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

CBM Benefits for War Fighters

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

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

- **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

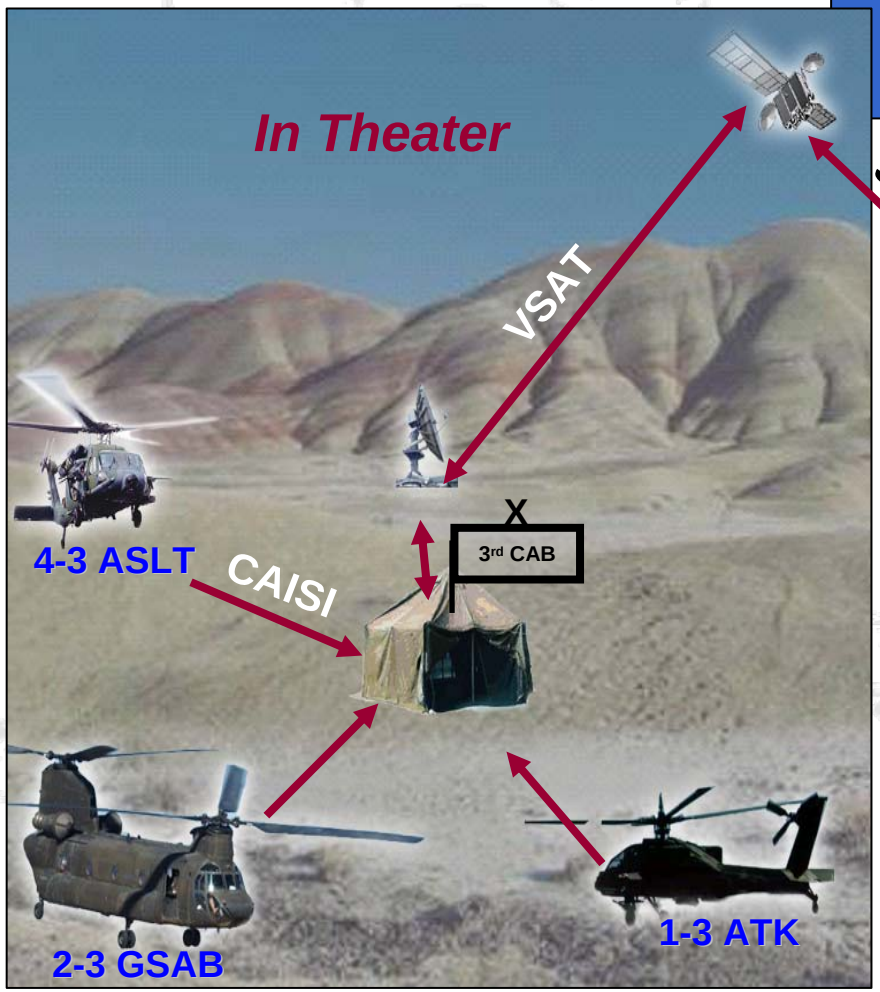
- **Reactive**
- **Time Based Overhauls / Inspections**

