, primarily by shifting from reactive to proactive maintenance.
- **Reduced Personnel on Board and Lower Inspection Costs:** AI-based systems significantly reduce the reliance on human inspectors, thereby decreasing the number of personnel required on board (PoB). This reduction in PoB contributes to an approximately 50% decrease in inspection costs compared to traditional manned inspections, while also mitigating safety risks associated with human presence in hazardous environments.
- **Versatile Remote Deployment:** The adaptability of AI-driven systems allows for deployment across diverse asset types and environments, including underwater, terrestrial, and aerial platforms, facilitating comprehensive remote inspection capabilities.

4.3 Technology Overview

The following section outlines the technical foundation of an AI-enabled approach to corrosion detection and integrity management. It describes how machine learning, multi-view processing, and data integration techniques are used to improve the consistency, coverage, and accuracy of inspection workflows. The section also highlights how these tools can support risk-based decision-making, inspection planning, and alignment with asset management systems. Finally, it addresses how system performance is evaluated and improved through structured validation and continuous learning.

4.3.1 AI-Powered Corrosion Severity Classification and Measurement

Machine learning algorithms are at the core of automatically detecting and classifying corrosion severity, providing objective and quantifiable insights:

- **Automated Detection and Classification:** AI algorithms are trained to identify corrosion patterns and classify their severity. The detected corrosion is intuitively overlaid on the inspection imagery, utilizing a color-coded scheme to denote severity levels: light (cyan), medium (yellow), and heavy (red).
- **Quantitative Measurement and Prioritization:** Beyond qualitative classification, the system precisely calculates the physical area, dimensions, and exact location of detected corrosion. This quantitative data is crucial for improved damage estimation, enabling more accurate and strategic prioritization of remediation efforts.

- **Adherence to Industry Standards:** The degree of surface degradation, such as rusting, can be determined in accordance with recognized industry standards, like ISO 4628-3, ensuring consistency and comparability of assessments.

4.3.2 Multi-View Processing for Enhanced Accuracy

To overcome challenges posed by obstructions, poor lighting, or complex geometries, multi-view processing is employed:

- **Comprehensive Coverage from Multiple Viewpoints:** The system intelligently combines data from multiple viewpoints of the same equipment, ensuring comprehensive coverage and significantly reducing the risk of missed corrosion due to occlusions or suboptimal viewing angles.
- **Spatial Location and Refinement:** Images and laser data are spatially located within a common frame of reference. This allows the system to accurately merge predictions from various viewpoints, refining the overall detection and classification results for enhanced accuracy.
- **Multi-View Geometry Pooling Modules:** Sophisticated pooling modules fuse information derived from different images, irrespective of whether their regions overlap or not, to build a more robust and complete understanding of the corrosion state.

4.3.3 Seamless Integration with Asset Management Workflows

The true value of AI-driven corrosion detection is realized through its seamless integration into existing asset management workflows:

- **Equipment-Specific Anomaly Registration:** Detected corrosion anomalies are meticulously registered to individual pieces of equipment within the asset management system. This capability enables rapid searching and provides an immediate, up-to-date state of every item on the platform.
- **Comprehensive Condition Reporting and Querying:** The system generates detailed condition reports for all equipment. Operators gain the ability to query and filter objects based on various parameters such as pipe diameter, pressure, and service designation, enabling highly specific data retrieval and analysis.
- **Optimized Inspection Workpacks and Prioritization Schedules:** AI-detected corrosion directly informs the creation of optimized inspection workpacks. Prioritization schedules are automatically generated to ensure that remediation and follow-up actions are executed efficiently, focusing resources where they are most critically needed.
- **Efficient Database Updates:** The structured corrosion database facilitates efficient updates whenever re-inspections are conducted, ensuring that the asset's condition records remain current and accurate.

