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TITRE : HUMS AVIONIQUE NOUVELLE

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Abstract

Out of Eurocopter HUMS product policy, based on a customised approach for its light, medium and heavy helicopters, emerged a new product line, consistant with our « Avionique Nouvelle » avionics suite dedicated to light/medium helicopters. This product, now in developpement, is called « HUMS AVIONIQUE NOUVELLE ».

It is composed of « Avionique Nouvelle » standardized modules and a DTU (« PCMCIA » Data Transfer Unit), communicating with the VEMD (Vehicule and Engine Monitoring Display). This modular approach is aimed to fulfill customers requirements for HUMS functions for the EC Light/Medium helicopter range.

The advantages of this modular concept is a reduction of recurring costs, a commonality of product and operating procedures on the different EC helicopters and the capability to propose a progressive implementation of HUMS, from « mini HUMS » to « full HUMS » functionnalities.

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1. INTRODUCTION

The first goal of the HUMS was to increase the operational safety through the monitoring of critical components and systems. The HUMS also provides a higher degree of helicopter availability and is a help for the optimization of maintenance activities, with the aim to reduce the operator's operational costs.

Avionique Nouvelle HUMS is composed of standardised modules and a DTU (PCMCIA Data Transfer Unit), communicating with the VEMD (Vehicle and Engine Multifunction Display) or other Avionique Nouvelle modules. This modular approach meets customer requirements for HUMS functions in the EC light/ medium helicopter range.

2. GENERAL CONCEPT

The EC Avionique Nouvelle HUMS takes into account the operator needs to optimize its fleet maintenance. The reduction of helicopter operational costs is realised through the three following functions:

- Maintenance program management
- Design safety level preservation
- Operational availability management

EC Avionique Nouvelle HUMS monitors the most important data of the main helicopter subsystems, especially of the propulsion system: gearboxes and engines. A few health functions are monitored to check for the system and to verify the usage functions. The system works autonomously. There are quite no actions for the pilot during flight and the system gives no warnings to the pilot. All results of HUMS are provided to the ground maintenance crew. There the necessary maintenance actions are started or planned for the future.

All the data acquisition, data reduction and data storage is performed on board. The data are transferred to the Ground Station for the evaluation. Modifications of the algorithms affect the Ground Station only. In this way, the system is very flexible and easy to handle.

The system consists of 2 general parts:

- the on board part for the data acquisition, management and storage,
- the on ground part for the evaluation.

The interface between both is a PCMCIA memory card for storage and data transfer.

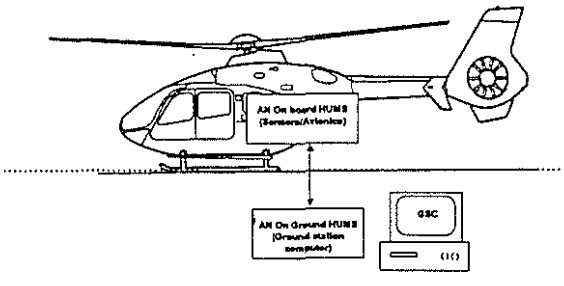


Figure 1 : General System Architecture: on board / on ground

3. ON BOARD SYSTEM

3.1 Functional modularity

The function list for lighter helicopters is a sub set of the list of the heavier helicopters. This leads to a functional modularity, that can be described according to three functional levels: minimum, standard and upgraded configurations.

Minimum configuration

This configuration consists of a usage monitoring which drives the maintenance program with flight hours, cycles counting, exceedances monitoring, the engine power check as a health function and the recording of alarms and failures. The minimum configuration is compliant with the project of JAR OPS ¾ concerning engine parameters recording.

Standard configuration

In addition to the minimum configuration functions, a complete set of health functions including transmissions and rotor vibration analysis and rotor tuninng is implemented.

Future upgraded configuration

It is an upgrade of the standard configuration that implements:

- improvements in health monitoring diagnostic
- a complete damage computation using an automatic FSR (Flight State Recognition).

