AMCOM CBM+
Program Overview

for the

DoD Maintenance Symposium

Christopher Smith
Director, Condition Based Maintenance

AMCOM CBM+

PREVENTIVE	INDICATORS	DIAGNOSTICS	PROGNOSTICS	ON-CONDITION

- Digital Source Collector Installation
- Health Monitoring Unit (HMU) Installation
- Knowledge Development

- CI / HI Development
- Flight Line Diagnostics
- Institutionalized Training

- Remaining Useful Life Calculation
- Inspection Targeting
- Mission-Based Forecasting

CBM Program Supporting ARFORGEN

CBM Program Objectives:

- Decrease Maintenance Burden on the Soldier
- Increase Platform Availability and Readiness
- Enhance Safety
- Reduce Operations & Support (O&S) Costs

Key CBM Enablers

- Digital Source Collectors
- Health Monitoring Units
- Flight Line Diagnostics
- Data Fusion/Analysis

The purpose of Army Maintenance is to generate Combat Power.

AR 750-1

Warfighter Will Not Deploy Without CBM

Enabling the Weapon System

DSC Fielding Through 7 SEP 11

Aircraft Type	Total # of Aircraft	DSC Equipped		Percent Complete	Percent Complete EOY FY11	Percent Complete EOY FY12
AH-64 A*	104	0	580	80%	81%	84%
AH-64 D	621	580				
CH-47 D	479	132	190	40%	41%	55%
CH-47 F**		0				
MH-47 G		58				
UH-60 A	2016	551	1451	72%	72%	77%
UH-60 L		525				
UH-60 M		350				
MH-60 L		15				
MH-60M		10				
MH-6	51	15		29%	29%	59%
OH-58 D	326	207		63%	64%	80%
TOTAL	**3546** [1]	**2443** EOY FY11/2459		65%	69%	75% [2]

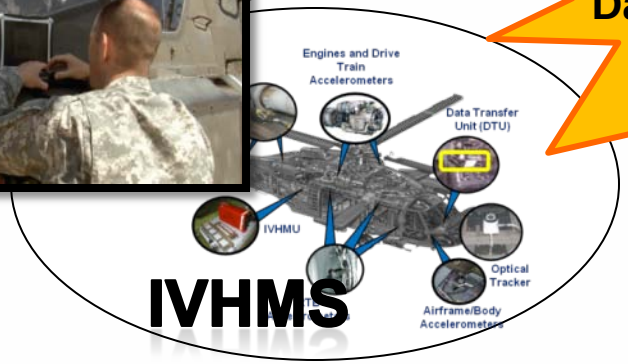
CBM Generating Combat Power

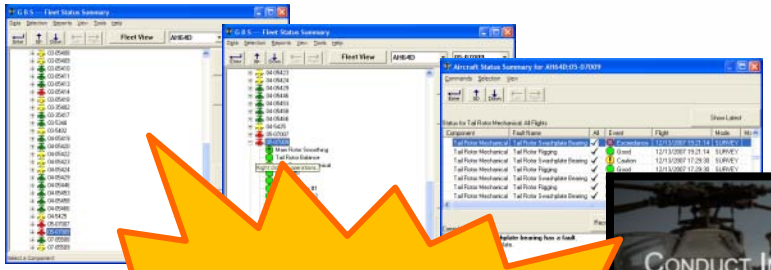
- 4-12% NMC Reduction
- 12-22% Class IX Cost Reduction
- 5-8% Increase in Readiness
- 1-4% Reduction in Maintenance Test Flight
- 1 Less Mission Abort Per 100 Flt Hrs
- Avoided 4 Class A (Major) Mishaps

For Every 20 CBM-Equipped Aircraft, Equivalent to 1 More Available for Missions

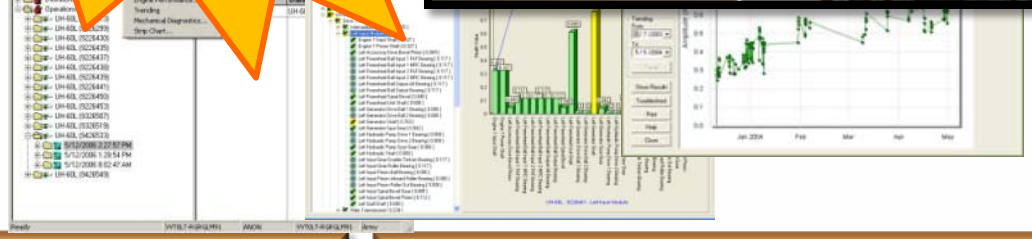
Enabling the Maintainer

Platform Data → ***Diagnostics & Decision Support*** → ***Corrective Maintenance Action***





