Smart Affordable Condition Based Maintenance Tools, Technology and Services

Introduction

The Department of Defense faces an acute need to drive efficiency in its maintenance activities. The combination of a rapidly aging inventory of planes, ground vehicles, and ships and ongoing budget reductions is stretching the capabilities of our existing maintenance resources. DoD has embraced, at least conceptually, a move to Condition Based Maintenance plus (CBM+) as a way to deliver these efficiencies.

CBM+ seeks to schedule maintenance according to the actual condition of a given asset at the time, rather than rigidly following a maintenance schedule that takes viable assets offline too early and may, on the flip side, leave failing assets in the field too long. The DoD's goal in promoting CBM+ is to "enable greater productivity, lower costs, better availability, and enhanced reliability of materiel resources." Unfortunately, the Pentagon's efforts to implement CBM+ have met with uneven results, due largely to the mismatch between the ambition of the effort and the funds dedicated to implement it.

The good news is that currently-deployed commercial technologies used for a variety of industrial solutions could enable the DoD to go beyond conventional CBM+ using these affordable, high technology readiness level (TRL) solutions. The advent of predictive analytics now accelerated by cloud computing and Big Data connectivity have created solutions that offer true predictive maintenance, telling maintainers about impending failure modes before most CBM+ systems would even pick up the signal. Predictive analytics is the best technique to pair with protection systems so that both slow developing- and instantaneous failures are managed most effectively. Not only are these programs lower-cost than "ground-up" custom CBM+ approaches, they can leverage data from existing instrumentation, without expanding the maintainers' regular workload.

This paper examines the maintenance challenges facing DoD, the goals of the CBM+ initiative, and the revolutionary potential of cloud-based predictive analytics for military maintenance applications.
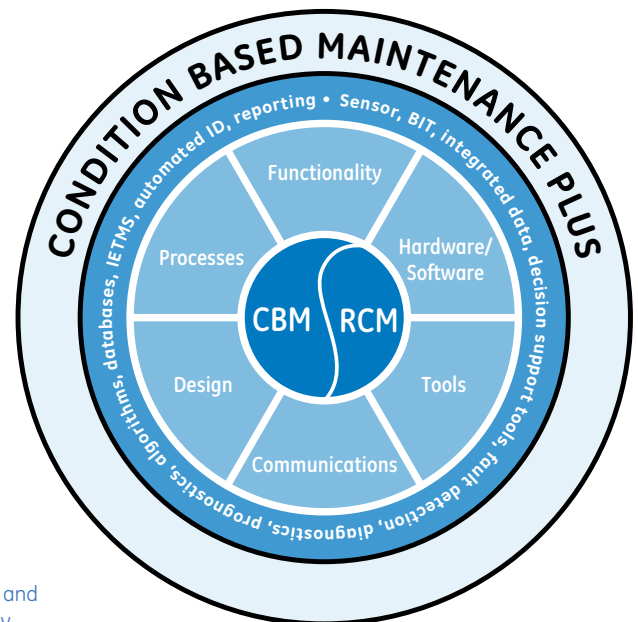
The Pentagon's CBM+ Concept and Construct" Maintenance Activity

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Commercial Industry Maintenance Tools Manage Billions in Industrial Assets

Aging Platforms, Shrinking Funds

Department of Defense (DoD) program managers, logistics support activities and front line technicians must maintain critical equipment and weapon systems to the highest possible levels of reliability, readiness, and performance. This is a challenging task under the best of circumstances but many of these systems are at or beyond their planned service life, adding additional performance risk and maintenance burden. Moreover, DoD staff budget reductions and a contracting supply of experienced engineers further complicate the task of keeping these weapon- and support systems operational

Condition Based Maintenance (CBM) initiatives work to address these challenges and the goal of ubiquitous CBM implementation is now established DoD policy per DoD Instruction 4151.22. In this instruction, "CBM+ is maintenance performed on evidence of need provided by reliability centered maintenance (RCM) analysis and other enabling processes and technologies." Condition Based Maintenance distinguishes itself from its time-based alternative by only servicing equipment that is specifically determined to require maintenance.

CBM requires platform sub-system health status knowledge. Depending on the platform or equipment, and the process used to ascertain equipment health, the amount of data logistics support engineers must analyze can be a limiting factor to operational readiness. A high Operational Tempo (OPTEMPO) can also dramatically increase operations and maintenance (O&M) demands.

