SAE Aerospace Standards Summit

Condition Based Maintenance

Greg Kilchenstein
Director, Enterprise Maintenance Technology
Office of DASD, Maintenance

08 July 2015
CBM⁺ Policy

DoDI 4151.22 - Condition Based Maintenance Plus (CBM⁺) for Materiel Maintenance - CBM⁺ is OSD’s strategy to apply and integrate appropriate processes, technologies, and knowledge-based capabilities to achieve the target availability, reliability, and operation and support costs of DoD systems and components across their life cycle.

- The CBM⁺ initiative envisions a shared set of practices and tools to enable maintenance improvements across DoD.
- As the services’ plans evolve and CBM⁺ efforts are implemented, OSD encourages the development of new technologies, processes, tools, and procedures in a shared environment.
- The goal of CBM⁺ is proactive maintenance based on evidence of need performed at an optimal time by maintainers with the right knowledge, right tools, and right support.
CBM+ Overview

CBM+ is built on a foundation of
- Condition Based Maintenance (CBM) &
- Reliability Centered Maintenance (RCM)

- At its core, CBM+ is maintenance performed based on evidence of need
- Relies on RCM to determine optimal failure management strategy
- Applied to both new design and fielded weapon systems
- Achieved through enabling technologies, tools, and processes from public and private sources
- Incorporated in organic capabilities and commercial contracts
- Measured with sustainment metrics of materiel & operational availability, reliability, and operation & support costs
CBM+ Enablers

- CBM+ implements an optimum mix of maintenance technologies, best practices, RCM-based processes, and enablers within the integrated total life cycle framework.

Built on a foundation of CBM & RCM

- CBM+ enablers can also include sensor technology, dynamic modeling & simulation, wireless data communications, condition/health monitoring systems, and neural networks.
CBM+ Guidance

- **DoD 4151.22M** – RCM Manual - guidance to achieve inherent reliability
- **DoD Guidebook** - reference for CBM+ project development, implementation and execution
- **Service Issuances**
  - AR 750-1 - Army Materiel Maintenance Policy
  - OPNAV 4790.16A - CBM Policy
  - NAVSEA 4790.27A - RCM, CBM, and CBM+ Policy for Ships, Ship Systems & Equipment
  - NAVAIR 00-25-403 – Naval Aviation RCM Process
  - MCO 4790.25 - Ground Equipment Maintenance Program
Standards Used in CBM

- **MIL-STD 3034A** – “RCM Process” describes the methodology used for determination of maintenance requirements (NAVSEA sponsored).
- **MIL-HDBK 1814** – “Integrated Diagnostics” contains requirements and verifications for incorporating ID into acquisition program events, such as, creating documents & plans, accomplishing studies & tradeoffs, and conducting reviews & audits (USAF sponsored).
- **ISO 13374** - Condition monitoring and diagnostics of machines standard provides the basic requirements for open condition monitoring and diagnostics (CM&D) software architecture to allow CM&D information to be processed, communicated, and displayed by various software packages independent of platform or hardware-specific protocols.
- **MIMOSA OSA-CBM** - The Open System Architecture for Condition Based Maintenance specification is a standard architecture for moving information in a CBM system. OSA-CBM implements the ISO-13374 functional specification by adding data structures and defining interface methods for the functionality blocks defined by the ISO standard.
- **MIMOSA OSA-EAI** - The Open Systems Architecture for Enterprise Application Integration defines data structures for storing and moving collective information about all aspects of equipment, including platform health and future capability, into enterprise applications.
- **SAE Standards JA 1011/1012** – RCM evaluation criteria and guide.
CBM+ Outcomes

Air Force CBM+ empowers the systems experts to make knowledge-based decisions that increase system availability and decrease cost.

