Applying HUMS

CBM, Readiness and Safety Benefits

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Transformation

- Goals/areas of concentration that set CBM on course:
  - Goodrich
    - Automate inspections & tests
    - Opportunistic maintenance
    - Change unscheduled maintenance to scheduled
  - AMCOM
    - Reduce workload on the maintainer
    - Increase mission readiness/availability
      - Mission planning tied to maintenance

Platforms w/ Goodrich HUMS

USN\USM

V-22

CH-53E, CH-53K

SH-60B, MH-60S, MH-60R

UH-1Y, AH-1Z

COMMERCIAL

S-92

S-76D

US ARMY

UH-60A, UH-60L, UH-60M

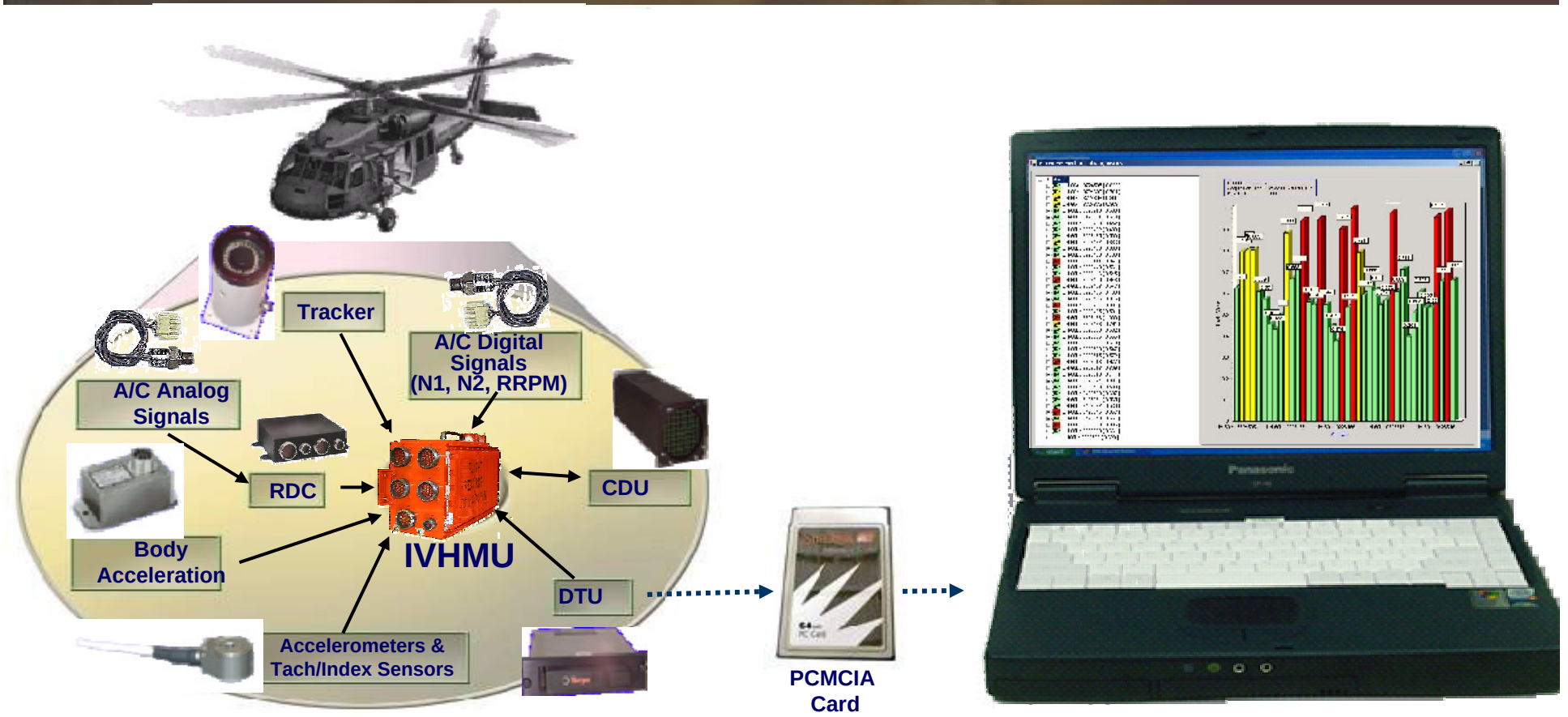
CH-47D

> 700 UH-60 & CH-47

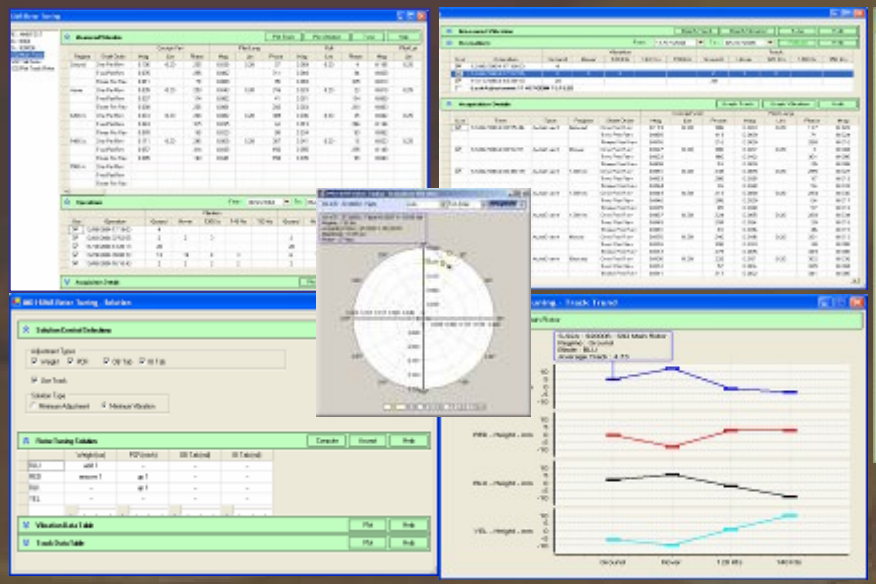
> 150,00 combat flight hours

IVHMS

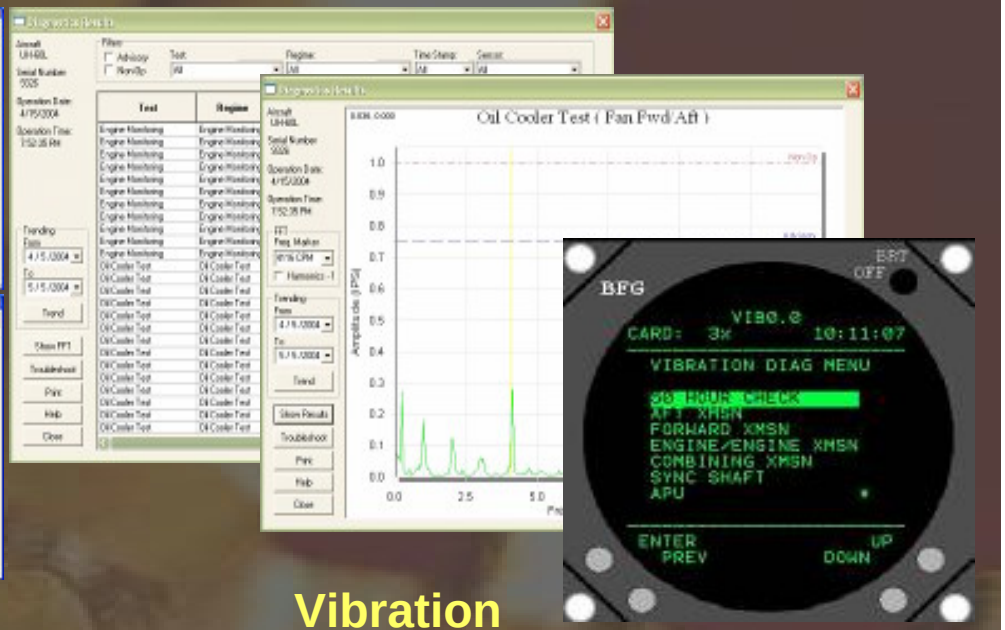
On Board System | **Ground Station System**



