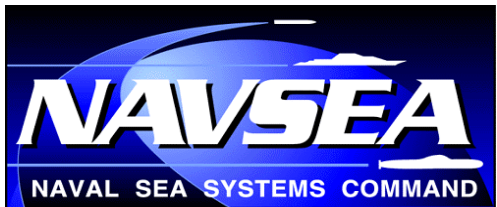


NAVSEA's Condition Based Maintenance Plus (CBM+) Initiative



PRESENTED BY

Marc Borkowski

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America's Navy: The Next Generation





BLUF

- CBM+ builds upon DoD's CBM strategy of performing maintenance based on the objective evidence of need as determined by RCM
- NAVSEA is embracing advanced technology to optimize maintenance costs while increasing materiel readiness through the use of sensor based technologies and prognostic health monitoring
- NAVSEA is moving forward with CBM+ to increase use of CBM+ technologies where applicable and cost effective

CBM+ Expected Benefits



Improve Readiness and Availability of Assets

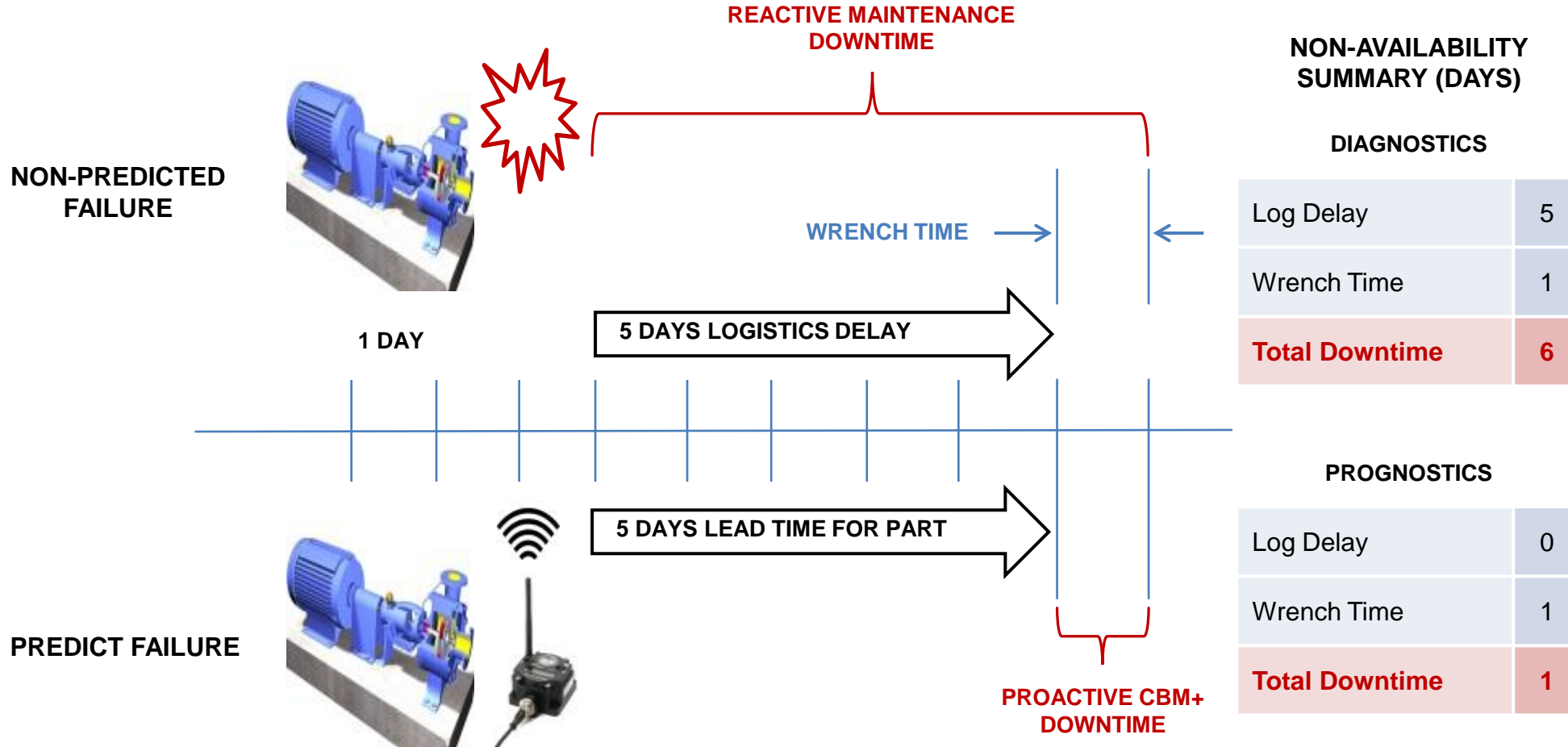


Improve Equipment Health to Achieve
Expected Service Life (ESL)