User's Must Transmit Data in Order for CBM to be Effective

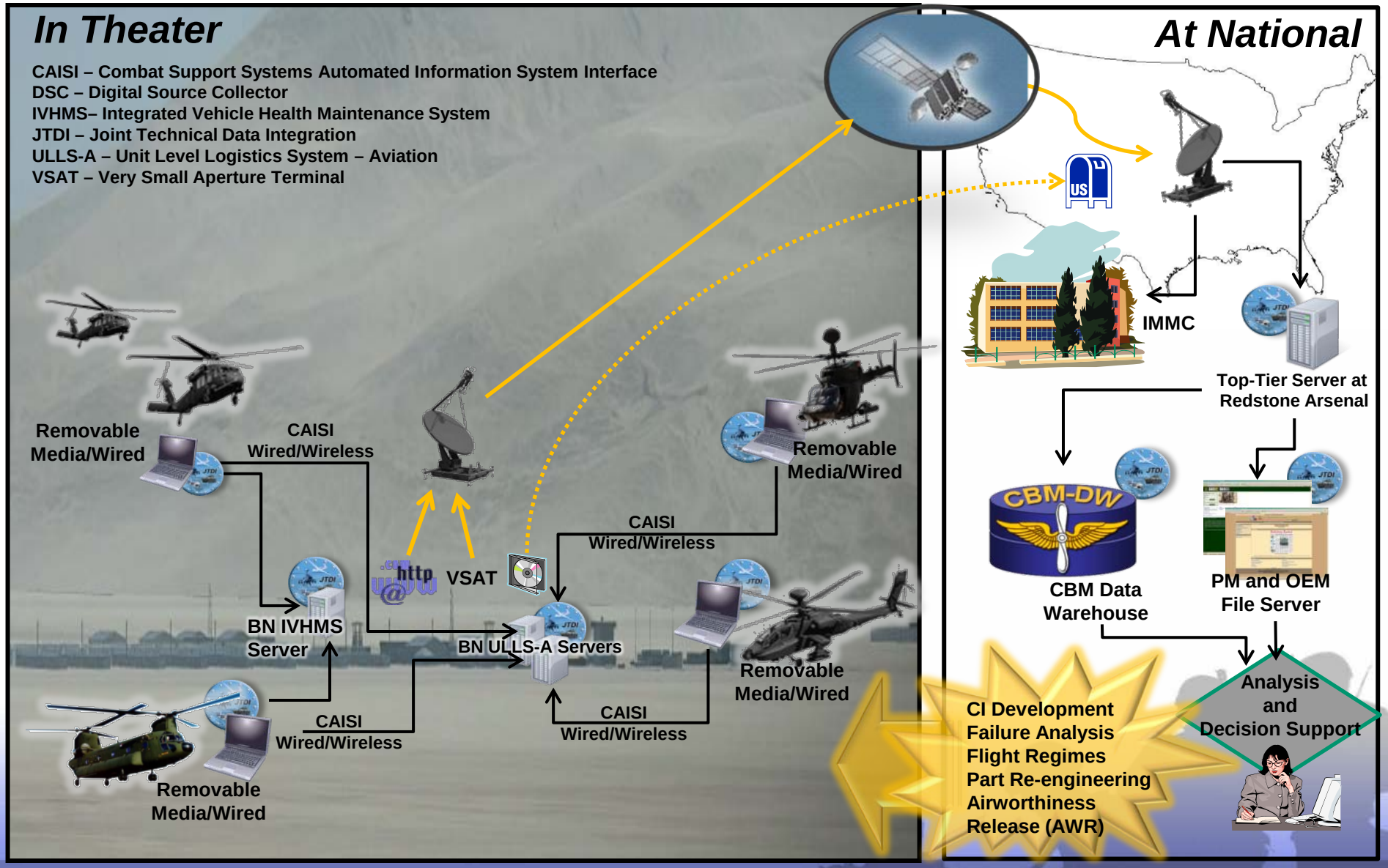


Provides Recommended Corrective Actions to Maintain Vibration Levels at a Minimum

Minimizes the Number of Dedicated Maintenance Test Flights, Aircraft Down Time, and Mission Aborts Due to Excessive Vibrations

Monitors the Status or Health of Dynamic Drive System Components and Advises When a Limit Has Been Exceeded

CBM Operational Environment



Net Centric Maintenance Process

1 Digital Source Collectors (DSC)
1. Suite of Sensors and LRU (MSPU, ECA, IV-HMS)
2. Monitor Component Health ("EKG" of Systems Health)

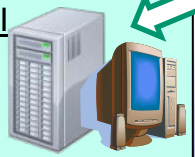
2 At Platform Work Stations
1. Transfer DSC Data & Processed Information to ULLS-A(E)
2. Immediate Action Information

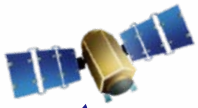
Scheduled Maintenance

Process and Display DSC/HMU Data

Preventive Maintenance

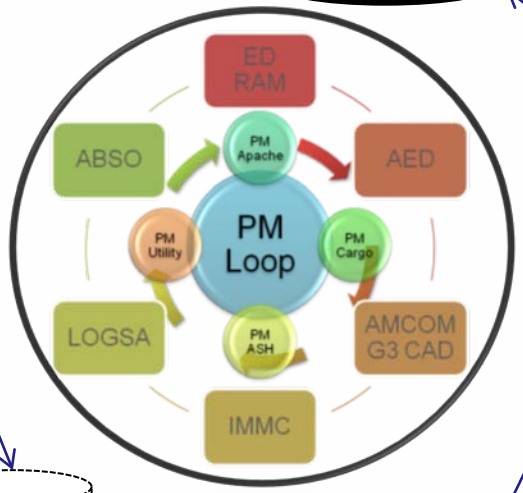
3 BN Production Control
1. Plans Maintenance Activities
2. Collates Unit Data
3. Portal Into STAMIS





VSAT

JTDI
Top Tier Server



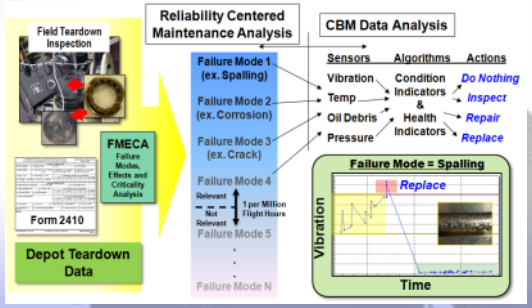
LIW

4 Data Loaded
Into CBM Data Warehouse

Flight Regimes | CI Development
Data Warehouse
Failure Analysis | Prognostics

- •IETM Updates
- •QDR Requests
- •Aircraft Watch List
- • Threshold Updates
- •Safety of Flight MSG
- •Maintenance Changes
- •Aircraft Health Status

5 Engineering Analysis
Component Health and Remaining Life

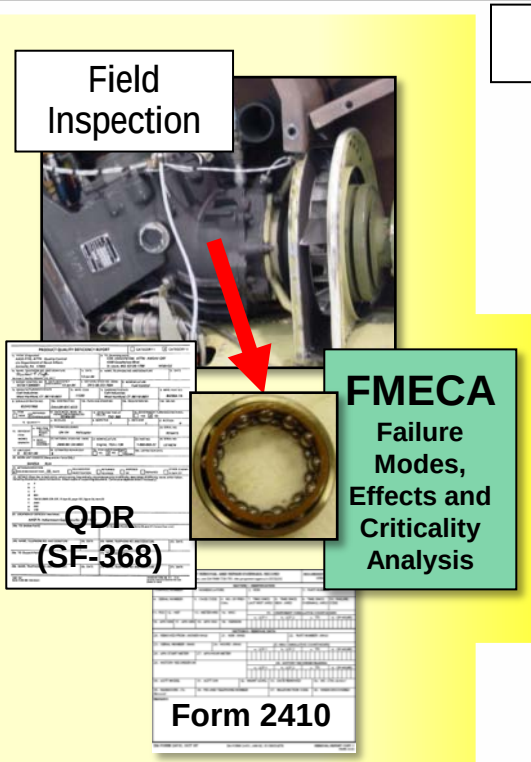


6 Actionable Maintenance & Supply Information Returned to Unit

A Net Centric Maintenance Environment Supports the Collection, Transmission, and Storage of Important Health Data to Improve Maintenance

Data Analysis Method

***Diagnostics for the Connected Maintainer: Begins with* Analyzed & Correlated Data**



RIMFIRE Depot Teardown Data

RCM Data Analysis

Failure Mode 1 (ex. Spalling)

Failure Mode 2 (ex. Corrosion)

Failure Mode 3 (ex. Crack)

Failure Mode 4

Relevant — 1 per Million Flight Hours — Not Relevant

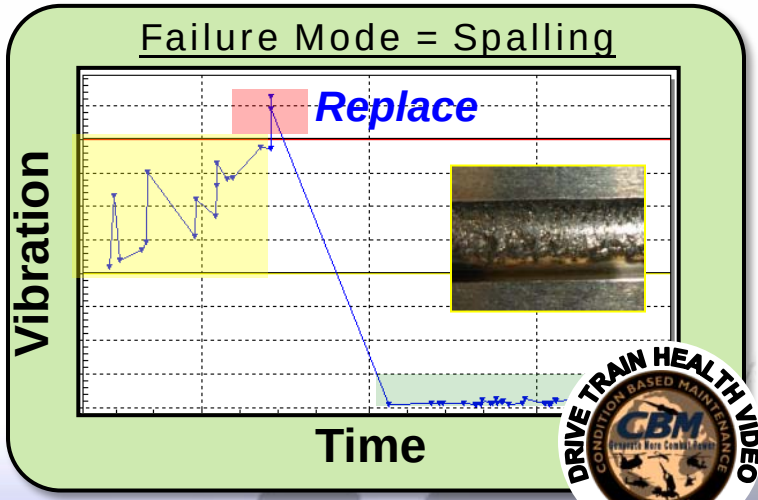
Failure Mode 5

.
.
.