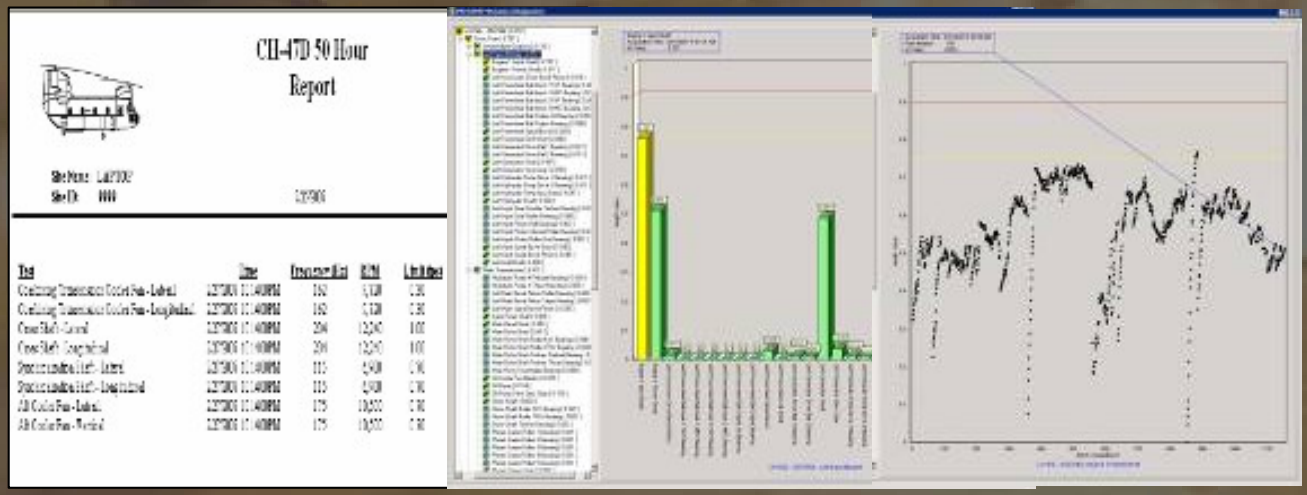
Automated Traditional Checks



MR & TR Track & Balance

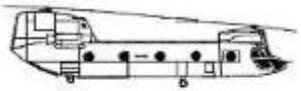


Vibration



50/120HR Vibe Checks

50/120HR Auto Checks



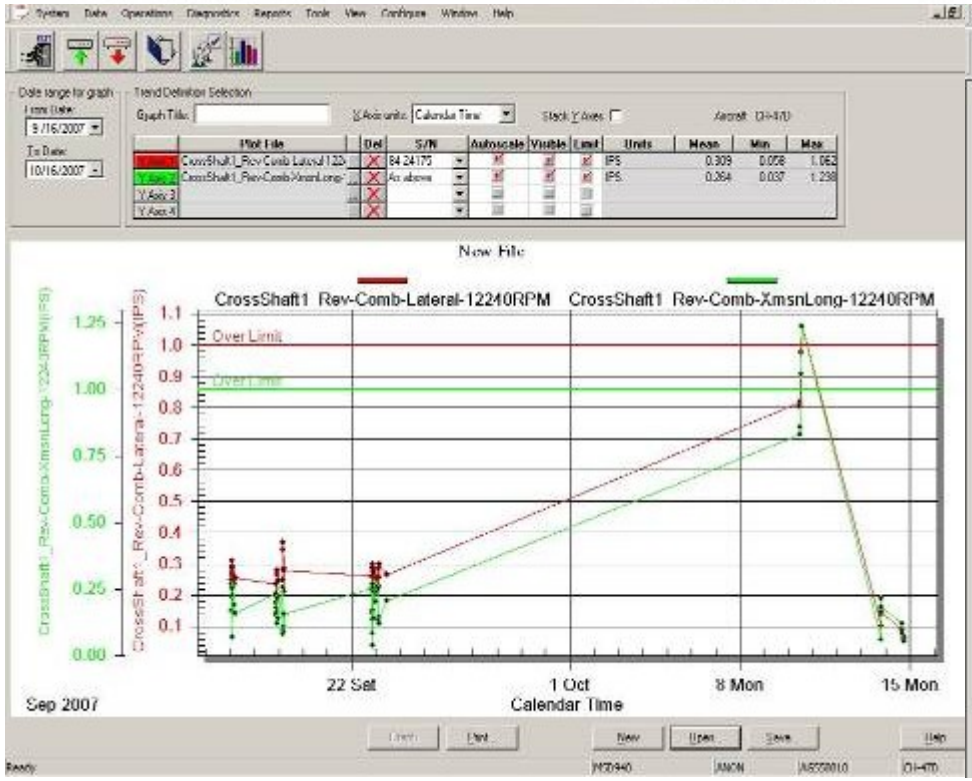
CH-47D 50 Hour Report

Site Name: AGSS0010
Site ID: 2235

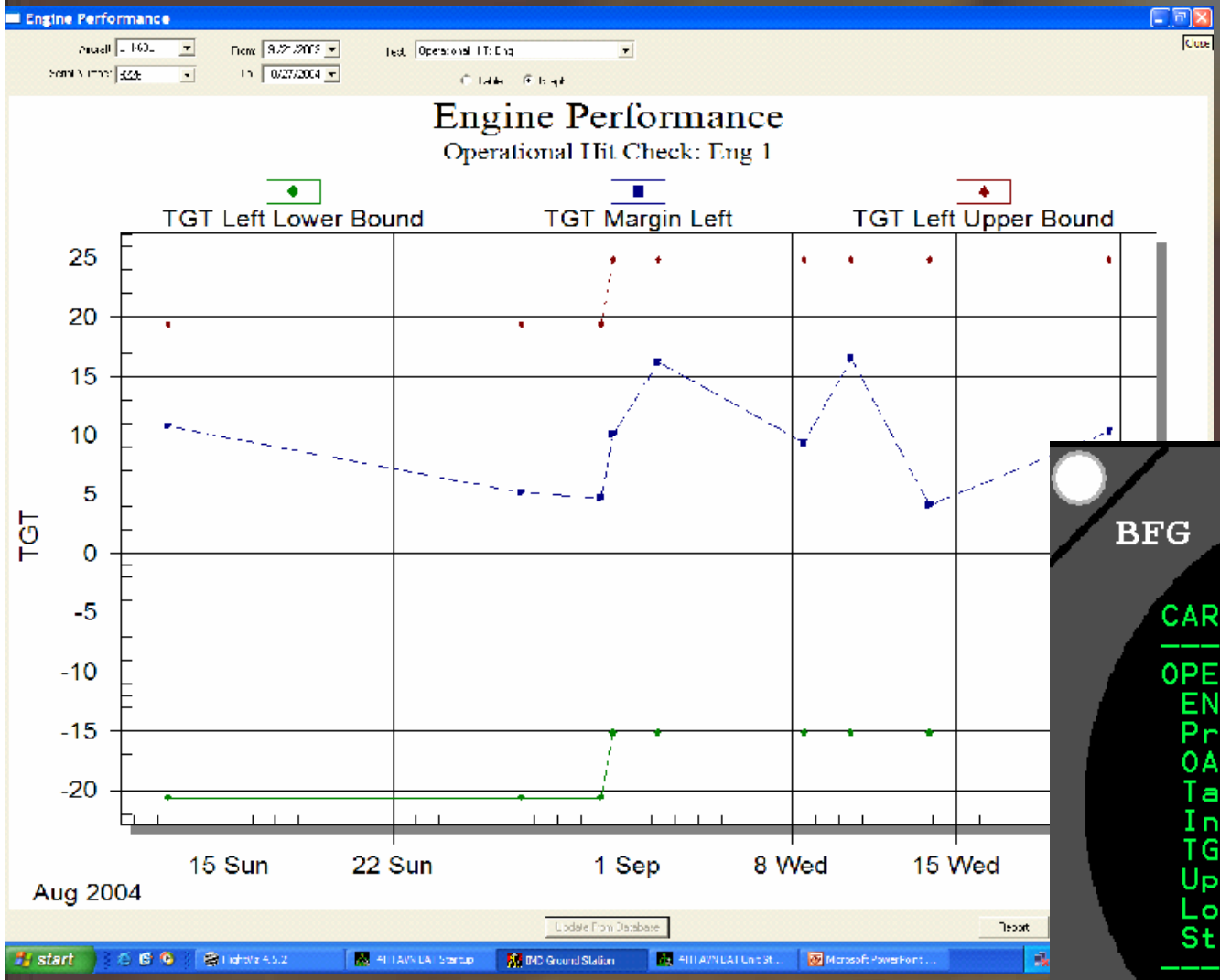
10/11/2007

A/C: CH-47D
S/N:
FROM: 10/9/2007 12:00:00AM
TO: 10/10/2007 11:59:59PM

Test	Time	Frequency (Hz)	RPM	Limit (ips)	Measured Vib (ips)	Pass/Fail
Combining Transmission Cooler Fan - Lateral	10/10/2007 12:53:00PM	162	9,720	0.30	0.06	PASS
Combining Transmission Cooler Fan - Longitudinal	10/10/2007 12:53:00PM	162	9,720	0.30	0.11	PASS
Cross Shaft - Lateral	10/10/2007 12:53:00PM	204	12,240	1.00	1.06	FAIL
Cross Shaft - Longitudinal	10/10/2007 12:53:00PM	204	12,240	1.00	1.24	FAIL
Synchronization Shaft - Lateral	10/10/2007 12:53:00PM	115	6,900	0.70	0.54	PASS
Synchronization Shaft - Longitudinal	10/10/2007 12:53:00PM	115	6,900	0.70	0.12	PASS
Aft Cooler Fan - Lateral	10/10/2007 12:53:00PM	175	10,500	0.70	0.24	PASS
Aft Cooler Fan - Vertical	10/10/2007 12:53:00PM	175	10,500	0.70	0.21	PASS

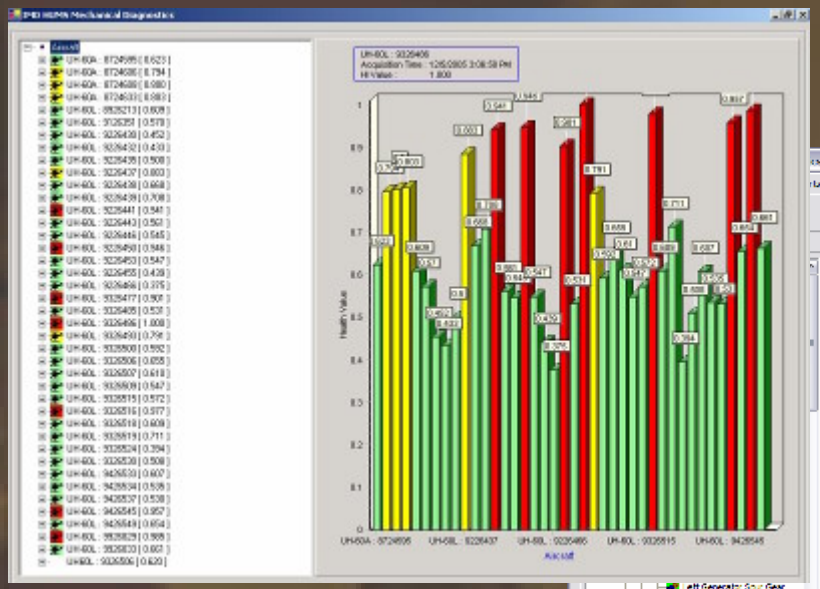


Semi-Automated Engine Power Assurance

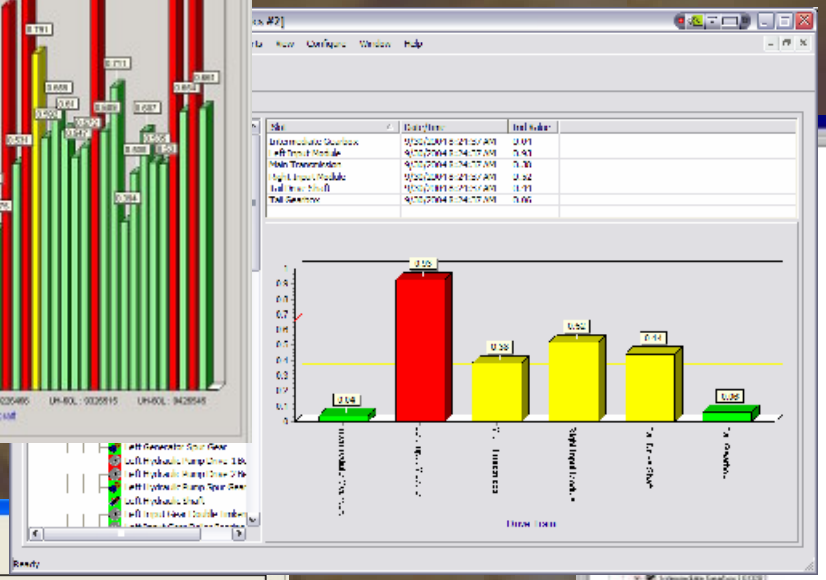


Advanced Mechanical Diagnostics

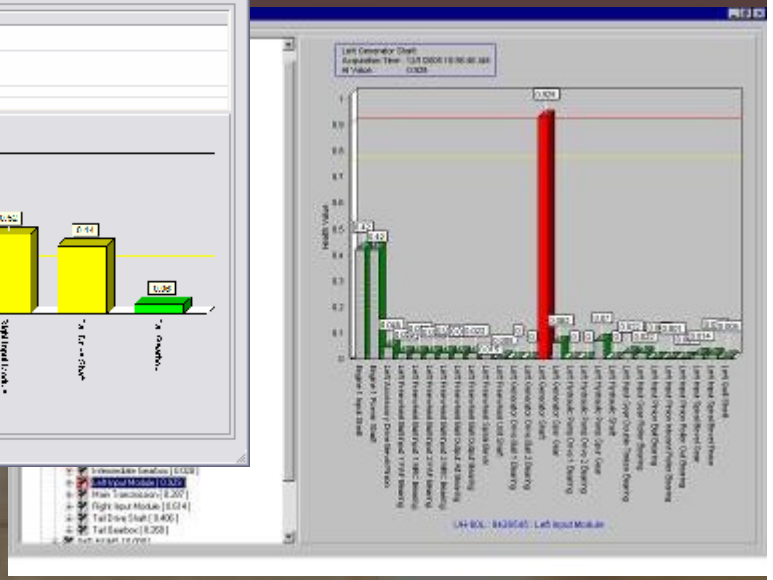
Fleet



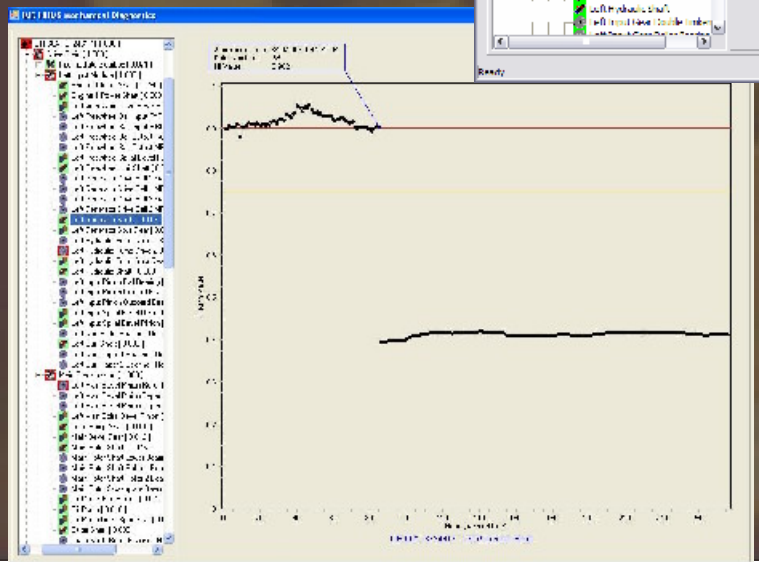
Aircraft



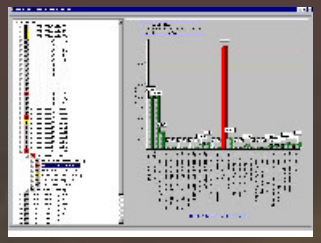
Main Component



Sub-Component



Opportunistic HI/Maintenance Removal



Unit Bearing, Gear & Shaft HI Review

Or

Other detection

(AOAP, Visual)

Evaluate/Adjust HI Thresholds

Verify Damage & Match Severity to HIs

CBM WG Evaluate and make recommendation

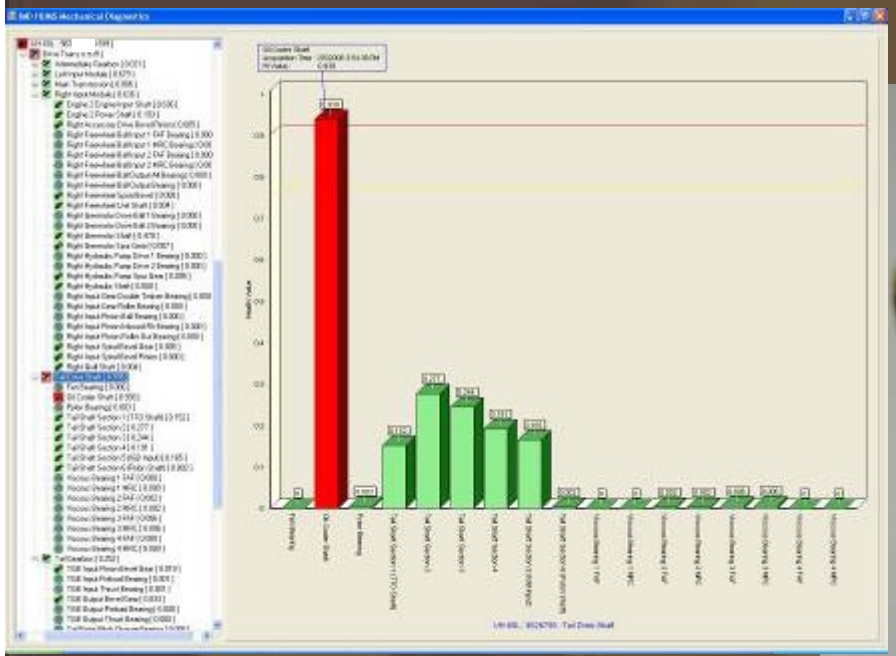
CAT 1 QDR

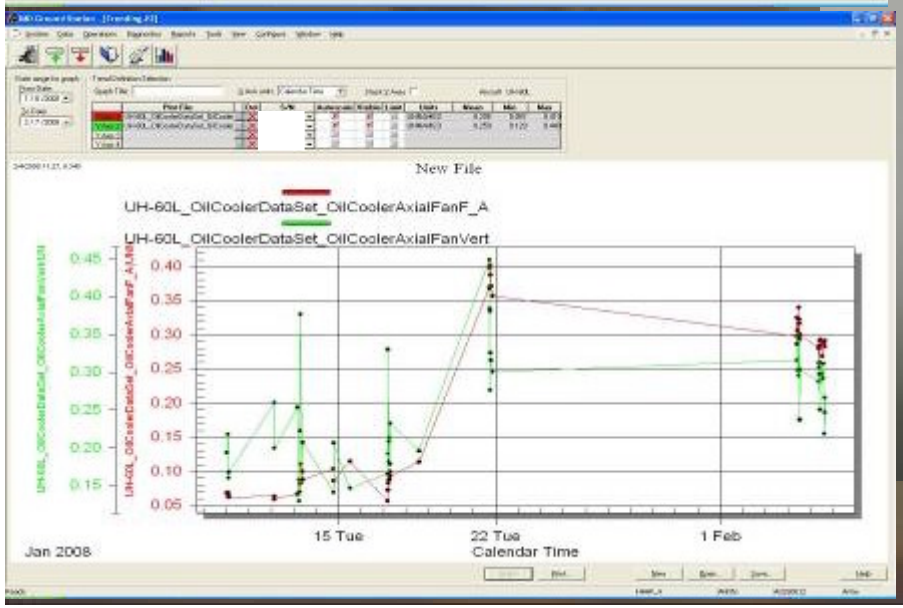
QDR Paperwork Completed & Part Shipped to AED for Teardown Inspection and/or Test Stand Runs