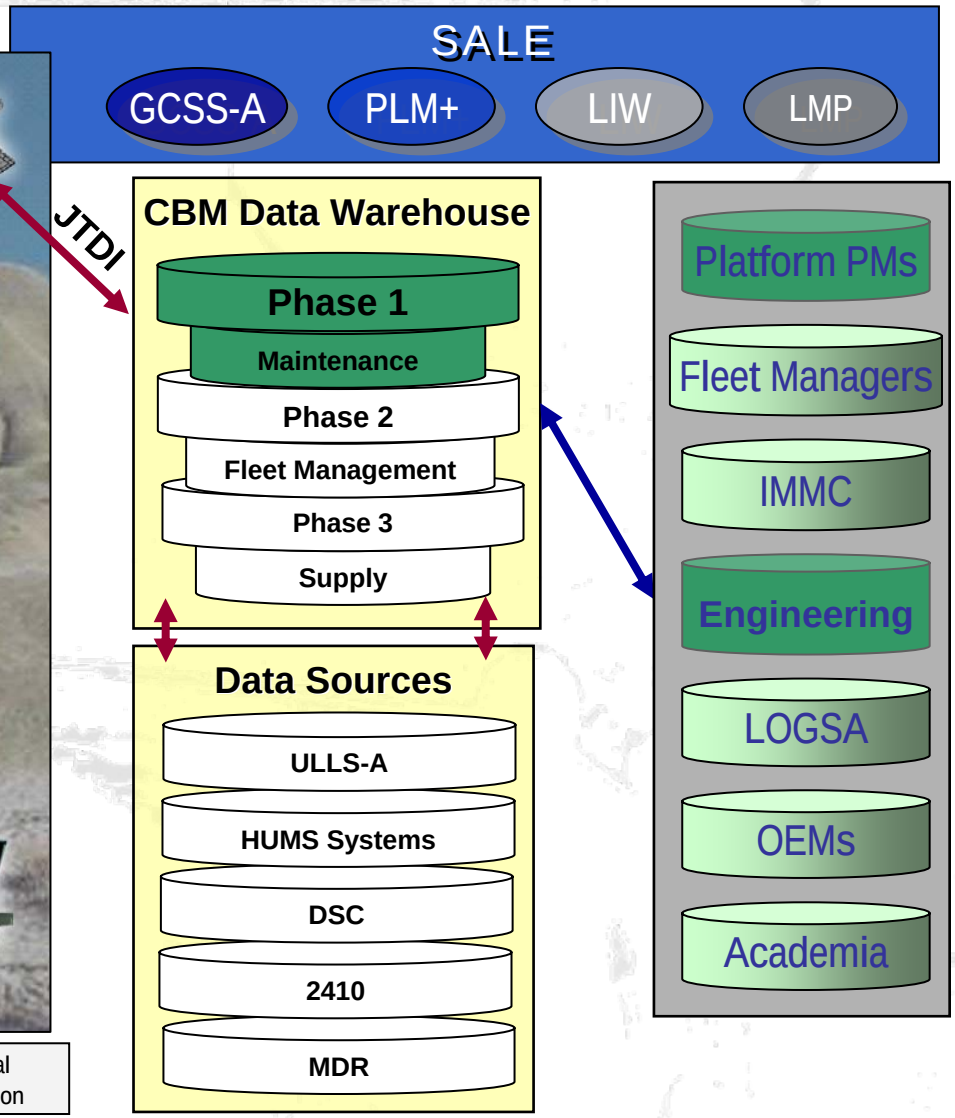
- **Inspection & Maintenance Action Interval Extension**
- **Platform Diagnostic / Prognostic Equipment Installation**

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

Aviation CBM

OIF Units Sending Standard Army STAMIS Data and HUMS Data





CAISI – Combat Service Support Automated Information System Interface	VSAT – Very Small Aperture Terminal JTDI – Joint Technical Data Integration

Dependent Components of CBM

Funding Outlays and S&T Efforts

PLATFORMS
- **HUMS**
  - **VMEP**
  - **HUMS**
  - **Future**
- **Parts**
  - **Remediation**
- **RCM**
- **"Off Systems"**

OIF/OEF
CONUS
OCONUS
OEM
Academia

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

Extract
Transform
Load

User Needs

CBM DWH
T&E
Warehousing 3
IMMC
PM Flt Mgt Sys
OEM
LOGSA
Academia

Analysis 4
Supply
Engineering
Other

Collection 1

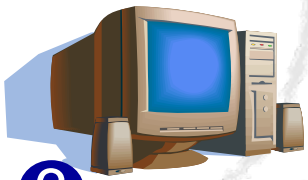
Transmission 2

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

Soldiers
Perform Immediate Maintenance Actions

3 Production Control Office
1. Plans Maintenance Activities
2. Enters Proactive Supply Actions Into STAMIS

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

Actionable Maintenance and Supply Notifications

Data Loaded Into CBM Data Warehouse

4 Data Warehouse
- Failure Analysis
- CI Development
- Flight Regimes
- Prognostics

Engineering Analysis to Determine Component Health and Remaining Life (Prognostics)