4.3.4 Risk Assessment and Prioritization in AI-Driven Corrosion Management

A critical aspect of the AI-driven approach is its ability to integrate risk assessment directly into the corrosion management process:

- **Automated Risk Analysis:** The AI system automatically conducts a sophisticated risk analysis for each piece of equipment and identified defect. This involves computing risk matrices and evaluations by comparing the severity of corrosion and coating degradation against the criticality of the equipment (e.g., its role in operational safety or production).
- **Identification of High-Risk Assets:** High-risk assets, such as high-pressure gas lines exhibiting severe corrosion, are clearly identified for immediate and priority remediation. This risk-based prioritization ensures that resources are allocated optimally to address the most pressing integrity threats.
- **Demonstrable Risk Reduction:** This proactive prioritization of remediation efforts, based on comprehensive risk profiles, demonstrates a quantifiable reduction in asset integrity risk across the entire facility, leading to safer and more reliable operations.

4.3.5 Performance Evaluation and Continuous Improvement of the AI System

The performance and ongoing enhancement of the AI-based corrosion detection system are rigorously managed through a continuous improvement loop:

- **F1-Score as Performance Metric:** The performance of the AI model is quantifiably measured using the F1-score[4], a metric that effectively balances both precision (minimizing false positives) and recall (minimizing false negatives) in the detection and classification of coating defects and corrosion.
- **Validation Datasets and Real-Life Evaluation:** Robust validation datasets, constructed using hold-out images not seen during training, are crucial for evaluating the system's performance under realistic operational conditions.
- **Error Analysis and Targeted Improvements:** Detailed analysis of false positives (incorrectly identified corrosion) and false negatives (missed corrosion) is conducted to pinpoint specific areas for improvement. This might include enhancing detection capabilities in challenging conditions such as blurry, dark, or distant regions, or improving the identification of subtle corrosion on floor surfaces.
- **Continuous Learning and Adaptability:** The AI platform is designed for continuous learning, enabling rapid and low-cost extension to identify new fault and feature types as they emerge, or as new operational insights are gained.
- **Quality Assurance (QA) Module:** A dedicated QA module is configured to systematically identify areas or tasks where the system's performance is suboptimal. This module then triggers adjustments to existing processes and algorithms, ensuring the system continually improves its accuracy and efficiency across all tasks.

[4] The F1 score is a metric used to evaluate the performance of AI models, particularly in classification tasks. It represents the harmonic mean of precision and recall, providing a balanced measure of a model's accuracy and ability to capture all relevant instances. A higher F1 score (closer to 1) indicates better performance.

4.4 Case Studies: Applications in AI

This section of the white Paper provides case study information from Abyss on how AI was deployed in supporting offshore operators in integrating inspection data to facilitate optimized IM decisions. The first two present information associated with automatic corrosion detection and management, while the last one addresses an Automated Condition Assessment System.

4.4.1 Case Study #1: AI Corrosion Detection in Offshore Operations

An AI-based corrosion detection and management system was deployed across an offshore oil and gas platform located in the Gulf of America. The offshore platform is a 10,000 tonnage semi-submersible, with 80,000 barrels per day production. this case study demonstrates the value of corrosion detection and management with the AI-based system. It demonstrates the cost reduction of inspection programs when using the AI system vs. traditional manual visual inspections, the reduction of risk across a platform through the prioritization of inspection and remediation, the benefits associated with prioritization and optimization of painting campaigns, and benefits associated with the optimization of platform maintenance programs. A traditional manned General Vision Inspection (GVI) campaign is compared directly against the AI-based corrosion detection and management system.

The coverage of equipment across the platform, the number of production lines inspected, the approximate cost, and the number of personnel on-board the platform required to complete an inspection, are all compared. Similar performance of the AI-based corrosion detection and management system have been experienced on a number of platforms in the Gulf of America.

A direct comparison between inspection coverage from the AI-based corrosion detection/management system and inspection results from traditional inspections is provided in Table 1. Approximately 75% of all equipment is covered by deck-level scans. Coverage is improved to approximately 97% through the capture of scans in positions that consider corner-cases such as tight spaces, complex pipework, and equipment at heights. In contrast, only 20% of equipment was covered in the 2019 GVI campaign. The AI system provided approximately 77% more coverage. Further, the full platform health assessment provided by the AI-system was $0.5 million less than the proposed annual budget for traditional manned GVI. The direct recurring savings for each following year would be about $1 million annually for the example platform. Further, the coverage of each AI-based inspection includes >97% of equipment, compared with about 20% coverage of the 2019 GVI campaign.

