



AW Experience in the Helicopter Diagnostics/Prognostics

Bruno MAINO





Overview

- AW status on HUM Systems
- HUMs architecture
- On board functions
- Ground station
- AW new techniques under test



HUMS Present Status

EH/AW101



HUM system fully integrated

In-service since 1995
(146 H/C delivered)

Data feedback policy not defined.

Vib data sent to AW in case of assistance requested by the customer

AW139



HUM system - KIT

In service since 2004
(612 H/C delivered, 335 with HUMS)

Data feedback can be part of the support contract.

In case of contract acceptance, all HUM data are sent to AW

NH90



HUM system fully integrated

In service since 2008

HUM data feedback to NHI
Definition of the data retrieval policy in progress



HUMS Present Status

AW149/189



HUM system fully integrated

In-service since 2014

Automatic Data feedback

AW169



HUM system fully integrated

Under certification

Automatic Data feedback

AW609



HUM system fully integrated

In development

Automatic Data feedback



HUMS Present Status

AW109



AW119



HUM systems provided by 3rd party companies



Family concept

- Same Diagnostic (HUM) System
 - Same H/W
 - Same SW functions
 - Same infrastructure for HUM data support

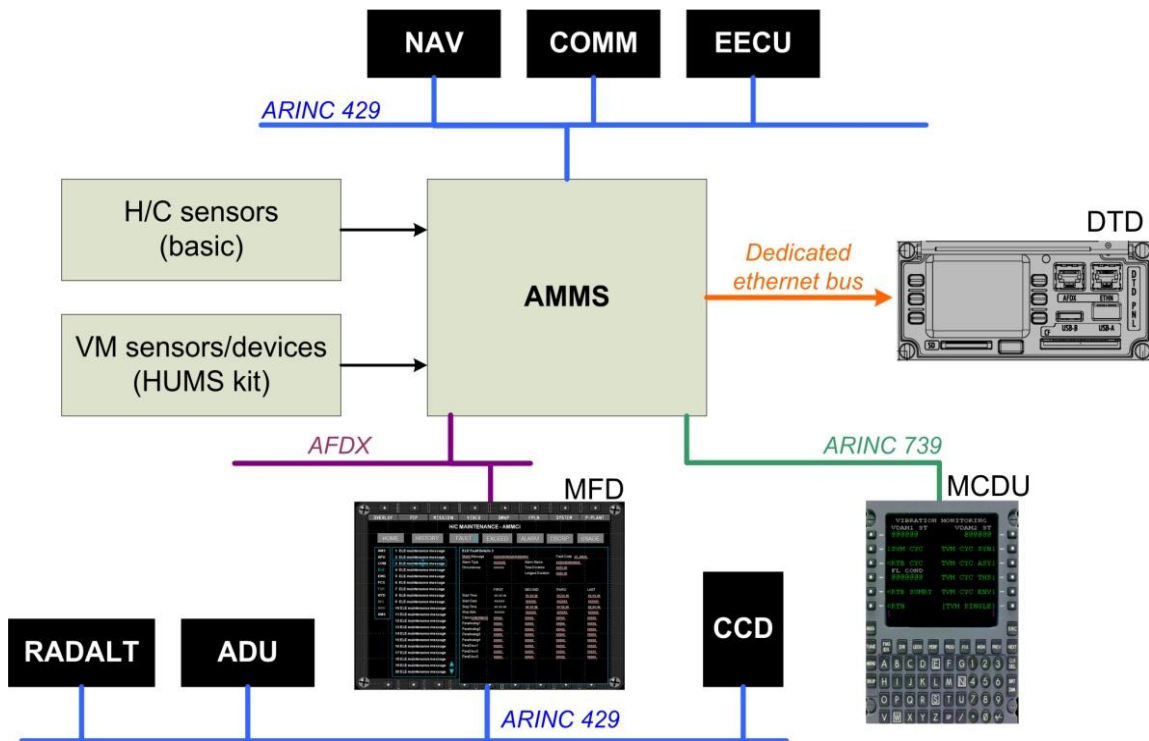


Architecture





On-Board Architecture





On-Board Capabilities

- Data recording
- Data cross correlation (diagnostic function)
- C.I. (Condition Indicators) Computation for VM
- Exceedance detection
- Data storage
- Data transfer



Data cross correlation

Great effort devolved to the cross correlation in order to increase **fault isolation**

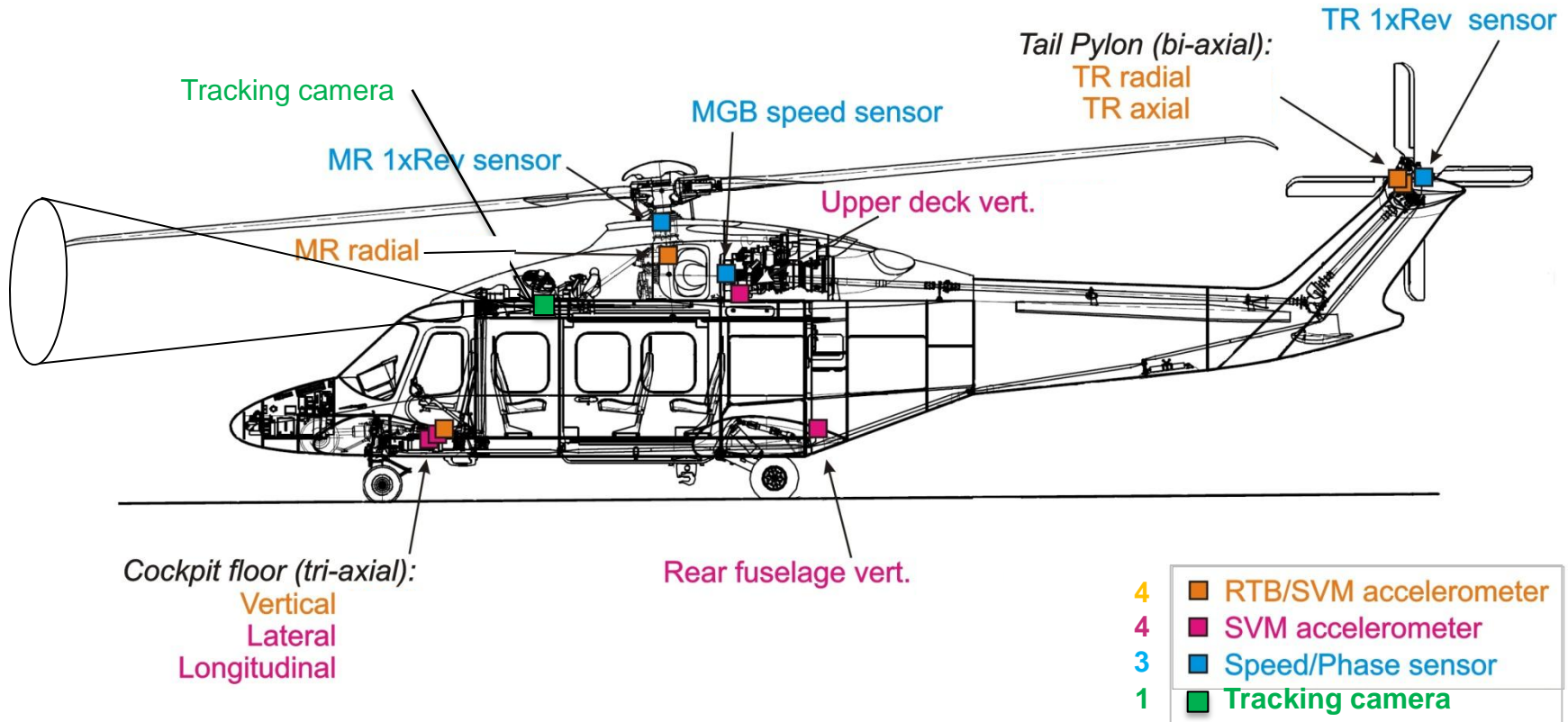


Main Functions

- Rotor Track and Balance (RTB)
- Structural Vibration Monitoring (SVM)
- Engine Health and Usage Monitoring (EHUM)
- Structure and Transmission Usage Monitoring (SUM and TUM)
- Transmission Vibration Monitoring (TVM)