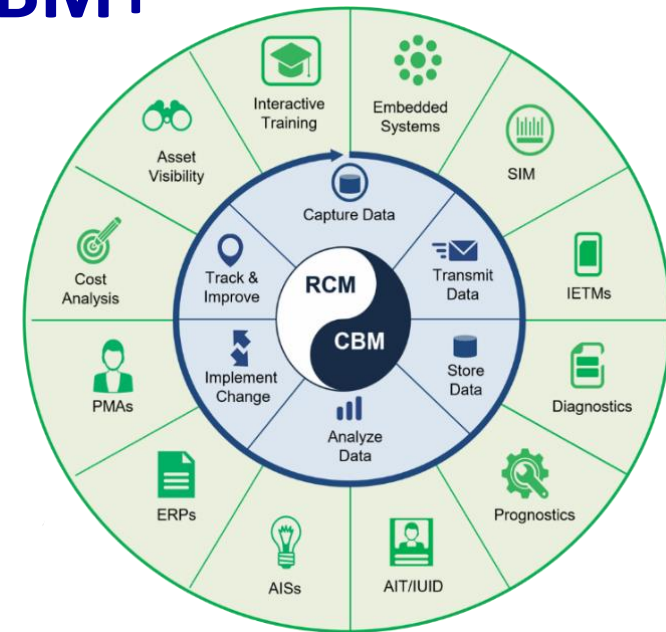
Maximize Efficiency and Reduce Life-cycle
Maintenance Costs Through Data-driven
Maintenance Decisions

