AI-Driven Maintenance for Non- Intrusive Inspection Systems

White Paper

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Introduction

In the past few decades, the European Union and its allies have been facing unprecedented threats to their security and financial interests[1]. Societies have been suffering the consequences of ever increasing human[2] and drug trafficking[3], and economies have been losing billions to counterfeiters. Users of X-ray systems, i.e. Non- Intrusive Inspection Systems (NIIS), such as airports, ports, and customs and border control authorities tackle this myriad of threats by using NIIS to inspect parcels, baggage, palletised cargo, containers, vehicles, and trains.

The purpose of this document is to provide information and insights about the AI-driven Maintenance Solution (AI-MS), the new generation service strategy for NIIS.

Introducing the AI-MS will streamline the maintenance workflow so that costly, unnecessary and time-consuming interventions are removed or automated. The deployment of the AI-MS will replace the run-to-failure reactive maintenance approach with pro-active data- driven service models. To achieve operational efficiency for the end users of NIIS, the AI-MS must be a comprehensive platform and tool, covering the full portfolio of X-ray systems, namely low- and high-energy NIIS for all key applications.

The AI-MS must also include all key stakeholders:

- X-ray Manufacturers
- Service Providers
- End Users, such as:
    - Ports and Airports
    - Customs and Border Control
    - Cargo Industry and Freight Forwarders
    - Security organisations

The Problem

The importance of providing effective, time and cost-saving maintenance of Non-Intrusive Inspection Systems (NIIS) cannot be overstated. With the average NIIS lifespan of 10 years, the routine maintenance approach has proven to be insufficient with significant maintenance cost[4] totalling 100% of NIIS purchase price over the 10-year lifecycle.
The routine maintenance approach and service models in the X-ray industry usually comprise:

<u>Preventive Maintenance:</u> an inefficient assumption- based maintenance approach, performed at predetermined time intervals, and not based on the equipment's condition, which interrupts its operation with no real impact on its performance.

<u>Corrective Maintenance:</u> A costly "run until it breaks" reactive maintenance strategy resulting in downtime and high life cycle costs of NIIS, where repairs are unpredictable in terms of time, manpower, and costs.

<u>Inventory:</u> costly large stockpiles of spare parts due to the unpredictability of NIIS performance.

A paper on predictive maintenance by Roland Berger[5] suggests that around 30% of preventive maintenance efforts are unnecessary, while experts at Emerson Process Management point out that 30% of such efforts are counterproductive, with up to 70% of failures occurring shortly after major preventive maintenance[6]. Furthermore, more than 90% of failures are typically caused by conditions that can occur unexpectedly at any time.

There is **an urgent need to radically improve** the current NIIS service strategy and align it with the specific requirements and needs of end users. To ensure value for money, it is important that NIIS operate with maximum efficiency and at the lowest possible level of maintenance and life cycle costs. **Key priorities** are shorter service response time, lower lifecycle costs, 95% or higher NIIS availability, and 24/7 service desk & hotline support, provided through an outcome-based Service Level Agreement (SLA).

The AI-Driven Maintenance Solution (AI-MS)

The AI-MS, powered by artificial intelligence and machine learning algorithms, includes real- time asset health monitoring, an early-warning system for sending automatic alert notifications to service specialists, and provision of remote resolution management with recommended actions in response to errors, malfunctions, and failures.

The AI-MS transforms the reactive maintenance strategy into a new proactive data-driven service excellence that includes **three main capabilities (Condition-based models, Predictive models, and Survival models)**, providing the **three building blocks** of the new generation service strategy for NIIS:

Condition-based maintenance (CbM)

a) Replaces routine preventive maintenance.

b) Uses sensor data collected during 24/7 real-time monitoring to perform maintenance at the moment it is needed and before a critical failure occurs.

c) Incorporates **Condition-based models** and measurements to assess the condition of NIIS and uses this assessment to proactively prevent NIIS failure.

d) Helps avoid unnecessary maintenance work on NIIS, i.e., not needed or is not critical.

e) Helps provide effective remote diagnostics and resolution management.

Predictive Maintenance (PdM)

a) Uses aggregated data and patterns to predict future degradation and failure of critical components/subsystems of NIIS.

b) Incorporates **Predictive models** to reduce or even prevent downtime of NIIS.

c) Incorporates **Survival models** to estimate the remaining useful life of key components of NIIS to optimise inventory management.

d) Enables service specialists in 24/7 mode to assess and identify risks of failure and take appropriate actions.

e) Uses **AI and ML algorithms** to build more accurate predictions over time.

f) Helps conduct prompt, proactive maintenance on critical components to extend their useful life and improve the reliability of NIIS.

g) Helps develop Prescriptive maintenance of NIIS to intelligently schedule and plan future NIIS maintenance.