For all configurations, an electronic documentation of the EC Maintenance Servicing Recommendations is implemented in the Ground Station Computer, which uses the results of health, usage and status functions for on ground maintenance management.

3.2 Hardware modularity

The hardware architecture is based on the use of the following modules:

- a CPDS (Central Panel Display System) composed of a VEMD (Vehicle and Engine Multifunction Display) installed as basis and fitted with a set of HUMS functions.
- an analogue/ digital acquisition module MFDAU (Miscellaneous Flight Data Acquisition Unit) basically used to feed a CVFDR, and fitted with a set of HUMS functions.
- a health monitoring module fitted with vibration data acquisition and vibration analysis pre-processing.

- a HUMS control panel (HUMS-CP) used for on-board flight report validation by the pilot.
- a DTU (Data Transfer Unit) which records the flight data for transmission to the GSC.
- a GSC (Ground Station Computer) to complete the on-board processing and provide maintenance management.

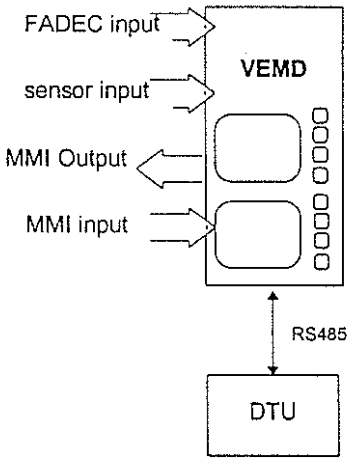
3.3 Versions

3.3.1 Minimum HUMS Configuration

Two configurations are defined to be fitted on light helicopters (single engine) and on medium helicopters (twin engines).

Single engine configuration

This configuration is based on a VEMD and a DTU with an additional processing that shall be implemented to perform the HUMS functionalities. The architecture consists in the following:



Figuer 2 : Minimum HUMS architecture for single engine helicopter

The VEMD acquires all relevant data and computes the relevant functions during the flight. After the flight, the downloading is performed automatically from VEMD to DTU via maintenance bus. Avionics status of equipment connected to the bus will be downloaded also.

Twin engines configuration

This configuration is based on the MFDAU already implemented for the CVFDR function. The MFDAU is fitted with additional processing to perform HUMS functions and is interfaced with a DTU and a HUMS-CP.

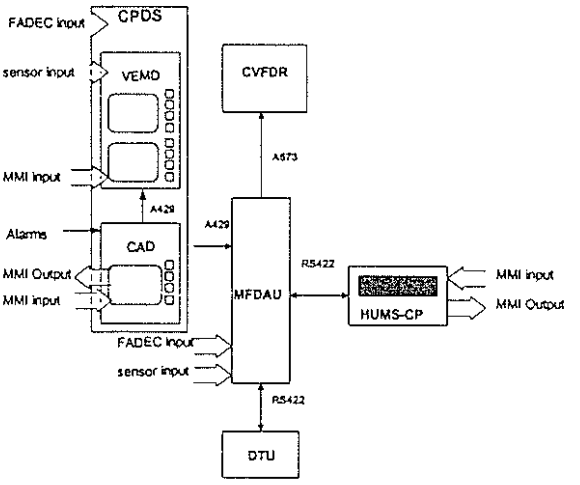


Figure 3 : Minimum HUMS architecture for twin engine helicopters

The MFDAU acquires all relevant data and computes the relevant functions during the flight. After the flight, a Flight Report is displayed to the pilot. The pilot can validate this Flight Report on board. The downloading is then performed automatically from MFDAU to DTU.

The following functions are available in these configurations:

Usage monitoring	
All subsystems	operating time and flight time
Rotors	NR cycles, NR exceedances
Transmissions	Torques cycles, Torques exceedances
Engines	N1 and N2 cycles, engines start up counting, TOT, N1 and N2 exceedances
Fuselage	landing counting
Health monitoring	
Engines	engines power assurance check
Status monitoring	
All subsystems	alarms and avionics status recording

All functions are performed automatically during the flight and results stored in the on-board system for downloading to the Ground Station at the end of the flight.