CBM+ Increases Material Readiness: Proactive vs. Reactive Maintenance



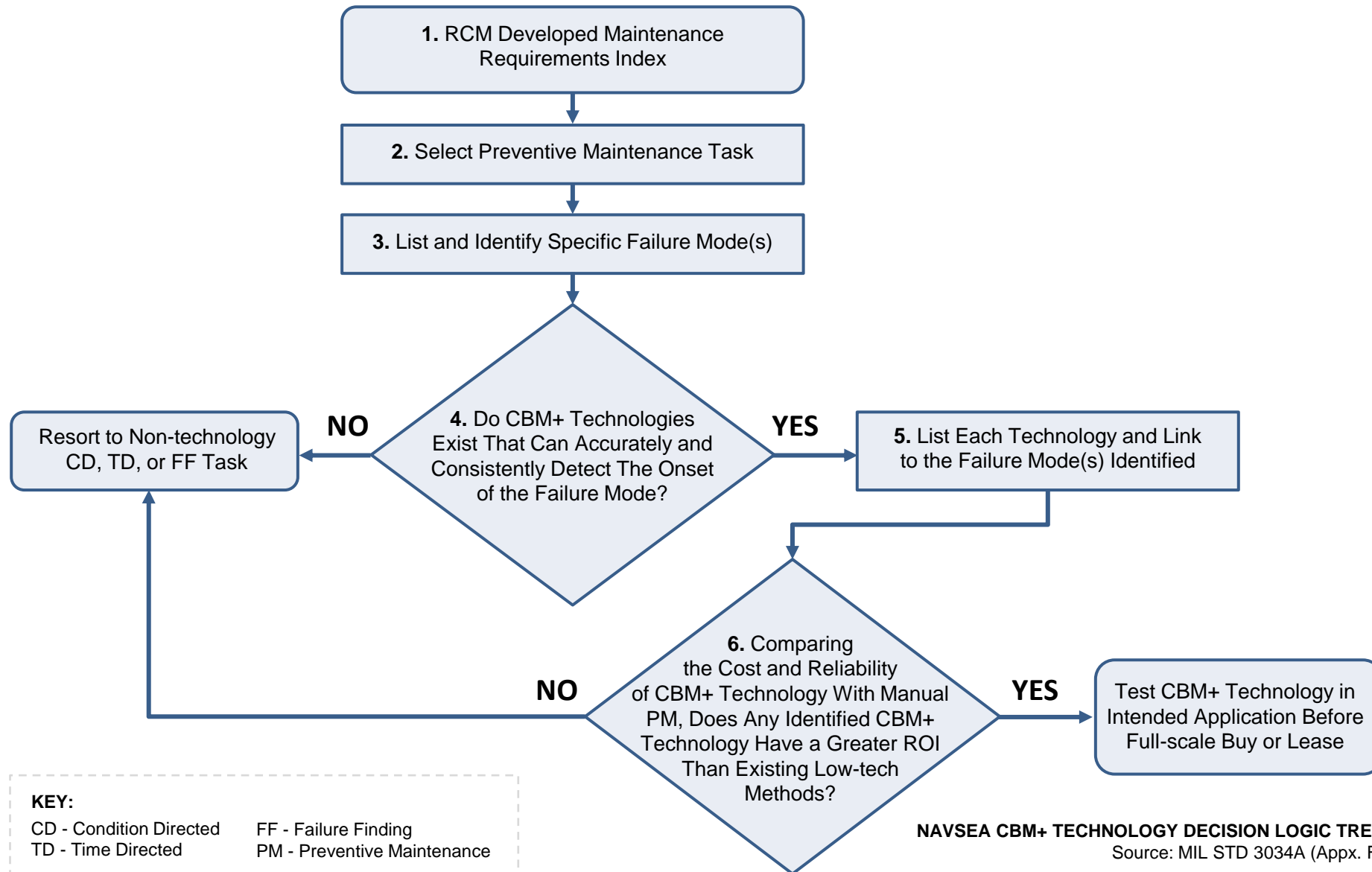
RCM is the Basis for CBM+

- **Classic RCM** is the Engineering Analysis Process used to develop Organizational, Intermediate and Depot level maintenance requirements for new equipment and systems
- **Backfit RCM** is the Continuous Process Improvement review of existing approved Organizational, Intermediate, and Depot level maintenance tasks
- Both processes are fully described in **MIL-STD-3034A** and are essential to achieving CBM+
- Since 2001, NAVSEA has trained and certified **6773** in Backfit RCM and **4419** in Classic RCM
- NAVSEA has instituted online training for our Backfit RCM certification via ePMS Gateway:
<https://epmsgateway.pmsmis.navy.mil>



- CBM+ connects the maintenance tasks that RCM tells us to do with the cost-effective technology available to assist in evaluating system and equipment performance.
- CBM+ uses RCM analysis to determine failure modes. This aids in sensor placement.
- CBM+ uses prognostics to schedule maintenance to **REDUCE DOWNTIME**

NAVSEA RCM & CBM+ Relationship





Technology & Tools: NAVSEA CBM+ Enterprise System IT Applications

Integrated Condition Assessment System (ICAS) is:

- Program of Record
- NAVSEA's common tool to support Condition Based Maintenance (CBM) for the past 20 + years
- Installed on over 100 ships across the Fleet
- Monitoring mechanical and electrical systems including:

Gas Turbine Engines	Fuel Oil System	Main Reduction Gears
Propulsion Diesel Engines	Potable Water	Controllable Pitch Propeller
Refrigeration Plants	Gas Turbine Generators	Lube Oil System
Air Compressors	Ships Diesel Generators	Line Shaft Bearings
Distilling Plants	Sewage & Waste Water	
Air Conditioning Units	Evaporators	

- Performing diagnostics, parametric trend analysis and providing condition alerts via Consolidated Machinery Assessment System ashore (CMAS)