The plus in CBM+ is about going beyond knowing the current status of a platform or subsystem to knowing its most likely future state; in other words, being able to predict future main-

tenance requirements before they emerge. Predictive Analytics can reduce and, in some cases, eliminate the need to perform time-based maintenance. By drawing attention to abnormal equipment behavior, Predictive Analytics optimizes equipment monitoring, resulting in increased maintenance lead time and reduced maintenance and operating costs. Properly implemented, CBM+ can preclude costly event-based maintenance or reliability-centered inspection and overhaul processes.

Challenges of CBM+ Implementation

Despite its superiority over legacy maintenance approaches, implementation of CBM+ has been uneven across and within the US military services. Adoption by non-US militaries has been extremely limited. The problem for many is that CBM+ approaches to date have been expensive, inflexible, and overly complicated. Many proposals, from both the government and prime contractors, have envisaged solutions that require significant hardware investments and that add size, weight, and power requirements in already constrained platforms. Moreover, many platform developers are inclined to push partial CBM+ solutions that are inflexibly tied to their own proprietary hardware.

Given the pressing need for CBM+ implementation and the resource constraints facing the military today, a viable way forward would:

- Require minimal development time and non-recurring engineering (NRE) funding to implement
- Use new commercial industry software algorithms and data analytic techniques while leveraging existing hardware instrumentation
- Be hardware/OEM agnostic and applicable across a broad range of platforms
- Leverage Big Data experience from already deployed assets that can be used for benchmarking and analysis
- Collect and transmit real time data without eating up valuable bandwidth

The DoD saves money applying common, reusable technologies. This would be no different with CBM or other maintenance analytical tools. Complexity, asset value and operational environments vary considerably across airborne, sea-based and ground tactical platforms. Adaptability of any maintenance process, technology and tool set across the organizational scope would have to be a primary requirement for portability. Maintenance requirements also differ dramatically between a manned tactical fighter aircraft and those of a submarine for instance, and include different subsystems. So it is critical that any common and reusable maintenance and monitoring solution has the ability to integrate into any equipment context – despite the manufacturer or lifecycle stage – any operating condition, and any operational culture.

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Looking to Industry for Answers

DoD has looked to traditional OEMs and suppliers for CBM+ solutions and has so far been disappointed with the results. But military operating environments have many similarities to large industrial manufacturing, energy production or mining enterprises. They all require tightly coupled and cost-efficient O&M processes. They all need to work with systems data from many different locations. They also have many similarities in the types of equipment and mechanical systems. There are maintenance planning products and technologies available from these adjacent industrial enterprises that directly apply to DoD CBM programs.

Engineers increasingly turn to real-time model-based analytical solutions to drive maintenance processes. Real-time systems are capable of creating actionable intelligence from large amounts and diverse sources of current data on many key pieces of equipment. Such solutions can detect problems automatically, and can effectively provide the basis for diagnosis and maintenance prioritization. They can extend capability with better predictive analytics, enable CBM capability on systems not currently served by CBM, provide a more common tool across multiple platforms, and reduce overall CBM deployment costs.

GE Proficy* SmartSignal*: A Better Way

GE Intelligent Platforms helps customers apply Industrial Data Intelligence across several industries including oil and gas, power systems, aircraft engines and energy management to name a few. GE's Proficy SmartSignal solution helps to detect, localize and diagnose problems before they impact operations or become catastrophic. In doing so, Proficy SmartSignal helps customers transform from reactive maintenance to a predictive and proactive strategy. GE leverages customers' existing

Predictive Analytics Reduces Maintenance Costs and Increases Readiness

data and infrastructure to provide early, actionable warnings of impending equipment and process problems—allowing their workforce to focus on avoiding problems, not looking for them or reacting after the problem has arrived.

GE's off-the-shelf predictive analytical solution can enhance DoD's existing CBM capabilities and provide immediate return on investment by:

- Reducing the time logistics support engineers spend analyzing data and more time acting on it. The software and applications identify problems well before they occur – often weeks or months before other health management systems. Early warnings allow users to shift from costly reactive maintenance to efficient planned maintenance. The result is improved readiness, and faster and more cost effective logistics.
- Enabling less complex HUMS or provide CBM- like capabilities to equipment without adding new hardware: SmartSignal can potentially leverage existing on-board systems and data collection.
- Dramatically reducing the data load on disadvantaged networks: collecting, storing, correlating and moving data can be a limiting CBM factor in deployed environments (tens of megabytes per flying hour for Army Aviation).
- Enabling analytics across multiple platforms for many signal and data sets independent of the original manufacturer: SmartSignal is equipment-agnostic.
- Being deployable more broadly onto platforms that cannot afford the added cost, weight or power.
- Dramatically increasing the number of assets that a given analyst or maintainer can monitor.