Only the engines power assurance check is to be launched by the pilot. This is performed during the flight in a stabilised flight configuration. The result is displayed to the pilot. On ground a history file indicates the development of the engine health.

3.3.2 Standard HUMS Configuration

This configuration will be fitted on medium helicopters.

An additional health monitoring module is implemented to provide a complete set of health functions. This module also manages the complete system logic and controls data downloading to DTU. The architecture consists in the following:

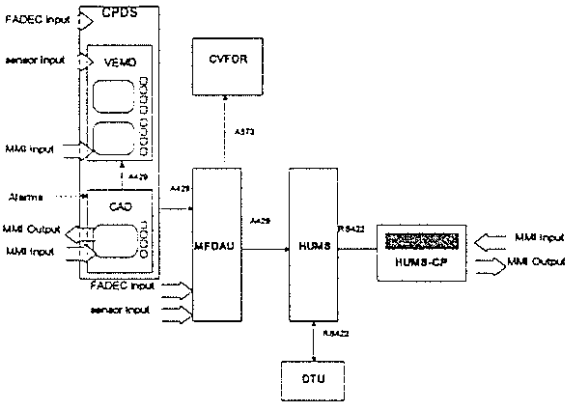


Figure 3 : Standard HUMS architecture

The following additional functions are available in this configuration:

Health monitoring	
Engines	engine vibration monitoring (N1 and N2 shafts)
Rotors	Rotors tuning, rotors vibration monitoring
Transmissions	Vibration monitoring for all gears, shafts and bearings, direct damage computation

⇒ Direct damage computation

With a more precise recording of the context around exceedances, it is possible to calculate a damage on elements which life time is given in hours or cycles. These elements get then an individual life time as result of their real use. For the EC135 the torque input and output of the main gearbox is measured and give the basis for life time calculation of all gearbox elements.

⇒ Rotor tuning

Accelerometers data acquisition is made during the flight in four different configurations. The vibration files are downloaded at the end of the flight via the DTU to the Ground Station or a maintenance tool (portable PC) which will propose appropriate rotors tuning.

⇒ Vibrations monitoring

Several accelerometers are mounted on the engines, gearbox and tail drive shaft. The signals give information about the health situation of all these systems.

Vibration levels measured on Super Puma and EC135 gear boxes have shown that failures of bearings and gears can be recognised in time. Vibration files will be downloaded via the DTU to the Ground Station which will display all indicators necessary for a diagnostic.

Presently ground tests are running at ZFL facilities in Kassel-Calden with a EC135 main gearbox. This box is running with high loads to produce failures in bearings and gears. 4 accelerometers are mounted on the box and the signals are acquired and analysed under normal load conditions. Each element in the gearbox produces a characteristic frequency signal. An increase of this amplitude (see Fig. 4) indicates an upcoming failure. Fig. 4 shows the signal of the output shaft bearing to the tail rotor. The bearing was replaced before a secondary damage occurred. On another run a tooth crack was indicated. This gear was also replaced before the failure became critical. In the future the threshold definition will be a main task.

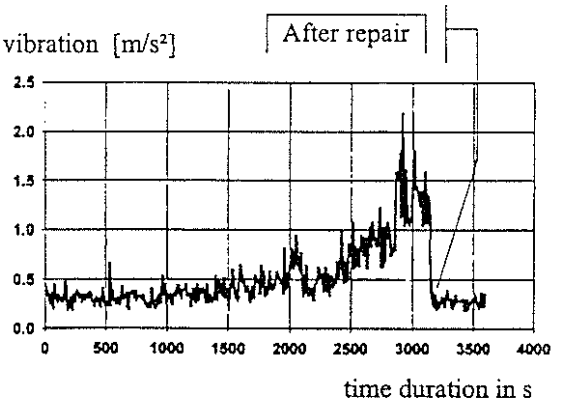


Figure 4 : Amplitudes of the output bearing frequency

3.3.3 Future Upgraded HUMS Configuration

This configuration will be fitted on medium helicopters in a third step. It consists of an upgrade of the standard configuration, based on the same hardware with an improved software. The architecture is the same as described above.

