Aviation Condition Based Maintenance (CBM)

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DoD Maintenance Symposium
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CBM Implementation

- Over 118 DSC Systems Supporting the Warfighter in OIF/OEF
- Over 430 Aircraft Instrumented
- Over 100,000 Flight Hours of Experience
- Currently Have 5 Data Sources in CBM-DW
  - ULLS-A(E)
  - MSPU
  - MDR
  - IVHMS
  - 2410
- Engineering Analysis of Data Ongoing
To Battlefield Commanders and Soldiers, CBM Is:
- The Ability to Support Mission Requirements With **Proactive, Planned Maintenance**
- **Greater Availability** With More Predictability in Fleet Health
- **Smaller Sustainment Footprint**
- **More Efficient** Fault Detection, Diagnosis, and Troubleshooting
- **Less Time** on Specific Maintenance Tasks Such as Rotor Track and Balance
- Arduous, Time Consuming Physical Inspections Are **Reduced or Eliminated**
- **Reduced** Parts Requisition Wait Times
- **Unambiguous** Maintenance Instructions Based on Actual Condition, Usage, and Evidence of Need
- **Enhanced Safety** for Crews and Maintenance Personnel

**CBM Program Objectives Supported:**
- Decrease the Maintenance Burden on the Soldier
- Increase Platform Availability and Readiness
- Reduce O&S Costs
- Enhance Safety
CBM Goals

- **Maintenance to Improve Operational Availability and Reduce Maintenance Burden on Soldier by:**
  - Enhancing Diagnostics
  - Evolving to Predicting Remaining Component Life
  - Then Evolving to Proactive Supply Transactions

- **Derived From Near Real-time Assessment & Analysis of Data From:**
  - Embedded Sensors
  - Platform Maintenance Environments
  - Aircraft and Supply Historical Data

**Current**
- Reactive
- Time Based Overhauls / Inspections

**Transition**
- Inspection & Maintenance Action Interval Extension
- Platform Diagnostic / Prognostic Equipment Installation

**End State**
- Proactive
- Condition Based Overhauls / Inspections

**AMCOM Goal**
- 2011

**Key CBM Enablers**
- Embedded Sensors
- Plane Side Diagnostics
- Data Fusion
Aviation CBM

OIF Units Sending Standard Army STAMIS Data and HUMS Data

CBM Data Warehouse

**Phase 1**
- Maintenance

**Phase 2**
- Fleet Management

**Phase 3**
- Supply

Data Sources

- ULLS-A
- HUMS Systems
- DSC
- 2410
- MDR

**SALE**

- GCSS-A
- PLM+
- LIW
- LMP

Platform PMs
- Fleet Managers
- IMMC
- Engineering
- LOGSA
- OEMs
- Academia

In Theater

CAISI – Combat Service Support Automated Information System Interface

VSAT – Very Small Aperture Terminal

JTDI – Joint Technical Data Integration

CAISI

4-3 ASLT

2-3 GSAB

3rd CAB

1-3 ATK

V SAT

JTDI
Dependent Components of CBM

PLATFOMS
- HUMS
  - VMEP
  - HUMS
  - Future
- Parts
  - Remediation
- RCM
- “Off Systems”

OIF/OEF
CONUS
OCONUS
OEM
Academia

Funding Outlays and S&T Efforts

Collection 1

Pipeline of Transmission
- Commercial Satellite
- Fed Ex
- Mail
- Military

Transmission 2

Extract
Transform
Load

User Needs

Warehousing

Analysis 4
Supply Engineering
Other

Decision/Action 5
- Maintenance Concept Impacts
- Training Impacts
- Part Re-engineering
- AWR
- Supply Stockage

Overarching Architecture Compliance
How Does the CBM Process Work?