Failure Mode N

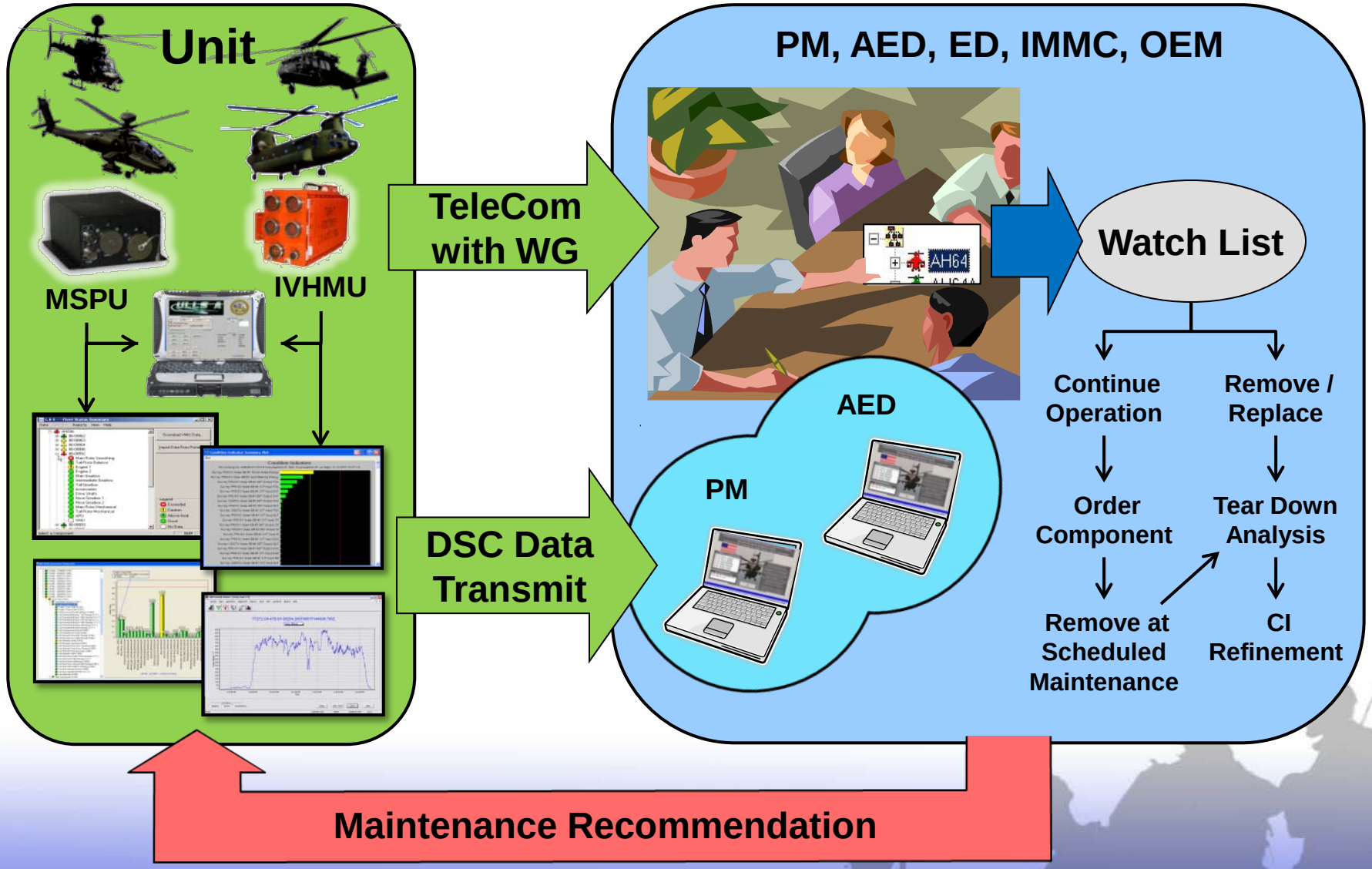
CBM Data Analysis

Sensors	Algorithms	Actions
Vibration	Condition Indicators & Health Indicators	*Do Nothing*
Temp		*Inspect*
Oil Debris		*Repair*
Pressure		*Replace*



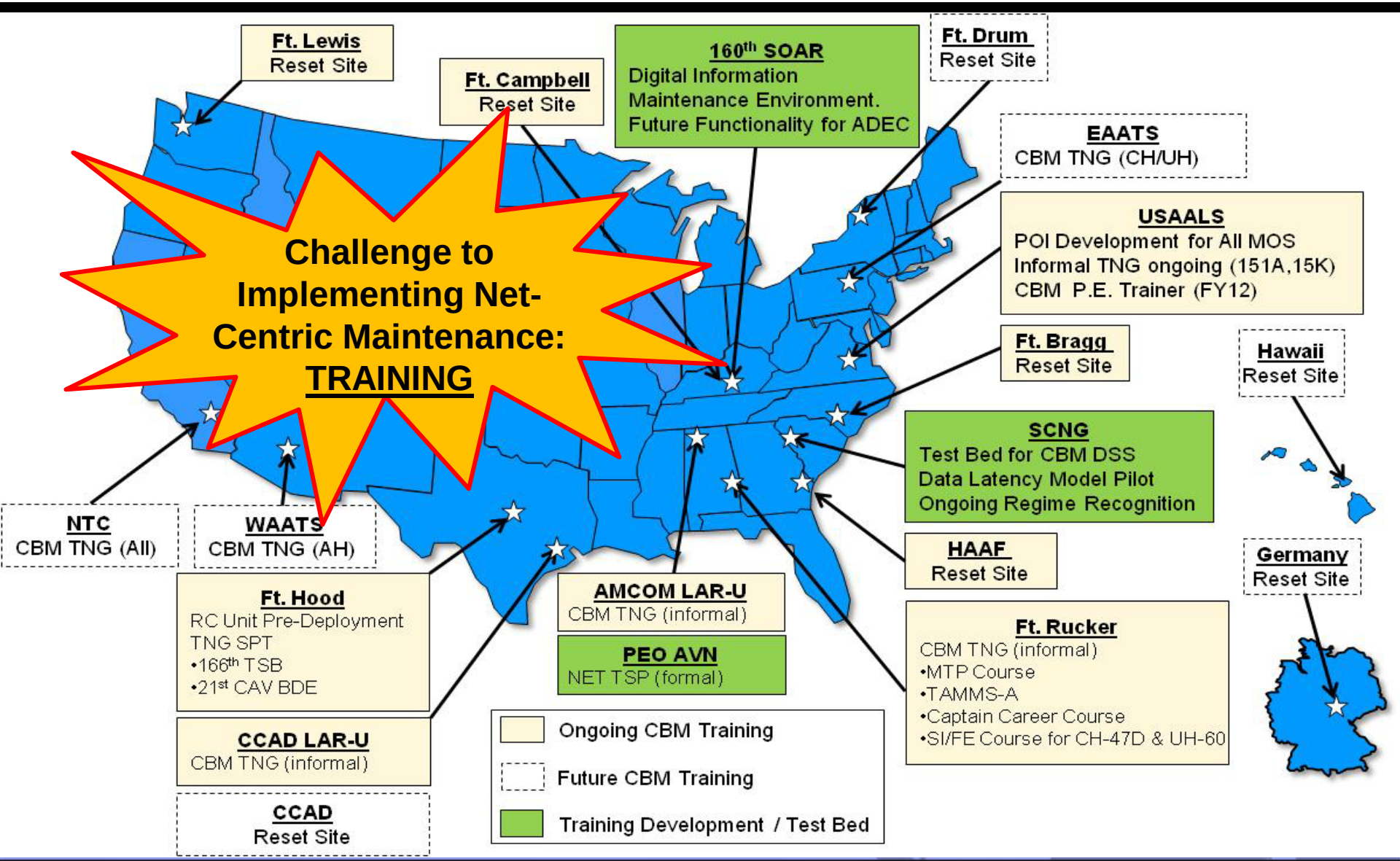
Data Analysis is Important to Develop A National Level Knowledge Foundation to Give Actionable Information to Maintainers in the Field