5

Program Objectives
- **Decrease Maintenance Burden**
- **Increase Platform Readiness**
- **Enhance Safety**
- **Reduce O & S Cost**

Monitored Master Parts List
AH-64 A/D - 53 Parts

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

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

Drive Shafts (#1 - #7)
Hanger Brngs (Fwd & Aft)
Intermediate GB
Drive Flange

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 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

M/R Blade
M/R Blade Tip Cap
M/R Blade Expandable Pin
M/R Blade Cuff

Tail Rotor GB
Retention Plates (2)
Gearshaft

Viscous Bearings (4)

T/R Driveshafts (7)

Vibration Absorbers (2)

Intermediate GB

Main Transmission Module
Accessory Module
Generators (2)
Hydraulic Pumps (2)
Planetary Carrier

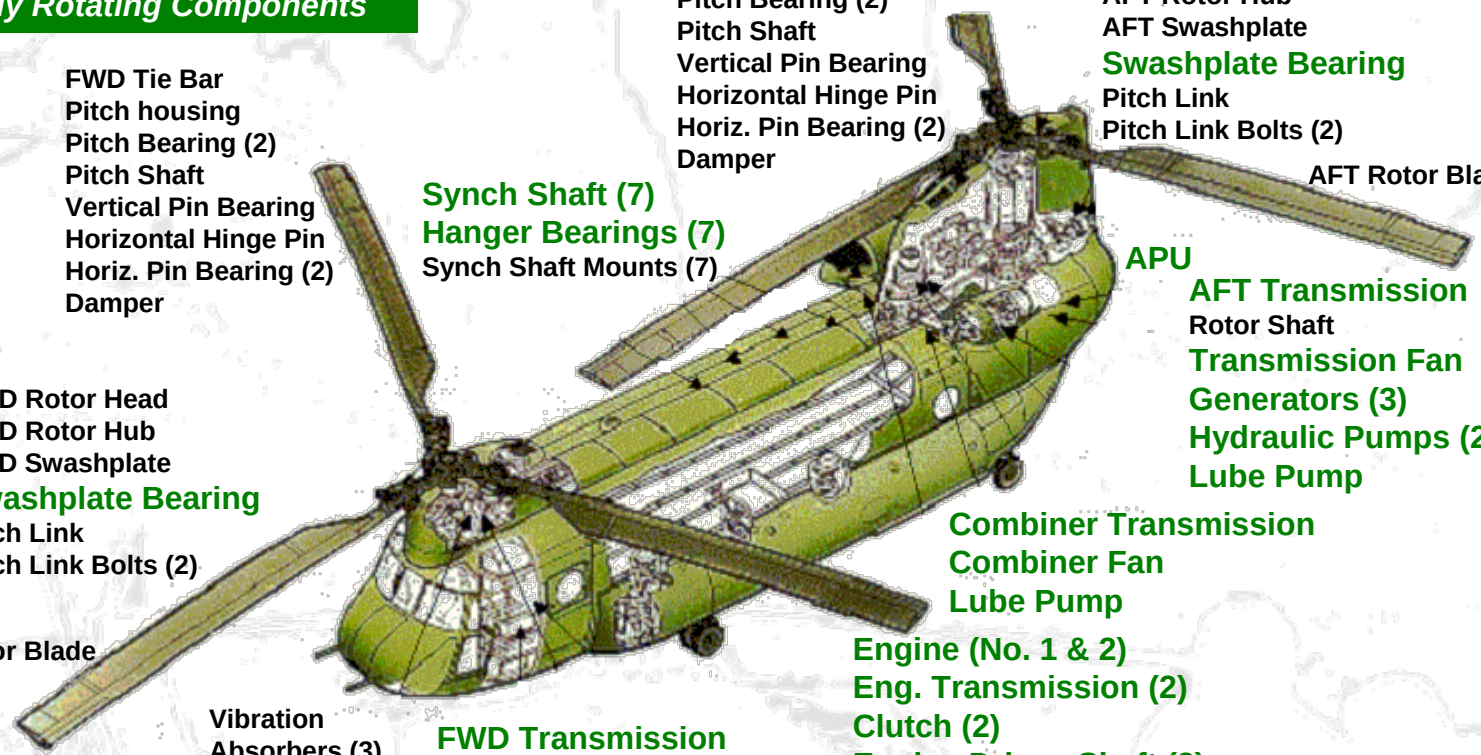
Engine (No. 1 & 2)
Driveshafts (2)
Input Modules (2)