New Acquisitions:
- C-17 CBM+ Pilot Program
- JSF Prognostic Health Management
- F-22 Integrity Data and Reporting System (IDARS)

Legacy Systems:
- C-130 Automated Inspection, Repair, Corrosion and Aircraft Tracking (AIRCAT)
- C-5 Aging Fleet Integrity Management (AFIRM)
- Engine Health Management Plus (EHM+)

Programs:
- C5 MSG-3
- C-130 and B-1 HVM Programs
- Collective Wind Predictive Trending
- CBM+ Research Environment and Web Services
- Systems Lifecycle Integrity Management (SLIM) AFIT Educational Course

Technologies and processes that improve the maintenance decisions and integrate logistics:
- NET Centric Integrated Logistics
- Joint Intelligence/Integration Command and Control
- Organized
- Optimized
- Modernized
- Postured

Global Information Grid
- Vision & Strategy 2025
- Sense & Respond Logistics

Anticipatory Logistics
- Enterprise Health Management
- Failure Management Strategies
- Reliability Availability Maintainability

Autonomic Logistics Services
- Combat Power Assessment
- Embedded Platform Logistics Systems
Army CBM+ Program Highlights

Aviation

- Equipped **85% of the Manned Aviation Fleet**
- Transmitting Critical Engineering and Logistics Data to the Enterprise
- Tangible Improvements in Readiness, Safety, and Maintenance
- Burden reduction

Wheeled and Tracked Vehicles

- Majority of platforms come with embedded sensors and data buses from OEM
- TACOM Tactical Wheeled Vehicle CBM+ Pilot Program proving out data/analysis approaches and ROI
- CBM+ Supported System anticipated in next 5 years include Abrams, Stryker, JLTV, Paladin, and Tactical Wheeled Vehicles

Mobile Electric Power & C4ISR

- Demonstrated the ability to collect and transmit CBM data from electromechanical platforms
- CECOM Tactical Quiet Generator (TQG) CBM+ Pilot Program proving out data collection/approaches and ROI
- Emerging programs supporting CBM+ include Mobile Electric Power, WIN-T, and AN/TPQ 53 Radar System
CBM+ Value -> Examples

Apache AH-64D

Issue: High XMSN Removal Due to Sprag Clutch Life Limit (42% of XMSN changes)

CBM+ analysis enabled extending Retirement Change interval for Sprag Clutch

- 131 Fewer Requisitions over 27 months
- Cumulative Additional Time on Wing (TOW): 36,054 Flight Hours
- Avg Cost Avoidance - $12M/Year

Tactical Wheeled Vehicles

Issue: Distance / Miles based oil change intervals offer POOR correlation with Oil Life

Baseline (AMSAA Oil Life Algorithm)...
Number of Oil Changes (2 Year Period) = 3,167

Lower Bound Savings Potential
- Oil Changed Per IETM
  - Number of Oil Changes (2 Year Period) = 3,538
  - Percent Reduction using Algorithm = 10.4% or $720K/YR

Upper Bound Savings Potential
- Oil Changed at 6 Month Interval
  - Number of Oil Changes (2 Year Period) = 6,676
  - Percent Reduction using Algorithm = 52.5% or $3.6M/YR

CBM+ Analysis -> Proven Results
### AH-64
- Relief of MRSP 50 hour inspection
- Relief of MRPC link 50 hour Dial Indicator inspection
- Relief of APU Clutch Vibration Check
- COSSI clutch TC extended from 1500 to 2000 hours
- Hanger Bearing TC extended from 2500 to 3250 hour
- Main Transmission Accessory Sprag Clutch RC extended from 1000 to 1500 hours
- Hanger Bearings permitted to leak grease to align with scheduled maintenance
- Main Transmission TC time extended from 2000 to 3000 hours
- TRSP TC extended from 1500 to 1750 hours
- Added task to replace Tail Rotor Gearbox Output seal at AVUM/AVIM
- Enhanced Rotor Track and Balance capability via PC-GBS interface
- Improved drive system health capability via PC-GBS interface
- Enhanced safety capability via critical component health monitoring and trending

### UH-60
- Improved Condition Indicators (ground truth)
- Reduced false indications
- Tail Rotor Bias CI
- Prevent chronic pylon vibes/fatigue
- Acc Module Pre-chip CI
- Prevent precautionary landing
- Avoid drain and flush
- Avoid 5-pack contamination
- Mechanical Diagnostics Application (MDA)
- Automated Fleet Screening
- Weekly scans using new CI’s (not yet fielded)
- Accident Investigation