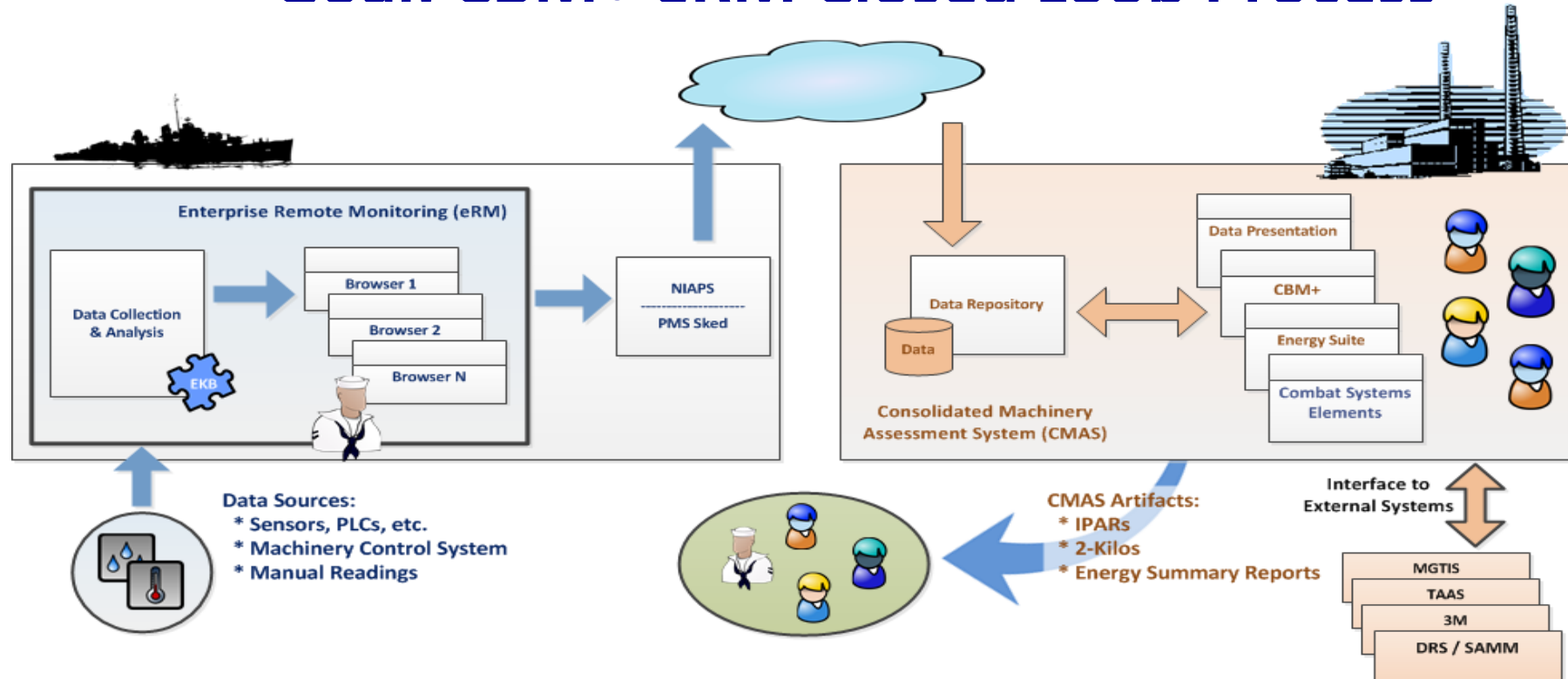


Enterprise Remote Monitoring (eRM)

- The Navy is moving to replace ICAS with eRM beginning FY18
- eRM Improvements over ICAS Include:
 - Government owned/developed system
 - Increased cybersecurity posture
 - Enhanced diagnostics, fault analysis & trending
 - Enhanced feedback to ships force
 - Highly scalable, faster data processing
 - Supports rapid development and revision of CBM+ algorithms
 - Phased transition to automated predictive analytics/prognostics
 - Digital Twin capability
 - Linkage to existing and new Navy policy and doctrine, infrastructure, business strategy, architectural framework, RCM, and open systems and data strategy

OBJECTIVES: Real-Time Equipment Health Monitoring & Reduced Downtime

Goal: CBM+ eRM Closed Loop Process



eRM will provide ...

- * Data Acquisition from disparate Data Sources
- * Event Recognition, Diagnostics, Prognostics, Alarms
- * Real-time Data Presentation & Reporting
- * Equipment Operating Logs
- * Energy Dashboard / GENISYS
- * Maintenance Recommendations to PMS Sked



Engineering Knowledgebase (EKB) provides ship-specific configuration including equipment definitions, sensors, interfaces, etc.

CMAS Sub-Systems will include ...

- * Data Presentation: Time series data as Charts & Tables, also available for Export
- * CBM+: Diagnostics, Prognostics, Condition Assessment, Recommendations, 2-Kilo Generation, Triton
- * Energy Suite: Energy Summary Report
- * Combat Systems Elements (CSE)



CMAS users include ISEAs, Waterfront Maintenance Community, Tech Warrant Holders, and Ship's Force

CMAS is in The Early Stages of Realizing Digital Twin Capability for CBM+

Conclusions

- NAVSEA's CBM+ process, when properly executed and resourced, will ensure:
 - The right maintenance is performed
 - On the right equipment
 - At the right time
 - For the right cost
 - And improve operational availability
- CBM+ technology must be considered as a key attribute in ship design and be ingrained into the acquisition, modernization, sustainment and management processes that are critical to ensuring ship material readiness throughout service life



QUESTIONS?