1. **Embedded Sensors**
   - Monitor Component Health
   - Data is downloaded after each flight

2. **Plane Side Work Stations**
   - 1. Provide any immediate actions
   - 2. Transfer data into the STAMIS

3. **Production Control Office**
   - 1. Plans maintenance activities
   - 2. Enters proactive supply actions into STAMIS

4. **Data Loaded into CBM Data Warehouse**

5. **Data Warehouse**
   - Failure Analysis
   - CI Development
   - Flight Regimes
   - Prognostics

**Key Enablers:**
1. Embedded Sensors
2. Plane Side Diagnostics
3. Planned Maintenance
4. Data Fusion
5. Engineering Analysis

**Program Objectives**
- Decrease maintenance burden
- Increase platform readiness
- Enhance safety
- Reduce O & S cost

**Actionable Maintenance and Supply Notifications**

**Soldiers Perform Immediate Maintenance Actions**
Monitored Master Parts List
AH-64 A/D - 53 Parts

Main rotor head
M/R Hub
Trunion damper
Upper bearing
Lower bearing
M/R Swashplate
M/R Swashplate Bearing
PC link
PC link rod ends

Air Data Processor bearing (A-model)
Derotation Unit (D-model)
Straps
Pitch housing
Lead-lag link
Feathering bearing
Lead-lag damper
Rod end (damper)

Main rotor blade
Tip cap
M/R blade attach pin

Tail rotor head
T/R fork
T/R hub
T/R GB
T/R Swashplate & Bearing
T/R PC links
T/R strap
T/R blade

Main Transmission
Clutch (left/right)
Sprag clutch (primary/secondary)
M/R drive plate
M/R drive shaft (Gearshaft-spur)

APU
APU clutch
APU shaft

Hydraulic Pump
(Primary & Utility)
Lube Pumps
Generator
Shaft Driven Compressor
(A-model only)

Engine (No. 1 & 2)
Nose GB (No. 1 & 2)
Quill Shaft
Engine Starter

Currently Lists -2410 Tracked Parts
And Additional Life Limited Parts
---Mainly Rotating Components

Currently Monitored by Vibration
Structural Part, Possible Addition for Monitoring in FY08
### Monitored Master Parts List

**UH-60A/L - 56 Parts**

**Currently Lists -2410 Tracked Parts And Additional Life Limited Parts And Additional Rotating Components**

- Main Rotor Hub
- Main Rotor Shaft
- Bifilars
- Swashplate ASSY
- Swashplate Guide
- Swashplate Bearing
- PC Links
- M/R Spindle
- Spherical Bearing
- M/R Spindle Tie Rod
- Control Horn
- M/R Shaft Extender
- M/R Damper
- T/R Blade
- T/R Pitch Change Horn
- PC Links
- T/R Pitch Change Shaft
- T/R Pitch Change Bearing
- Tail Rotor GB
- Retention Plates (2)
- Gearshaft
- Viscous Bearings (4)
- T/R Driveshafts (7)
- Intermediate GB
- Main Transmission Module
- Accessory Module
- Generators (2)
- Hydraulic Pumps (2)
- Planetary Carrier
- Engine (No. 1 & 2)
- Driveshafts (2)
- Input Modules (2)
- Oil Cooler Axial Fan
- Oil Cooler Fan Bearing
- APU

**Currently Monitored by Vibration**

Structural Part, Possible Addition for Monitoring in FY08
Monitored Master Parts List
CH-47D - 88 Parts

Currently lists -2410 Tracked Parts
And Additional Life Limited Parts
---Mainly Rotating Components

FWD Tie Bar
Pitch housing
Pitch Bearing (2)
Pitch Shaft
Vertical Pin Bearing
Horizontal Hinge Pin
Horiz. Pin Bearing (2)
Damper

FWD Rotor Head
FWD Rotor Hub
FWD Swashplate
Swashplate Bearing
Pitch Link
Pitch Link Bolts (2)

APU
AFT Transmission
Rotor Shaft
Transmission Fan
Generators (3)
Hydraulic Pumps (2)
Lube Pump

Combiner Transmission
Combiner Fan
Lube Pump

Engine (No. 1 & 2)
Eng. Transmission (2)
Clutch (2)
Engine Driven Shaft (2)
Cross Shaft (2)

Currently Monitored by Vibration
Structural Part, Possible Addition for Monitoring in FY08
AH-64 Main Rotor Swash Plate Bearing