GE's Proficy SmartSignal has more than 30,000 systems under management across multiple industries today and has extensive experience monitoring mobile assets in the air, on land, and on sea. GE operates the monitoring solution for 5,000 of those assets with experienced technical personnel, providing operating and maintenance personnel with coaching and guidance as they move from reactive to proactive strategies.

GE supports a major airline as it monitors engines and airframes throughout their network. Mining companies rely on GE to monitor their rolling stock as they haul massive quantities of earth around work sites. And major global oil companies use GE's SmartSignal to monitor conditions on floating oil rigs. One third of North America's power generation relies on GE predictive monitoring for equipment health, covering assets from any and all OEMs.

GE further supports the analytics with historical data analysis and other services through Proficy Historian and other tools. Proficy Historian is a powerful enterprise-wide data historian
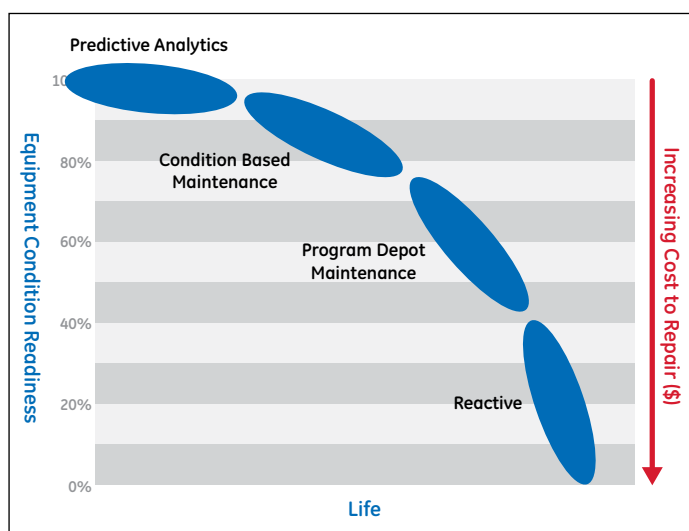
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	FLOATING	
	FLYING	
	ROLLING	