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



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

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

AFT Rotor Blade

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

Synch Shaft (7)
Hanger Bearings (7)
Synch Shaft Mounts (7)

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

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

Combiner Transmission
Combiner Fan
Lube Pump

FWD Rotor Blade

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

Vibration Absorbers (3)

FWD Transmission
FWD Rotor Shaft
Hydraulic Pump
Lube Pumps (2)

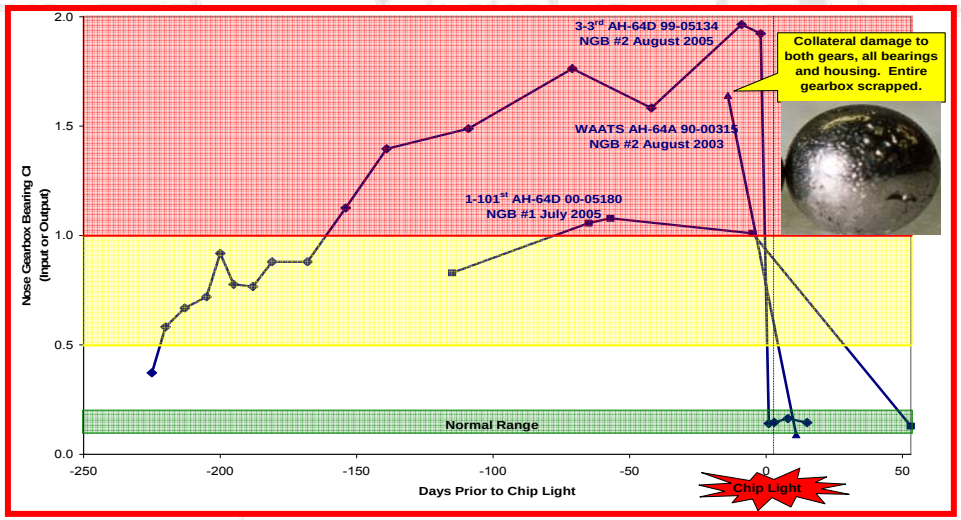
Currently Monitored by Vibration
Structural Part, Possible Addition for Monitoring in FY08

AH-64 Main Rotor Swash Plate Bearing

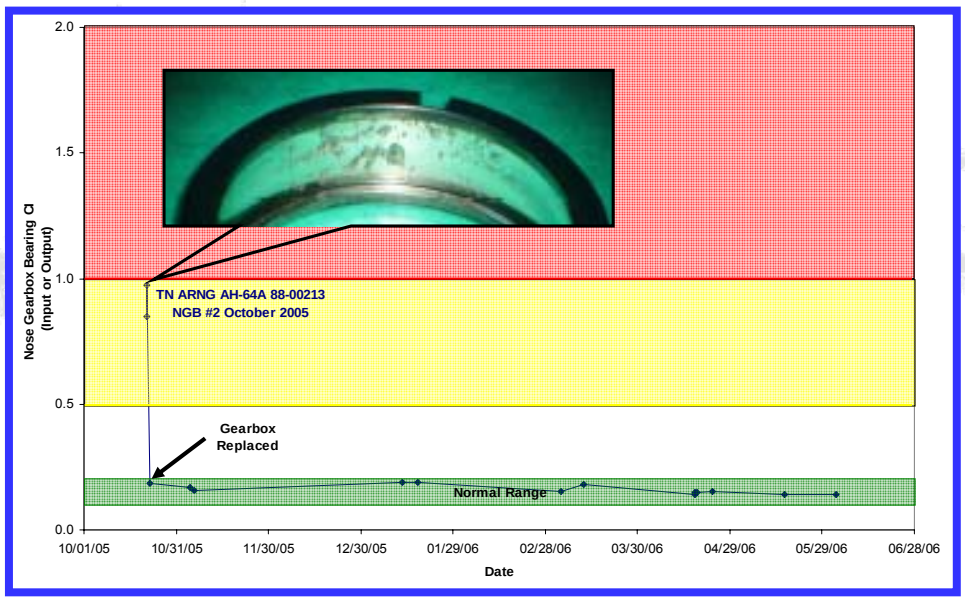
- **Unit Conducted Manual Inspection Per Technical Manual – "Checked and Found OK" Three Times**
- **Spalling, Corrosion and Broken Cage Discovered – Onboard Sensors Detected Fault, Teardown Analysis Confirmed Fault**