The following additional functions are available in this configuration:

Health monitoring	
All life limited elements	Indirect damage monitoring
Engines	(EES, future function)
Rotors	Rotors tuning, rotors vibration monitoring improvement
Transmissions	Vibration monitoring improvement for all gears, shafts and bearings, oil temperature and pressure monitoring, (IDM, QDM future function)

⇒ **Indirect damage monitoring**

This function allows to recognise the flight profile through flight states and allows then to calculate a damage consistent with the real usage of the helicopter. For this function a set of standard flight parameter are measured such as air speed, altitude, attitude, control angles, mast bending moment and torques. These data are stored as a time history on the DTU. On ground a special Flight State Recognition (FSR) software recognises the flight states flown, connects them with a load data base and calculates the used life of all life limited components. All parts of the helicopter have now an individual life time.

The flight state recognition software is mainly based on a neural network. With the above mentioned input parameters the network recognises a set of basic flight states and all manoeuvers. With a logical calculation, which takes into regard the weight, centre of gravity and flying altitude, the recognised flight states are completed. A number of over 1000 flight states can be recognised by this method. The neural network was trained with real flight data from the flight test centre. The life time calculation method is basically the same as for helicopter certification.

⇒ **Future functions**

Special equipments are under development to detect metal particles in the exhaust gas of the engines (EES) or in the oil flow of engines and gear boxes (IDM; QDM). These equipments will be installed when the engine and gear box manufacturer can provide limits for the number and size of particles in gas and oil.

4. GROUND STATION

4.1 General overview and system objectives

The ground station used for HUMS Avionique Nouvelle is a multi-purpose ground station capable of EC complete helicopter range. It is also a multi-users ground station where four different access groups have been defined (crew, maintenance, customer expert, EC expert and administrator).

The general purpose of the ground station is to analyse flight data representative of the effective operation of the helicopter in order to adapt the maintenance to the actual usage. For each helicopter, the ground station controls the equipment configuration (installation/removal) and their associated lives (according to EC Maintenance Servicing Recommendations).

The objectives of the ground station are as follows:

mini-HUMS configuration:

- Automating the flight follow-up process (downloading the helicopter data recorded during flight and issuing the flight report).
- Automating the flight analysis (integrating the data into the database and issuing the helicopter maintenance report).
- Ensuring the follow-up process and ensuring maintenance management assistance for the helicopter (Maintenance scheduler).
- Providing direct connection to the electronic documentation.

standard HUMS configuration:

- Providing rotors, transmissions and engines health indications to allow assistance before the degradation of the element.
- Providing helicopter usage and damage indications to allow scheduled and unscheduled maintenance optimisation.

future evolutions:

- Providing real helicopter usage spectrum.

The main functions of the ground station can be divided in three levels:

- flight follow-up and analysis level
- maintenance level
- expert level.

4.2 Flight follow-up and analysis

4.2.1 Cartridge downloading

The crew initiates the downloading of the cartridge containing the data of the past flights on the ground station. After notification of the downloading of a cartridge, the system checks the flight data consistency, reads and formats the data (conversions, coefficients...) and stores them in the database by assigning them to a helicopter.

4.2.2 Flight data validation and Flight Report edition

The data recorded by the system cannot be modified and will be kept in any case in the database. However, before editing the Flight Report, the data have to be « locked » by the pilot. The ground station offers the possibility for the pilot either to confirm the system data or to modify them when they are erroneous or inconsistent with the pilot notes. Once the data are « locked » by the pilot, the Flight Report is edited and the system proposes to initiate the flight analysis.

In case the flight data are not available on the cartridge (malfunction of the on-board system or of the cartridge, loss of the cartridge, downloading omitted...), the pilot has the possibility to create himself the missing flight.

