



Integrating AI and ML for Predictive Maintenance Advantages

For over two decades, NCMS has been at the forefront of advancing predictive maintenance by leading many technology development initiatives that have brought together experts from industry, academia, and government. This Technology Brief series on predictive maintenance covers NCMS initiatives that have advanced predictive maintenance in several key areas: (1) telematics, (2) AI and ML, (3) portable maintenance devices, and (4) vehicles, including electric and autonomous.



Introduction

Predictive maintenance utilizes continuous monitoring and data analytics to identify optimal maintenance interventions, reducing costly unplanned downtime and asset failures. A recent [study](#) found that predictive maintenance advantages include 25 percent higher productivity, 70 percent lower breakdowns, and 25 percent lower maintenance costs, on average. AI is revolutionizing predictive maintenance to optimize the life cycle of assets in many sectors: manufacturing, energy, utilities, oil and gas, transportation, automotive, aerospace, defense, and more.

A subset of AI, machine learning (ML), uses algorithms to analyze large amounts of data from sensors on assets and equipment, identifying patterns and trends that support data-driven decision-making. Electronic sensors on assets pull data into a cloud environment, and ML algorithms analyze the sensor data to identify appropriate maintenance interventions before a failure of a component shuts down production. The use of ML algorithms in predictive maintenance software helps organizations resolve maintenance issues quickly, improve asset availability, increase

production output, reduce unscheduled downtime, and lower operating and maintenance costs.

This Technology Brief—the second of a four-part series on predictive maintenance—will cover practical steps for getting started with using AI and ML in predictive maintenance software, drawn from NCMS initiatives that have advanced the application of AI and ML to improve predictive maintenance.

Using AI and ML for Predictive Maintenance

For companies looking to get started with applying AI and ML for predictive maintenance advantages, the first step is to ensure that the organization has a clearly defined [maintenance strategy](#) for high-value assets. The International Standards Organization's [ISO 55000](#) establishes the framework for organizations to effectively manage their assets over their life cycles, and [ISO 9001](#) is the most widely used quality management standard in the world.

The next step is to perform an asset [criticality analysis](#), which helps organizations identify and better understand the assets that are most

essential to operations. It's important to identify the specific, quantifiable benefits to be sought by applying AI/ML such as reduced downtime, increased operational efficiency, extended equipment lifespan, and cost savings. Begin with a small pilot project to demonstrate value before scaling.

Step three involves establishing a system of sensors. If assets are not already equipped with Industrial Internet of Things (IIoT) sensors, then select and integrate appropriate sensors to capture real-time data such as run-time hours, temperature, vibration, pressure, power consumption, and more. There are multiple resources available to support the integration of IIoT and other Industry 4.0 technologies to gain predictive maintenance advantages, including the [Manufacturing Extension Partnership \(MEP\) National Network](#).

Step four encompasses gathering historical maintenance records, operational logs, production data, and other relevant information related to equipment performance and failures. Data processing will be necessary, either from in-house experts or from a third-party data analysis provider. It is essential to use [DataOps](#), a set of practices, processes, and technologies that manage and optimize data throughout its lifecycle. DataOps forms the foundation of any successful ML system.

Step five requires identifying the most appropriate predictive maintenance software. There are many platforms that connect with IIoT sensors, maintenance logs, and other enterprise systems to gather large amounts of data and apply ML algorithms to identify patterns, detect anomalies, and predict potential failures before they occur.

NCMS has collaborated on multiple initiatives that have developed software that utilizes ML to yield predictive maintenance advantages. This Technology Brief reviews two projects that successfully developed and implemented such software tools: (1) an Integrated Repair Data tool that uses ML algorithms to automatically prioritize maintenance needs, and (2) a Predictive Asset Readiness solution that utilizes ML algorithms to make predictions about asset readiness and optimize maintenance activities.