Unit Decides & Schedules Removal

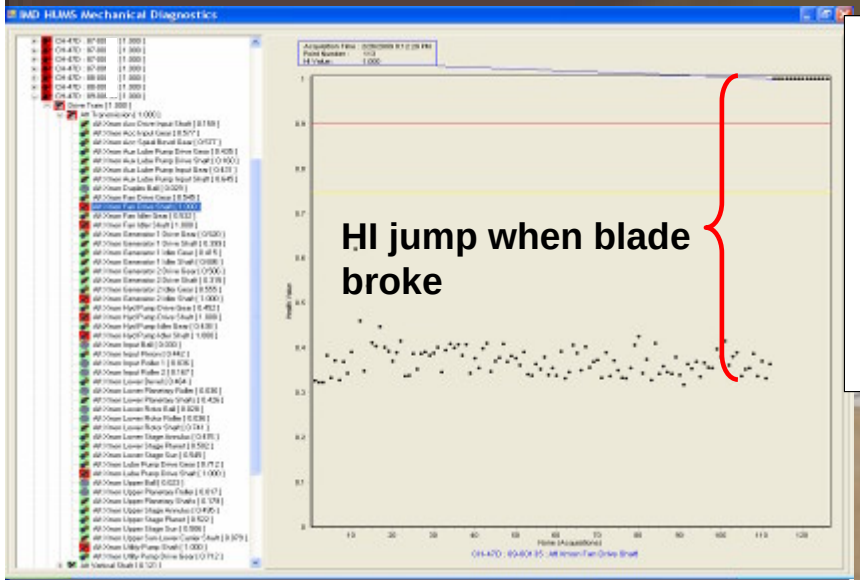
Part Removed during Scheduled Maintenance