### CH-47F
- A/C MWO installation
- 3 A/C Coefficient Development activities
- SW drop A in flight testing
- Safety Release (SR) for Demonstration
- Unit Demo – kicked off May 2014

**AH-64: Extended Time on Wing by Component**

454,000 Additional Hours Time-on-Wing through 25 Implemented Changes
CBM Enables Identification of Systemic Issues

- Joint effort between AMSAA and TACOM
- Costly Misdiagnosis and significant downtime
- High Cost Avoidance Potential already realized on small samples
- HET A1 Engine Warranty Claim Validation ~$2M
- Speed Sensor: Estimated Cost Avoidance ~$2M
- Oil Change Reduction ~1.6M
- ABS Sensor Fault ~$1.3M

Fleet – Vehicle Speed Sensor DTC
- Frequent observance of Vehicle Speed DTC
- Per IETM, corrective actions are not specified for listed DTC and frequently result in misdiagnosed corrective actions
  - Can result in costly replacements that do not resolve problem (e.g. engine or transmission)
- Common Symptoms: zero vehicle speed reading on speedometer while driving vehicle along with potential loss in vehicle power or shifting irregularities
- Code Observed on 8% of HEMTT Vehicles

Fleet – ABS Power Supply DTC
- Malfunction/Symptom: Large sample of medium and heavy trucks reported ABS light on and stays on
- Failure Mode(s): Incorrect adjustment of ABS speed sensor and failure of ABS controller (Gen 4) software
- Effect(s): IETM deficiencies causing costly misdiagnoses and significant downtime
- Average Misdiagnosis Parts Cost To Date: $2,641 per misdiagnosis

M1070A1 – Engine Overspeed
- Warranty claims on trucks denied due to engine overspeed condition
- The engine speed is driven up by transmission due to trucks inertia when traveling down hills with heavy loads
- CBM showed it was a fleet wide issue
- Potentially millions in cost avoidances over life of engine
- Warranty claims valid – OEM issue
The Cost Benefit Analysis (CBA) for Tactical Wheeled Vehicles shows positive financial benefits for the implementation of CBM+.

Four of the seven benefits or 90% of the benefits are enabled through vehicle data driven analyses.

The CBA data are very conservative:
- Fuel Cost per Gallon = $3.13
- No war activity benefits are included
- Savings/cost avoidance = 5%

Additional Non-Monetary Benefits:
- Warranty Claim Validation
- Accident Investigation Capability
Condition Based Maintenance/Remote Monitoring

Integrated Condition Assessment System

**Background**
- Remote Monitoring used to identify and solve in service problems
  - Below LPD 17 MPDE EPAR is used to identify class wide problem
    - Engine light loading condition identified over 95% of operational time during the last 365 days on LPD-19
  - Lower right depicts an LPD-19 IPAR data screen used to identify that the existing system design is not capable of maintaining the Diesel fluids operational temperatures within design specification

**Engine Issues**
- **Light Loading - Mission Profile operations indicate higher than anticipated time at light load condition** — result is higher than anticipated maintenance costs and reduced service life.
  - **Recommended solutions**
    - Continue to investigate alternate light load propulsion and “on-engine” light load mitigation technologies

**Engine Issues**
- **MPDE cooling system not capable of maintaining engine AV / LO / Intercolder within OEM operational temperatures**
  - **Recommended solutions**
    - Modify cooling system valves/controls to allow for greater control of AV / LO temps throughout engine operational range.

**ICAS data instrumental in USS HUE CITY (CG-66) Fire Investigation performed by FRB**
- Data used to determine time line of events
- Data used to verify expected cause of fire

**ISEAs had access to shipboard and shoreside data**

- The GTG ISEA, RMC & ICAS team has further evolved the GTG IPAR
  - “Start Vibrations High” discovered (2005 – Gonzalez)
    - applicable to approx 180 GTGs monitored by ICAS
  - Further analysis yielded an unsat amount of “false positives”
  - Failure mode split between “cold start”, “hot start” or “running high” vibe condition
  - Better assessment with close to zero false positives