RCM & CBM+ Policy

The following policy documents require or govern the use of RCM, CBM and CBM+ across DoD and NAVSEA:

- **DODI 4151.22 CBM+ for Materiel Maintenance** - Capstone policy instruction that drives CBM+ policy for NAVSEA.
- **OPNAVINST 4790.16B (CBM and CBM+ Policy)** - Establishes policy and responsibility for the implementation and integration of Condition-Based Maintenance (CBM) and Condition-Based Maintenance Plus for naval ships, carriers, submarines, expeditionary equipment, aircraft, and associated systems, equipment and infrastructure.
- **OPNAVINST 4700.7L (Maintenance Policy for US Navy Ships)** - Establishes maintenance policy for U.S. Navy ships and directs the common use of NAVSEA's Reliability Centered Maintenance (RCM) methodology in developing maintenance requirements.
- **OPNAVINST 4790.4F (Ships' Maintenance & Materiel Management Policy)** - Establishes policy and assigns responsibilities for the Ship's 3-M System which is designed to provide for managing maintenance and maintenance support to achieve maximum equipment operation readiness.
- **NAVSEAINST 4790.27A (RCM, CBM, & CBM+ Policy for Ships, Ship Systems and Equipment)** - Aligns NAVSEA policy with DoD and OPNAV's RCM, CBM and CBM+ policies, specifically, requiring RCM based CBM program that includes organizational, intermediate and depot level maintenance requirements.
- **MIL-STD-3034A (Reliability Centered Maintenance (RCM) Process)** - Delineates the 12 phase fully detailed RCM Process and includes the associated Data Item Descriptions (DIDs) for each phase. Also contains the Backfit RCM process. Appendix F describes relationships between RCM and CBM+. It is available for use by all Services.

Technology Demonstrations That Will Shape the Enterprise Solution - eRM



- **LCS Machinery Readiness Management System (MRMS)**
 - Predictive analytics/prognostics to be demonstrated as part of demo
 - Ship-to-Shore concept for centralized analysis and data warehousing
 - Onboard equipment health monitoring and maintenance scheduling integration also planned
 - Web-based user-interfaces planned for onboard and ashore teams (digital twin)
- **General Electric (GE) Smart Signal**
 - Exploring options for enhanced CBM+ architectures, including predictive analytics and shipboard data visualization, across six ship classes
- **DEI and NSWCPD Main Reduction Gear Health Improvement**
 - Improvement of Main Reduction Gear health through unlocking of ICAS inherent capabilities
 - Employ elements of DEI PreMA for system prognostics
 - Identify improvements in system assessment capabilities with enhanced DDG 51 Class sensors; e.g., lube oil sensors
- **Ship's Force Machinery Vibration Analysis Program (Including Thermal Imaging)**
 - Allows ships force to identify mechanical/electrical problems on over 400 pieces of installed machinery before failures occur



Technology Demonstrations That Will Shape the Enterprise Solution - eRM

- **CBM+ Pilot Projects**
 - Using Penn State University support, include online condition monitoring, diagnostics, and vibration based predictive analytics for high pressure air compressors, trim & drain system, and CO2 scrubbers
- **(INSCAT) Integrated Naval Ship Condition Assessment Toolset**
 - Provides automated structural health monitoring data management from hull sensor data. Current Phase II SBIR effort (lab-environment only to date)
- **Distributed Sensor Network for Structural Health Monitoring**
 - Structural health monitoring technology uses installed sensors to monitor hull condition. Current Phase II SBIR effort (lab-environment only to date)
- **CBM+ Sense & Respond Crew Interface Technology**
 - Monitors & analyzes system performance data on LCS. Provides potential failure alerts, system health status and troubleshooting enhancements to currently installed computer network. Current Phase II SBIR effort (lab-environment only to date)
- **Diesel Engine Data Analytics (CTMA)**
 - Four phase project with first phase to collect sample diesel engine run data and evaluate effectiveness of CBM+ algorithms
 - Have recently begun data collection on several diesel powered test ships