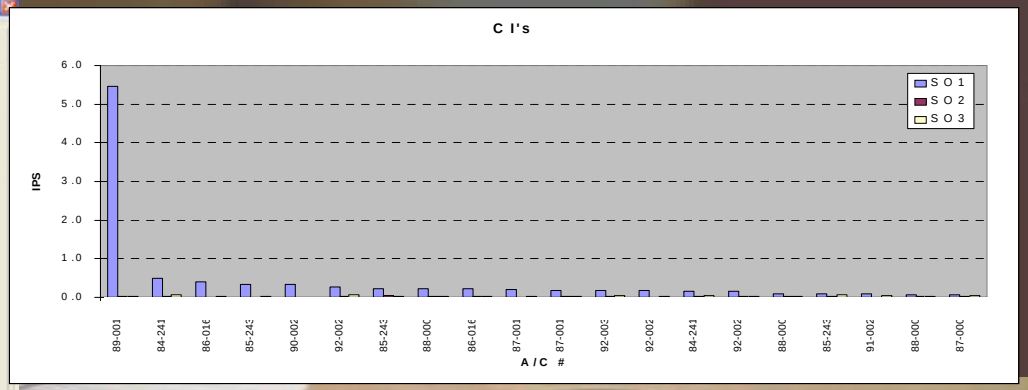
Opportunistic Maintenance

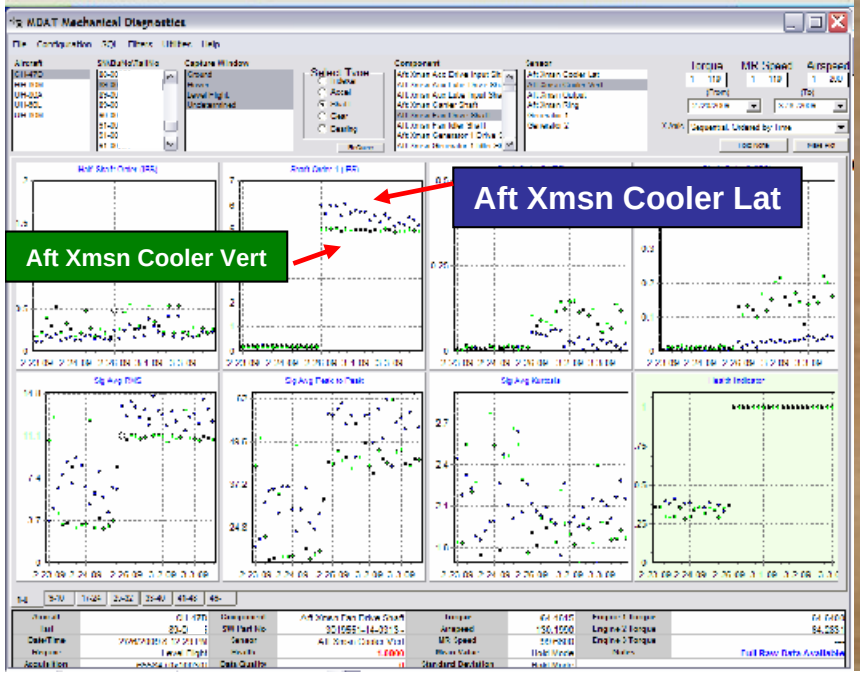




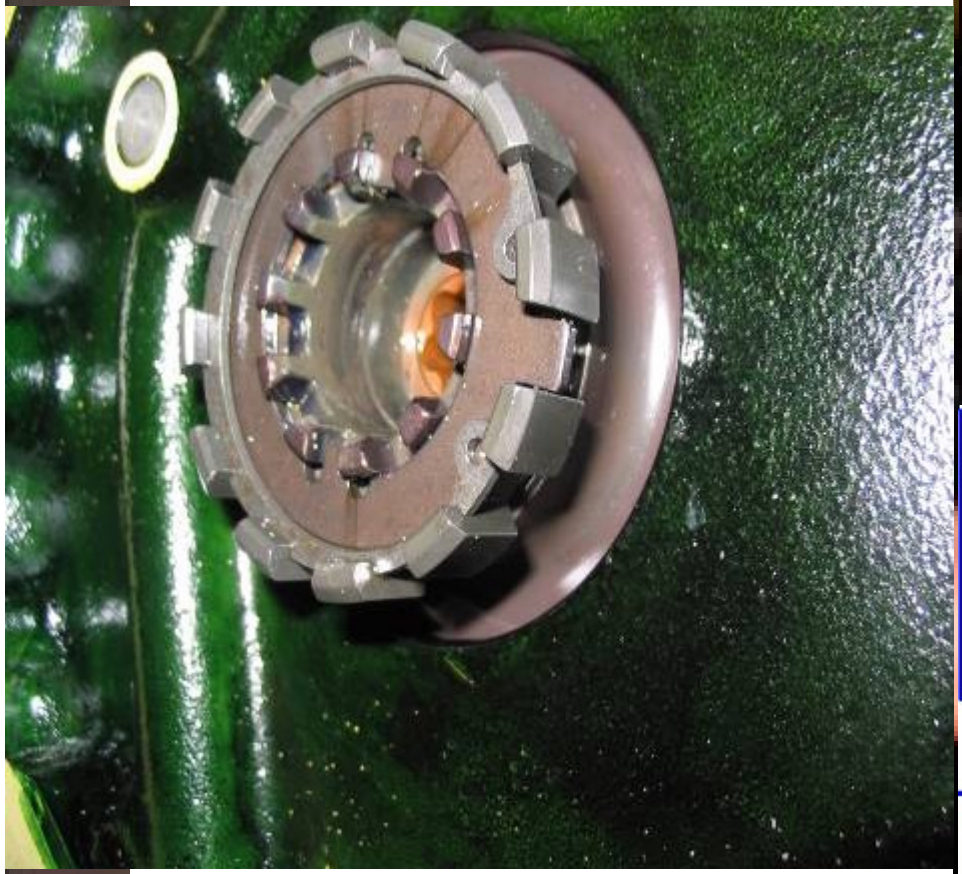
Opportunistic Maintenance

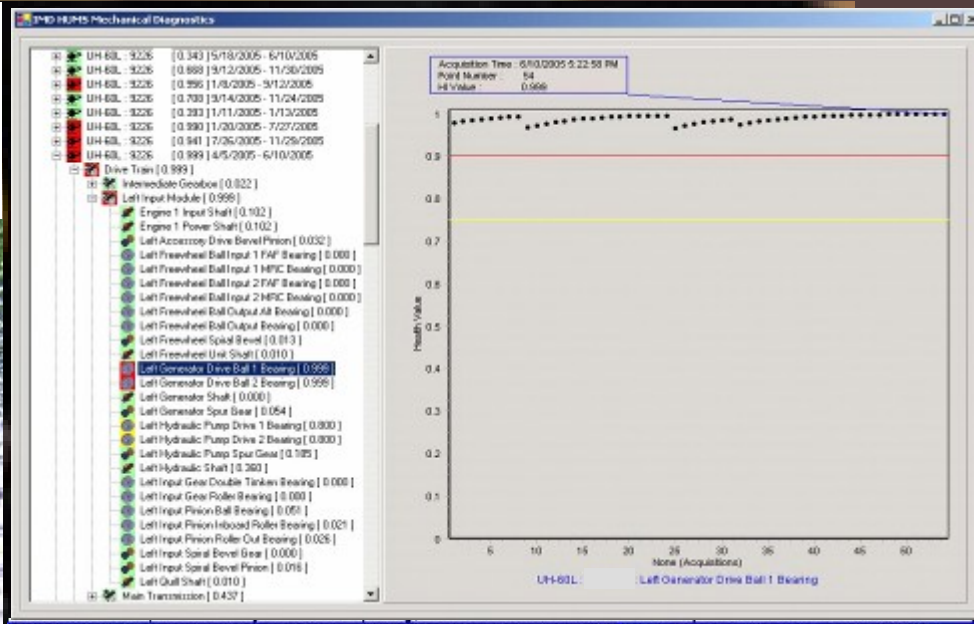




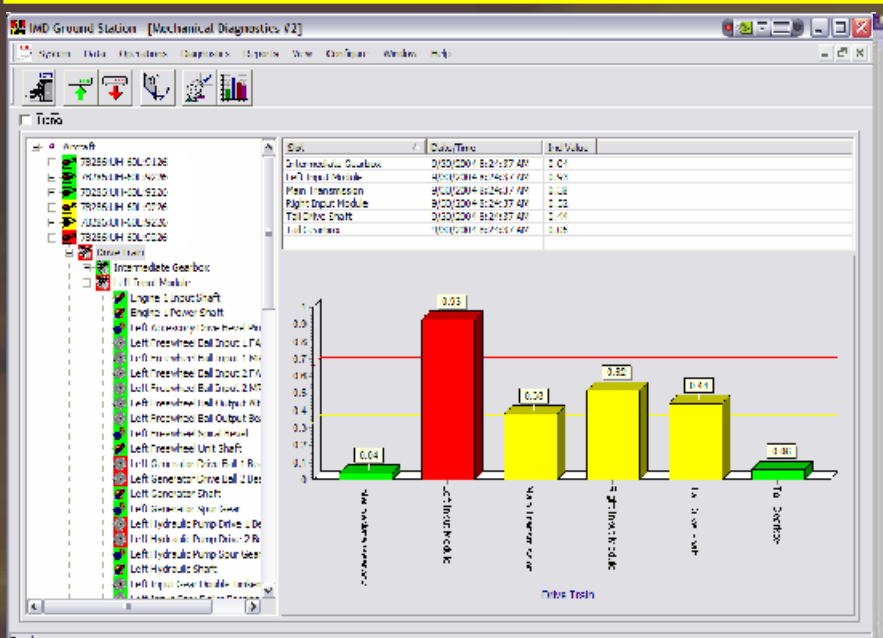


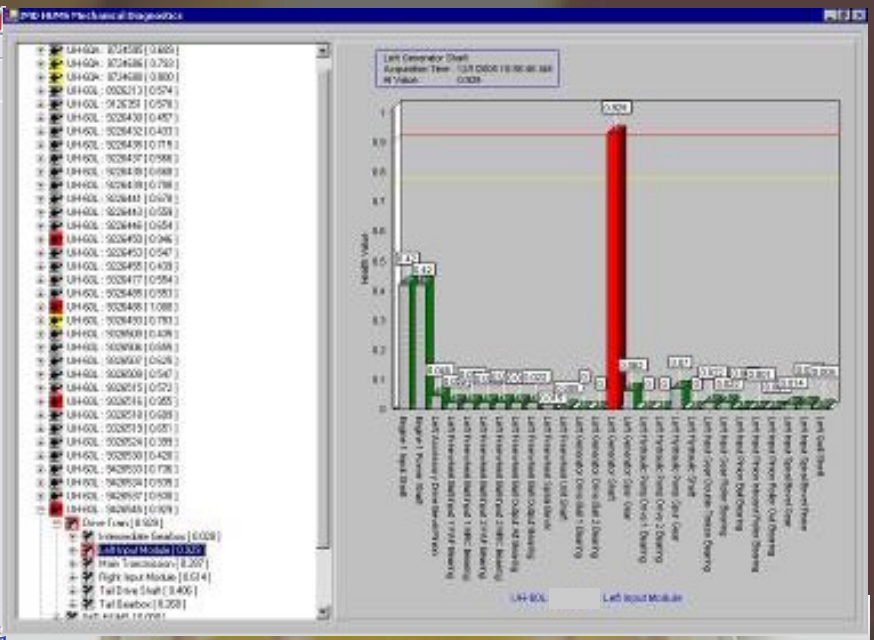
Opportunistic Maintenance

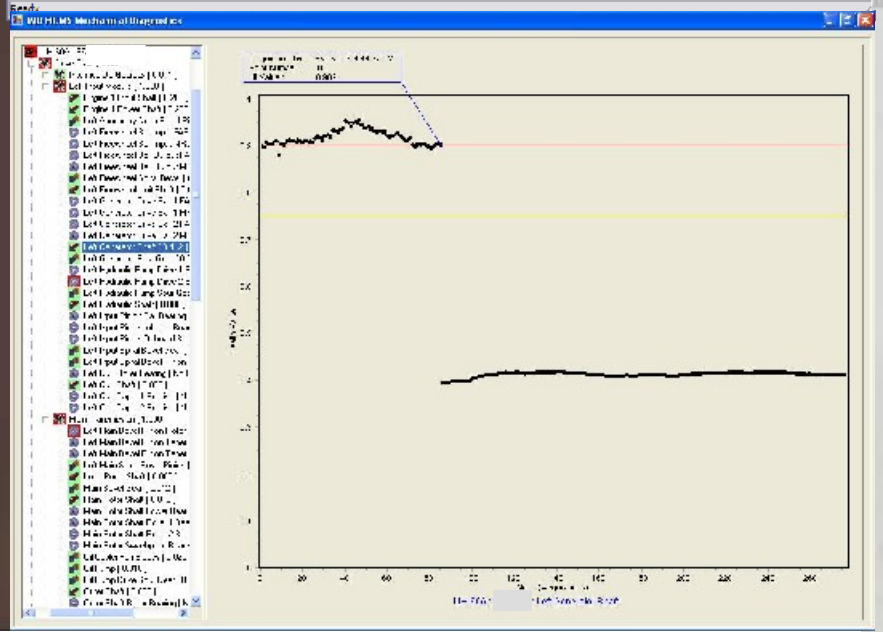




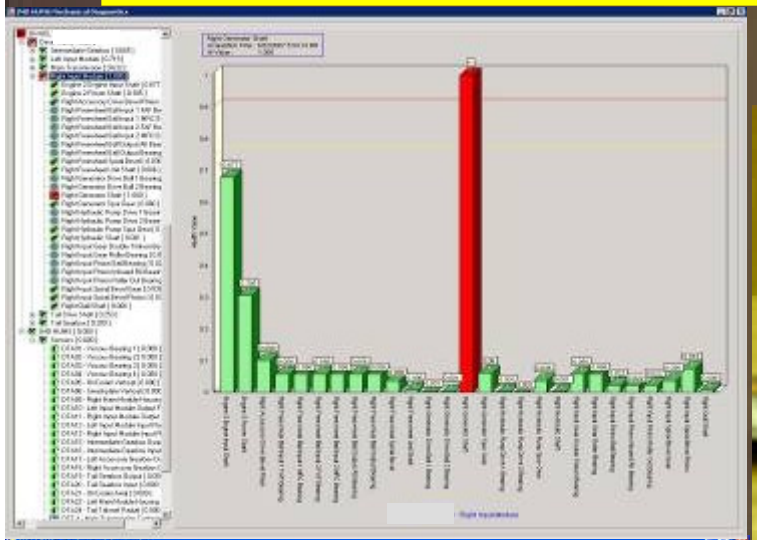
Converting Unscheduled to Scheduled

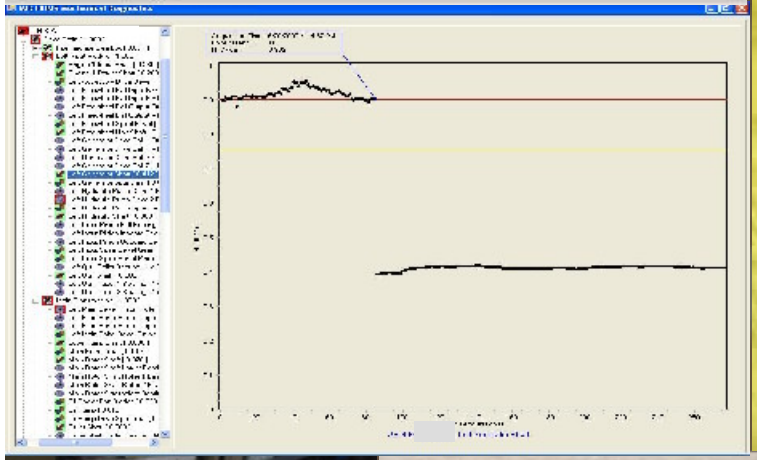


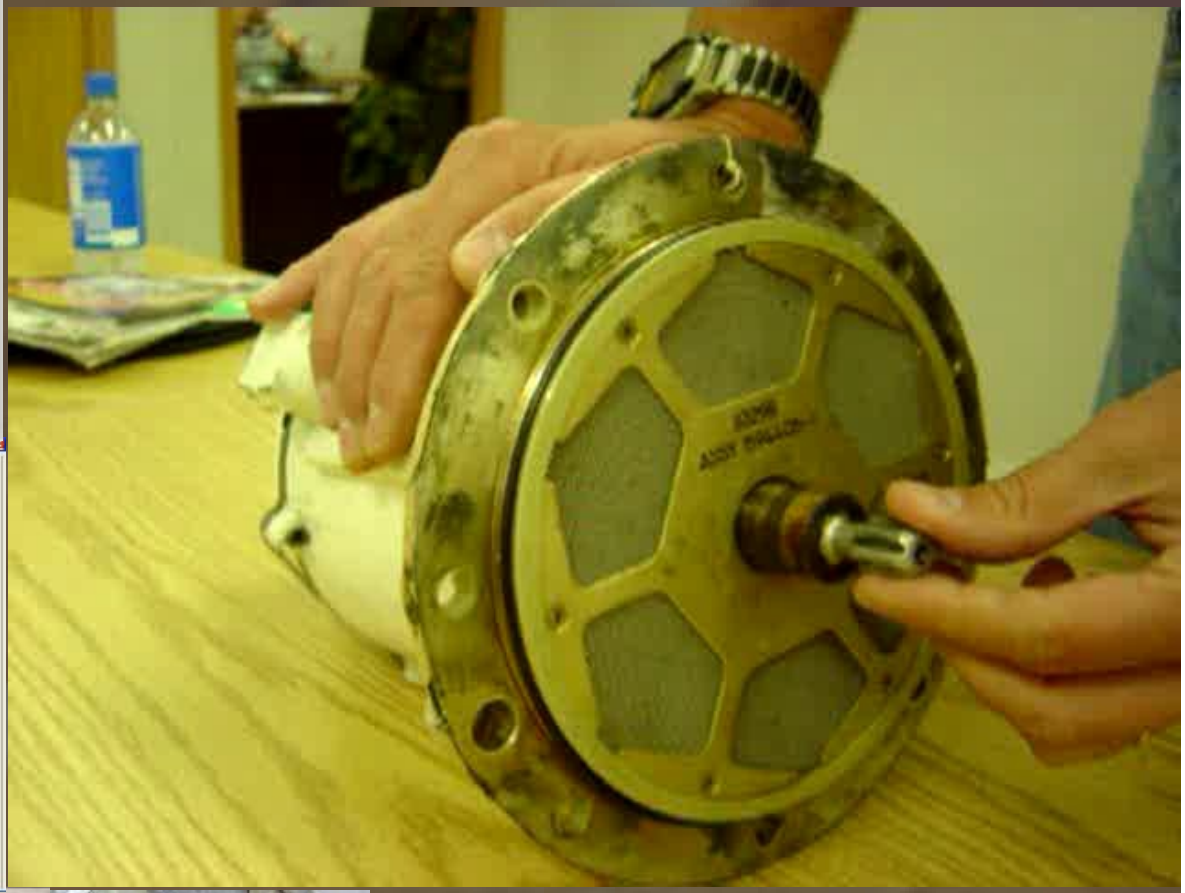




Unscheduled to Scheduled

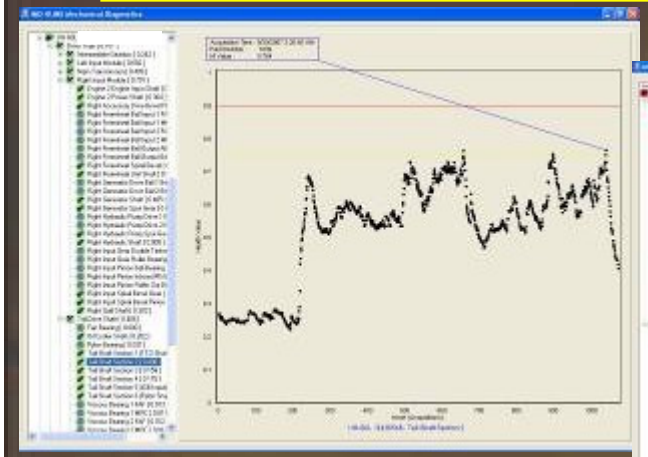


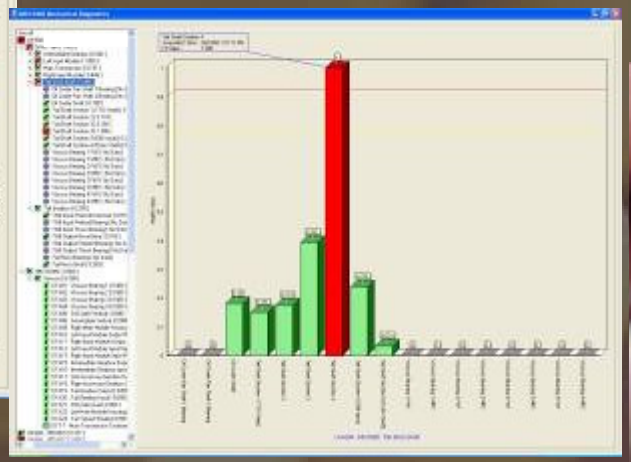


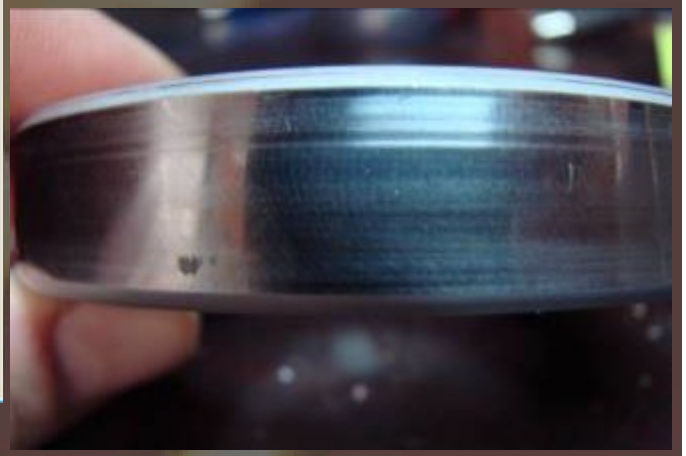


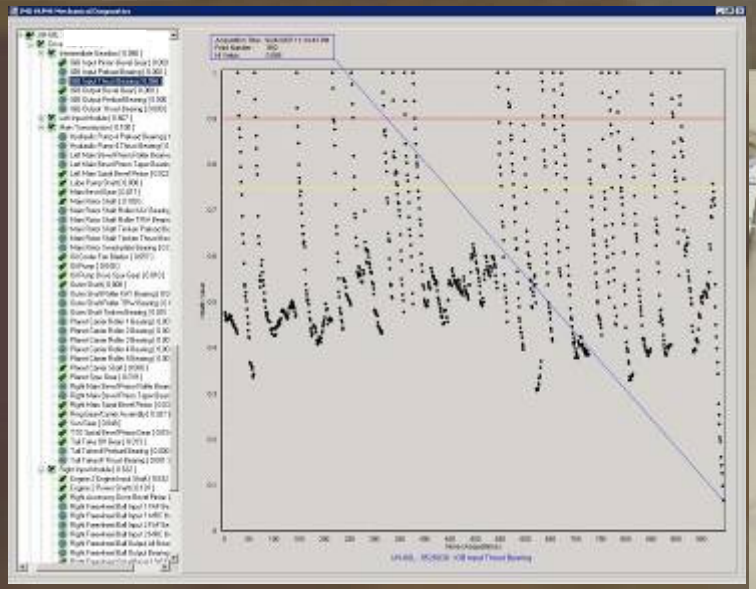
> 60 maintenance events

Unscheduled to Scheduled









Mission Planning

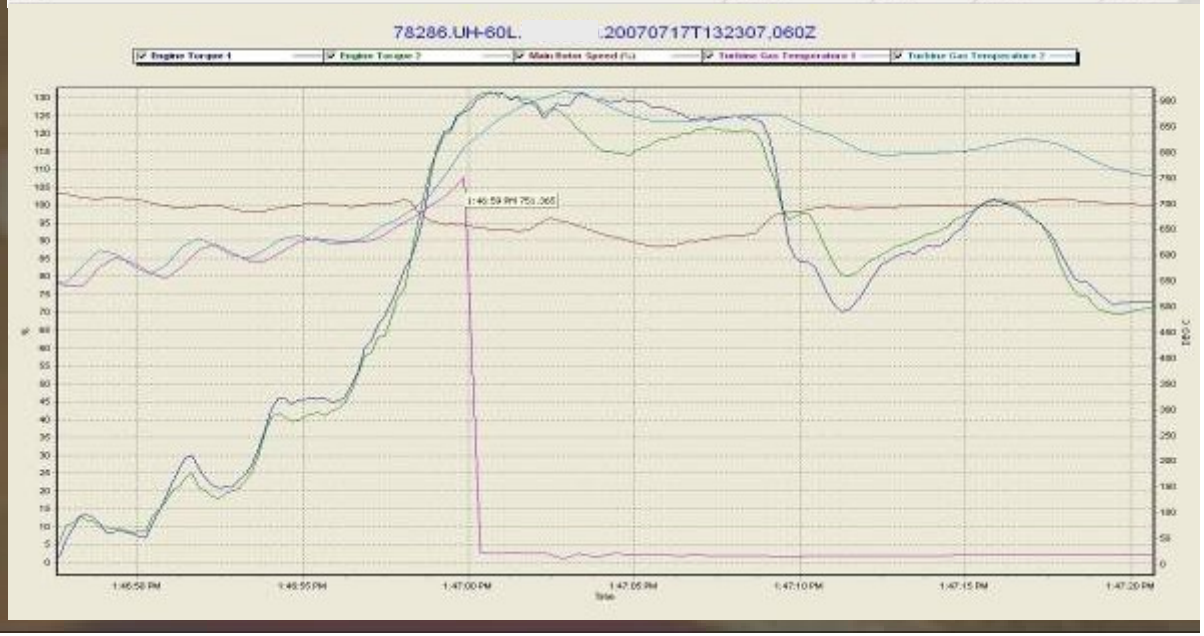
Predicted Benefits

- Exceedance Analysis
- MFOQA

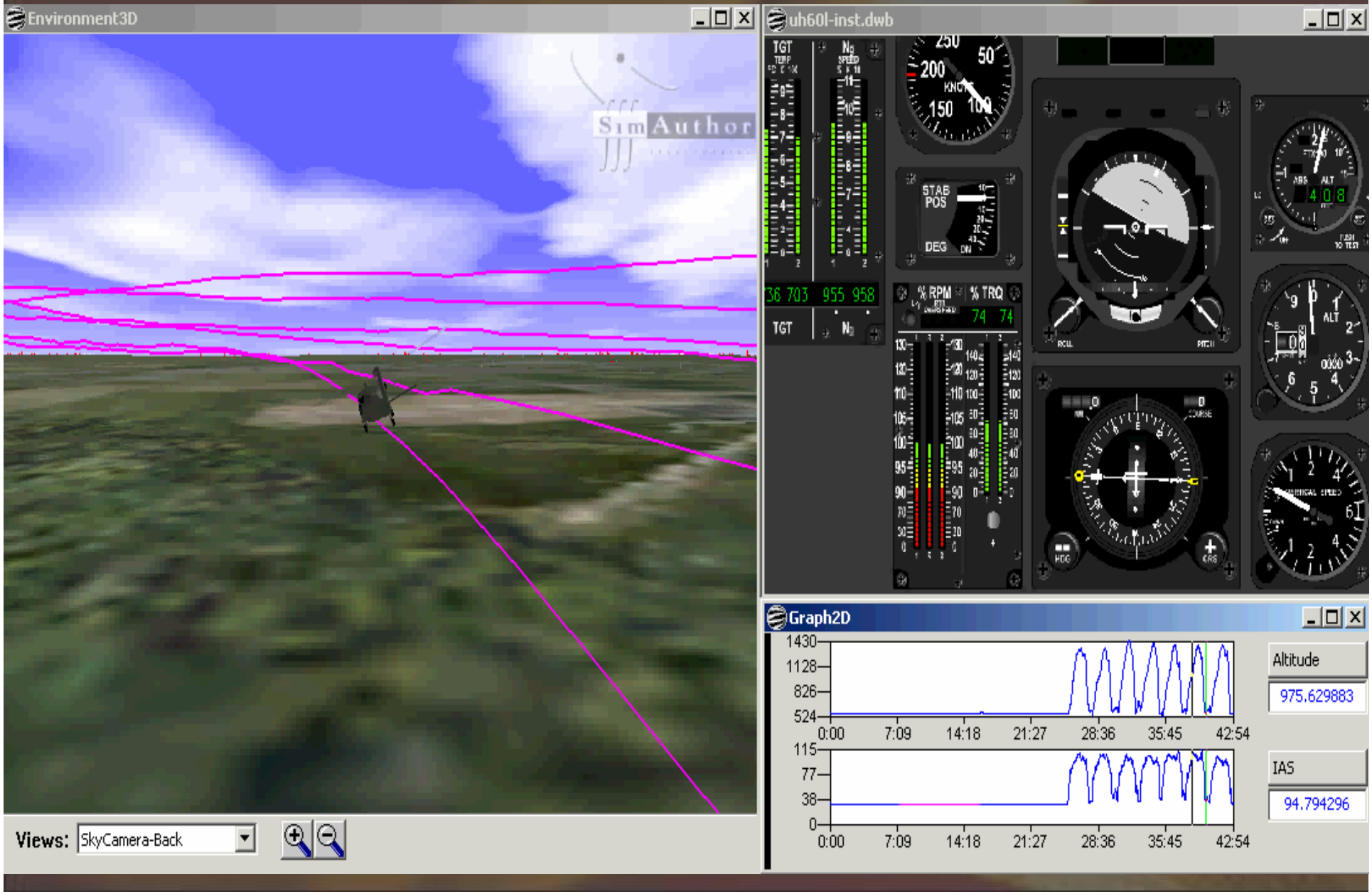
Exceedance Analysis

UH-60 and CH-47

- **OBS programmed per -10 and -23 limitations to generate and log exceedances**
- **Exceedances can be viewed under "Exceedance History" on CDU**
- **Exceedances are reviewed during download/debrief**
- **Data review validates severity and duration of exceedances**



MFOQA


Environment3D
SimAuthor