Items of Interest	Standard Visual Inspections (Historical GVI 2019 Campaign)	AI-Based Corrosion Detection and Management System: First Year Setup (2020)	AI-Based Corrosion Detection and Management System: Reinspection and Reprioritization (2021 onward)
Equipment covered in inspection	Approx. 20%	Approx. 97%	< 97%
Number of production lines inspected	Approx. 500	Approx. 3,000	Approx. 3,000
Approximate cost of general visual inspection	Approx. $1.5 million	Approx. $0.6 million	Approx. $0.4 million
PoB required to complete inspection	Approx. 120	Approx. 20	Approx. 20
Notes: Projected results are provided for subsequent inspections. The coverage of equipment across the platform by each inspection, the number of production lines inspected, the approximate cost of the inspection, and the number of PoB on the platform to complete an inspection, are all compared.			

4.4.2 Case Study #2: AI-Driven Prioritization of Inspection and Remediation

Inspection workpacks are created based on corrosion and coating degradation across the platform, a detected by the AI-based system. Workpacks are organized and prioritization schedules are provided which enables optimization of remediation, follow up inspection, NDT, or replacement actions Prioritization is achieved by automatically conducting a risk analysis for each piece of equipment and defect. Risk matrices and evaluations for each production asset are computed by comparing the severity of corrosion and coating degradation against the criticality of the equipment (e.g., a high-pressure gas line may have a high consequence of equipment failure, have severe corrosion detected, and should therefore have a high follow-up inspection or remediation priority). By prioritizing the remediation of corrosion and coating degradation based on the risk profile of equipment on which these defects are detected, asset integrity risk reduction across the entire facility is demonstrated.

The inspection outcomes of the AI-based corrosion detection and management system are summarized as follows based on a previous body of work:

- 83 nominations for “urgent equipment replacement”, where equipment had an estimated time-to-failure of 6 to 12 months.
- 217 high-priority painting nominations, where if equipment is painted, it will degrade to the point of requiring urgent equipment replacement within 12 to 24 months.

The cost of equipment replacement for all 83 "urgent" items was approximately $15 million. The total cost of failure for a single item of equipment ranged from $0.5 million to $52 million, based on the platform operators estimates. The detection of corrosion and subsequent "urgent replacement" of the equipment prioritized by the AI-based corrosion detection and management system represented a significant reduction in financial risk for facility operators.

For each of the 217 high-priority-for-painting lines, savings were approximately $100,000 to $250,000, when compared against the cost of inaction. Based on operators' estimates against the cost of "urgent replacement," this equated to a risk reduction of $21 million to $55 million. All "urgent equipment replacement" items were confirmed by the client as critical at the next planned shutdown of the platform. All nominated lines were targeted by maintenance crews for high-priority remediation by the platform operators. The detection of coating degradation and subsequent prioritization of painting schedules by the AI-based corrosion detection and management system represented a significant reduction in financial risk for facility operators.

4.4.3 Case Study #3: Impacts of an Automated Condition Assessment System

The Automated Condition Assessment System (ACAS) provides a structured approach to prioritizing painting campaigns based on severity classifications (CAT levels), enabling operators to take preventive action before degradation escalates. This system enhances maintenance planning by identifying equipment at risk of transitioning to higher-cost remediation categories, helping avoid unplanned shutdowns and unnecessary replacements. The figures and tables that follow demonstrate the substantial financial and operational impact of ACAS on one offshore platform, offering compelling evidence for the system's value in managing maintenance backlogs and reducing long-term asset risk.

Provided in Figure 4 is a schematic showing painting recommendations in order to avoid replacement. The ACAS identifies what CAT level each asset is in and highlights the assets that are closest to reaching the next stage of severity. Preventing CAT-level change and maintaining equipment to avoid replacement is a critical tool for reducing maintenance backlog/cost as reflected in the following:

- CAT3 paint remediation is the least expensive remediation to undertake.
- CAT2 replacement remediation typically involves a planned shutdown and costs in the range of 10 to 20 times more than a CAT3 remediation.
- CAT1 replacement remediation typically involves an unplanned shutdown and costs in the range of 20 to 25 times more than a CAT3 remediation.