PM CBM Working Groups
Direct Connection: Maintainer/PM



CBM Working Groups Provides Feedback to the Unit

Implementing Tactics, Techniques & Procedures



Availability of Training will Make CBM More Useful to the Soldier in the Field

Where Are We Going

We are working to:

- Take Advantage of the CBM Momentum to Derive Solutions to Benefit the Soldier
- Facilitate Data Exchange from the Field After Each Mission Day
- Communicate with Field Maintainers
- Relate Benefits to Metrics and ROI
- Institutionalize RCM

Challenges

You Can Help By:

- Sending Data on a Regular Basis
- Calling Into PM/CBM Working Groups
- Soliciting your LAR Support to Assist with CBM Issues, Questions, or Concerns
- Point of Contact at IMMC CBM Office:

James D. Webster

jdwebster@us.army.mil

Questions

Backup

AMCOM CBM+

The purpose of Army Maintenance is to Generate Combat Power (AR 750-1)

Over 62% of the Aviation fleet (2121 of 3434 aircraft) CBM equipped.

CBM Generates Combat Power

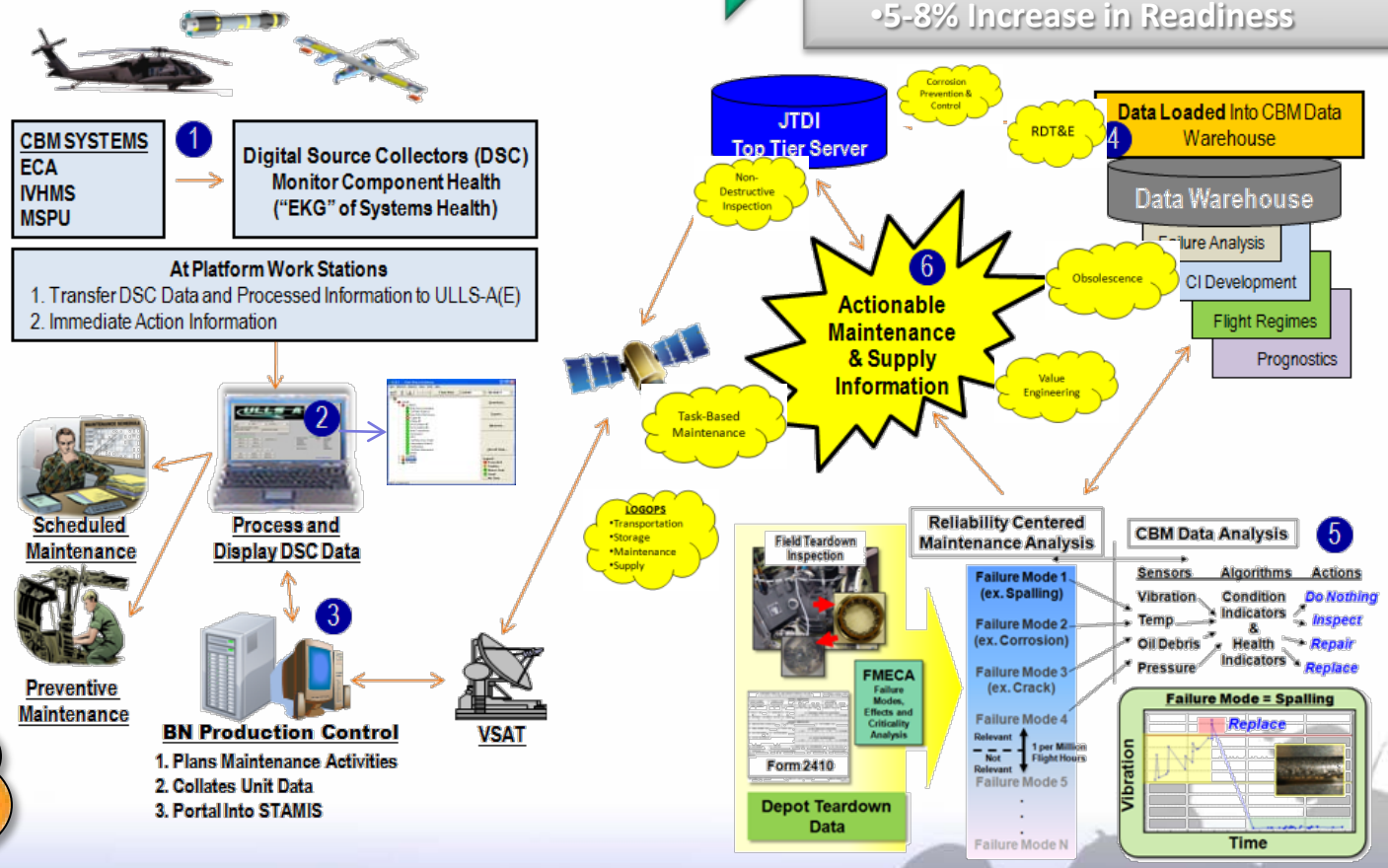
- 4-12% NMC Reduction
- 12-22% Class IX Cost Reduction
- 5-8% Increase in Readiness

Program Objectives:

- Decrease Maintenance Burden on the Soldier
- Increase Platform Availability and Readiness
- Enhance Safety
- Reduce Operations & Support (O&S) Costs