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)

System	Item	Action / Benefit		
		Eliminates	Extends	Saves / Improves
AH-64	M/R Swashplate	• 50 hr bearing inspection (between 1750 and 2250 hrs) • Maintenance Operational Check (approx 1 hr)		• MMH per Inspection - 7.4 hrs • Downtime Saved per Aircraft - 5.9 hrs
AH-64	Main Rotor	• AVA installation for main rotor smoothing procedure		• MMH Saved - 2.0 Hrs
AH-64	Tail Rotor	• AVA installation for tail rotor balancing procedure		• MMH Saved - 2.0 Hrs
AH-64	APU Clutch	• AVA installation for vibration check at APU installation and phase	APU mount inspection from 250 to 500 hrs	• MMH Saved per Inspection - 28 hrs • Downtime per Aircraft - 9 hrs
AH-64	Aft Hanger Bearing		TBO from 2500 to 2750 hrs	• MMH Saved per Inspection - 4.4 hrs • Downtime Saved per Aircraft - 2.2 hrs • Improves Safety w/ Continuous Diagnostic Monitoring
AH-64	Fwd Hanger Bearing		TBO from 2500 to 2750 hrs	• MMH Saved per Inspection - 4.4 hrs • Downtime Saved per Aircraft - 2.2 hrs • Improves Safety w/ Continuous Diagnostic Monitoring
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)		• MMH Saved per Inspection - 3.3 hrs. • Downtime Saved per Aircraft - 1.8 hrs
UH-60	Main Rotor, Nose Absorber	• AVA installation for main rotor smoothing and nose absorber tuning procedure		MMH Saved - 17.2 Hrs
UH-60	Tail Rotor	• AVA installation for tail rotor balancing procedure		MMH Saved - 2.0 Hrs
UH-60	Cabin Absorber	• AVA installation for cabin absorber tuning procedure		MMH Saved - 2.0 Hrs
UH-60	Accessory Gearbox Spline Adapter			Identifies potentially cracked splines reducing probability of generator, or gear damage due to adapter chips migrating into the gearbox.
CH-47	Aft Transmission Fan Comb Transmission Fan	• AVA installation for 50-hour vibration check		• MMH Saved per event - 4 hrs • Downtime Saved per event - 1.5 hrs/aircraft.
CH-47	Main Rotor	• AVA installation for main rotor smoothing procedure		MMH - 2.0 Hrs
CH-47	Engines	• AVA installation for T55 engine vibration check at engine installation		MMH - 2.0 Hrs

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)