AW189 RTB & SVM Sensors

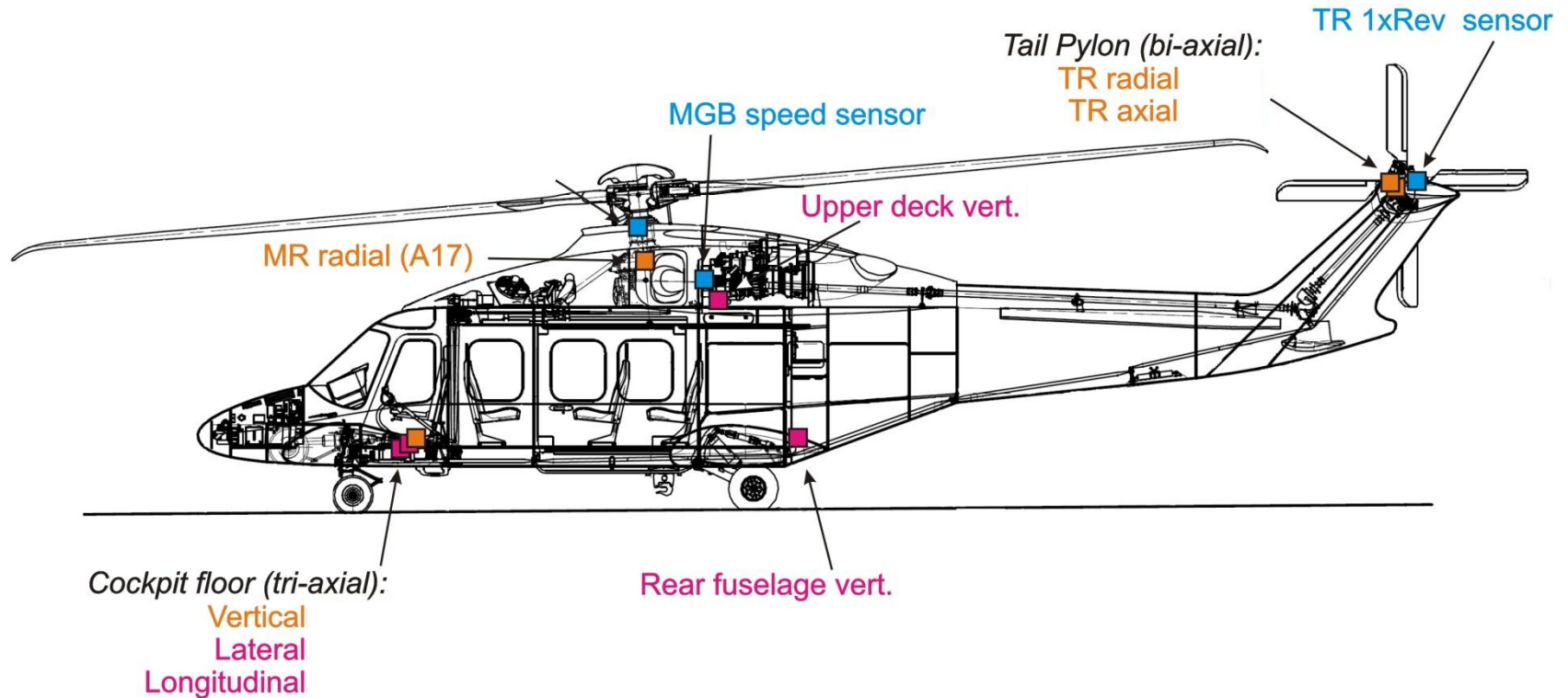


RTB Function

- 1, 2 and (Nr of blades) x Rev vibration is monitored at 4 key locations at prescribed flight conditions



SVM Function



- (Nr of blades) x Rev vibration is monitored at 4 to 8 key locations (same as for RTB + n) at prescribed flight conditions
- On some H/C a continuous vibration recorder is installed



Structure, Rotor and Transmission Usage Monitoring

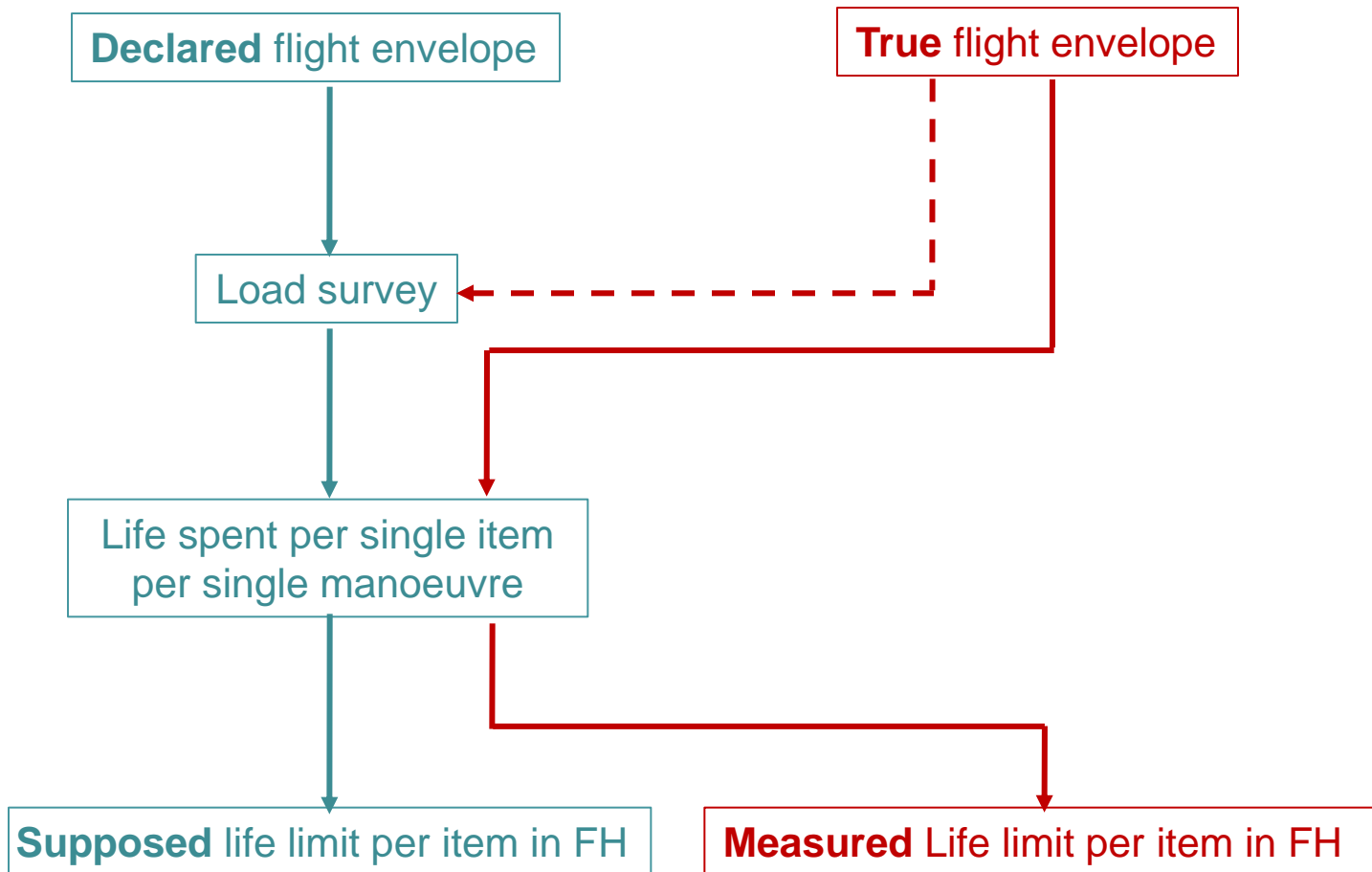
The Usage Monitoring system aims at

- detecting the true flight envelope and
- assessing the remaining life of life-limited components

through analysis of the on-board flight parameters and a FCR (Flight Condition Recognition) process.



Usage Monitoring Logic





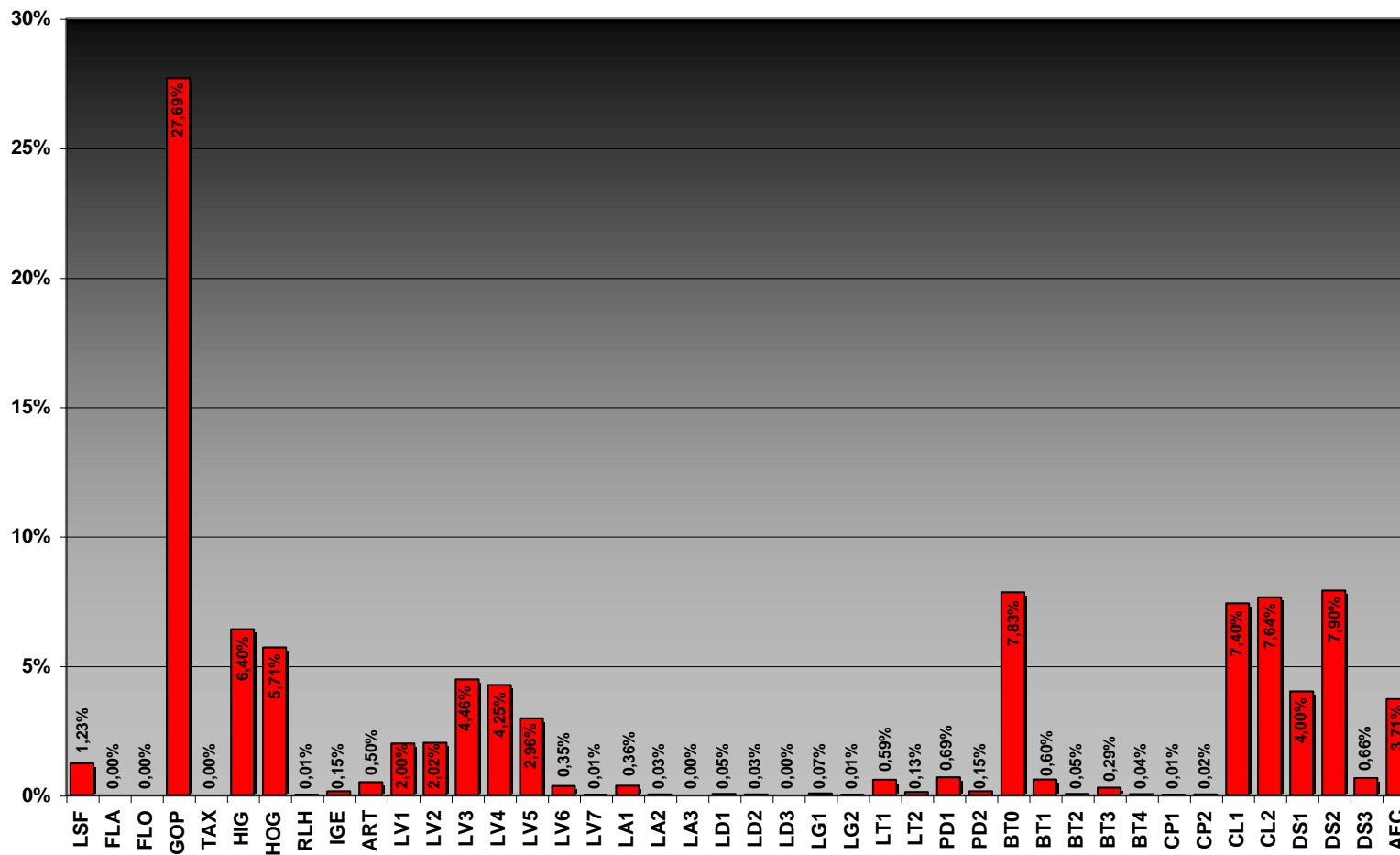
Flight Condition Recognition

Flight Condition Recognition (FCR) performed by sampling and recording:

- Rotor start to stop time
- Engine start to stop time
- Weight off wheels to weight on wheels time
- Attitudes, speeds, accelerations
- NR, altitude, G spectra
- Torques time in predefined bands

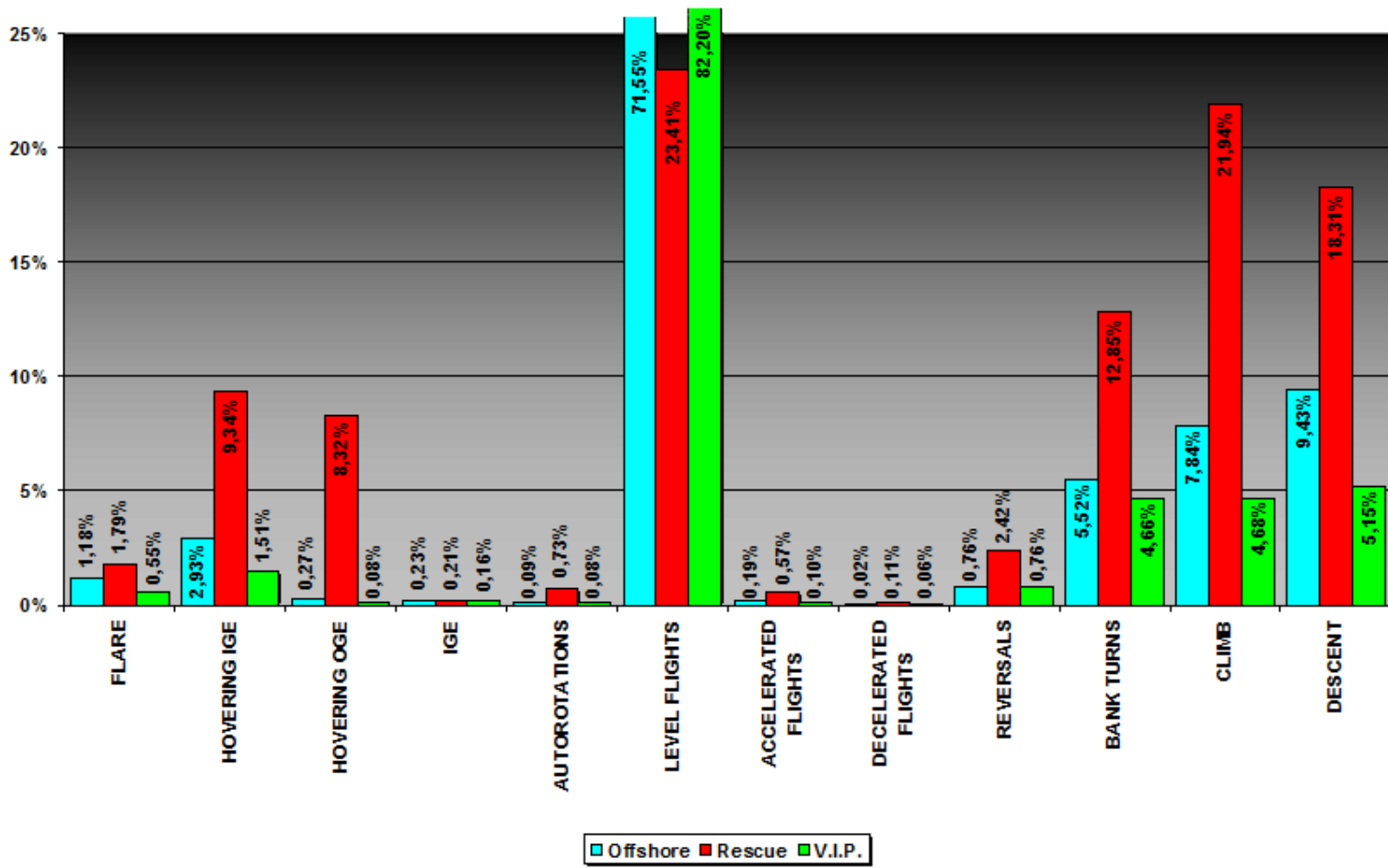


Flight Condition Recognition Output





Flight Condition Recognition Output





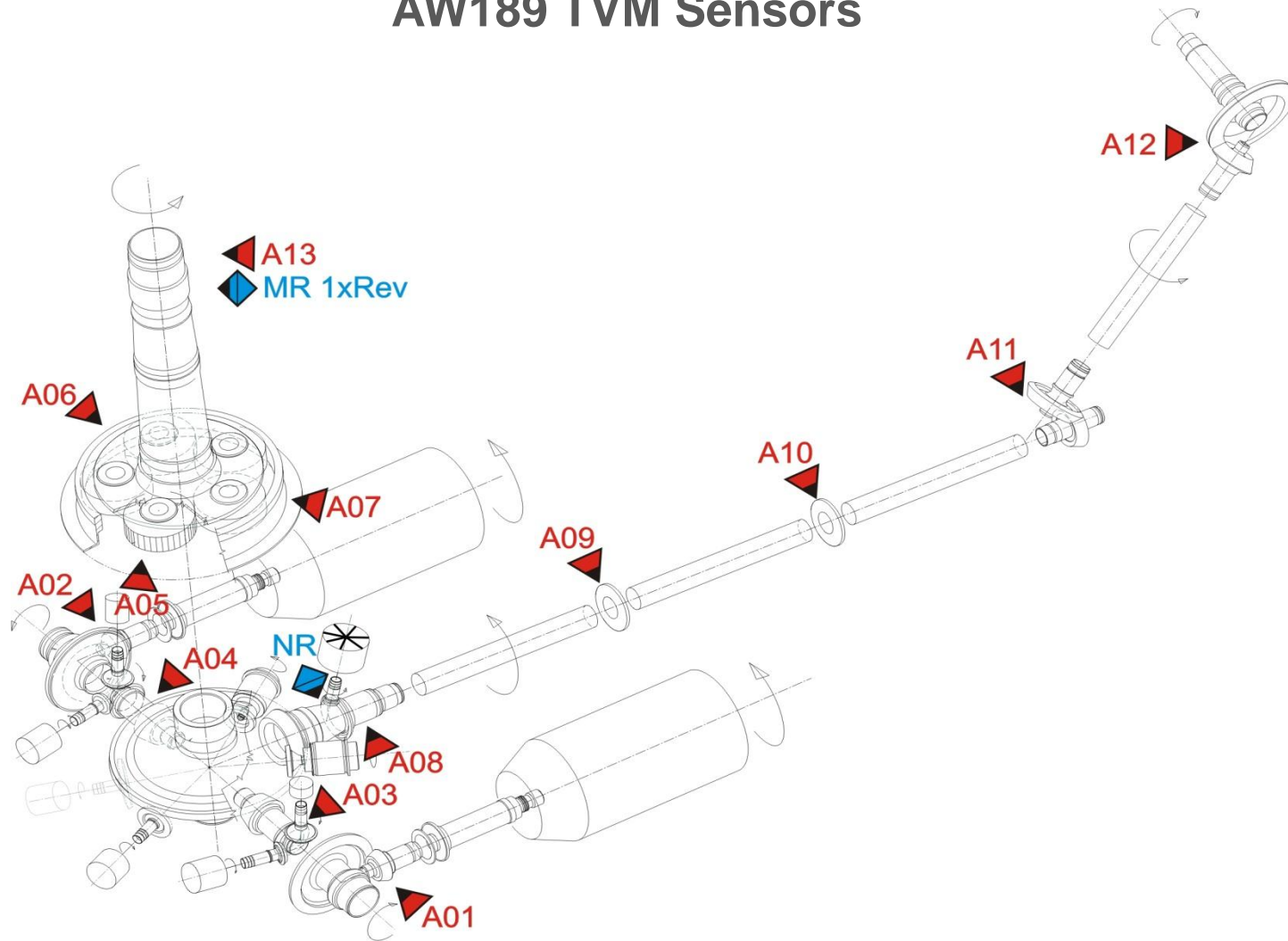
Transmission Vibration Monitoring

MONITORED COMPONENTS

- Engine to main gearbox input drive shafts
- Gearboxes gears, shafts and bearings
- Tail rotor drive shaft and hanger bearings
- Swashplate bearing



AW189 TVM Sensors





TVM Components and Condition Indicators (Cis)

Monitored components:

- MGB (50 components)
- TAIL ROTOR DRIVE (2 comp.)
- IGB (4 comp.)
- TGB (4 comp.)