Enhanced Knowledge Base & Troubleshooting (EKB&T)

a) Collects and categorises all data gathered from NIIS performance and service interventions to improve and enhance the troubleshooting skills of service specialists.

b) Improves the efficiency of maintenance teams by allowing them to focus on the most critical tasks.

c) Helps quickly introduce new service desk specialists.

d) Supports efficient training of service specialists and technical managers.

e) Helps identify measures to improve the reliability of NIIS.

f) Provides a valuable data base for manufacturers for improved future NIIS performance.

g) Provides valuable insights for Prescriptive maintenance of NIIS.

Case Study

Condition-based maintenance (CbM)

Use Case 1: Continuous monitoring of the main power supply of the high-energy X-ray system

<u>Observation</u>: Continuous monitoring of the main power supply detects incorrect operation of the UPS. As shown in Figure 1, many unexpected voltage drops were detected - anomalies that should not occur under normal conditions. When such events are detected, the AI-driven maintenance solution automatically triggers an alert to the Service Specialist for further investigation.

<u>The result</u>: The UPS was proactively replaced, reducing the risk of critical component failure and ensuring uninterrupted operation.

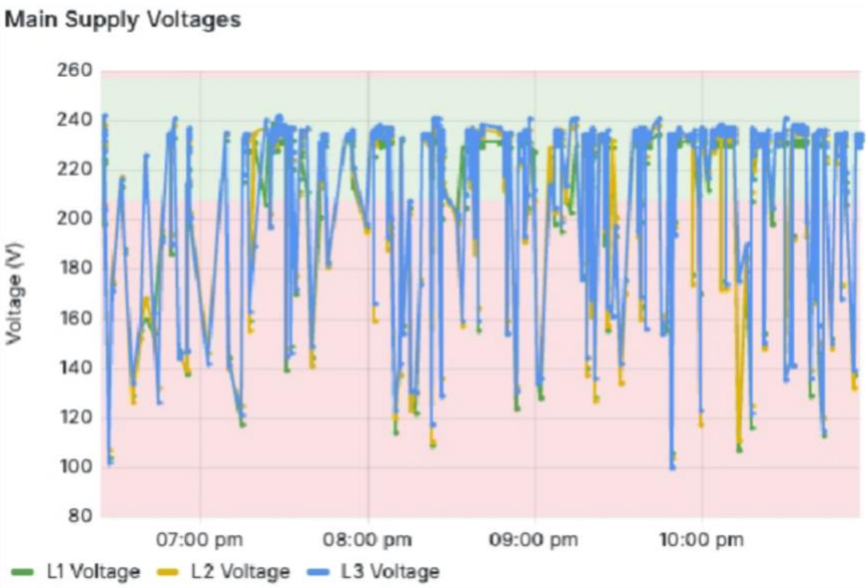

Figure 1. *Plot showing the values of the mains supply voltage. An automatic alarm is sent to the service technician when an event occurs, such as the voltage falling below 215V.*

Use Case 2: Monitoring environmental parameters

<u>Observation</u>: Environmental parameters inside the boom of the high-energy X- ray system began to exceed acceptable levels (Figure 2), causing abnormal behaviour. Condition-based and anomaly detection algorithms recognised this pattern, prompting the AI-driven maintenance system to automatically alert a Service Specialist for further investigation.

<u>The result</u>: The remote diagnosis identified two potential causes: either the fan had failed, or the air conditioning circuit breaker had tripped. With this information in hand, a service missioned was scheduled for the repair of the problem. Upon inspection, the problem was confirmed to be a failed fan, which was promptly replaced, restoring optimal system performance.

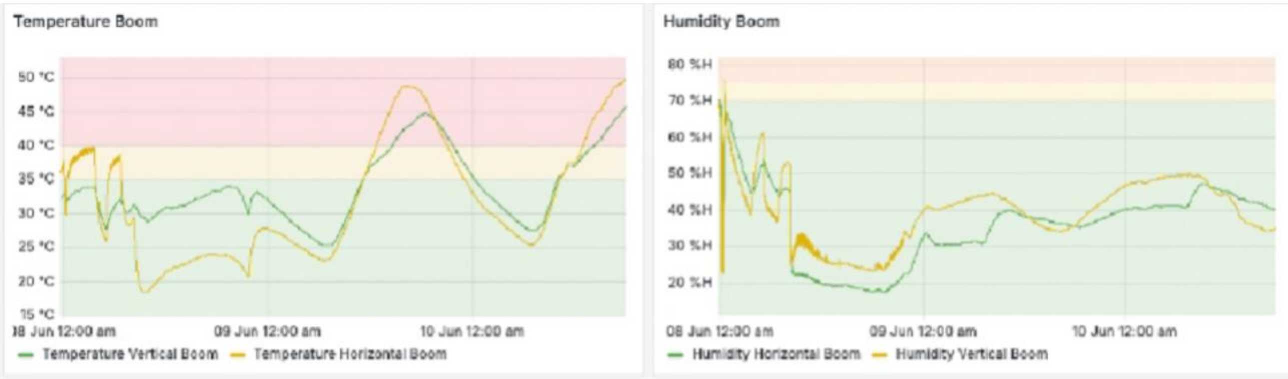

Figure 2. *Plot showing temperature and humidity inside the boom of a high-energy X-ray system.*

