Cutter Readiness Through Condition-Based Maintenance

Interim Report to Congress

December 27, 2023

U.S. Coast Guard

Foreword

December 27, 2023

I am pleased to present the following report, "Cutter Readiness Through Condition-Based Maintenance," prepared by the U.S. Coast Guard.

The Don Young Coast Guard Authorization Act of 2022 directs the submission of an interim report on the implementation progress of a pilot project to enhance cutter readiness and reduce lost patrol days through deployment of condition-based program standards for cutter maintenance.

Pursuant to Congressional requirements, this report is provided to the following members of Congress:

The Honorable Maria Cantwell
Chair, Senate Committee on Commerce, Science, and Transportation

The Honorable Ted Cruz
Ranking Member, Senate Committee on Commerce, Science, and Transportation

The Honorable Sam Graves
Chairman, House Committee on Transportation and Infrastructure

The Honorable Rick Larsen
Ranking Member, House Committee on Transportation and Infrastructure.

I would be pleased to answer any questions, or your staff may contact my Senate Liaison Office at (202) 224-2913 or House Liaison Office at (202) 225-4775.

Sincerely,

Linda L. Fagan
Admiral, U.S. Coast Guard
Commandant

Cutter Readiness Through Condition-Based Maintenance

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I. Legislative Language

This report responds to the language set forth in Section 11208(d)(1) of the Don Young Coast Guard Authorization Act of 2022 (Pub. L. No. 117-263), which reads:

SEC. 11208. PILOT PROJECT FOR ENHANCING COAST GUARD CUTTER READINESS THROUGH CONDITION-BASED MAINTENANCE

(a) IN GENERAL.—Not later than 3 years after the date of enactment of this Act, the Commandant shall conduct a pilot project to enhance cutter readiness and reduce lost patrol days through the deployment of condition-based program standards for cutter maintenance, in accordance with the criteria set forth in subsection (b).

(b) CRITERIA FOR CONDITION-BASED MAINTENANCE EVALUATION.—In conducting the pilot project under subsection (a), the Commandant, in cooperation with government and industry partners, shall—

(1) select at least 1 class of cutters under construction with respect to which the application of the pilot project would enhance readiness;

(2) use condition-based program standards which incorporate artificial intelligence, prognostic based maintenance planning;

(3) create and model a full ship digital twin for the cutters selected under paragraph (1);

(4) install or modify instrumentation capable of producing full hull, mechanical, and electrical data necessary to analyze cutter operational conditions with active maintenance alerts; and

(5) evaluate and weigh efficacy of potential emergent repairs as well as planned depot maintenance activities.

(c) CONSIDERATION.—Prior to developing the pilot project in this section, the Commandant shall evaluate commercially available products, technology, applications, standards, and technology for development and implementation of the pilot program.

(d) REPORT TO CONGRESS.—The Commandant shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Transportation and Infrastructure of the House of Representatives—

(1) an interim report not later than 12 months after the date of enactment of this Act on the progress in carrying out the pilot project described in subsection (a); and

(2) a final report not later than 3 years after the date of enactment of this Act on the results of the pilot project described in subsection (a) that includes—

(A) options to integrate condition-based program standards with prognostic based maintenance planning to Coast Guard cutters; and

(B) plans to deploy condition-based program standards with prognostic based maintenance planning to Coast Guard cutters.

II. Background

The Coast Guard's Condition-Based Maintenance (CBM) program is established by Commandant Instruction (COMDTINST) M9000.6G, the *Coast Guard Naval Engineering Manual,* and the Coast Guard closely follows the Department of Defense Instruction 4151.22, *Condition-Based Maintenance Plus (CBM+) For Materiel Maintenance Instruction*, to create a whole-of-government, interoperable environment. This doctrine creates a CBM framework using a systems engineering approach to collect data, enable analysis, and support decision-making for system acquisition, sustainment, and operations.

The Coast Guard utilizes diagnostic and prognostic technologies to detect pre-failure conditions to inform CBM programs. Real-time and offline data in our CBM programs are captured and analyzed to establish baseline operating conditions, modify Original Equipment Manufacturer (OEM) maintenance interval recommendations, and develop new, condition-triggered inspections and maintenance actions. The Coast Guard's CBM overarching goal is to maximize reliability and operational availability, and lower total ownership costs.