Key CBM Enablers

- Digital Source Collectors
- Flight Line Diagnostics
- Data Fusion/Analysis



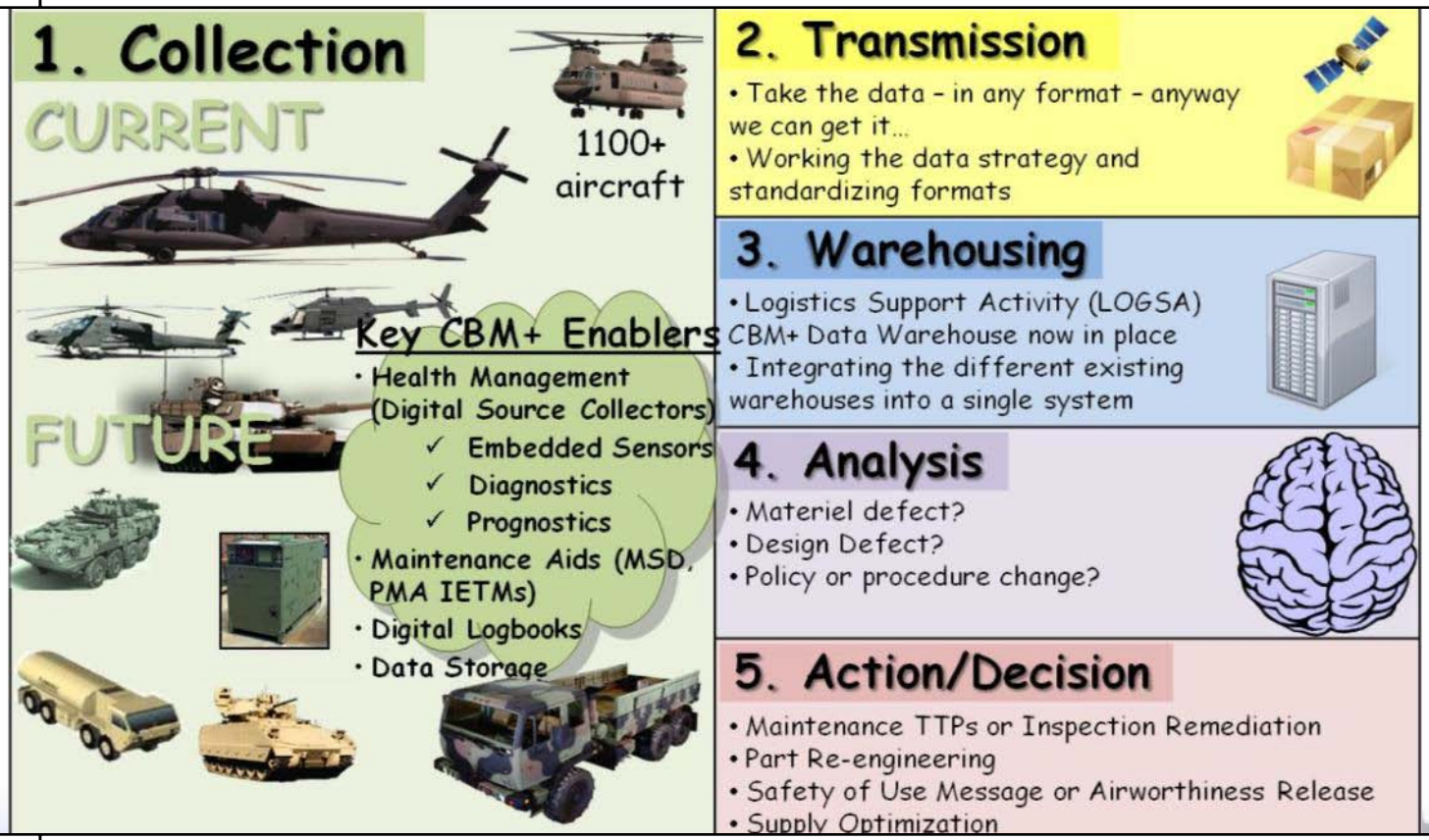
Preventive – Indicators – Diagnostics – Prognostics – On-Condition

CBM is Transforming Maintenance

Time/Process-Based – Reliability Centered Maintenance – Product Lifecycle Management – Total Life Cycle Systems Management

CBM+ Overview

Program Objectives	• Decrease Maintenance Burden on the Soldier • Increase Platform Availability and Readiness • Enhance Safety • Reduce Operations & Support Costs



Success Stories	• 4 aircraft Class A Accidents Avoided ~ $49M • 57 UH60/AH64 engines not replaced ~$27M • 6-9% decrease in aircraft maint non-avail • Reduced Operations & Support Costs • Abrams TIGER Project –1400 hours between Depot repairs, fewer new parts, less disassembly/assembly, reduced Depot time

Five CBM Domains

Direct Funding and S&T Leverage

- DSC Data
  - UH-60
  - AH-64
  - CH-47
  - OH-58
- ULLS-A (E)
- Component Historical data (2410)

OIF/OEF
CONUS
OCONUS
OEM
LCMC

Collection 1

Flight Line Decisions

- Improved diagnostics
- Maintenance actions based on component health
- Reduced MMH
- Planned maintenance
  - Unscheduled vs. Scheduled

Transmission Pipeline

- Satellite
- Fed Ex
- Mail
- NIPR

Transmission 2

Extract
Transform
Load

User Needs

CBM DWH
T&E

Warehousing 3

IMMC
PM Flt Mgt Sys
OEM
LOGSA
Academia

Analysis 4

Supply
Engineering
Other

Action/Decision 5

- Maintenance TTP
- Inspection Remediation
- Part Re-engineering
- Airworthiness Release (AWR)
- Supply Optimization

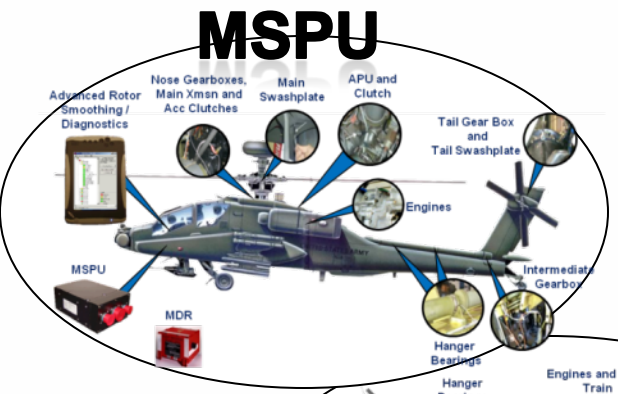
Overarching Architecture Compliance

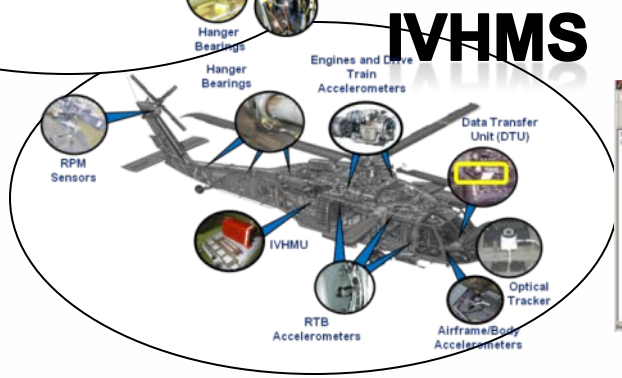
What Does it Do?