uh60l-inst.dwb
TGT
Ng
% RPM
% TRQ
74 74
STAB POS
DEG
Views:
SkyCamera-Back
Graph2D
1430
1128
826
524
0:00
7:09
14:18
21:27
28:36
35:45
42:54
Altitude
975.629883
115
77
38
0
IAS
94.794296

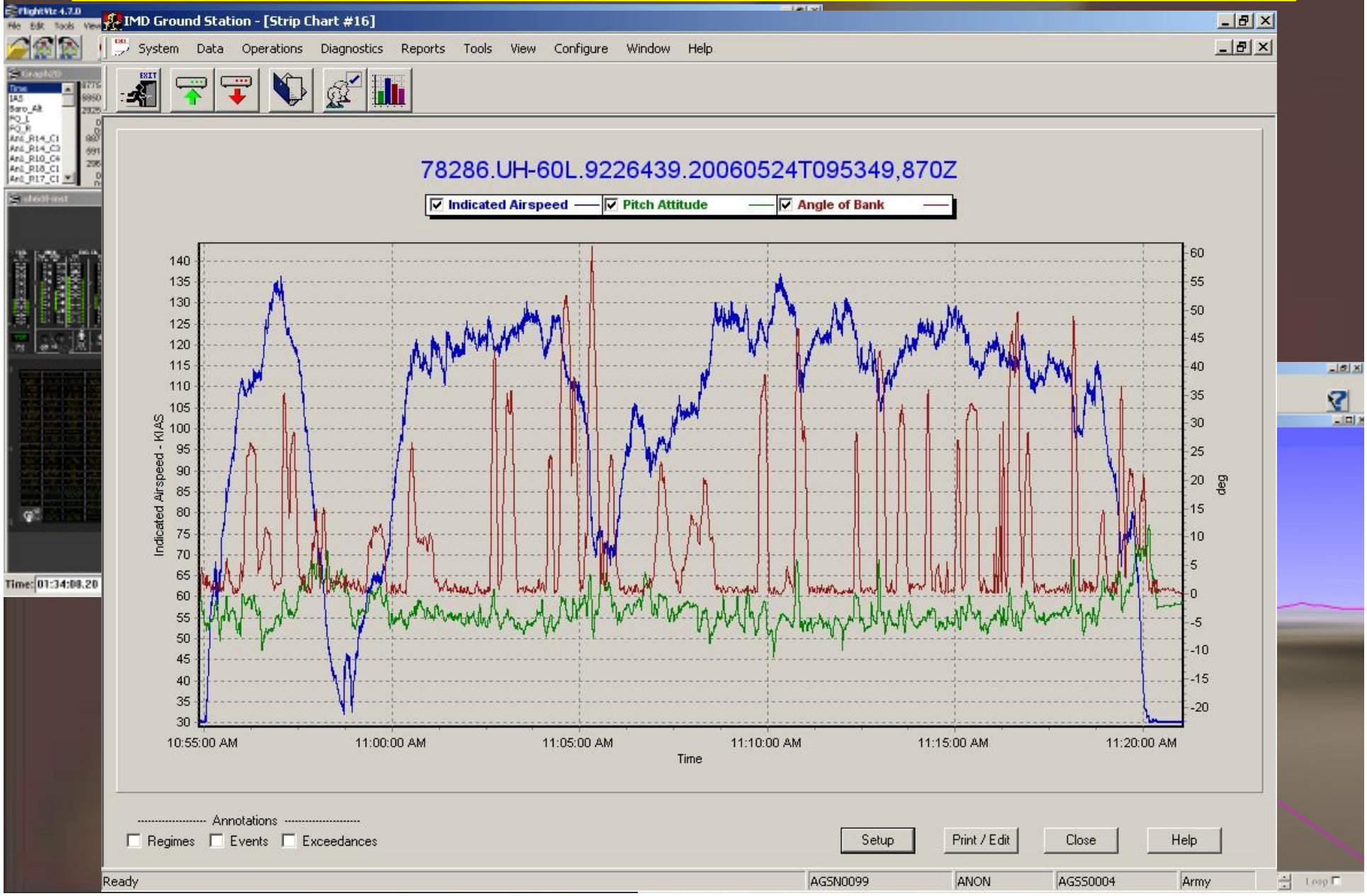
Flight Viz - MFOQA

Flight playback used for:

- **Pilot training and validation**
  - **IPs required extra iterations of environmental training in Kuwait after viewing landings on Flight Viz**
  - **Action on contact reviewed and trained within 24 hours**
  - **Cleared pilots of flying misconduct**

- **Accident/Incident Investigations**
  - **Class A investigation**
  - **Horizontal strike at schoolhouse**
  - **Hard Landings**
  - **Brownout incidents**
  - **Maintenance incidents**

MFOQA

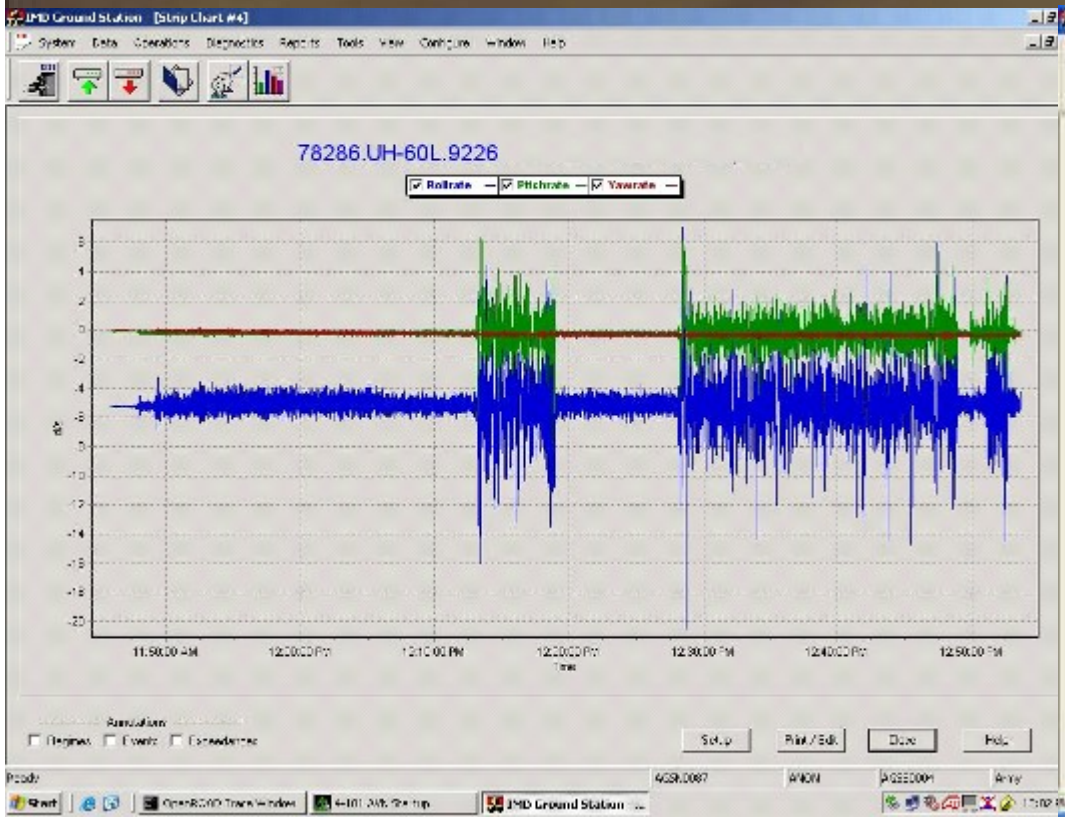

IMD Ground Station - [Strip Chart #16]
System Data Operations Diagnostics Reports Tools View Configure Window Help
78286.UH-60L.9226439.20060524T095349,870Z
Indicated Airspeed
Pitch Attitude
Angle of Bank
Indicated Airspeed - KIAS
deg
10:55:00 AM
11:00:00 AM
11:05:00 AM
11:10:00 AM
11:15:00 AM
11:20:00 AM
Time
Annotations
Regimes
Events
Exceedances
Setup
Print / Edit
Close
Help
Ready
AGSN0099
ANON
AGSS0004
Army

Greatest Unforeseen Benefits

- Troubleshooting Aircraft Systems
- Maintenance Verification
- Battle Damage Assessment