As illustrated in Figure 4, maintaining equipment with paint remediation to avoid replacement is a critical tool for reducing maintenance backlog and maintenance costs, thus supporting the critical role that AI can play in enhancing the operation of facilities.

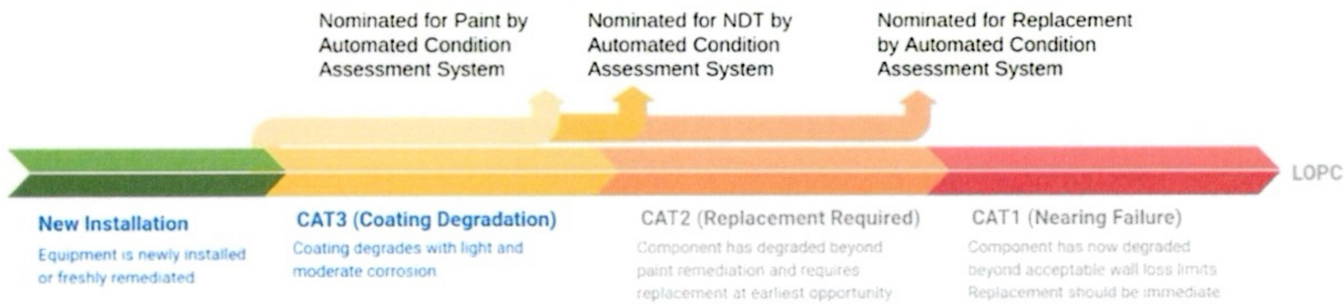

Figure 4: Prioritization of painting recommendations in order to avoid replacement.

Table 2 details the improved paint block surveys directly resulting in more impactful paint remediation actions, for a single platform. Across the four platforms, 620 CAT3 status lines were nominated for paint remediation before they could transition to CAT2 status, which would require planned shutdown replacement. These lines were not scheduled to be inspected in the next two years and were estimated to require replacement within those two years if no remediation action was taken. Catching these lines for paint remediation reduced maintenance costs by approximately ten times, over the two-year period.

Further, 160 CAT2 status lines were nominated for replacement via planned shutdown. These lines were not scheduled for inspection within the next year and had an estimated time of failure within six to twelve months. The 160 lines nominated were associated with 20 to 25 major circuits, per platform, and avoided the high cost of failure and unplanned shutdown for the platform operator. All nominated lines were targeted by maintenance crews for high-priority remediation by the platform operators. The detection of coating degradation and subsequent prioritization of painting schedules by the Automated Condition Assessment System represents a significant reduction in financial risk and maintenance costs for facility operators. The system enabled better campaign planning for painting chase teams, allowing for their efforts to focus on areas of high importance and impact. The impact has been measured for a single large offshore platform in the Gulf of America.

Table 2: The impact of the Automated Condition Assessment System on paint block remediation

Impact to paint block remediation	Automated Condition Assessment System: First Year Setup (2020)
Paint Block Survey Coverage	x8.5 increased coverage
Lines Painted	17% more
Line requiring MI inspection before painting	16% less
High consequence lines painted	53% more
Low consequence lines painted	60% less
Undeteriorated lines painted	18% less
Fabric Maintenance Savings	86% reduction in maintenance costs due to early intervention

4.5 Concluding Remarks

The adoption of AI-driven corrosion detection and management represents a significant leap forward in maintaining the integrity and operational efficiency of offshore platforms. By addressing the critical limitations of traditional fabric maintenance, this technology not only promises substantial cost savings and reduced PoB, but also delivers unparalleled inspection coverage, objective assessment, and risk-based prioritization. This foundational white paper provides an overview of the system's capabilities, setting the stage for subsequent, highly technical papers that will delve into the intricate details of the underlying AI algorithms, data fusion techniques, and machine learning methodologies that power this transformative solution. The future of offshore asset integrity is unequivocally intelligent, and data driven.