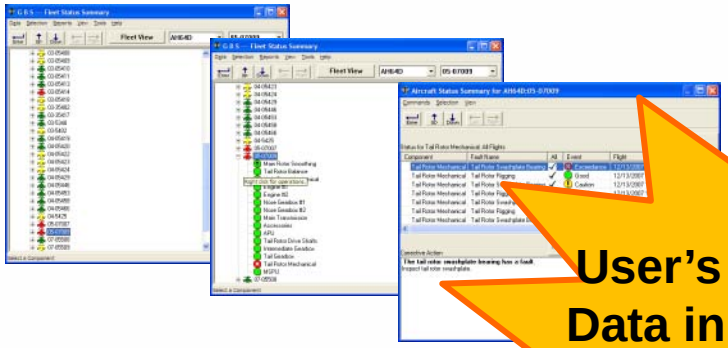
Digital Source Collector

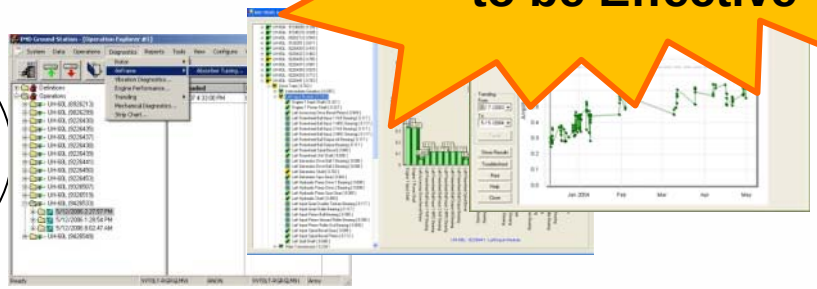
Diagnostics Decision Support

Corrective Maintenance Action









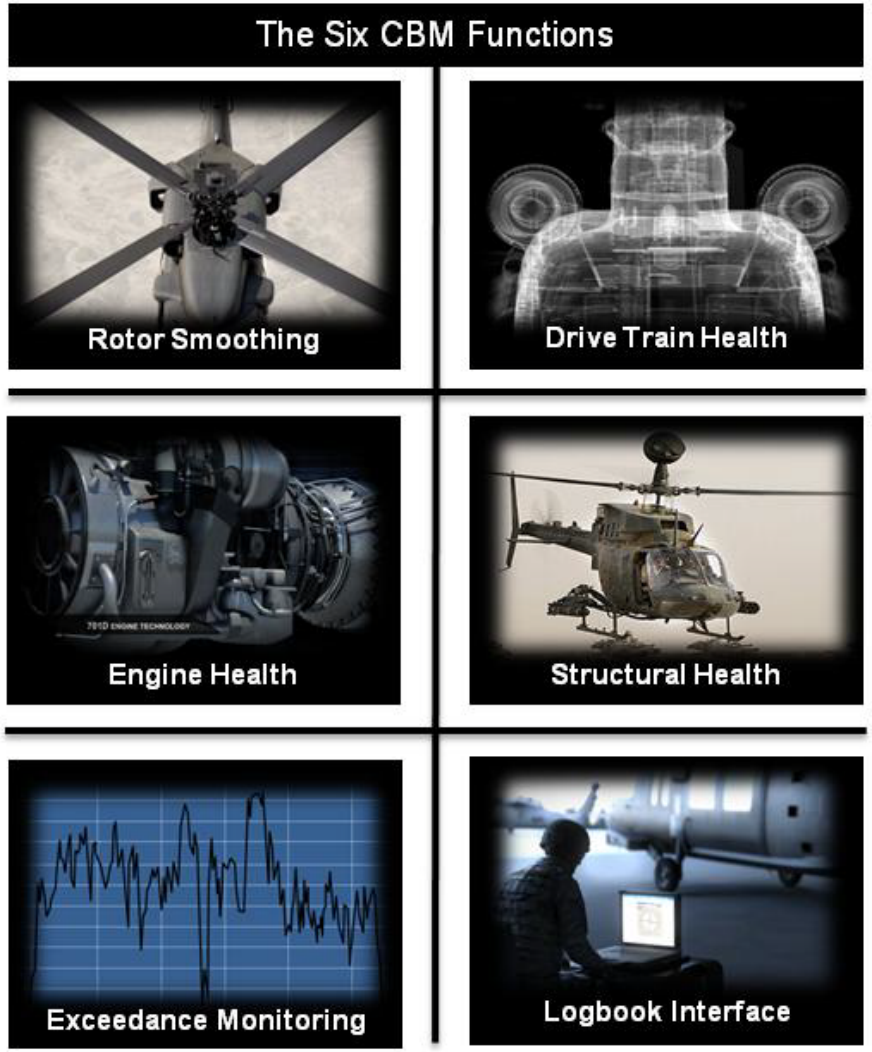
User's Must Transmit Data in Order for CBM to be Effective

Provides Recommended Corrective Actions to Maintain Vibration Levels at a Minimum

Minimizes the Number of Dedicated Maintenance Test Flights, Aircraft Down Time, and Mission Aborts Due to Excessive Vibrations

Monitors the Status or Health of Dynamic Drive System Components and Advises When a Limit Has Been Exceeded

The Six CBM Functions



1. Rotor Smoothing

Continual assessment/correction of rotor induced vibrations to ensure a smoother flying aircraft, limiting component damage and aircrew fatigue.

Reduces maintenance burden by reducing the frequency of maintenance test flights, increasing mission readiness.

2. Drive Train Health

Provides increased awareness of drive train health, increasing flight safety and aircrew confidence.

Enables more accurate maintenance management and enhancing logistics planning to always be ready for the mission.

3. Engine Health

Pre-Flight Power Assurance check utilizing engine data already recorded on the aircraft.

Increased accuracy and repeatability for mission planning, reduction in routine engine performance checks, and data trending to optimize scheduled engine maintenance.

4. Structural Health

Fatigue Life Management / Damage Fraction for component re-lifing based on actual usage and remediation to extend TM/DMWR damage limits.

5. Exceedance Monitoring

Post-flight data analysis of parametric data (vibration, torque, speed, temperature, and pressure).

Provides more accurate assessment of actual exceedance values, reducing human error.

6. Logbook Interface

Automated population of computerized forms and records, downloading CBM data to flightline analysis software.

DSC Installation

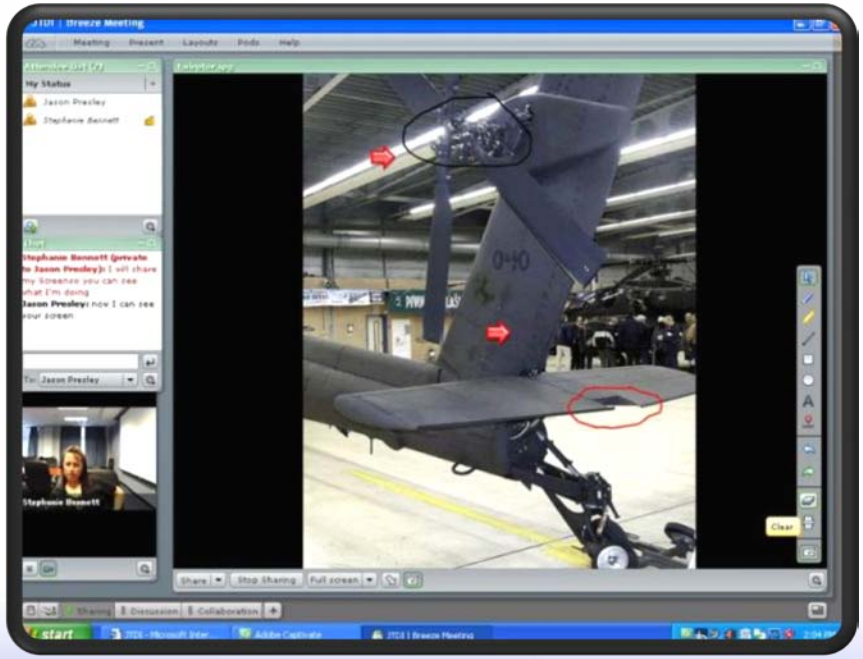
DSC Fielding Through 7 SEP 11

Aircraft Type	Total # of Aircraft	DSC Equipped		Percent Complete	Percent Complete EOY FY11	Percent Complete EOY FY12
AH-64 A*	104	0	580	80%	81%	84%
AH-64 D	621	580				
CH-47 D	479	132	190	40%	41%	55%
CH-47 F**		0				
MH-47 G		58				
UH-60 A	2016	551	1451	72%	72%	77%
UH-60 L		525				
UH-60 M		350				
MH-60 L		15				
MH-60M		10				
MH-6	51	15		29%	29%	59%
OH-58 D	326	207		63%	64%	80%
TOTAL	3546 [1]	2443 EOY FY11/2459		65%	69%	75% [2]