- Unit Conducted Manual Inspection Per Technical Manual – “Checked and Found OK” Three Times
- Spalling, Corrosion and Broken Cage Discovered – Onboard Sensors Detected Fault, Teardown Analysis Confirmed Fault

Broken Cage

Spalling/Corrosion
CBM Benefits From the Field

- Unit Waited Until Chip Light to Replace Nose Gearbox (NGB)
  - Result:
    - Collateral Damage
    - Increased Cost of Repair
    - Unnecessary Impact on Readiness

- Unit Replaced Gearbox Due to Indication From VMEP
  - Results:
    - Teardown Analysis Showed No Collateral Damage
    - Vibe Levels Normal After Replacement
    - Minimal Cost of Repair
    - Minimal Down Time
## FY07 CBM Benefits - 9 Months (Oct 06 - Jul 07)

<table>
<thead>
<tr>
<th>System</th>
<th>Item</th>
<th>Action / Benefit</th>
</tr>
</thead>
</table>
| AH-64  | M/R Swashplate | **Eliminates**  
  - 50 hr bearing inspection (between 1750 and 2250 hrs)  
  - Maintenance Operational Check (approx 1 hr)  
**Extends**  
- MMH per Inspection - 7.4 hrs  
- Downtime Saved per Aircraft - 5.9 hrs  
**Saves / Improves**  
- MMH Saved - 2.0 Hrs  
- MMH Saved - 2.0 Hrs  
- MMH Saved - 2.0 Hrs  
- MMH Saved - 2.0 Hrs |
| AH-64  | Main Rotor | **AVA installation for main rotor smoothing procedure**  
**AVA installation for tail rotor balancing procedure** |
| AH-64  | Tail Rotor | **AVA installation for tail rotor balancing procedure** |
| AH-64  | APU Clutch | **AVA installation for vibration check at 500 installation and phase**  
**AVA installation for main rotor smoothing and nose absorber tuning procedure**  
**AVA installation for tail rotor balancing procedure**  
**AVA installation for cabin absorber tuning procedure** |
| AH-64  | Aft Hanger Bearing | **TBO of oil cooler fan assembly from 2500 to 3240 hrs** |
| AH-64  | Fwd Hanger Bearing | **TBO of oil cooler fan assembly from 2500 to 3240 hrs** |
| UH-60  | Oil Cooler Axial Fan Bearing | **TBO of oil cooler fan assembly from 2500 to 3240 hrs** |
| UH-60  | Engine Output Drive Shaft | **AVA installation for high speed shaft balancing procedure (Replace w/Continuous Diagnostic Monitoring)** |
| UH-60  | Main Rotor, Nose Absorber | **AVA installation for main rotor smoothing and nose absorber tuning procedure** |
| UH-60  | Tail Rotor | **AVA installation for tail rotor balancing procedure** |
| UH-60  | Cabin Absorber | **AVA installation for cabin absorber tuning procedure** |
| UH-60  | Accessory Gearbox Spline Adapter | **AVA installation for high speed shaft balancing procedure (Replace w/Continuous Diagnostic Monitoring)** |
| CH-47  | Aft Transmission Fan Comb Transmission Fan | **AVA installation for 50-hour vibration check** |
| CH-47  | Main Rotor | **AVA installation for main rotor smoothing procedure** |
| CH-47  | Engines | **AVA installation for 50-hour vibration check at engine installation** |

### AH-64: 171 AC/$2.1M Efficiencies
- **1% Readiness Increase (Not in $)**
- **2,254 MMH Avoided**
- **355 Hrs Downtime Avoided (Not in $)**
- **513 Hr Reduction in Maintenance Test Flights**

### UH-60: 143 AC/$295K Efficiencies
- **3.3% Readiness Increase**
- **1,237 MMH Avoided**
- **673 Hrs Downtime Avoided**
- **148 Hrs in MTFs**

### CH-47: 30 AC/$128K Efficiencies
- **1% Readiness Increase**
- **632 MMH Avoided**
- **203 Hrs Downtime Avoided**
- **32 Hrs Reduction in MTFs**
## Direct Comparison
### DSC Equipped vs. Non-equipped UH-60 Battalions (Bns)