Types of components monitored :

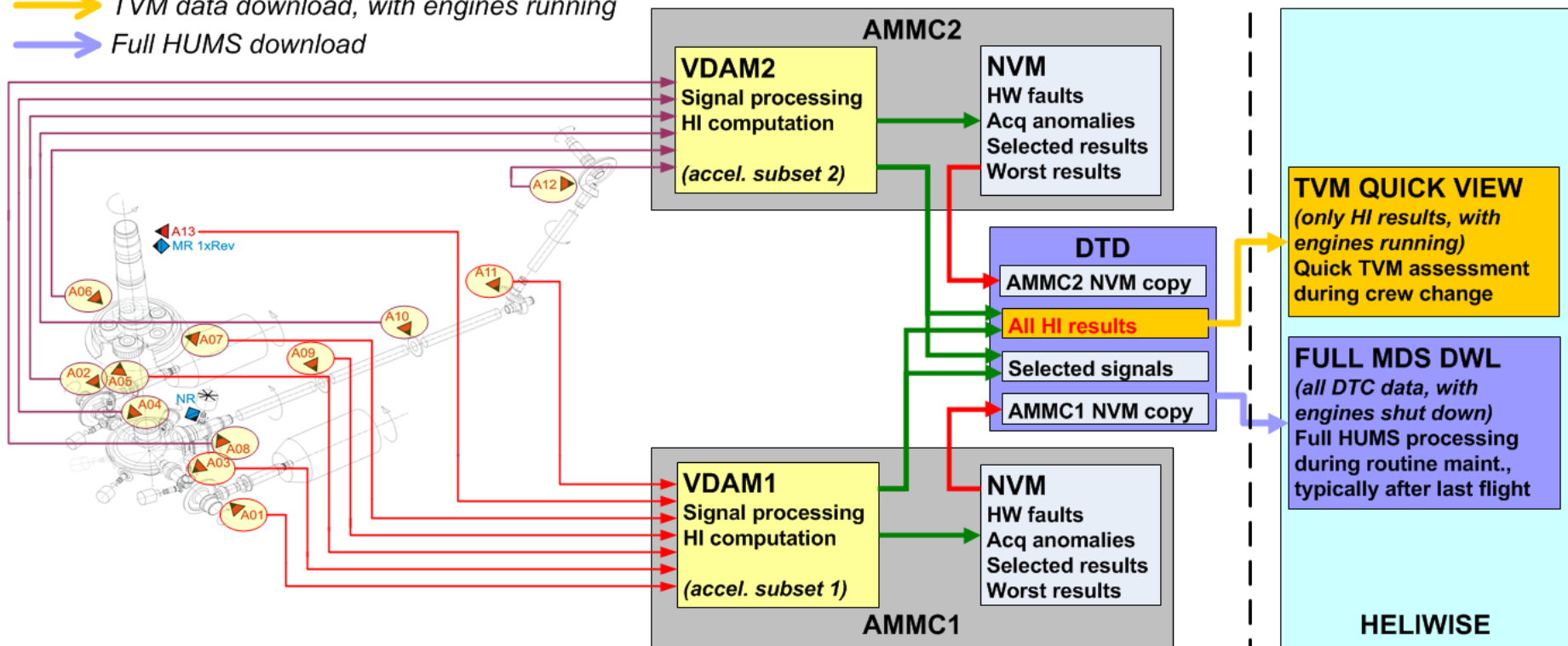
- GEARS (14 indicators per gear computed)
- SHAFTS (2 indicators per shaft computed)
- BEARINGS (12 indicators per bearing computed)

TOTAL: more than 700 C.I. computed for each set of acquisitions

Time spent: < 15 min

VHM Data Structure

- automatic data transfer within AMMC and from AMMC to DTD
- manual data transfer from AMMC to DTD
- TVM data download, with engines running
- Full HUMS download





VHM and RTB Data Controls

MAINTENANCE > AMMS CONFIG

AMMS CONFIG
DTD
HUMS

<div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">RTB MAIN</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">RTB MAIN STATUS</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: green;">COMPLETED WITH EXCEEDANCE</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">MAIN 1R VERT</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: green;">XX.YY IPS XXX deg</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">MAIN 1R LAT</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: green;">XX.YY IPS XXX deg</div>	<div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">RTB TAIL</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">RTB TAIL STATUS</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: orange;">UNSTABLE CONDITION</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">TAIL 1T RAD</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: green;">XX.YY IPS XXX deg</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">TAIL 1T AXL</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: green;">XX.YY IPS XXX deg</div>	<div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">FLIGHT CONDITION</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: green;">SLOW CRUISE POWER MODE</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">VDAM STATUS</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: orange;">1 NR OUT OF RANGE 2 TEST</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px;">TRACKER STATUS</div> <div style="background-color: #cccccc; padding: 5px; margin-bottom: 5px; color: orange;">TRACKER FAIL TRK SPLIT: 123 mm</div>
---	--	--

TVM ACQ...

TVM SYN CYC

TVM ASY CYC

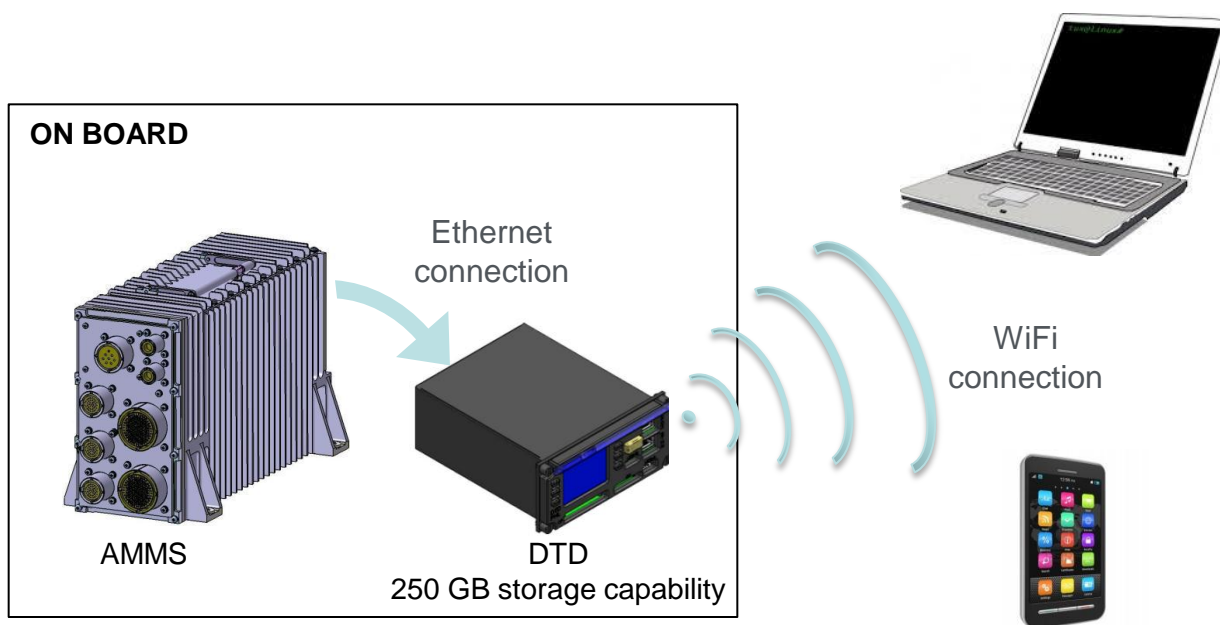
TVM THST CYC

TVM ENV CYC

SVM CYC



Data Transfer



Data transfer from H/C to GS possible via

- USB (pen or cable)
- SD card or compact flash
- Bluetooth
- WiFi
- Ethernet



Data Transfer



Salvataggio screenshot...
MDS Demo

	DOWNLOAD	SEND	RTS
Main Rotor Track and Balance			
Condition	Lat Am/Ph IPS/deg	Long Am/Ph IPS/deg	
FPOG	0.22/40	0.15/150	
Hover	---	---	
Slow Cruise	1.05/64	1.23/260	
Cruise	0.03/12	0.11/359	
Fast Cruise	0.66/35	2.12/274	
Tail Rotor Track and Balance			
Condition	Lat Am/Ph IPS/deg	Long Am/Ph IPS/deg	
FPOG	0.35/250	1.11/20	
Hover	1.15/22	0.65/10	
Slow Cruise	0.02/220	0.15/150	
Cruise	---	---	
Fast Cruise	0.15/150	0.45/97	



AW Android app for smartphones developed to

- Collect and browse on-board data
- Download data to GS



Ground station



Designed to:

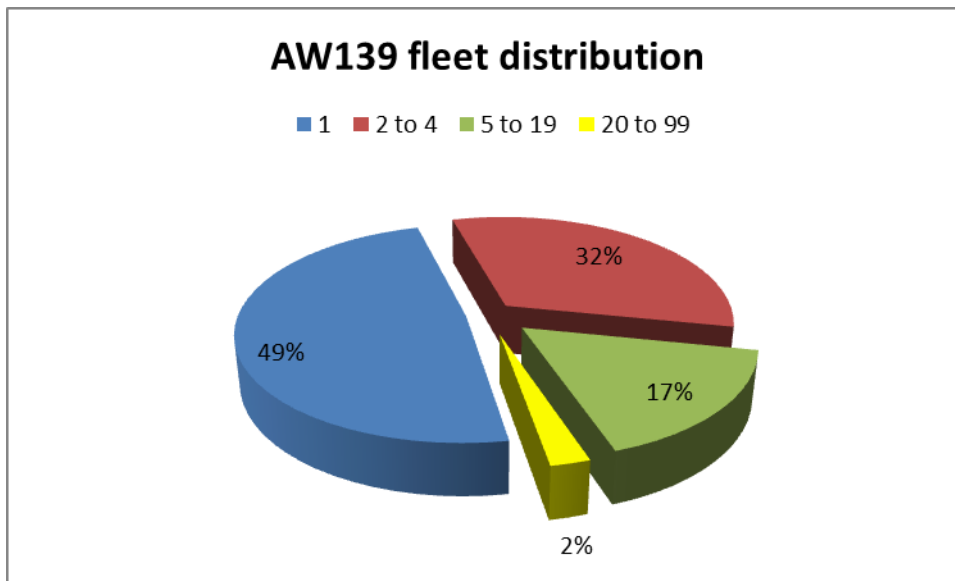
- Send data to central repository
- Access HUMS website
- Run Heliwise as cloud application