This report highlights two areas where the Coast Guard currently employs CBM and two areas where CBM programs can expand to more effectively align with the Don Young Coast Guard Authorization Act of 2022 (Pub. L. No. 117-263).

Current CBM Areas

- Propulsion System Data Analytics Team (DAT)
    - The Propulsion System DAT was established in 2019 to leverage embedded 154-foot Fast Response Cutter (WPC) Main Propulsion Diesel Engine (MPDE) data capture systems and Cutter shipboard automation and control systems to capture, offload, and analyze performance data for prognostics, diagnostics, and lifecycle sustainment decisions.
- Oil Analysis Program
    - Utilizes oil samples and spectrographic analysis to measure wear particles to assess engine health, hydraulic systems, and bearings.

New CBM Areas

- 154-foot WPC Electrical and Propulsion Systems
    - New CBM pilot to assess cutter electrical system health. Expanding Propulsion System Data Analysis Team (DAT) scope to additional major components in the propulsion system with additional sensors and measurement points.
- 418-foot National Security Cutter (WMSL) Main Gas Turbine (MGT) Project
    - Partnering with the U.S. Navy's (USN's) on their established CBM+ program: prognostics, digital twins, and real-time in-theater reach back diagnostics and remote technical assistance.

III. Report

The Coast Guard's CBM programs and systems engineering lines of effort to expand diagnostic and prognostic technologies to enhance cutter readiness are aligned with the Don Young Coast Guard Authorization Act of 2022 (Pub. L. No. 117-263). The Coast Guard is actively collaborating with the USN's CBM+ initiative to enhance Coast Guard CBM programs, increase USN interoperability and create a whole-of-government framework. These lines of effort pursue use of various hardware, software and processes defined below, as they pertain to CBM+:

- Hardware—system health monitoring and management using embedded sensors; integrated data bus; platform information technology cyber hardening.
- Software—decision support and analysis capabilities both on and off equipment; appropriate use of diagnostics and prognostics; automated maintenance information generation and retrieval; platform information technology cyber hardening.
- Design—open system architecture; integration of maintenance and logistics information systems; interface with operational systems; designing systems that require minimum maintenance; enabling maintenance decisions based on equipment condition.
- Processes—Reliability Centered Maintenance (RCM) analysis; a balance of corrective, preventive, and predictive maintenance processes; trend-based reliability and process improvements; integrated information systems providing logistics system response; Continuous Process Improvement; Serialized Item Management.
- Communications—databases; off-board interactive communication links; secure data transmission trunks to shoreside technical support.
- Tools—integrated electronic technical manuals (i.e., digitized data); automatic identification technology; item-unique identification; portable maintenance aids; embedded, data-based, interactive training.
- Functionality—low-ambiguity fault detection, isolation, and prediction; optimized maintenance requirements and reduced logistics support footprints; configuration management and asset visibility.

The Coast Guard's CBM initiatives are aligned with the RCM tenets set forth in Military Standards (MIL-STD) 3034A: "a method for determining maintenance requirements based on the analysis of the likely functional failures of components, equipment, subsystems, or systems having a significant impact on safety, operations, and life cycle cost. RCM supports the failure-management strategy for any component, equipment, subsystem, or system based on its inherent reliability and operating context."

Ongoing Coast Guard CBM Efforts:

Surface Forces Logistics Center Engineering Services Division Propulsion System Data Analysis Team (DAT). The Propulsion System DAT was established in 2019 to leverage embedded MPDE data capture systems of the 154' WPC and the Cutter's shipboard automation and control systems, to capture, offload, and analyze performance data for prognostics, diagnostics, and lifecycle sustainment decisions. Based on routine plant operating data and full power trials, Propulsion System DAT has: 1) promulgated updated plant configuration and normal operations protocols to reduce idle time and fuel consumption; 2) identified targeted MPDE component renewals to

increase reliability; and 3) significantly extended OEM planned service intervals, which is estimated to lower total ownership costs for the propulsion system by $150 million across the fleet of 154-foot WPCs over 20-years.