Predictive Maintenance (PdM)

Use Case 3: Generator Failures on low-energy X-ray system

Observation: The predictive models, powered by AI and machine learning algorithms, can assess the health of critical systems components before any thresholds are reached and estimate the remaining useful life. Figure 3 illustrates this capability: the red line represents the predictive model's score, while the blue dots indicate messages generated by the X-ray system. The generator failure occurred on 12 June. Notably, the predictive model reached a critical threshold on 15 May (green circle), almost a month before the failure and 11 days before the first generator-related error message appeared (purple circle).

The result: The predictive models offer several key benefits, including the ability to:

- Predict generator failures with a horizon of 2 weeks to 3 months.
- Optimise inventory management
- Mitigate the risk of stock shortages by ensuring critical components, like generators, are available when needed.

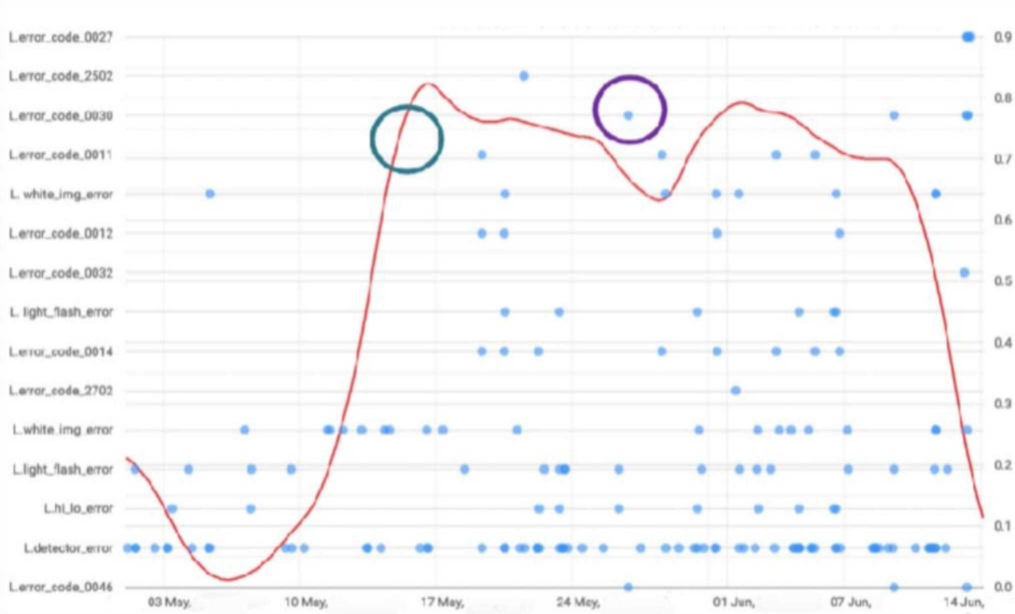

Figure 3. *Selected log file messages (blue dots) and prediction score (red line) for Case 3 – Generator failure. The blue dots represent the key messages shown on the left vertical axis, while the red horizontal line is the prediction with values on the right y-axis. The purple circle marks the first message that can be associated with generator failure, while the green one the reaching of the prediction threshold.*

Conclusion

The AI-MS transforms the reactive maintenance strategy into a new proactive data-driven service excellence that plays an important role in maintaining and improving NIIS performance, reliability, and availability.

The combination of the **three main capabilities** (Condition-based models, Predictive models, and Survival models) providing the **three building blocks** (CbM, PdM and EKB&T) of the AI-SM is the new generation service strategy for NIIS and the most effective approach that helps:

a) enhance operational efficiency by increasing NIIS availability.
b) reduce maintenance costs by optimising the maintenance process.
c) extend useful life of critical components by using AI and ML algorithms.
d) optimise equipment utilisation by planning service interventions in advance.

Test the AI-MS and experience the benefits of the new generation service strategy for NIIS.

Negotiate an outcome-based SLA that maximises equipment availability at fixed annual costs, including spare parts and full 24/7 advanced maintenance and service.

References

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3. Drug Trafficking: a $32 billion business affecting communities globally

4. Explosives, Weapons, and Contraband Detection Equipment Report, HIS Markit, 2018

5. Predictive Maintenance is the timing right for predictive maintenance in the manufacturing sector?, Roland Berger, 2014

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