- Display data acquired on board in graphical/tabular form
- Compute and apply learning thresholds
- Display data trending
- Compute and display advanced vibration analysis



Ground station

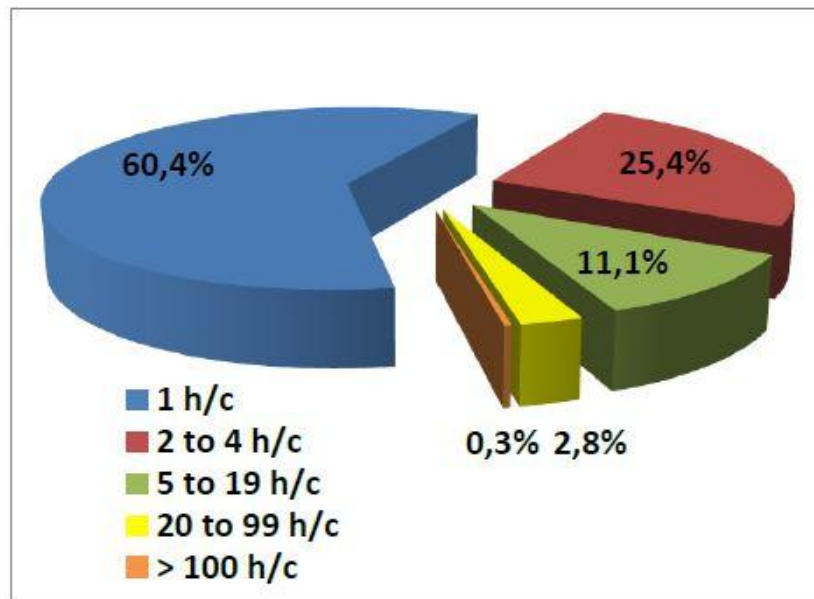




Number of helicopters per operator



Presented by Airbus Helicopter at 70° AHS Annual Forum (20-22/05/2014)



**Airbus Helicopters fleet distribution -
number of helicopter per operator.**




↑ SERVICEABLE - (6 items)

<p>49007</p> <p>S/N: 49007 14/07/2014 13:00</p> <p>TVM RTB SVM FAULT</p>	<p>49008</p> <p>S/N: 49008 04/07/2014 05:36</p> <p>TVM RTB SVM FAULT</p>	<p>49009</p> <p>S/N: 49009 11/07/2014 09:49</p> <p>TVM RTB SVM FAULT</p>
<p>49010</p> <p>S/N: 49010 07/07/2014 08:08</p> <p>TVM RTB SVM FAULT</p>	<p>49011</p> <p>S/N: 49011 12/06/2014 16:53</p> <p>TVM RTB SVM FAULT</p>	<p>49012</p> <p>S/N: 49012 09/07/2014 18:10</p> <p>TVM RTB SVM FAULT</p>

-
-
-
-
-
-
-
-
-
-
-
-



49009
—



TVM
RTB
SVM
FAULT

Status: SERVICEABLE

Tail Id: 49009
Hc SerialCode: 49009
Variant: TC1
S/W Version: 3.7.9
Role: OFF-SHORE
Environment: GENERIC
Location: VERGIATE

Last DSN Id: 37
Last DSN Start: 10/07/2014 07:56:08
Last DSN End: 11/07/2014 09:49:59
Last DSN FH Start: 05:57:37
Last DSN FH End: 06:08:15

Drag a column header and drop it here to group by that column

DSN	Description	Reason	Update Time	Update Author	Number	Status	Remarks
31	AMB EXC - Coll Gear RH (A04) - ENHM6A - SYNC - 008	Steady Amber	08/07/2014 10:27:09	BERTELLI	108	Accepted	
31	FAR TR EXC - TRDS #2-FWD-Brg (A10) - MFP - SYNC - 022	Far Trend	08/07/2014 10:27:09	BERTELLI	110	Pending	
31	CLS TR EXC - TRDS #2-FWD-Brg (A10) - S1R - SYNC - 022	Close Trend	08/07/2014 10:27:09	BERTELLI	111	Pending	
31	FAR TR EXC - TRDS #2-FWD-Brg (A10) - S1R - SYNC - 022	Far Trend	08/07/2014 10:27:09	BERTELLI	112	Pending	
31	FAR TR EXC - TGB Gear (A12) - S2R - SYNC - 026	Far Trend	08/07/2014 10:27:09	BERTELLI	113	Pending	
31	CLS TR EXC - RH Lub Pump Pin (A04) - S1R - SYNC - 034	Close Trend	08/07/2014 10:27:09	BERTELLI	114	Pending	
31	AMB EXC - TRDS #2-AFT HF (A10) - HHM6A - THIST - 067	Steady Amber	08/07/2014 10:27:09	BERTELLI	115	Accepted	
31	CLS TR EXC - TRDS #2-AFT HF (A10) - HHM6A - THIST - 067	Close Trend	08/07/2014 10:27:09	BERTELLI	116	Pending	
31	FAR TR EXC - TRDS #2-AFT HF (A10) - HHM6A - THIST - 067	Far Trend	08/07/2014 10:27:09	BERTELLI	117	Pending	
31	AMB EXC - 1st Stg Pin RH-Roll Brgs (A02) - OREB1B - HF ENVE - 085	Steady Amber	08/07/2014 10:27:09	BERTELLI	118	Accepted	
31	AMB EXC - 1st Stg Gear RH-Brgs (A02) - BPEB1A - HF ENVE - 087	Steady Amber	08/07/2014 10:27:09	BERTELLI	119	Accepted	
31	AMB EXC - 1st Stg Gear RH-Brgs (A02) - BPEB1B - HF ENVE - 087	Steady Amber	08/07/2014 10:27:09	BERTELLI	120	Accepted	
31	AMB EXC - 1st Sta Gear RH-Bras (A02) - BPEB2A - HF						