1 – End of Year FY11 Fleet Density
2 – 75% (2734 DSC aircraft) of total fleet based on end of year FY12 fleet inventory (3624)
* AH-64A will be equipped when modified to AH-64D Block III configuration.
** CH-47F DSC installation will begin 2013

DCO Connect Utility

- DCO Connect is a lightweight, two-way, audio-visual tool
- Enables communication with Engineering Technical Support.
- ETS personnel are able to provide maintenance assistance, helping to return the system to an operational status.



Screen shot using chat, video and white board

Screen shot using chat, and desktop sharing

Army Aviation System Impact

- 573 (92% of AH-64D Fleet) DSC Equipped
- 93 Monitored Components
- 58 Maintenance Tasks Eliminated
- 9.1% Fewer Mission Aborts / 100 Flight Hours

- 174 (52% of OH-58D Fleet) DSC Equipped
- 14 Monitored Components
- Significant MMH Reduction in RTB and Engine Vibration

- 189 (40% of C/MH-47D/G Fleet) DSC Equipped
- 163 Monitored Components
- 4.0% Reduction in Flight Hours Dedicated to MTF

- 1314 (68% of M/UH-60A/L/M Fleet) DSC Equipped
- 108 Monitored Components
- 9.2% Reduction in NMC-M
- 59 Maintenance Task Changes Increasing Aircraft Availability

For Every 20 CBM-Equipped Aircraft, Equivalent to 1 More Available for Missions

Decrease in Maintenance Cost & Soldier Burden

- Maintenance Test Flight Reduction 1-4%
- Over 127 Maintenance Procedures Improved or Eliminated

Gains in Readiness and Combat Power

- Experienced 3.8%-12.4% NMCM Reduction
- 1 Less Mission Abort Per 100 Flt Hrs
- 5-8% Increase in Readiness

Enhanced Safety

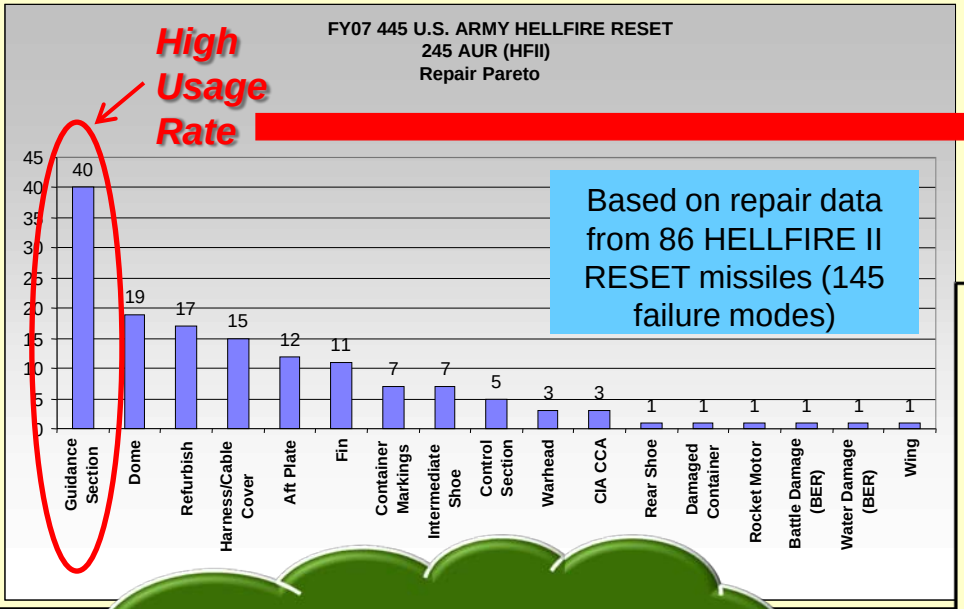
- Avoided 4 Class A (Major) Mishaps
- Predicted To Avoid 11-12 Additional Class A Mishaps Over Next 10 Years

CBM+ Generates Combat Power

Army Missile System Impact

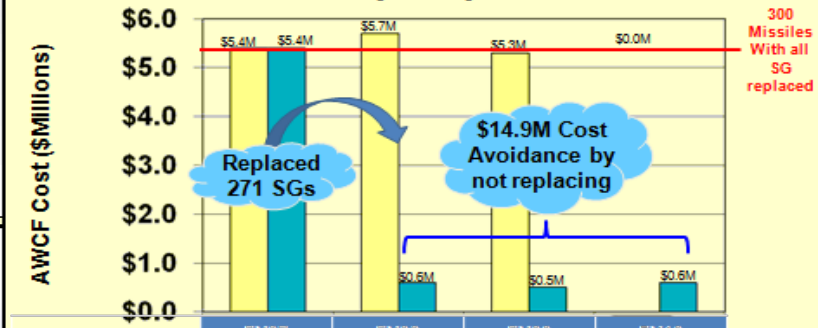
Army Missile Systems (AGM-114 Hellfire)

Pareto Plot of Defects - HFII



"Captive Carry hours impact HELLFIRE performance and drive repair and RESET activities by replacing Guidance Systems only when usage indicates.

HELLFIRE II Sensor Group Replacement



	FY07	FY08	FY09	FY10
Planned Cost	$5.4	$5.7	$5.3	$0.0
Actual Cost	$5.4	$0.6	$0.5	$0.6
Planned SG QTY	445	322	300	300
Actual SG QTY	445	86	72	79

$14.9M Cost savings over 3 years = Potential to Eliminate Many $M in Unnecessary Guidance System Replacements

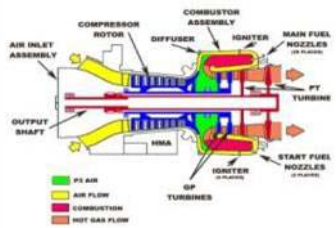
Technology Improvements

AMRDEC S&T is Working Technologies Across Entire Fleet

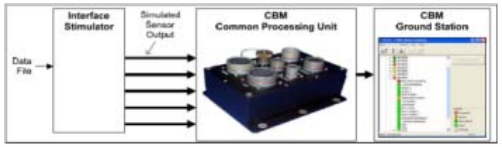
Purpose: Develop and demonstrate diagnostic, prognostic, and system health assessment technologies to enable transition to Condition Based Maintenance