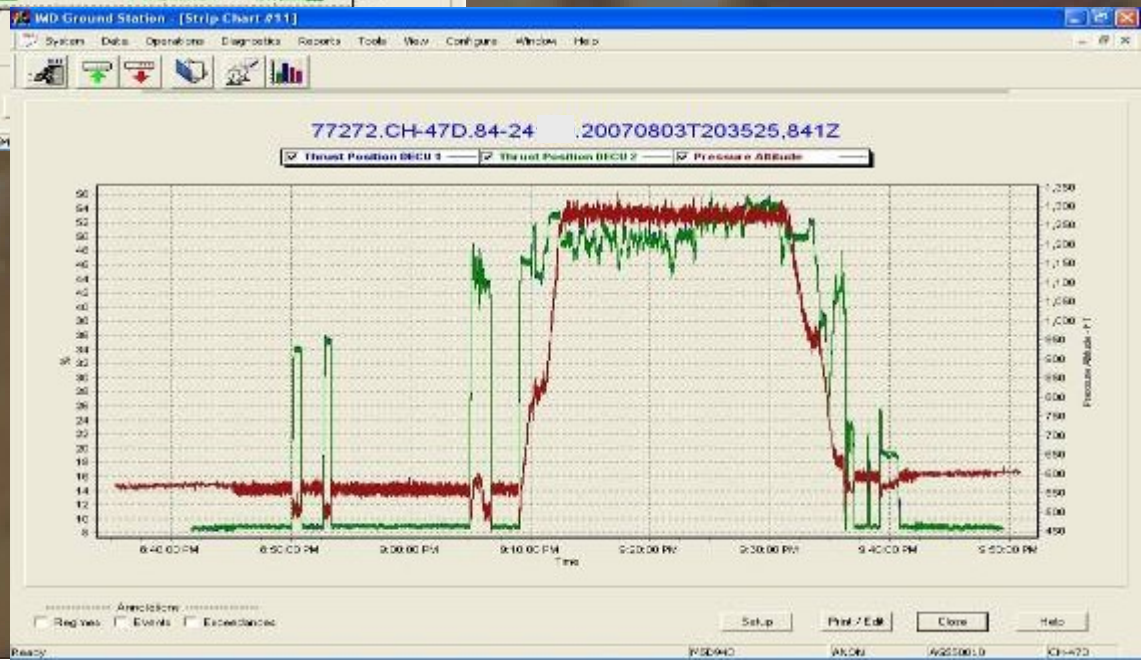
Troubleshooting

- Real-time on-board and post download analysis
- Signal comparison utilizing Strip Chart function provides easy identification of faulty aircraft sensors
- HUMS digitizes legacy aircraft signals and therefore has higher fidelity than analog aircraft systems
- HUMS can see problems and degradation before it appears on cockpit instrumentation



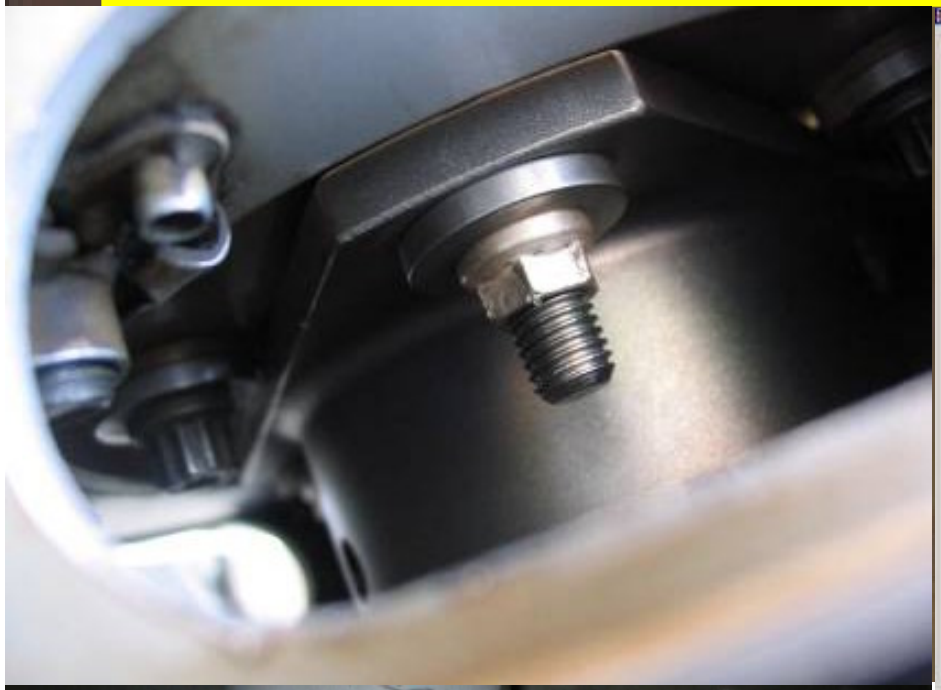
Troubleshooting

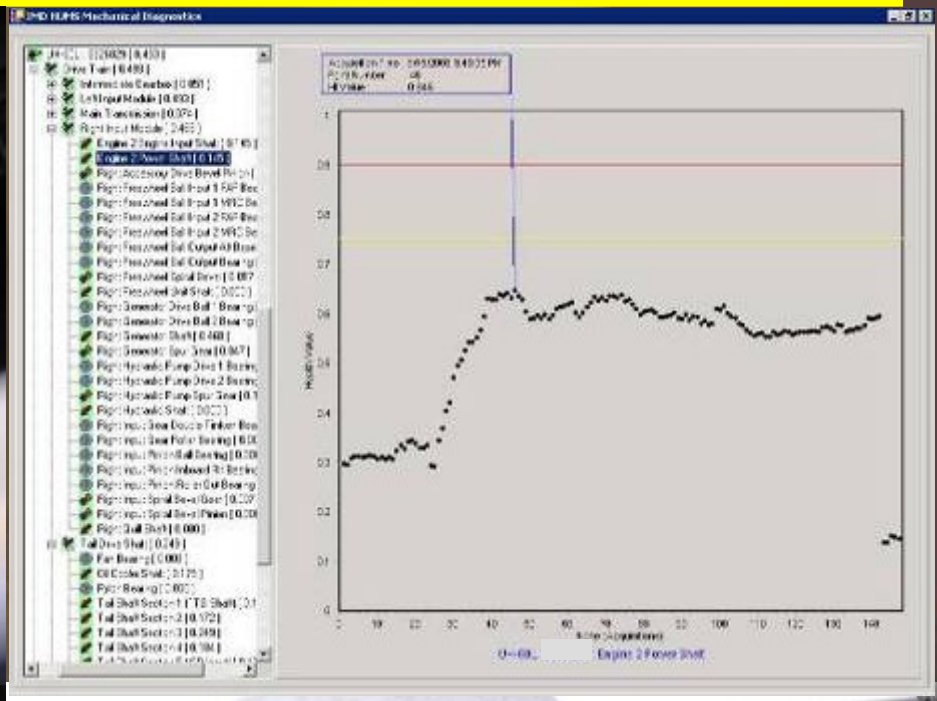
Aircraft experienced runaway thrust condition two times during flight, with the barometric altitude hold engaged

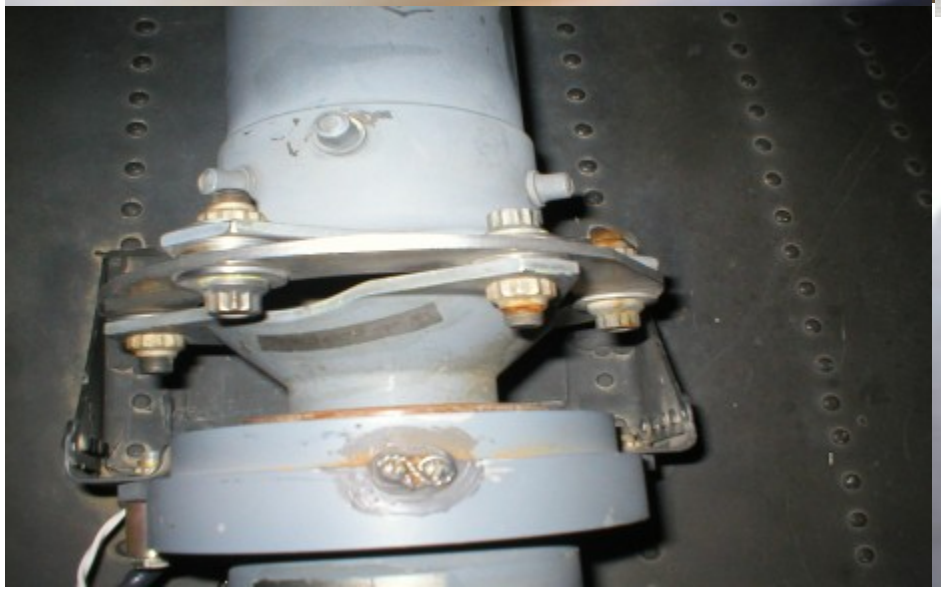


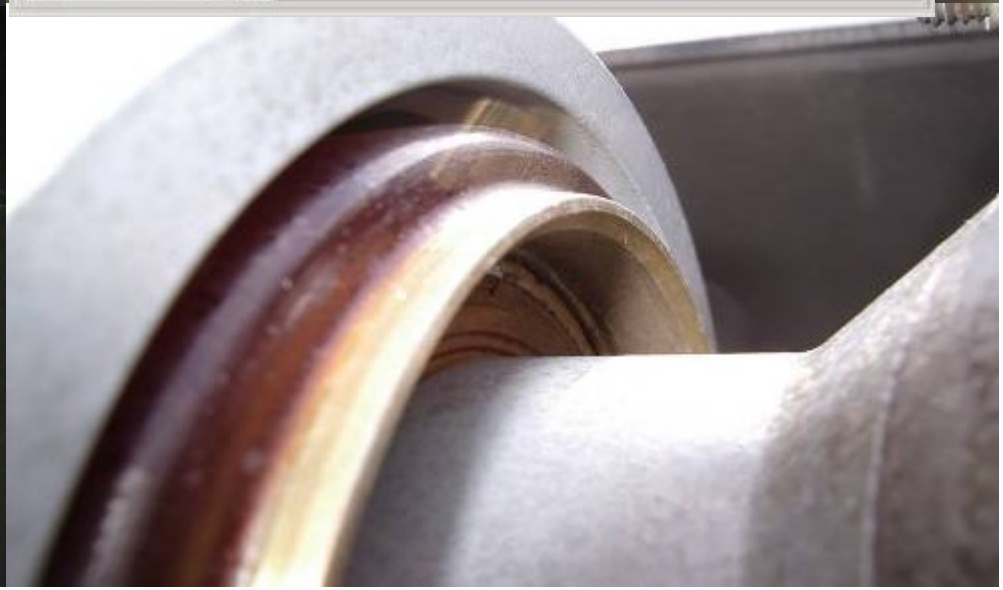
Thrust cockpit control drive actuator was replaced

Maintenance Verification









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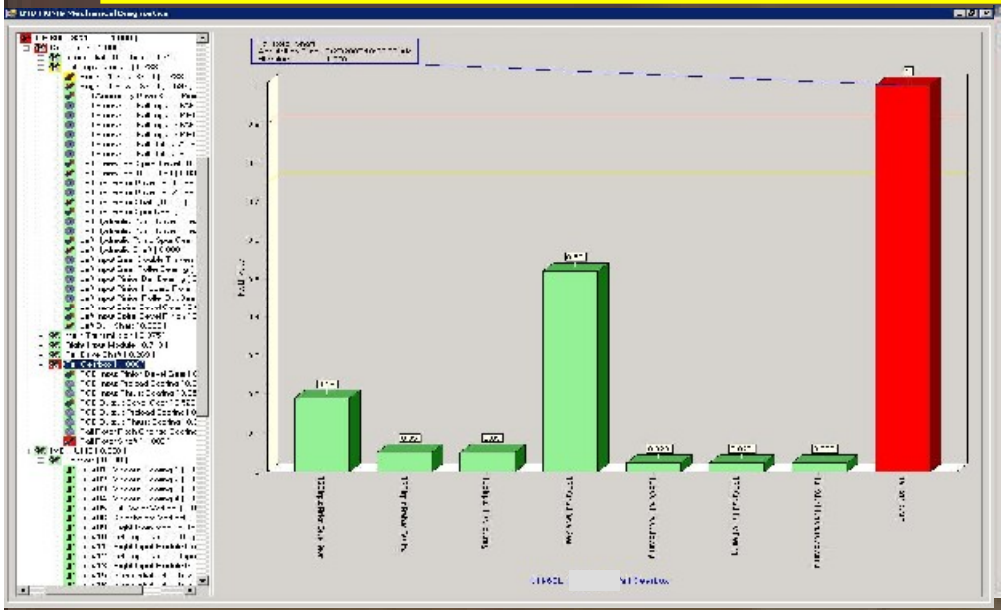
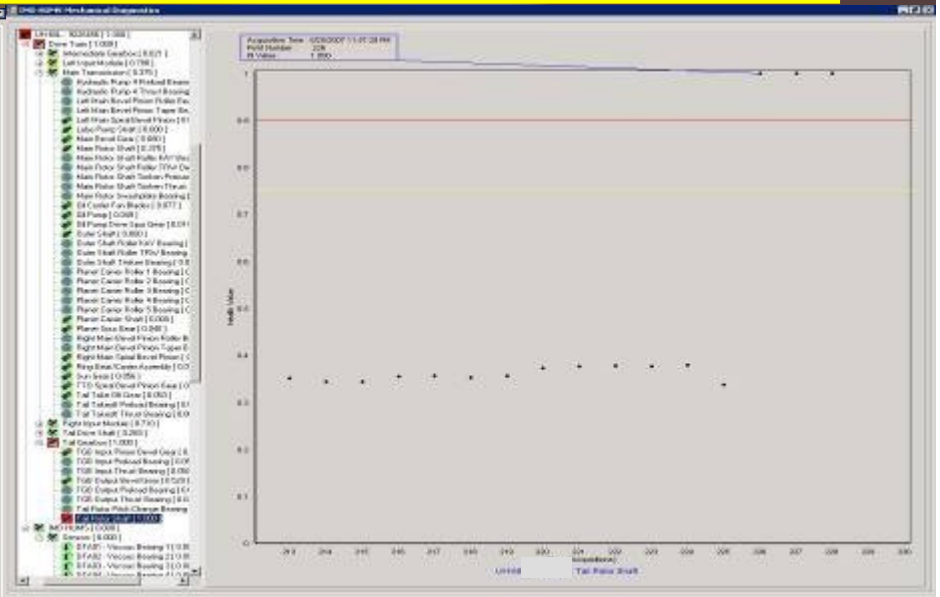
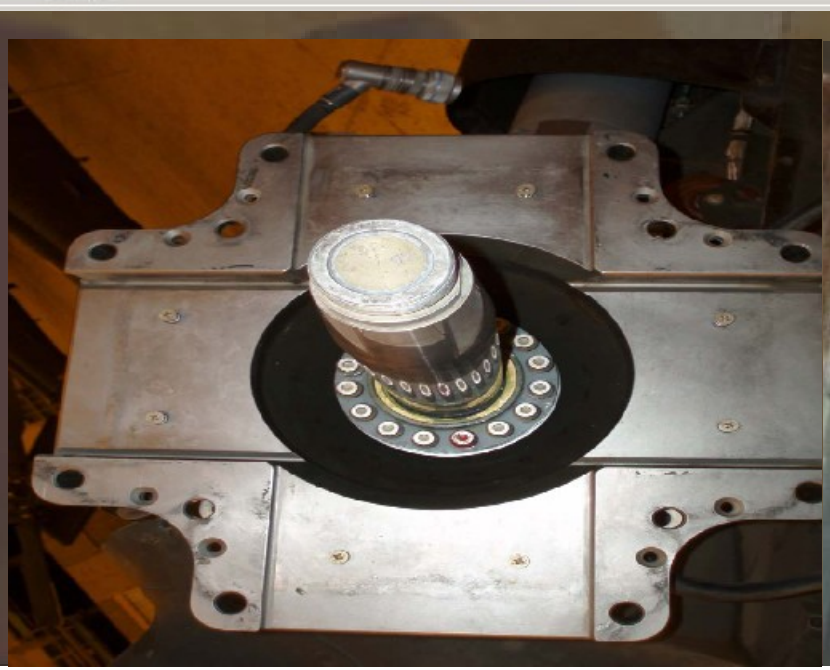
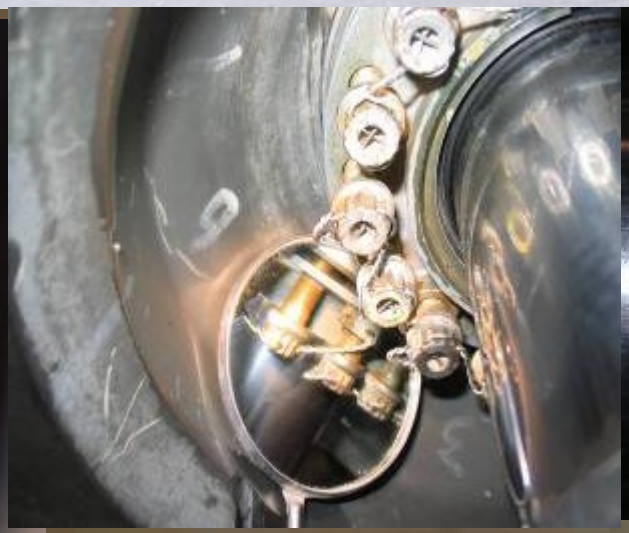