Integrated Repair Data

Establishing optimal maintenance for critical assets requires the integration of key datasets to identify support requirements and determine the most effective and efficient repair processes. Such optimization programs can be tailored for any high-value asset on which an organization relies—whether for manufacturing, transportation, or any other significant operational function. Proper management and integration of repair activity data is an essential building block for creating this system, ensuring that maintenance is timely, coordinated, and relevant to optimize asset reliability and uptime. A recent NCMS initiative developed a [predictive maintenance software program](#) that integrates all repair data on a fleet of F-35s overseen by the US military's F-35 Joint Program Office (JPO). The tool can be adapted to integrate repair data for many other types of assets.

The software program provides predictive maintenance advantages through an integrated data environment with visibility into all facets of repair activity for the F-35 JPO, including logistics, engineering, information technology, and cost data. The project created four integrated capabilities:

- The **Artificial Intelligence Prognostic Steering Tool (AIPS)** uses advanced ML algorithms to automatically prioritize and reprioritize maintenance solutions to improve the success rate of repairs, lower repair times, and reduce repair costs. Specifically, these ML algorithms forecast failures, optimize solutions, and seek to avoid unnecessary maintenance procedures.
- The **Equipment Manager** is a software module that provides life-cycle asset management capabilities from their contractual inception to the end of life.
- The **Modification Manager** demonstrates a centralized environment to view induction schedules, modification details, and supporting metrics and visualizations for asset modifications/upgrades.
- The **Supply Module** provides insight on current and predicted supply chain performance and associated costs.

This initiative created an integrated set of data, tools, and processes to provide a common operating picture of all resource requirements. Multiple industries—especially those that manage large, disparate fleets of vehicles—can use this approach to develop similar modules for maintenance and sustainment activities. Integrating all aspects of repair data, including logistics, engineering, IT, and costs, has multiple predictive maintenance advantages: (1) gains in maintenance throughput and reduced maintenance downtime, (2) increased visibility for facility and resource management, (3) amplified maintenance and supply data consumption and analysis capabilities. Any organization that manages vehicles or equipment could draw on the work done in this initiative to integrate their repair data with the objectives of reducing asset repair time and lowering costs.

Predictive Asset Readiness Solution

The need to predict asset failures before they happen is a critical challenge faced by asset-intensive companies including manufacturing, oil and gas, transportation, utilities, and mining. To help solve this challenge, a recent NCMS initiative created an AI-fueled software program—[Predictive Asset Readiness](#)—that dynamically assesses data analytics and predictions of an asset's future condition to proactively initiate corrective actions. This collaboration brought together the US Army Materiel Command (AMC) with two industry partners: DPRA and r4 Technologies. The project team worked in collaboration with [NCMS Digital Enterprise](#) experts to define and deliver predictive maintenance advantages using the r4 AI software platform.

To build this tool, the team began by reviewing authoritative data sources—including asset master data, daily status history, and maintenance history—for four weapon systems: the M1A2 Abrams Main Battle Tank, the M2/M3 Bradley Fighting Vehicle, the M109 Paladin self-propelled Howitzer, and the M88 Recovery Vehicle. While the predictive maintenance tool

was customized to operate with these weapons systems, it can be adapted for a range of assets used in the private sector for which appropriate life-cycle maintenance and repair data can be compiled.

The initiative prototyped three ML predictive models for the selected assets. The first two models use recurrent neural networks (RNN), which are trained on time series data to create ML models capable of using previous inputs and model temporal dependencies that enable the system to predict patterns over time. The three models are:

- **Asset Status Prediction**, which forecasts whether an asset is mission capable or non-mission capable to establish benchmarks for predictive analytics and their impact in sustainment mission scheduling.
- **Non-Mission Capable (NMC) Duration Prediction**, which considers assets that have become non-mission capable, predicting the time duration before they will become mission capable again to better enable operational decision-making and yield predictive maintenance advantages.
- **NMC Duration Driving Factors**, which assesses the specific features of each asset to identify factors that explain variability in time to return to mission capability. It pulls together data such as who operates the assets, where they have been used, and who is responsible for maintaining them. The drivers of readiness become demand signals that give planners and maintainers information about what they can do differently to reduce the time to return to capability when an asset is in maintenance, such as changing the sequence of maintenance activities or altering the levels of inventory for parts and supplies.