Propulsion

- Continuous power assurance
- PHM for rotating components
- Power management

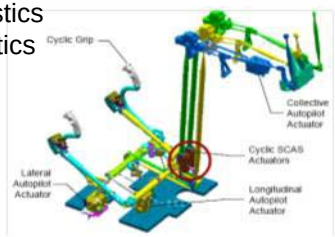


System Integration



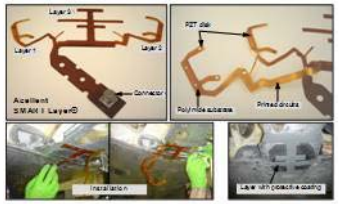
Flight Controls and Hydraulics

- Mechanical controls prognostics
- Pump and Actuator prognostics
- Hose chafing detection



Structures

- Corrosion detection
- Damage detection



Rotors & Hub Components

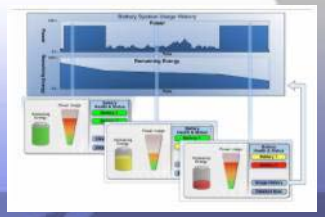
- Hub component diagnostics
- Blade damage detection
- Usage monitoring-direct load measurement
- Acoustic rotor blade delamination robot

Drive and Mechanical Systems

- Gear fault detection
- Wear detection prognostics
- Non-metallic debris monitoring
- Corrosion detection

Electrical/Electronic Systems

- Wiring prognostics/chafing
- Electrical component prognostics
- Electronic power supply prognostics



What Does the MSPU Do?

Item	Action / Benefit
Main Rotor	AVA installation for main rotor smoothing. Allows for minor adjustments without requiring MTF
Tail Rotor	Eliminates AVA installation for tail rotor balancing. Allows for minor adjustments without requiring MTF.
Main Rotor Swashplate	AWR eliminates 50 Hr bearing inspection. Eliminates Maintenance Test Flight required after 50 hr bearing inspection
APU Clutch	Eliminates AVA installation for vibration check at APU installation and phase and increases APU mount special inspection from 250 to 500
Fwd Hanger Bearing	Safety Improvement w/Continous Diagnostic Monitoring. Increase TBO from 2500 to 2750
Aft Hanger Bearing	Safety Improvement w/Continous Diagnostic Monitoring. Increase TBO from 2500 to 2750
Main Trans Primary Acc Clutch	Safety benefit: Can tell if Primary acc clutch has failed and operating on secondary clutch
Nose Gearbox	Safety and Maintenance planning benefit. Provides early warning of failure, can remove NGB prior to chip light, preventing internal damage and Precautionary Landing

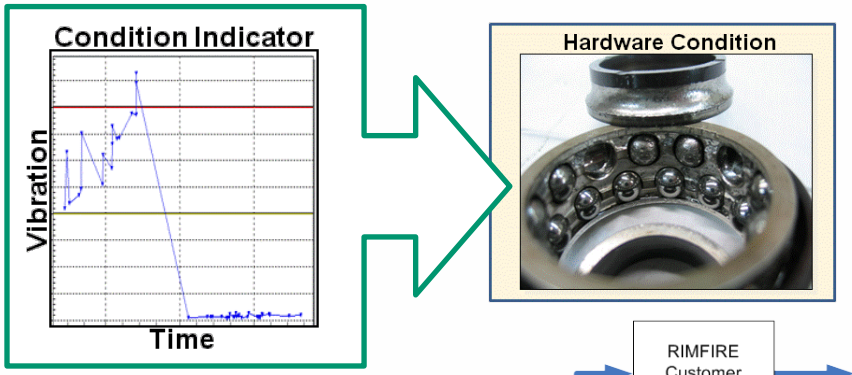
How Does IVHMS Help?

Item	Action / Benefit
Oil Cooler Axial Fan Bearing	Eliminates AVA Installation Requirement for 120 Hour Inspection. Extends TBO of oil cooler fan assembly from 2500 to 3240 hours.
Engine Output Drive Shaft	Eliminates AVA Installation Requirement for 120 Hour Inspection. Eliminates AVA installation for high speed shaft balancing procedure. Replace w/ Continuous Diagnostic Monitoring. MMH Saved per Inspection 3.3 hours. Downtime Saved per Aircraft 1.8 hours
Main Rotor, Nose Absorber	Eliminates AVA installation for main rotor smoothing and nose absorber tuning procedure. MMH Saved 17.2 Hours
Tail Rotor	Eliminates AVA Installation Requirement for 120 Hour Inspection. Eliminates AVA installation for tail rotor balancing procedure. MMH Saved 2.0 Hours
Cabin Absorber	Eliminates AVA installation for cabin absorber tuning procedure. MMH Saved 2.0 Hours
Accessory Gearbox Spline Adapter	Identifies potentially cracked splines reducing probability of generator, or gear damage due to adapter chips migrating into the gearbox.

How Does It Work?

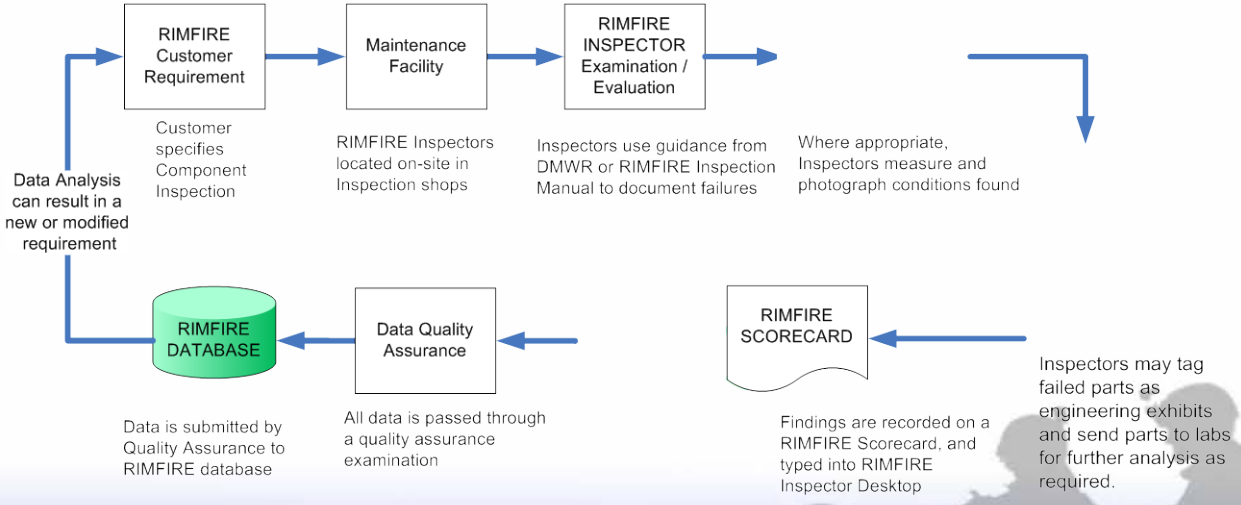
Correlate Hardware Condition to Sensor Data via RIMFIRE

RIMFIRE: Record of *Observation*



Correlation of equipment condition to indicators such as vibration sensors and metal chip detectors is necessary to improve confidence in the Health Monitoring System

RIMFIRE: Inspection Lifecycle



RIMFIRE data is utilized to Correlate Health/Condition Indicators with actual observed hardware condition

RIMFIRE identifies and tracks root removal cause, helps validate condition indicator thresholds and subsequently aids RCM in determining which components should be identified as candidates for corrective action thru CBM

How Does It Work?

Analyze & Correlate Data: Prognostics