49008
☰



TVM
RTB
SVM
FAULT

49007
☰



TVM
RTB
SVM
FAULT

49010
☰



TVM
RTB
SVM
FAULT

49011
☰



TVM
RTB
SVM
FAULT

49012
☰



TVM
RTB







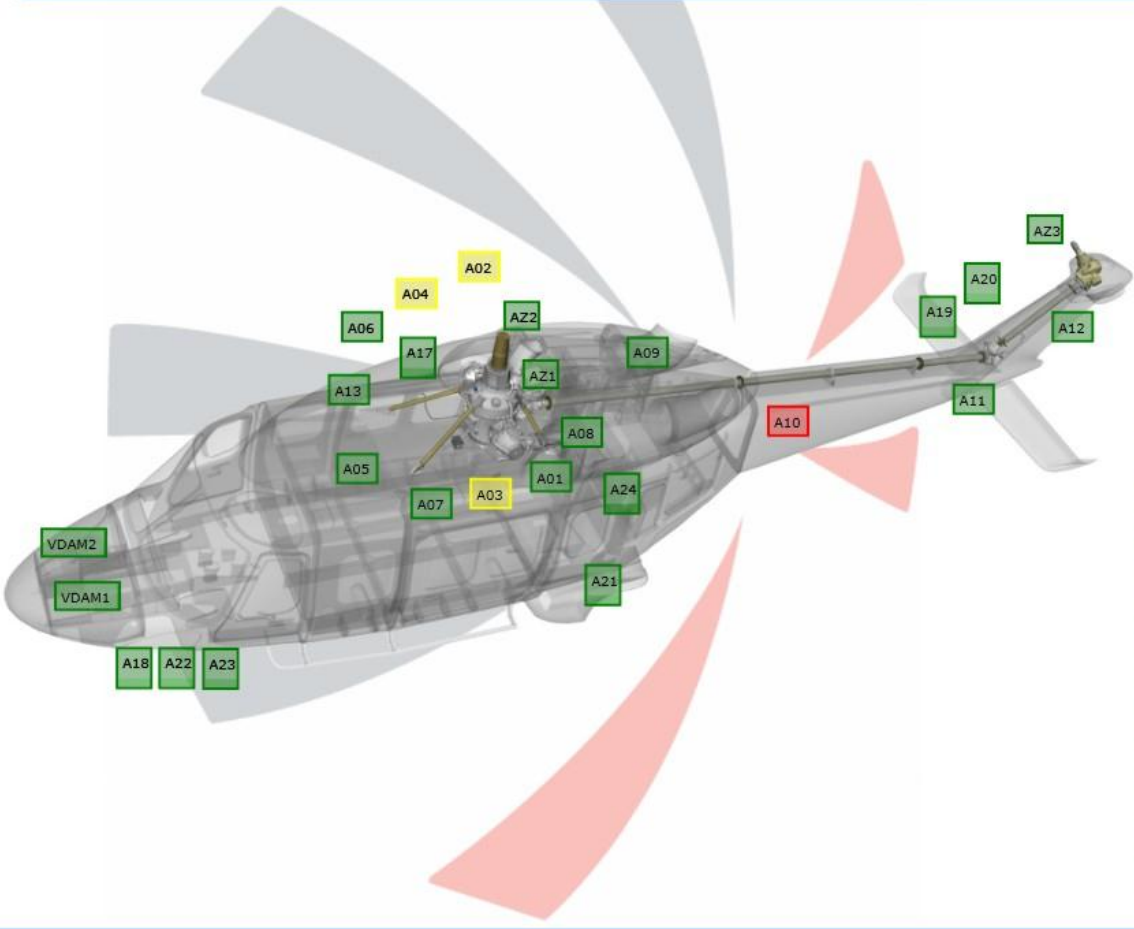






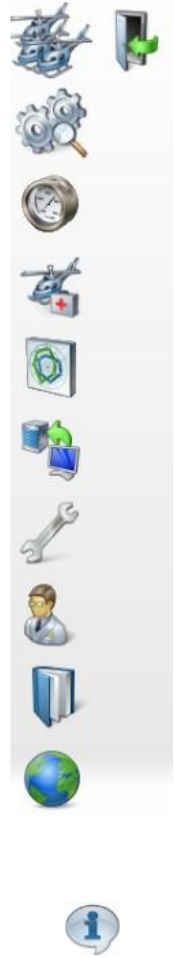


Tail ID 49009 Variant TC1 Last DSN 37 Flight Hours 06:08:15 Last DSN End 11/07/2014 09:49:59
 HC Status SERVICEABLE AMMC Ver 3.7.9 Running Hours 12:15:10



	No Exceedance
	Steady Blue
	Steady Amber - Close/Far Trend
	Steady Red
	Missing Data
	Close Monitoring Open
	Close Monitoring Expired

	A01	MGB, 1st Stage LH
	A02	MGB, 1st Stage RH
	A03	MGB, 2nd Stage LH
	A04	MGB, 2nd Stage RH
	A05	MGB, Planetary Stage FWD LH
	A06	MGB, Planetary Stage RH
	A07	MGB, Planetary Stage REAR LH
	A08	MGB, Tail Take Off
	A09	TRDS Support #1-FWD
	A10	TRDS Support #2-AFT
	A11	Intermediate Gearbox
	A12	Tail Gearbox
	A13	MR Swashplate
	A17	MGB mast, lateral - MR radial
	A18	Cockpit floor, fore/aft
	A19	Tail pylon, lateral - TR axial





Legend:

- No Exceedance
- Steady Blue
- Steady Amber - Close/Far Trend
- Steady Red
- Missing Data
- Close Monitoring Open
- Close Monitoring Expired

Item List:

- 007 2nd Stg Pin RH (A04) - SYNC
- 008 Coll Gear RH (A04) - SYNC
- 032 Hyd Pump 2 Gear (A04) - SYNC
- 033 Alternator 2 Gear (A04) - SYNC
- 034 RH Lub Pump Pin (A04) - SYNC
- 039 2nd Stg RH (A04) - FAVG
- 055 2nd Stg RH HF (A04) - THIST
- 056 2nd Stg RH LF (A04) - THIST

Navigation:

- TVM Accelerometer Status Browser
- TVM Exceedance Browser
- TVM Health Index Summary Chart

Item Details:

Id: 007

Type: SYNC

Description: 2nd Stg Pin RH (A04) - SYNC

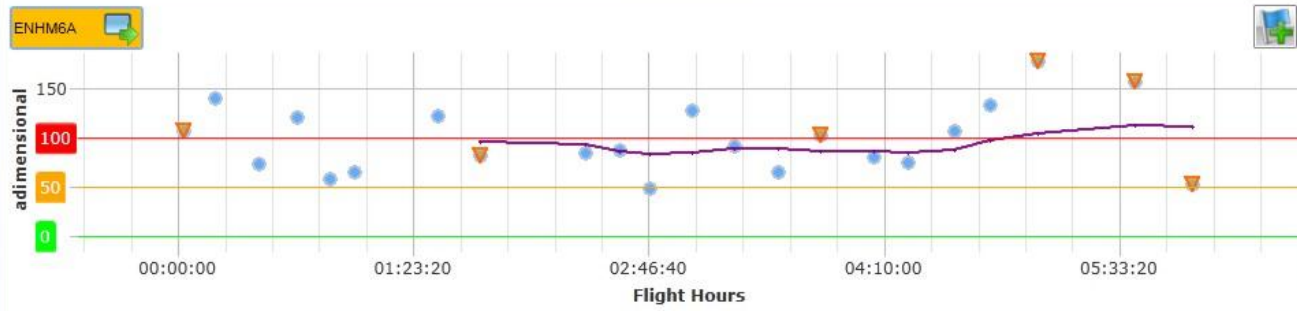
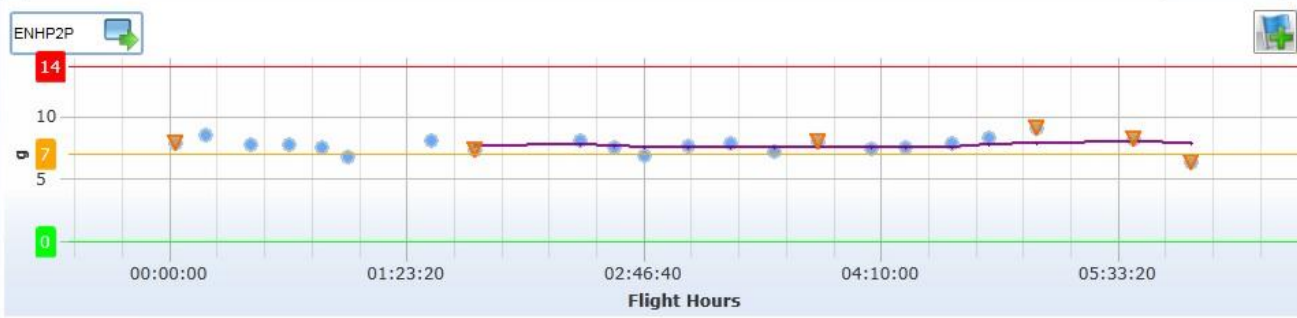


Tail ID 49009 **Variant** TC1 **Last DSN** 37 **Flight Hours** 06:08:15 **Last DSN End** 11/07/2014 09:49:59
HC Status SERVICEABLE **AMMC Ver** 3.7.9 **Running Hours** 12:15:10

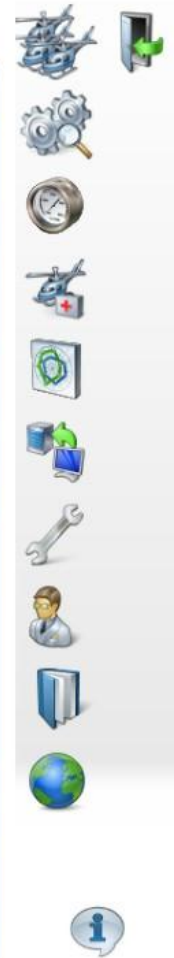
- Health Index Charts**
- S1R S T 0
 - S2R S T 0
 - SnRA S T 0
 - SnRB S T 0
 - SnRC S T 0
 - TAVSTD S T 0
 - TAVP2P S T 0
 - ENHSTD S T 0
 - ENHP2P S T 2
 - ENHKUR S T 0
 - ENHM6A S T 4
 - PMODnA S T 0
 - PMOD1A S T 0
 - MFP S T 0
 - MFPRES S T 0
 - ConvIdx

Acquisition 008 SYNC Coll Gear RH (A04) - SYNC 6 0 Close Monitoring None 2

DSN	Description	Reason	Update Time	Update User Code	Number	Status	Remarks
31	AMB EXC - Coll Gear RH (A04) - ENHM6A - SYNC - 008	Steady Amber	08/07/2014 10:27:09	BERTELLI	108	Accepted	
32	RED EXC - Coll Gear RH (A04) - ENHM6A - SYNC - 008	Steady Red	08/07/2014 10:31:07	BERTELLI	124	Accepted	
34	RED EXC - Coll Gear RH (A04) - ENHM6A - SYNC - 008	Steady Red	09/07/2014 08:15:40	BERTELLI	155	Accepted	



Arising List (60)





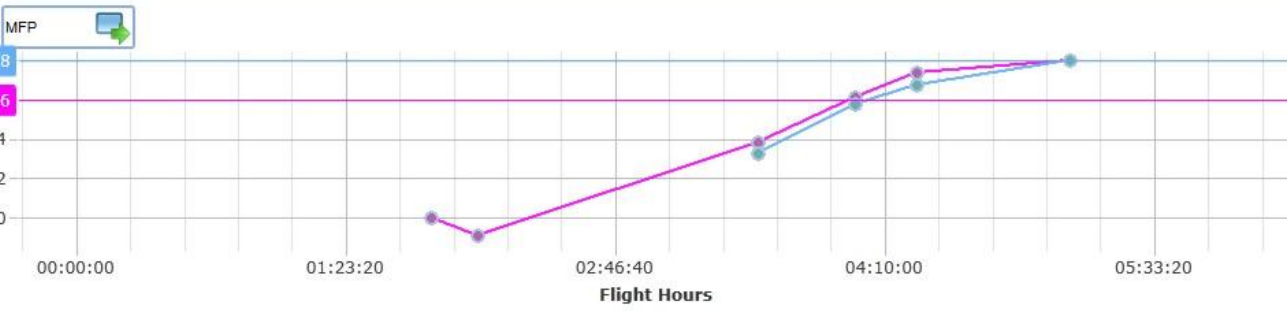
Tail ID 49009
 Variant TC1
 Last DSN 37
 Flight Hours 06:08:15
 Last DSN End 11/07/2014 09:49:59
HC Status SERVICEABLE
 AMMC Ver 3.7.9
Running Hours 12:15:10

dB Deviations Charts

Acquisition 022 SYNC TRDS #2-FWD-Brg (A10) - SYNC
 0 7
 Close Monitoring None
2

- S1R S T 4
- S2R S T 0
- SnRA S T 0
- SnRB S T 0
- TAVSTD S T 0
- TAVP2P S T 0
- ENHSTD S T 0
- ENHP2P S T 0
- ENHKUR S T 0
- ENHM6A S T 0
- MFP S T 3
- MFPRES S T 0
- ConvIdx