This software provides demand signals for maintenance activities and supplies, with greater precision at the point of need, for completing resource and mission planning, optimizing maintenance sequences, and ensuring supplies of critical parts and consumables. Companies in the manufacturing sector and

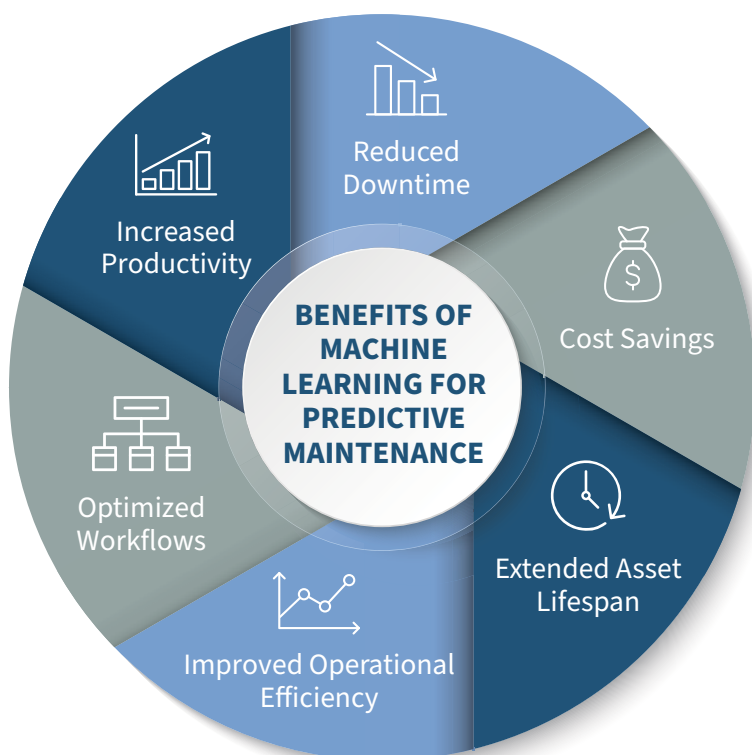
other industries can utilize a similar software solution to obtain granular and accurate demand signals that can be applied to dozens of use cases to improve operational planning and gain predictive maintenance advantages.

Once the appropriate software tool has been chosen, it is necessary to train the model by feeding processed data into the software to recognize patterns. Next, the [reliability of the ML model](#) must be evaluated through an analysis of appropriate metrics. Once the ML model has been tested and validated, companies can use the ML model's recommendations to schedule timely maintenance interventions and prevent unexpected asset downtime.

Predictive Maintenance Advantages

The application of ML algorithms to asset life-cycle histories and current sensor data produces a powerful predictive maintenance tool that optimizes operations. As a result, maintenance professionals working with expensive assets can perform optimal upkeep with smaller, more targeted repairs to avoid catastrophic problems.

Predictive maintenance advantages include the ability to obtain sufficient advance notice to deal with issues, resulting in more efficient repairs, cost savings, and a higher percentage of mission-ready vehicles, aircraft, equipment, and other assets. When data is consolidated and interpreted with ML algorithms, companies gain a more comprehensive understanding of not only individual assets but also the larger network of interdependent assets. It's important to provide training and support to help maintenance professionals understand and trust AI-driven systems. It's also possible to connect AI predictive maintenance solutions with existing maintenance management software and other enterprise systems for seamless workflows.



About NCMS

The National Center for Manufacturing Sciences (NCMS) is a cross-industry technology development consortium, dedicated to improving the competitiveness and strength of the US industrial base. As a member-based organization, it leverages its network of industry, government, and academic partners to develop, demonstrate, and transition innovative technologies efficiently, with less risk and lower cost.

NCMS enables world-class member companies to work effectively with other members and partners on new opportunities—bringing together highly capable companies with providers and end users who need their innovations and technology solutions. NCMS members and partners benefit from an accelerated progression of idea creation through execution.