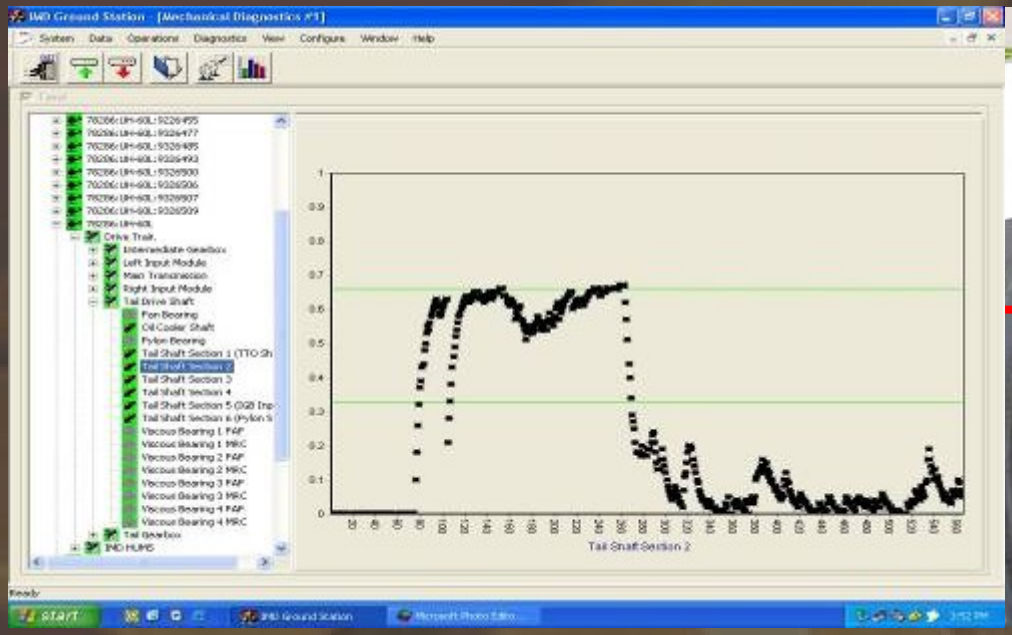


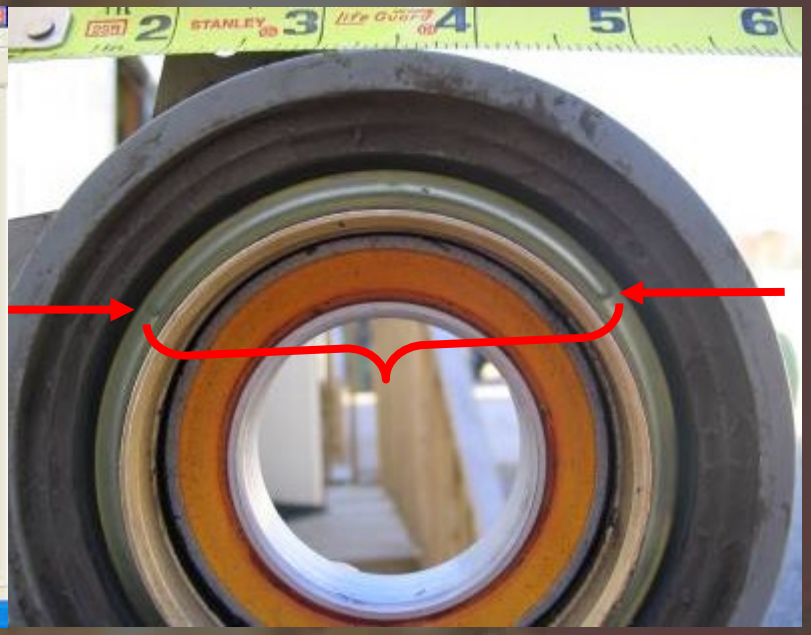


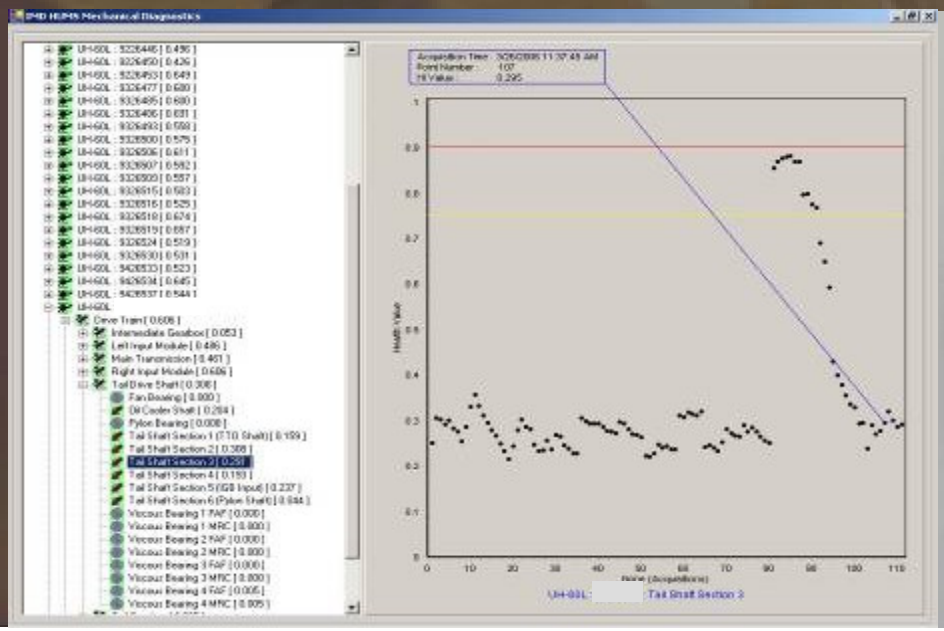
Maintenance Verification



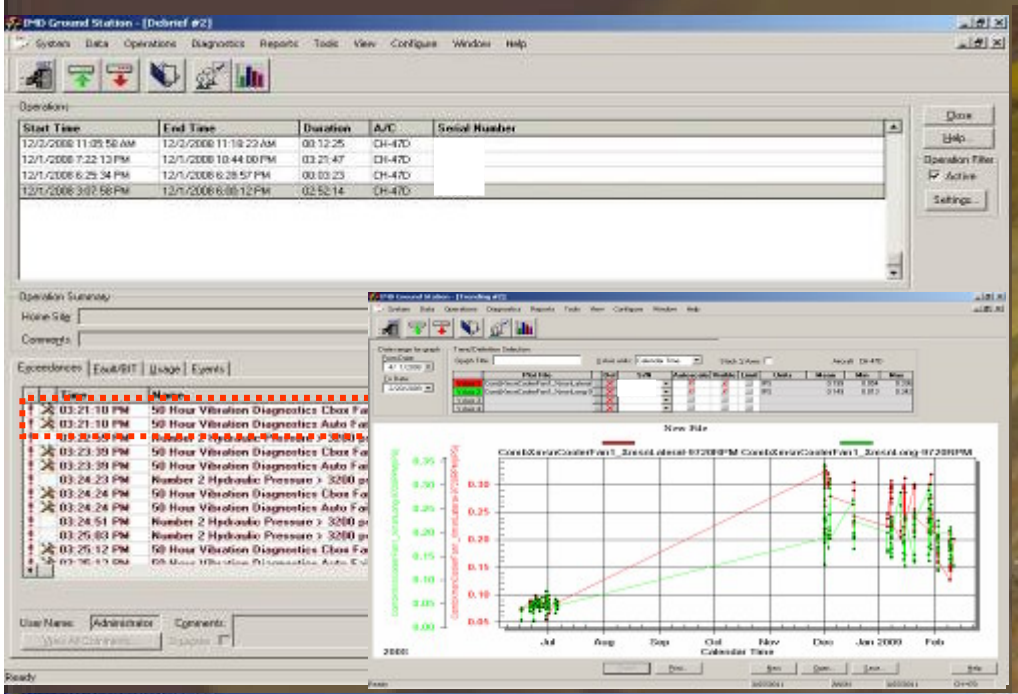
Maintenance Verification

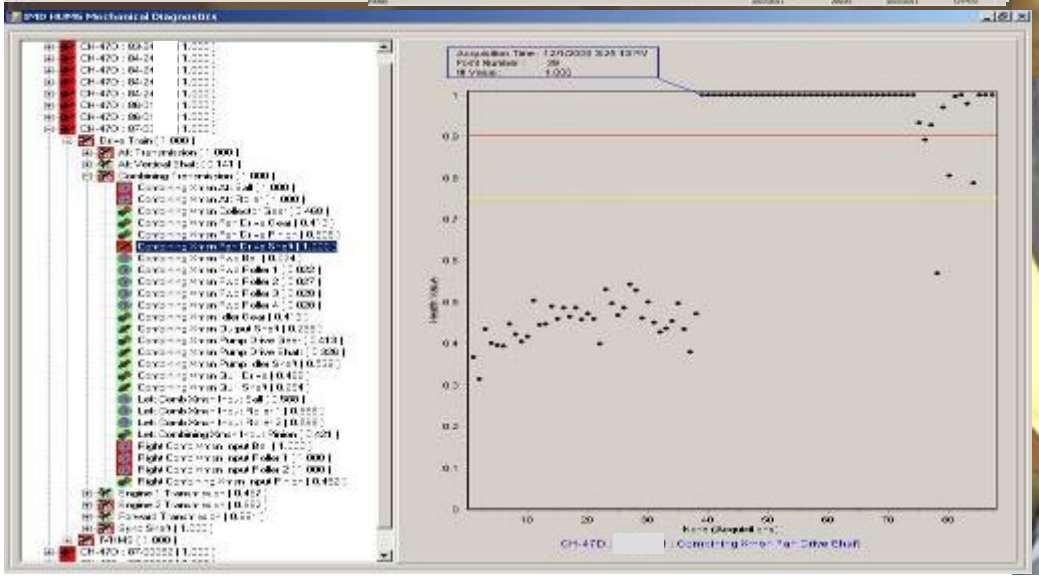






Maintenance Verification





Battle Damage Assessment

HUMS data used to determine location of incident:

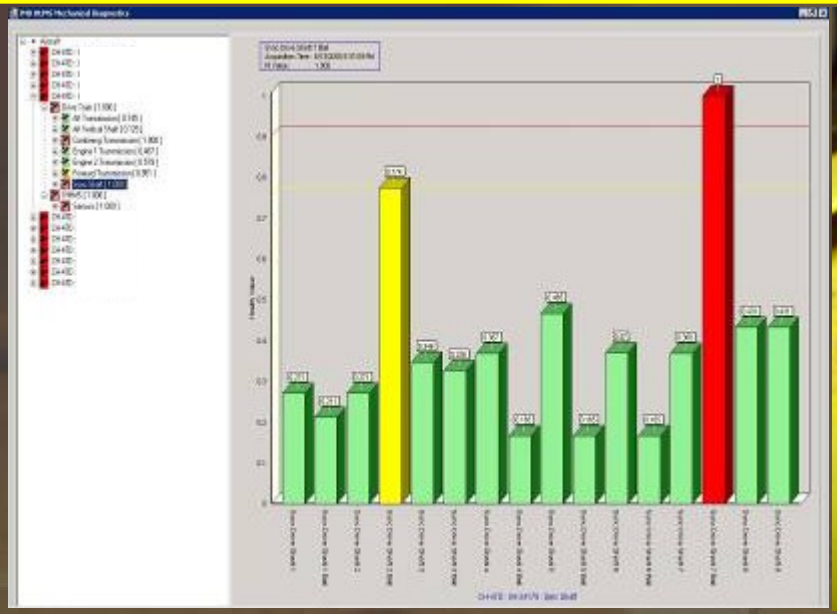
- **Some aircraft signals were lost due to hostile fire**
- **Data was reviewed to determine time of monitored signal failures**
- **Using GPS data collected by HUMS, the location of incident was determined when it coincided with the signal failures or evasive maneuvers**