Oil Analysis Program. The Coast Guard's Lube Oil Analysis Program uses oil samples and spectrographic analysis to measure wear particles to assess engine health, hydraulic systems, and bearings. Spectrographic analysis results are compared against OEM wear particle size, count, type, and level of metals and non-metals in oil. Abnormal test results are categorized by severity and maintenance alerts are issued to respective cutters with required corrective actions and recommended inspections.

The Coast Guard's Lube Oil Analysis Program was last updated in 2015. Cutters with long deployment lengths have onboard oil analysis capabilities, with follow up sampling at shore-based laboratories to validate in-field tests. Oil Analysis Program data was used by the DAT to extend Fast Response Cutter OEM's planned service interval for the MPDEs and to build a list of targeted component renewals.

Enhanced Coast Guard CBM Efforts:

WPC Electrical and Propulsion Systems. The WPC fleet, which is currently in construction, was selected as the best candidate platform for CBM pilot projects due to: embedded data and shipboard control systems, fleet size, and remaining service life. The Coast Guard used a minimum critical equipment list in our *Cutter Safe-To-Sail Minimum Critical Equipment Instruction* (COMDTINST 3120.21) to target engineering systems directly traceable to cutter readiness.

The first phase of this pilot project expands the scope of ongoing MPDE initiatives to additional major propulsion system components through via additional sensors and measurement points. The pilot will also start new CBM initiatives: 1) use technologies to assess cutter health electrical system health; 2) convert existing construction data and drawings into digital twins; and 3) use machine learning algorithms to analyze data collected. In support of these initiatives, the Coast Guard released a request for information on February 28, 2023, with responses due by March 28, 2023. The Coast Guard received nine commercial entity responses. The Coast Guard is evaluating these responses and utilizing the information to extend or eliminate maintenance intervals. The first round of proposed actions is anticipated in December 2023

To ensure Authority to Connect and Authority to Operate for CBM technologies in the pilot, the Coast Guard is adhering to requirements set forth in the Department of Defense's Risk Management Framework, as well as recommendations in the Government Accountability Office Report, *Actions Needed to Enhance IT Program Implementation*, (GAO-22-105092).

WMSL Main Gas Turbine (MGT) Project. Where the Coast Guard and the USN share equipment commonality, the Coast Guard is partnering with the USN to leverage their Integrated Condition Assessment capabilities. The USN has a Healthy Engine Model (HEM), digital twin, and machine learning algorithm for the MGT model installed on the 418-foot WMSL fleet. The HEM for the MGT analyzes data captured by embedded data systems and can identify pre-failure conditions for 22 known failure modes. The Coast Guard downloaded data from three WMSLs and sent it to

NAVSEA for analysis. NAVSEA is currenting updating the digital twin and HEM to account for configuration WMSL variants.

The Coast Guard is also evaluating the USN's Secure Data Tunnel line of effort to enable real-time reach back from cutters to shoreside support teams.

IV. Conclusion

The Coast Guard is prioritizing efforts along established CBM lines of effort to continue to maximize return on investment and increase cutter readiness. The Coast Guard in enhancing initiatives within an established CBM program in close coordination with the USN to maximize interoperability, interchangeability, and create a whole-of-government approach. The Service has embarked on a pilot project to evaluate impacts of CBM on WPC electrical systems, creation of digital twins, and use of machine learning. Efforts to date have yielded positive results in both the WPC and WMSL fleets by improving readiness and rightsizing maintenance intervals.

Appendix: Abbreviations

Abbreviations	Definition
CBM	Condition Based Maintenance
CBM+	Condition Based Maintenance Plus
DAT	Data Analysis Team
HEM	Healthy Engine Model
MDE	Main Diesel Engine
MGT	Main Gas Turbine
MIL-STD	Military Standard
NAVSEA	Naval Sea Systems Command
OEM	Original Equipment Manufacturer
RCM	Reliability-Centered Maintenance
USN	U.S. Navy
WMSL	418-foot National Security Cutter
WPC	154-foot Patrol Cutter