Sample Output form a SmartSignal Report
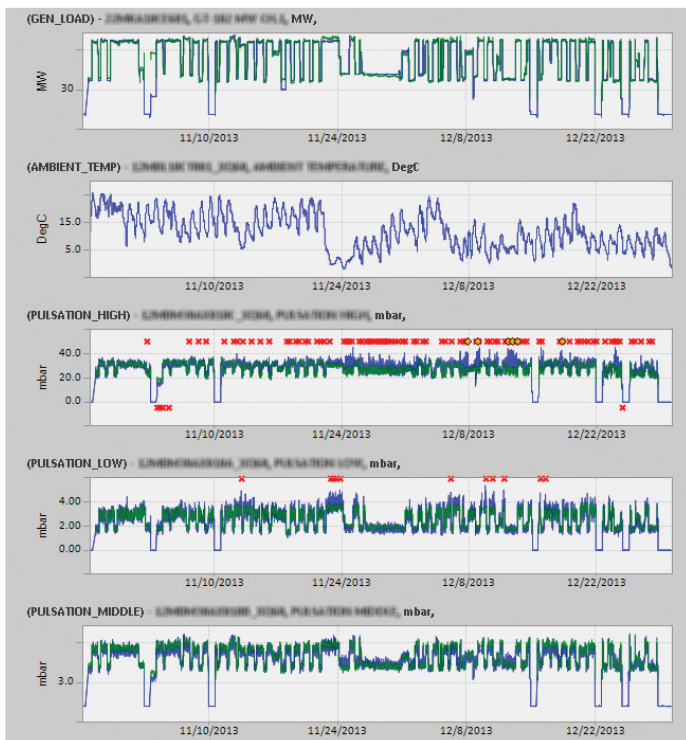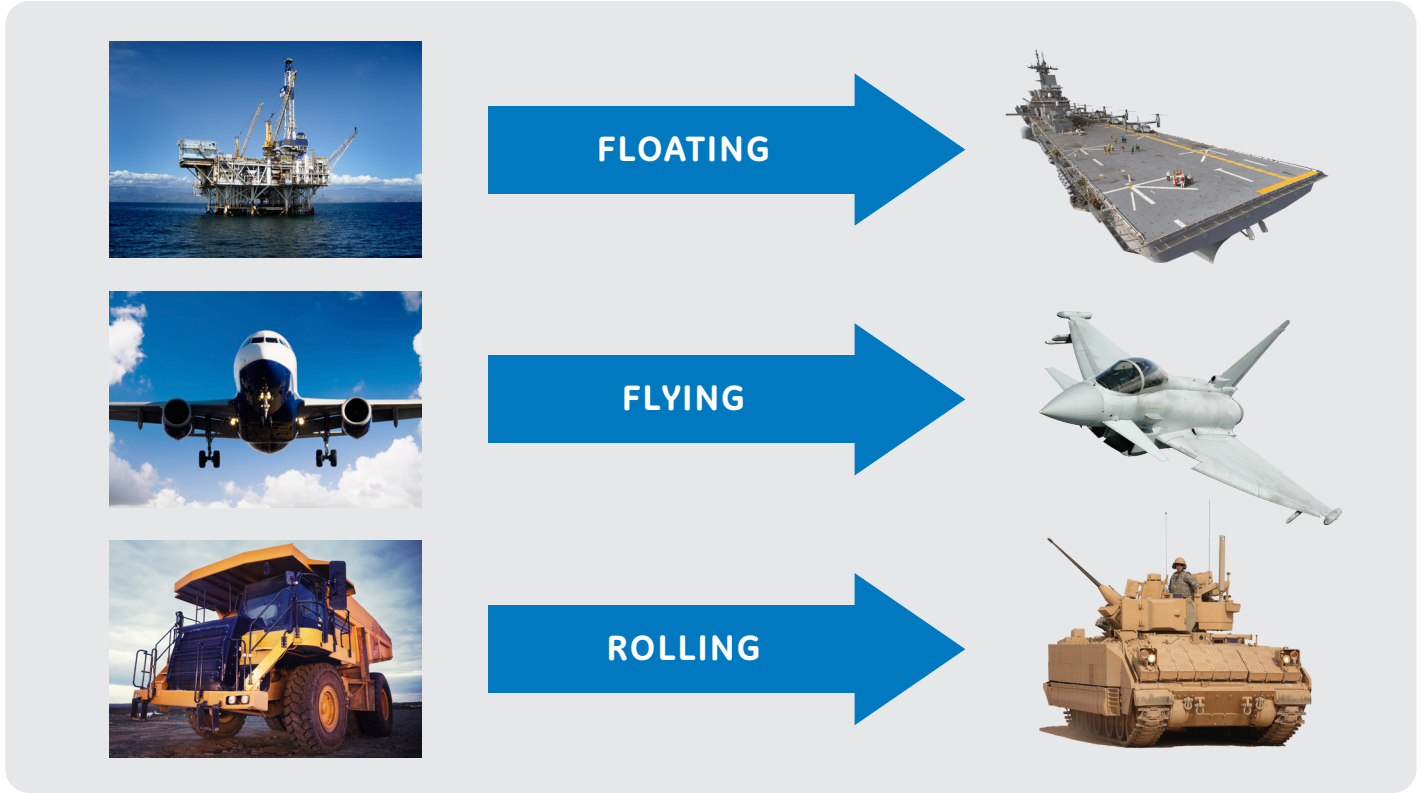
that collects, archives, and distributes tremendous volumes of operational information at extremely high speeds. It quickly provides the granularity of data needed to analyze and solve intense process application problems. Built specifically for process data acquisition and presentation, Proficy Historian delivers meaningful context to vast amounts of raw data from across operations.

The scale and breadth of GE industrial data analytics experience can offer DoD weapon and support systems significant benefits and advantages toward enabling better and smarter CBM. The requirements that drive industrial business decisions have direct parallels in the DoD enterprise:

INDUSTRIAL BUSINESS DRIVERS		DEPARTMENT OF DEFENSE
Operational efficiency	=	Cost of Ownership
Reliability	=	Operational Readiness
Safety	=	Safety
Continuity of Service	=	Operations Tempo

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Summary

Operational readiness and safety are critical on all DoD platforms. Cost avoidance in the maintenance process is paramount in this budget constrained environment. Traditional reliability-centered maintenance, although effective, is not an optimal solution for maintenance planning. Additional prognostics tools to further CBM efforts need to offer real cost advantages, flexibility and portability across multiple platforms and equipment. Adopted from industrial and commercial systems, GE Industrial Data Intelligence analytics product, predictive technology and proactive services meet all these requirements and can deliver military systems improved readiness and lower cost of ownership.