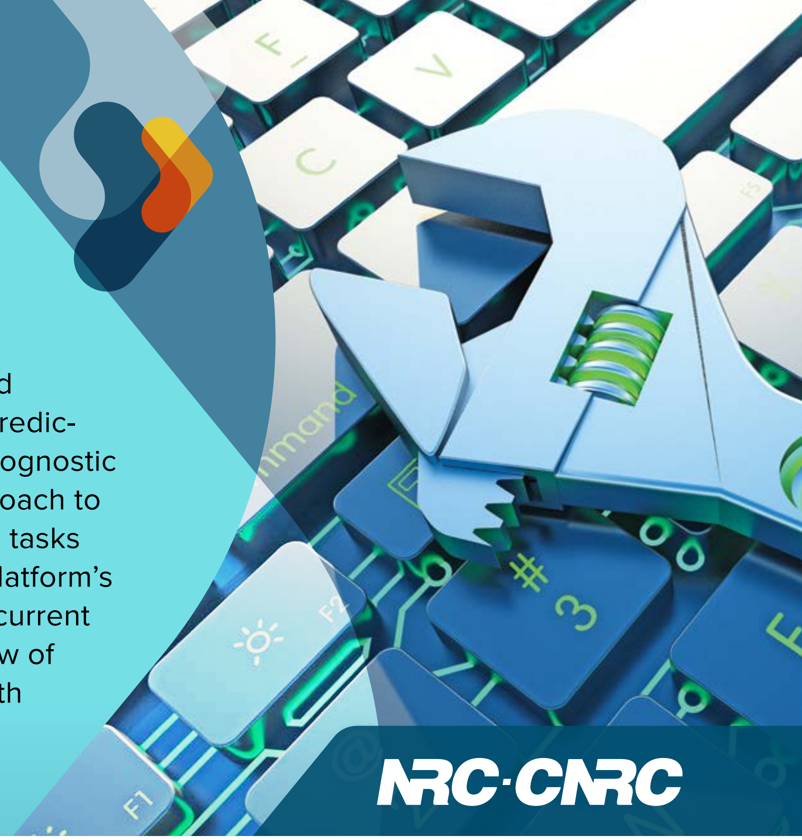
Intelligent Maintenance Systems for Platforms

Intelligent Maintenance Systems (IMS), or advanced Condition-Based Maintenance (CBM) systems, are predictive technologies that integrate diagnostic and/or prognostic tools to facilitate decision-making. This "smart" approach to identifying, scheduling and performing maintenance tasks is based on a holistic real-time understanding of a platform's critical components. Accumulation of historical and current data from sensors provide a continuous dynamic flow of information throughout the maintenance process with the goal of tracking health degradation to predict which components are likely to fail, and when.



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Internet of things (IoT)

IoT enables networked devices embedded with electronics to exchange data through the Internet, permitting the transmission of real-time maintenance data to predict failures, detect faults and respond to unanticipated asset degradation from remote locations. Intermittent connectivity of geographically dispersed platforms and analytic capacities to translate raw data from thousands of sensors into actionable findings remain challenging. Cost-effective ways to mitigate the overwhelming amount of data collected such as running analytics at the edge (i.e. on the device that collects data), will be required to reduce communication bandwidth between systems.

Network architectures and data management

End-to-end adaptable network architectures are an important IMS capability that enables data to be uploaded from the platform (or individual components) and transferred to enterprise data analysis tools. An open systems approach will facilitate the use of accepted standard products from multiple suppliers.

Digital twins (DT)

A DT uses integrated multi-physics models, sensor information and input data from an in-service vehicle to mirror and predict the life of its corresponding physical twin. One example is the US Navy Digital Twin (NDT) framework project led by Dr. Thomas C. Fu, which will utilize current and historical data to create optimal descriptions of ship susceptibility. Challenges for creating an NDT are cybersecurity, reduced-order approaches for multi-physics solvers, ship-to-shore data transfer and expressing prognostic data as prescriptive information.

Artificial Immune Systems (AIS)

IMS could be potentially transformed through the integration of AIS technologies, an emerging branch of artificial intelligence (AI) that strives to increase robustness, adaptability and autonomy in mechanical systems to eliminate and/or accommodate faults and failures. The development and implementation of prescriptive maintenance techniques, enabled by AI/Machine Learning technologies, are able to self-diagnose and schedule maintenance but are not widely adopted and should be monitored closely.

> ***It's the organization, structuring, contextualization and analysis of data to produce actionable information and to help us make decisions... Right now, we are at a point where the generation of data is so easy and so cheap that it would be foolish of us not to take advantage of it.***
>
> – **Trisha Shields** about US digital twin project, Lead of the aviation data analytics projects for Carderock's Sea-Based Aviation and Aeromechanics Branch (Feb 2018, US Navy website, NNS180227-09)

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Signals

Academic

The University of South Carolina Center for Predictive Maintenance (US) focuses on defence aviation and proposes a model encapsulating both data-driven and physics-based modeling techniques.

Government

The Royal Netherlands Navy was an early maritime adopter of CBM influenced by the research Dr. Tiedo Tinga (Chair of the Dynamics Based Maintenance group at the Netherlands Defence Academy, University of Trente).

Collaboration

Collaborations in IMS research are primarily domestic. Military platform maintenance is increasingly outsourced to private companies in some countries, such as UK, Sweden, and Australia.

Non-governmental organization

MIMOSA maintains the *Open System Architecture for Condition-Based Maintenance* standard which specifies inputs/outputs between disparate components to enhance interoperability between multiple vendors' subsystems. Current research projects focus on its integration and implementation.

Corporate

Top IMS corporate research organizations include Lockheed Martin and Airbus (health assessment/monitoring), GE (condition monitoring) and Rolls-Royce (engines).

> ***Predictive maintenance and advanced analytics are technologies of critical business interest... Digitization has the ability to change the entire industrial ecosystem in [Aerospace & Defense]... The savings potential and efficiency gains in production, as well as aftermarket and operations, are also huge.***
>
> – **Roland Berger,** Aerospace & Defense Top Management Issues Radar 2017.

Impact

Social

Intangible but important benefits of IMS include increased personnel morale, performance, sense of safety, time savings and confidence in the platform.

Policy

The US Department of Defense (DoD) continues to implement its 2007 Condition Based Maintenance Plus (CBM+) policy to achieve targeted system lifecycle availability, reliability, and costs within all DoD branches.

Economic

Cost reductions drive IMS adoption through increased efficiencies. The overall predictive maintenance market is expected to grow from US $1.5B in 2016 to US $10.96B in 2022.

Environmental

A reduction in unnecessary maintenance reduces waste and leads to more effective maintenance, which extends asset life and results in fewer negative environmental impacts.

Defence

IMS improves platform readiness and reliability, enables better decision making on equipment's operational service and decreases mean down time and operational failures during a mission.

> ***Prognostics is quickly evolving, but still needs more attention from governments, industries, and academia to become less of an art and more of a science.***
>
> – **Elattar et al.** "Prognostics: a literature review". *Complex Intelligent Systems*. 2016.

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