<table>
<thead>
<tr>
<th>30 Aircraft Per Bn</th>
<th>Non-equipped (Bn 1)</th>
<th>Non-equipped (Bn 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully Mission Capable (FMC)</td>
<td>65%</td>
<td>77%</td>
</tr>
<tr>
<td>Total Flt Hours</td>
<td>10,331</td>
<td>11,844</td>
</tr>
<tr>
<td>OPTEMPO (Hrs/Year/Acft)</td>
<td>334</td>
<td>395</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>30 Aircraft Per Bn</th>
<th>DSC Equipped (Bn 1)</th>
<th>Non-equipped (Bn 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMC</td>
<td>87%</td>
<td>82%</td>
</tr>
<tr>
<td>Total Flt Hours</td>
<td>21,819</td>
<td>20,388</td>
</tr>
<tr>
<td>OPTEMPO (Hrs/Year/Acft)</td>
<td>727</td>
<td>680</td>
</tr>
</tbody>
</table>

### Advantage of DSC Equipped Aircraft (05-06 Rotation)
- 5% Increase in FMC Gives You 1.5 More Aircraft
- 1,431 Increase in Hours Flown = 2 More Aircraft at OPTEMPO
- Units OPTEMPO Demonstrates 2 Aircraft Increase vs. 1.5 Expected

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**DSC Equipped Unit Had An Increase In Combat Power Equivalent To 2 Additional Aircraft**
Summary

• AMCOM’s Primary Focus Is Supporting the Warfighter!
• We Are Attacking Our Problems Along a Broad Front
• CBM Implementation Well Underway
• Tangible Benefits of CBM Already Demonstrated
• Data Warehouse Established and Operational – Continuing to Expand Capabilities
• Progress Has Been Made But We Have a Long Way to Go
BACKUPS
Major Phase Requirements

CBM Data Warehouse

• Phase 1 Maintenance
  – Data Analysis in Order to Make Airworthiness Decisions
  – Data Sets to Recommend Aviation Maintenance Procedural Changes
  – Hardware Maintenance and Single Sign on Capability

• Phase 2 Fleet Management
  – Component Management by Serial Number
  – Flight Regime by Individual Component
  – Fleet Health Visibility
  – Fleet Level Maintenance Issues and Actions

• Phase 3 Supply
  – Item Management by Health Instead of by Demand
  – Accurate Acquisition Planning Based on Health
  – Dollars Saved by Accurately Predicted Acquisition
Improper Spline Adapter
Found Aircraft 9426580

Notified the 82nd unit to inspect the generator spline adapter on aircraft 9426580 as soon as possible to avoid damage to the generator or the accessory module. The generator showed high vibration levels at Shaft Order 1 and Shaft Order 2. After inspection, it was found that the improper spline had been installed on the aircraft; it belonged to the APU Start Motor rather than the Generator. After changing out the spline to the correct part the vibration levels returned to normal.
### CBM-related Fieldings

#### Digital Source Collector (DSC) Equipped Aircraft

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Total # Aircraft</th>
<th>DSC Equipped</th>
<th>Percent Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH-64</td>
<td>686</td>
<td>194</td>
<td>28%</td>
</tr>
<tr>
<td>CH-47</td>
<td>452</td>
<td>41</td>
<td>9%</td>
</tr>
<tr>
<td>UH-60</td>
<td>1630</td>
<td>194</td>
<td>12%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2768</strong></td>
<td><strong>429</strong></td>
<td><strong>15%</strong></td>
</tr>
</tbody>
</table>

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#### Battalions Fielded

<table>
<thead>
<tr>
<th>Battalions Fielded</th>
<th>Total # Battalions</th>
<th>Percent Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>76</td>
<td>136</td>
<td>56%</td>
</tr>
</tbody>
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*Includes Active, Reserve, and National Guard Units

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Field 1+ Combat Aviation Brigade (CAB) A Year

3rd Infantry Div Deploying With Fully DSC-Equipped CAB