DSN	Description	Reason	Update Time	Update User Code	Number	Status	Remarks
31	FAR TR EXC - TRDS #2-FWD-Brg (A10) - S1R - SYNC - 022	Far Trend	08/07/2014 10:27:09	BERTELLI	112	Pending	
32	FAR TR EXC - TRDS #2-FWD-Brg (A10) - S1R - SYNC - 022	Far Trend	08/07/2014 10:31:07	BERTELLI	129	Pending	
31	FAR TR EXC - TRDS #2-FWD-Brg (A10) - MFP - SYNC - 022	Far Trend	08/07/2014 10:27:09	BERTELLI	110	Pending	



Arising List (60)

-
-
-
-
-
-
-
-
-
-
-



Advanced Vibration Analysis

Statistical multivariate analysis based on the assessment of correlations:

- among Condition indicators and
- between CIs and boundary conditions

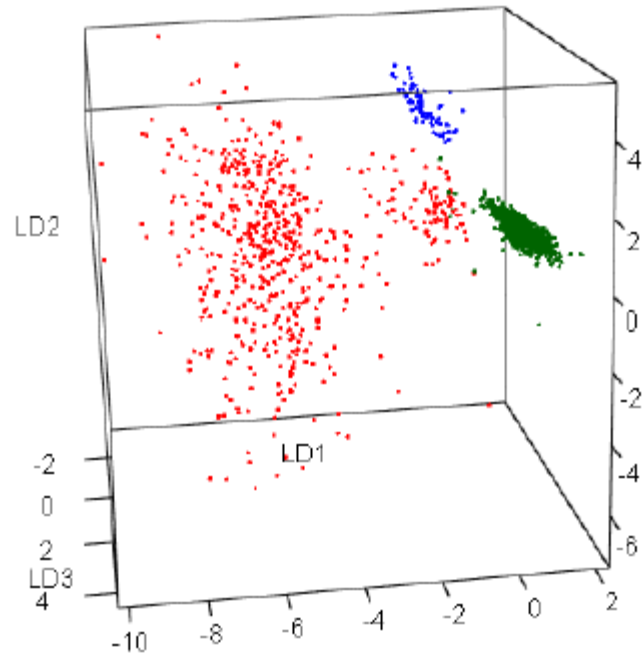
Aim: to increase the fault isolation capability and to reduce false alarm rate

Function developed with the assistance of Politecnico di Torino



Post Processing Functions

Advanced Vibration Data Analysis

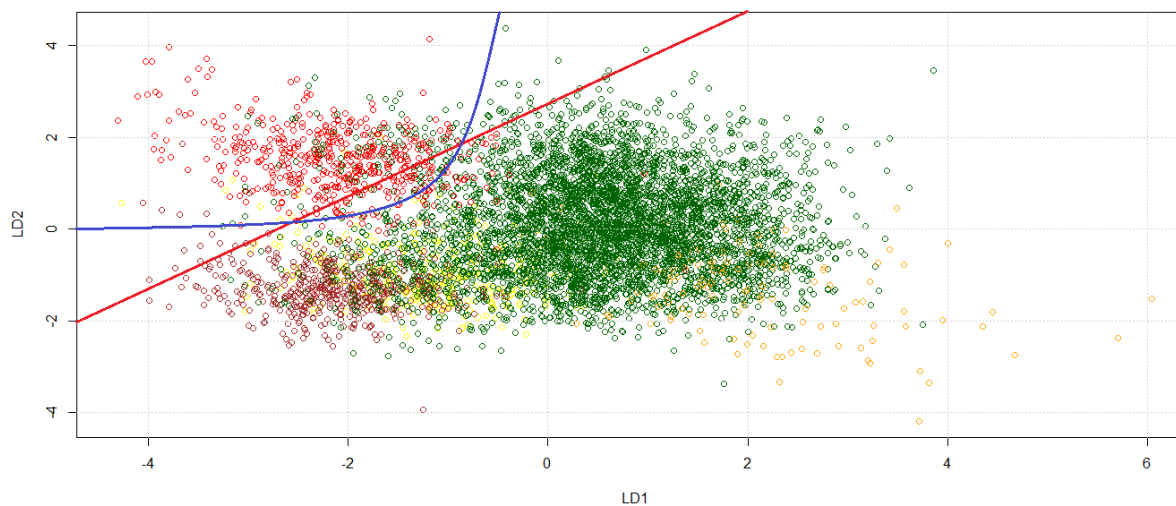
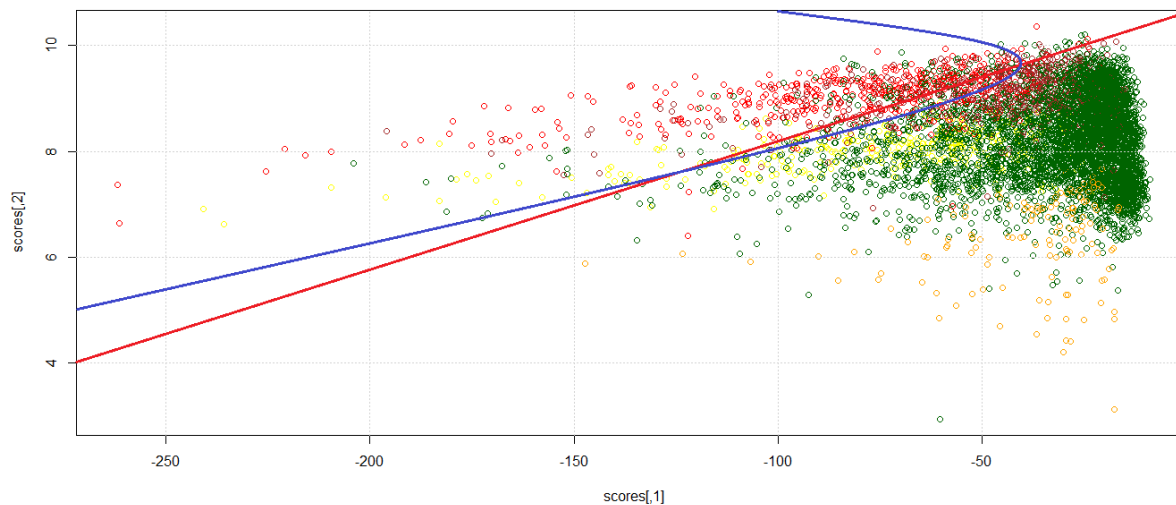


Example multivariate analysis



Post Processing Functions

Advanced Vibration Data Analysis





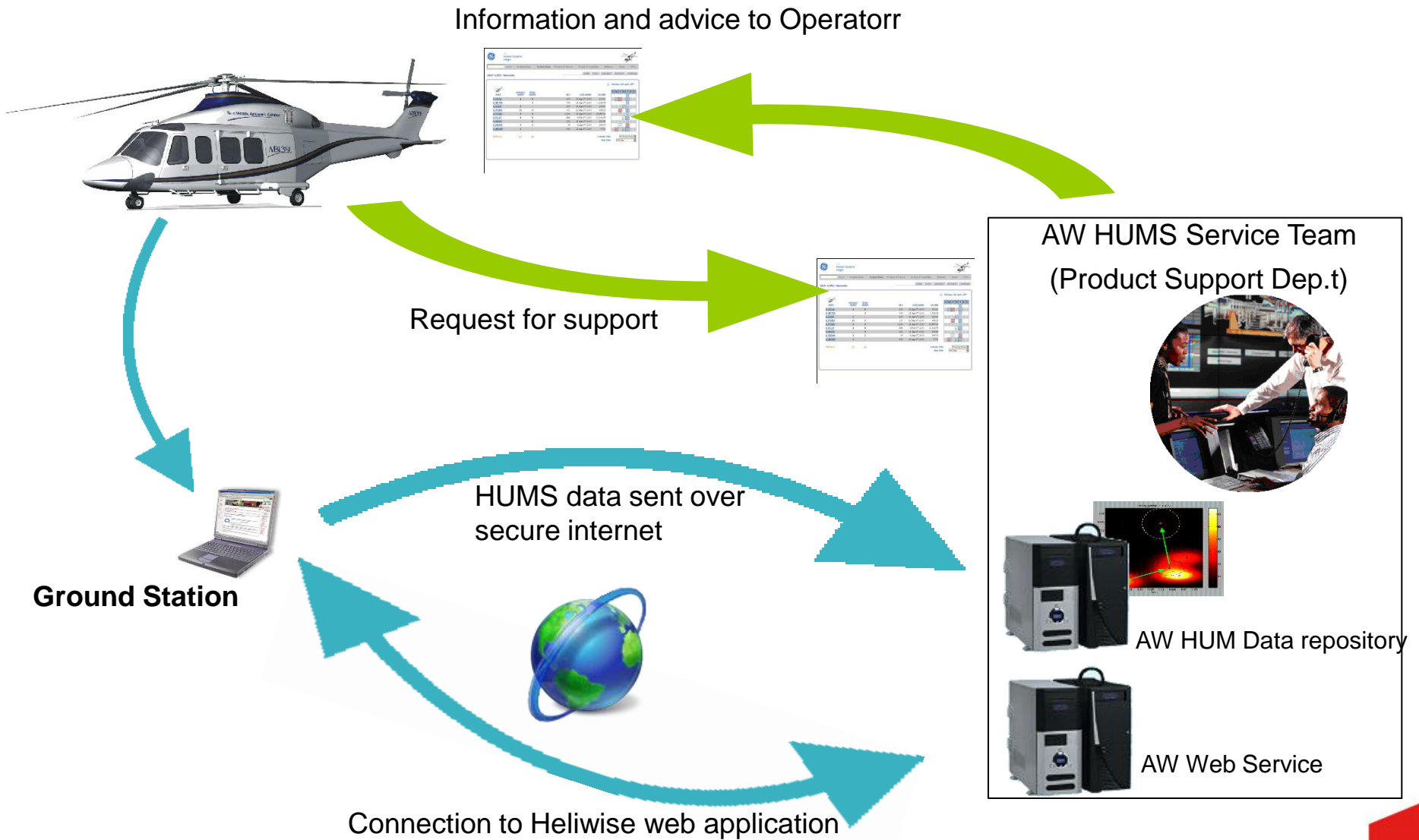
Advanced Vibration Data Analysis

Advanced Vibration data analysis developed making use of the **AW139** Database.