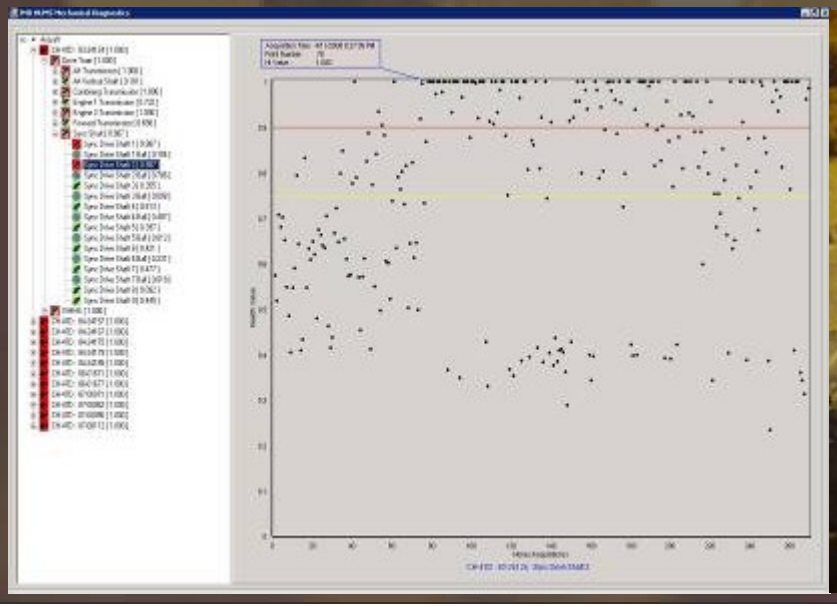
Battle Damage Assessment

Aircraft data is reviewed after taking hostile fire for:

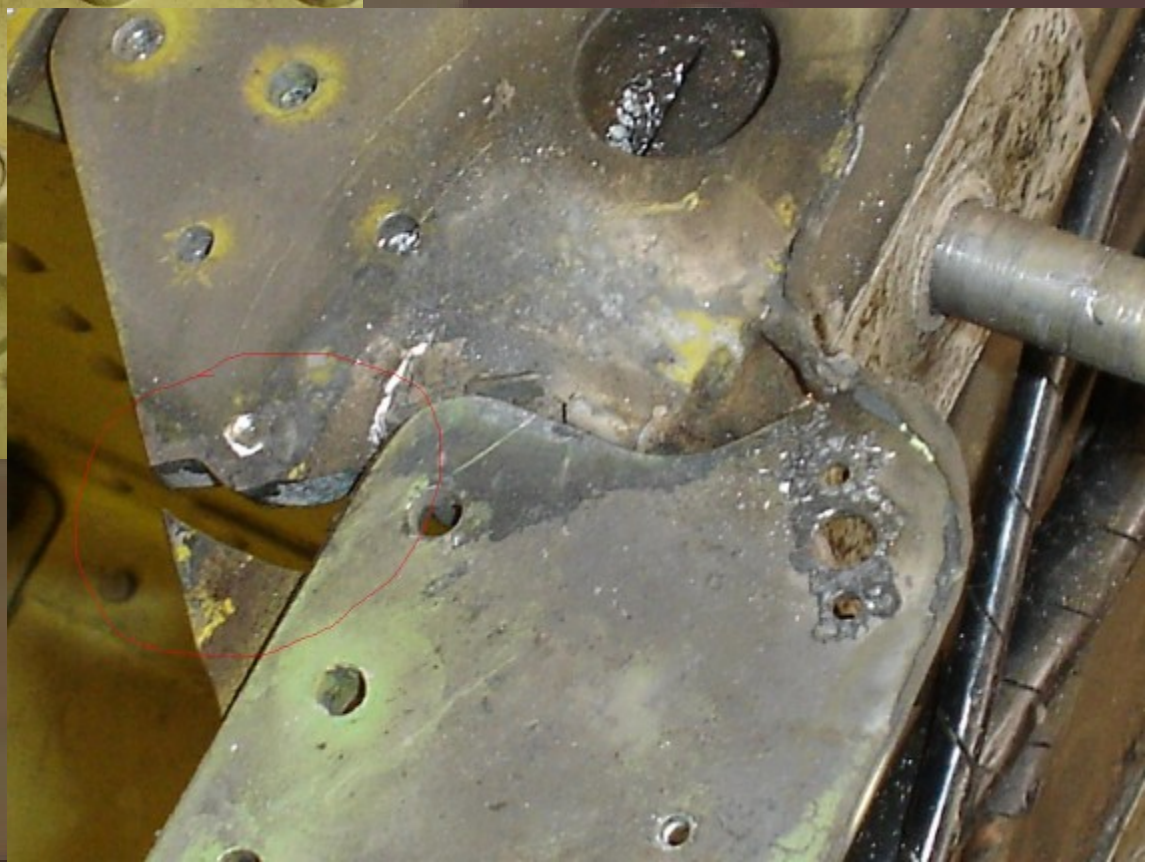
- **Possible exceedances during evasive action**
- **Damaged wiring and sensors identified by dropout in HUMS data**
- **Hit rotors and drive shafts**
    - **Verify no damage done to connected bearings and gearboxes by reviewing HI trends of components and ips levels of rotors**

Structural





Structural



US Army Metrics - Field Results

- **Emerging Metrics**
  - 52% less Unscheduled MMH/FH
  - 48% less Mission Aborts
  - 30% less MTFs
  - 17% less Total MMH/FH
  - 12% less Unscheduled MMH/Total MMH
  - 1.3% less Scheduled MMH/FH
  - 5-10% lower NMCM rates than non HUMS aircraft
  - 5% greater Operational Readiness Rate

- **Increased aircraft availability**
  - 4-101: No missions dropped due to maintenance in 26,000 flight hours (OIF 05-07, 38 BH)
  - 3ID: No missions dropped due to maintenance in 46,000 flight hours (OIF 07-08, 50 BH, 12 CH)

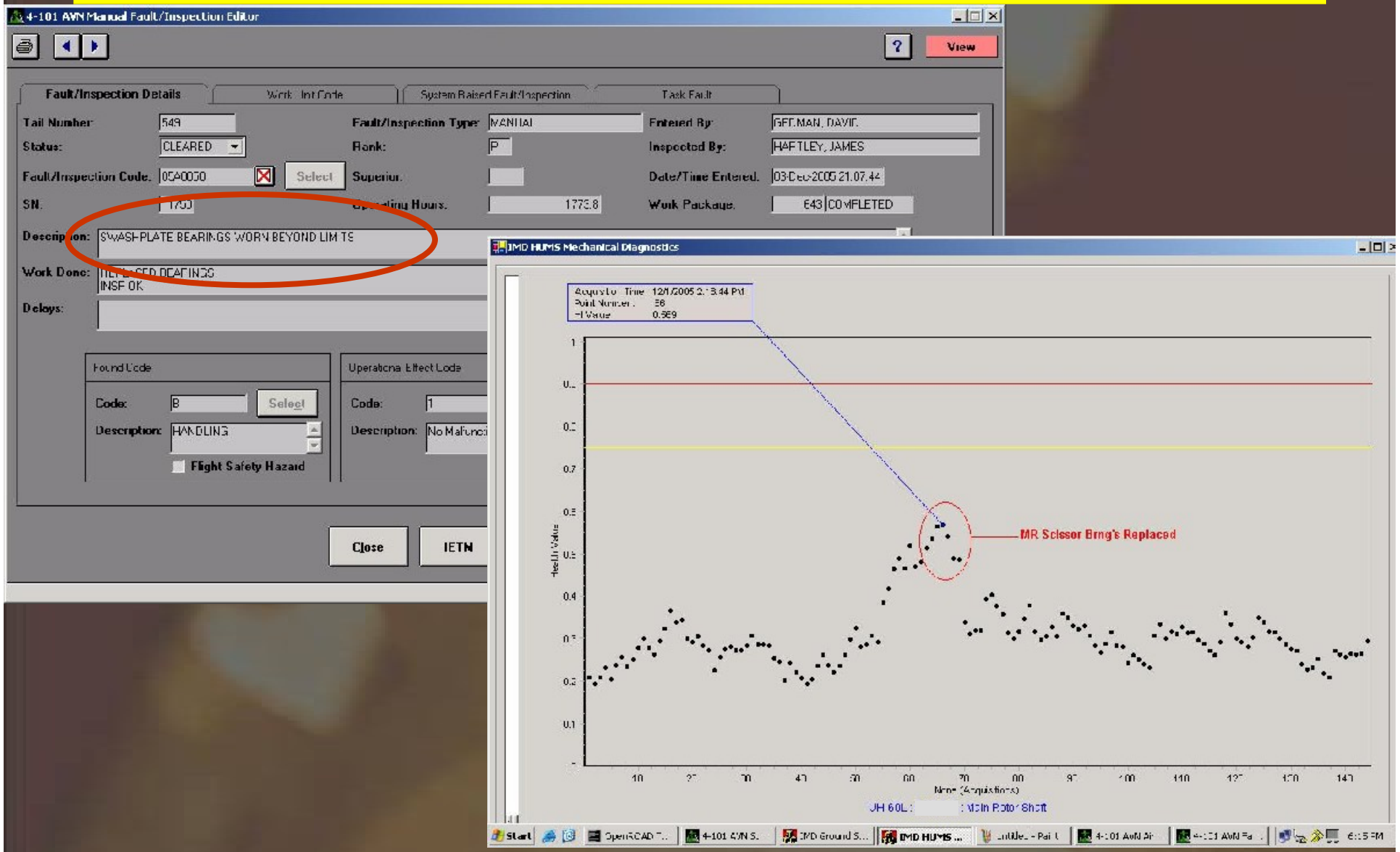
Road to Prognostics

- Diagnostics maturing
  - Know how to use the system
  - More to learn
    - Pin point faults
      - Tie failure modes to maintenance actions (starting)
      - 4 or more distinct failure modes on some components
- More items to monitor
  - LRUs w/ HUMS data (temp, raw & conditioned, cycles)
  - Oil
  - Hydraulic systems (pressures, temps)
  - Additional existing & new sensors
  - Structural
    - Corrosion
    - Hot spot strain

Road to Prognostics

- Data Fusion
  - Infancy
  - Signals + vibration + exceedances + MMIS + chips + etc
  - Use what we do have
  - Add sensors/signals

Data Fusion


4-101 AVN Manual Fault/Inspection Editor
View
Fault/Inspection Details
Work Int Code
System Raised Fault/Inspection
Task Fault
Tail Number: 549
Fault/Inspection Type: MANUAL
Entered By: GEERMAN, DAVID
Status: CLEARED
Rank: P
Inspected By: HAFTLEY, JAMES
Fault/Inspection Code: 0540050
Select
Superior:
Date/Time Entered: 03-Dec-2005 21:07:44
SN: 1750
1773.8
Work Package: 643 COMPLETED
Description: SWASHPLATE BEARINGS WORN BEYOND LIMITS
Work Done: REPLACED BEARINGS
INSP OK
Delays:
Found Code
Code: B
Select
Description: HANDLING
Flight Safety Hazard
Operational Effect Code
Code: 1
Description: No Malfunct
Close
IETN
IMD HUMS Mechanical Diagnostics
Acquisition Time: 12/1/2005 2:13:44 PM
Point Number: 58
H Value: 0.569
MR Scissor Brng's Replaced
Health Value
Main Rotor Shaft

Road to Prognostics

- Fleet Management
  - Capable MMIS linked to HUMS
    - Usage
    - Exceedances
    - Maintenance markers
  - Data analysis tools
  - IETM link
  - Logistics link
  - Depot maintenance using HUMS data

Road to Prognostics

- Prognostic Goal
  - Change out item right before failure
    - Most life from parts as safely possible
  - Exact remaining useful life
    - Usage
    - Flight regimes
    - Environmental
    - Rate of Change
- Maximum life =
  - Additional maintenance event
  - Reduced mission readiness

Road to Prognostics

- Tie remaining useful life to scheduled maintenance intervals
  - Integrated logbook/maintenance management
  - One 120hr and Phase 1 before failure
    - Parts planned
    - Choose appropriate event per workload
    - No additional maintenance event


Condition Based Maintenance
Capabilities in OIF/OEF
Safety, Pinpoint Fault & Planning Engine & Gear Box Chip Logging
Safety & Maintenance Engine Power Shaft
Droop Stop Pounding
Maintenance Verification Tail Rotor Assembly
Collateral Damage Avoidance Mission Abort Avoidance Tail Rotor Component Failures
Manufacturing Defect Identification
Collateral Damage Avoidance Planned Maintenance Generator Adapters
Maintenance Oil Cooler Auto Checks & Trending
Semi-Automated HIT Checks & Trending
A C Signal Detection & Troubleshooting
Nr
Collective Position
Yaw Rate Gyro
PCMCIA Card
Safety WOW Switch Exceedance
Maintenance Absorber Tuning
Maintenance Drive Shaft & Bearing Diagnostics
Main Rotor Damper Diagnostics
MFOQA Integrated CVFDR
Integrated Ground Station
Commander's Dashboard
Electronic Logbook w/ A C Build Structure (CBM Requirement)
MFOQA Training Flight Playback
CBM Requirement Regime Recognition