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

03-04 OIF Rotation

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

05-06 OIF Rotation

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

Both Units Operating in OIF Under Same Command Climate

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

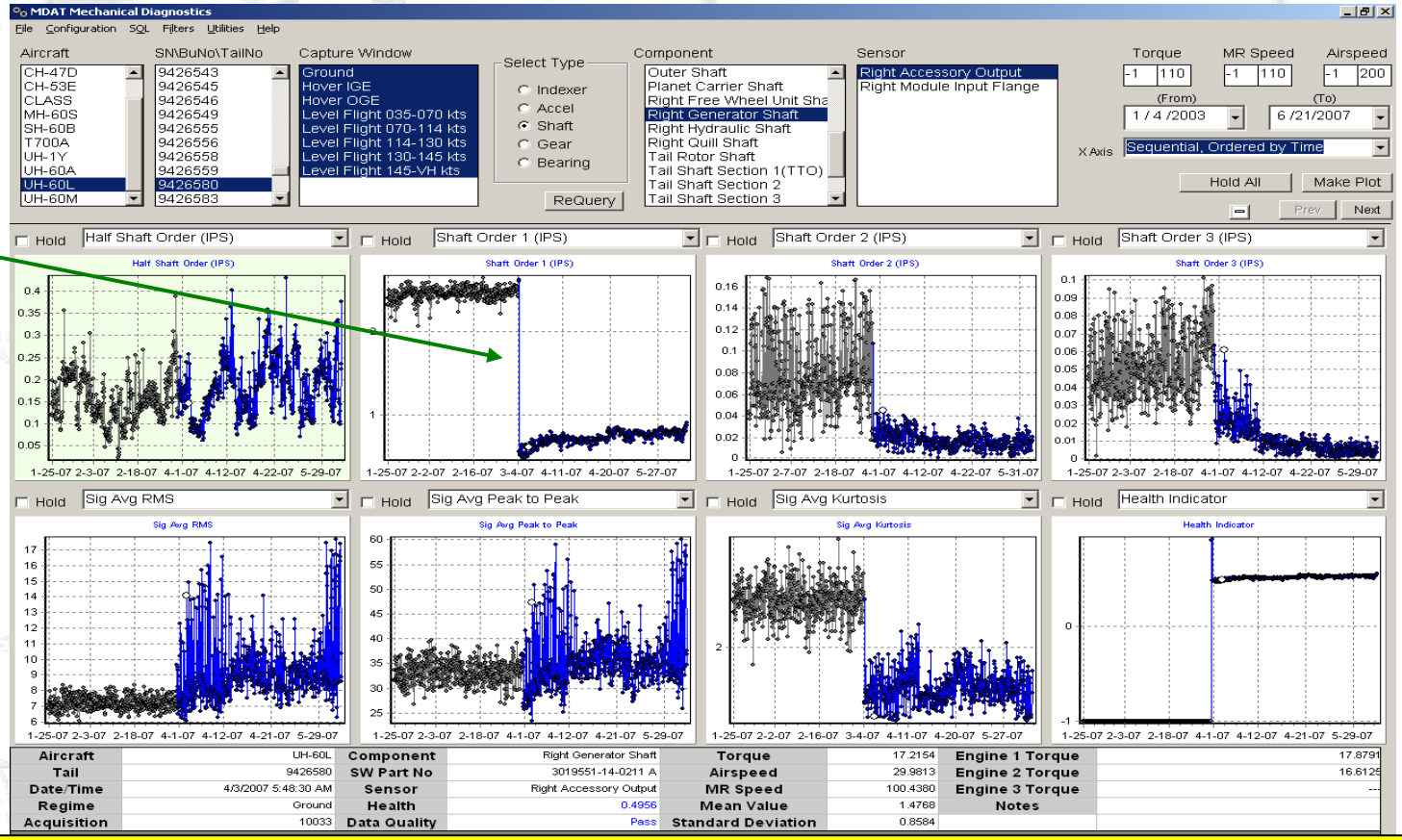
BACKUPS

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

Spline Replaced



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

3rd Infantry Div
Deploying With Fully
DSC-Equipped CAB

Digital Source Collector (DSC) Equipped Aircraft*			
Aircraft Type	**Total # Aircraft**	**DSC Equipped**	**Percent Complete**
AH-64	686	194	28%
CH-47	452	41	9%
UH-60	1630	194	12%
TOTAL	***2768***	***429***	***15%***

Battalions Fielded	**Total # Battalions**	**Percent Completed**
76	136	56%

** Includes Active, Reserve, and National Guard Units*

Field 1+ Combat Aviation Brigade (CAB) A Year