AW139 fleet status (June 2014):

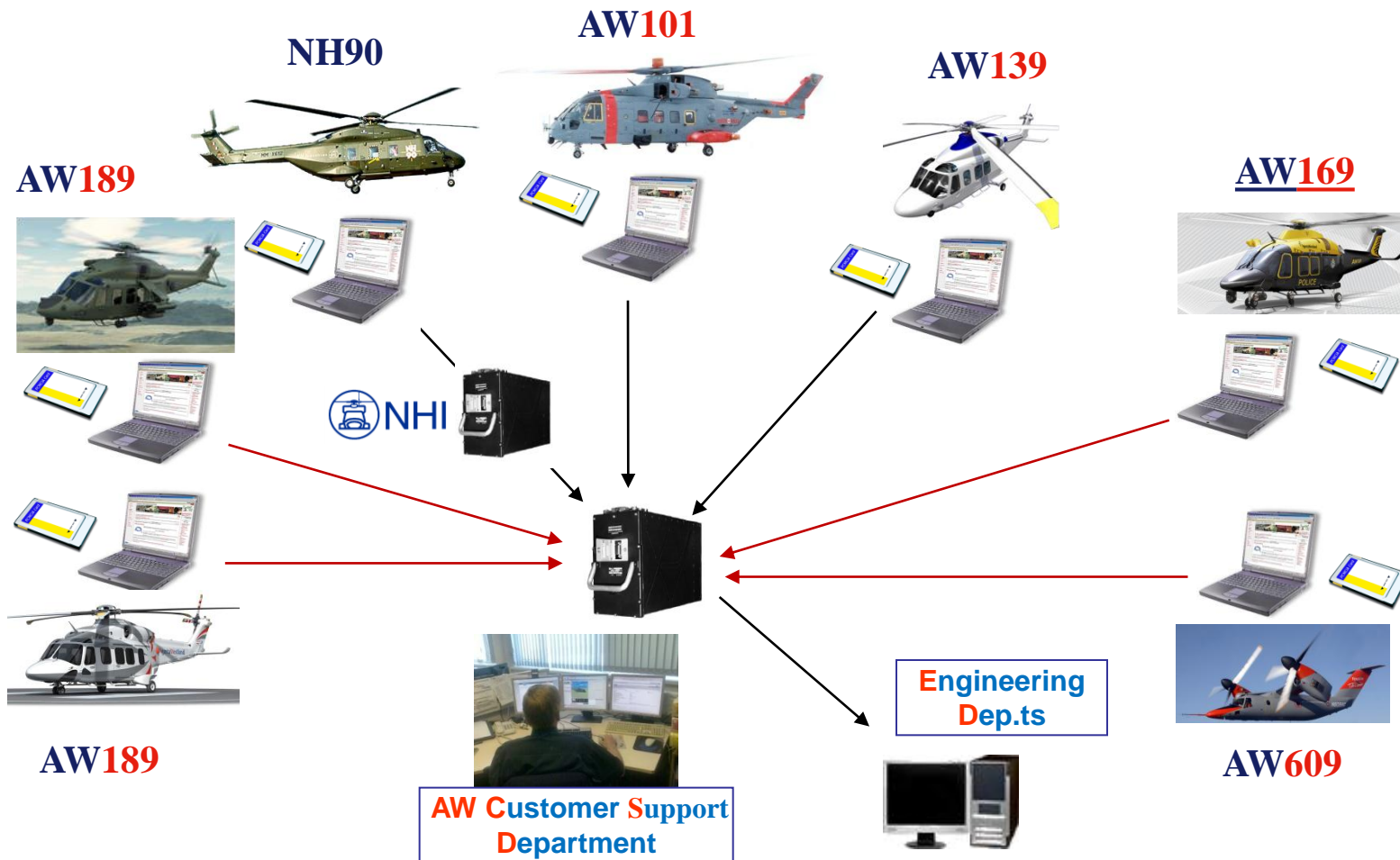
- Total of **372** helicopters monitored (Total fleet size = **740** H/Cs).
- Over **1 000 000** hrs flown
- Approximately **500 000** flight hours monitored.

Data retrieval architecture





AW Data Retrieval and Storage





Lesson Learnt

- Customer appreciation
 - Increase of safety (vibration monitoring)
 - Decrease of troubleshooting time (diagnostic function) → decrease of maintenance time
 - On line support
 - Ease of use

- Usefulness of data retrieval for Design Authority
 - Investigation of malfunctions/failures
 - Assessment of true flight profiles



Techniques presently Under Test

- High frequency vibration Analysis (4 MHz sampling frequency) for crack onset detection
- Wireless sensors with energy harvester on rotating components

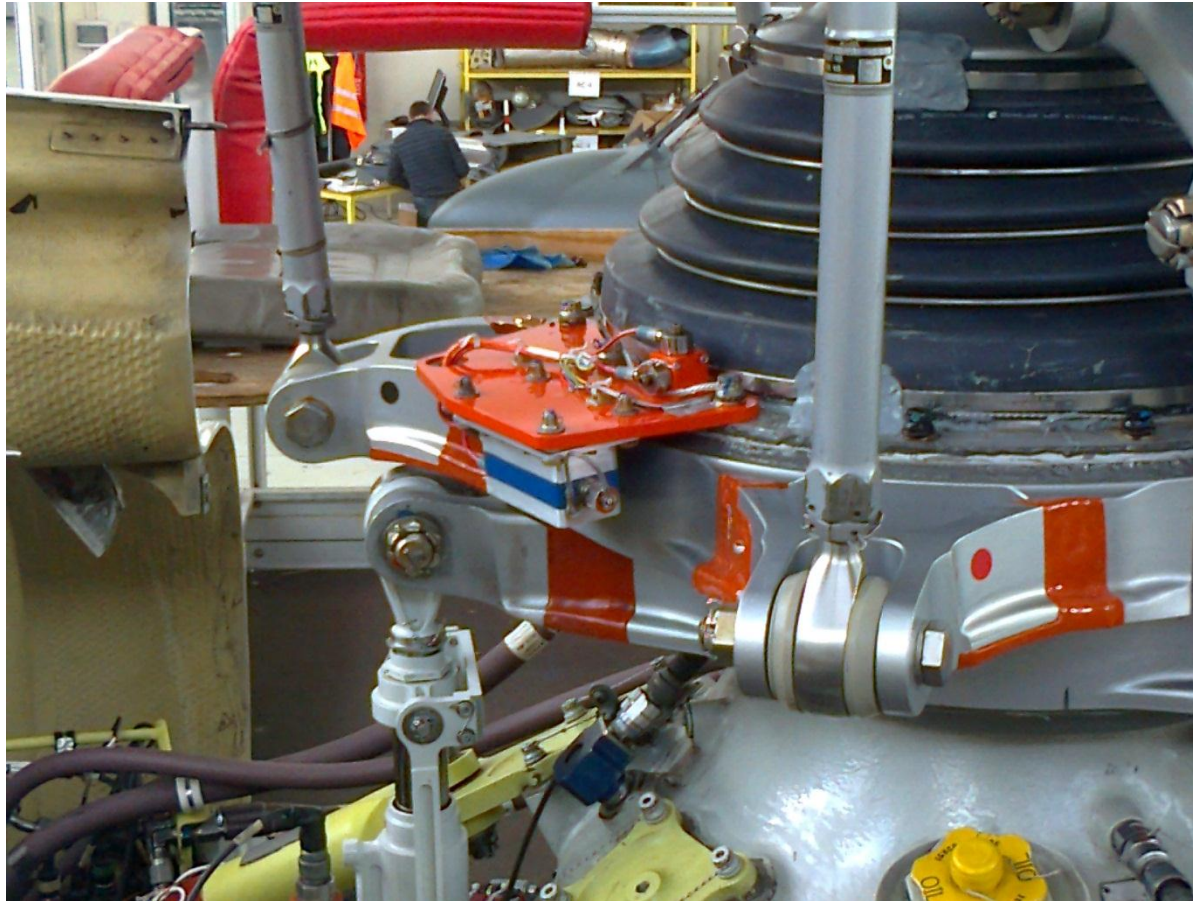


AE sensor installation on test rig





Wireless sensors prototype installation







Questions ?



Thank You