HUMS FLIGHT REPORT **print date: 12/10/1997**
session # 18

FLIGHT IDENTIFICATION

Type	:	AS 322 L2	Session date	12/04/1997	04:27:36 PM
Tail Number	:	F-WWON	Flight number	VTM3_VL9	
Departure base:		MAR	Pilot	JP. Roldan	
Arrival base	:	MAR	Copilot	JP. Meunier	

FLIGHT DATA

		System value	Pilot acknowledgement
Aircraft	:		
Operating time	:	00:32:18	
Flag OAT<-30°C	:	CLEAR	
Airborne time	:	00:22:09	
Taxiing time	:	00:01:39	
Landing count	:	1	
Landing speed	3,8m/s		
Engine #1			
Start up count		1	
Operating time		00:30:47	
NG cycle count		0.6	
NF cycle count		1.0	
Engine #2			
Start up count		1	
Operating time		00:32:07	
NG cycle count		0.7	
NF cycle count		1.0	

FLIGHT EVENTS

NR exceedances	:	0	Alarms	:	0
TQ exceedances	:	0			
Engine Exceedances	:	0	Power checks	:	0

PILOT REMARKS

Figure 5 : Example of Flight Report

4.2.3 Flight analysis and Maintenance Report edition

A certain number of counters are defined on the ground station, such as flight hours, airframe cycles, torque cycles, engine cycles, damage counter, health indicator counter...
Each element on the helicopter is assigned one or more counters with associated maximum thresholds, according to the Maintenance Manual.

The flight analysis is divided into three types of functions :

- « Usage »: Times, Cycles, Exceedances, damage computation.
- « Health »: Engine Power Assurance Check, transmissions and engines vibration analysis
- « Status »: Failures and Alarms.

The flight analysis consists in incrementing these counters by adding the last flight data to the previous ones and to compare these counters to the given thresholds. As soon as a threshold is exceeded, or a failure detected, a message is generated in the Maintenance Report. The Maintenance Report summarises all maintenance actions to be carried out by the maintenance team. The substantiation for these messages are accessible at the « expert » level.

The messages displayed in the Maintenance Report are grouped into 4 categories:

1 Messages for unscheduled maintenance as « usage » (incidents, exceedances, damage computation...).

2 Messages for unscheduled maintenance as « health » (exceeded health indicators thresholds, engine power assurance check margins, engine vibration monitoring...)

3 Messages for scheduled maintenance (exceedance of TBO, SLL, inspections).

4 « System » messages (system failures).

For the health indicator thresholds, the maintenance message always refer to the maintenance manual where the HUMS expert will be asked to make a diagnostic and deduce the corresponding maintenance actions.

Aircraft Registration:	**FWWON**	**Type: AS 332 L2**
Health Incident		
12/04/1997 04:27:36 PM	The indicator PGE_KR Amber threshold has been exceeded, 3.55 g (Part: 332 A 32 3075.20/M200. 20232527313645). Refer to MMA ch.45	
12/04/1997 04:27:36 PM	The indicator VBL_RMS Amber threshold has been exceeded, 25.70 g (Part: Bevel Bearings/ M2006). Refer to MMA ch.45	
12/04/1997 04:27:36 PM	The indicator PBM_RMS Red threshold has been exceeded, 30.24 g (Part: Epicyclic Bearings/ M2006). Refer to MMA ch.45	
12/04/1997 04:27:36 PM	The indicator BTIA_RMS Amber threshold has been exceeded, 20.47 g (Part: IGB Bearings/ M301). Refer to MMA ch.45	
12/04/1997 04:27:36 PM	The indicator LBR_RMS Red threshold has been exceeded, 49.87 g (Part: LH free wheel/ M2006). Refer to MMA ch.45	

Figure 6 : Example of Maintenance Report

4.3 Maintenance

4.3.1 Rotor tuning

This function presents the best fitted tuning to be applied on the rotors in hub weights, pitch links and trim tabs, in order to lower the unbalance.
The operator can have access to main and tail rotor vibration levels recorded during the flight in different flight configurations.

He also can have a presentation of the vibration levels at a given harmonic with the amplitudes recorded by all accelerometers and a polar representation of the unbalance (amplitude and phase).

4.3.2 Log Book (Equipment Log Cards)

This function enables the user to consult the Log Cards for a given equipment or sub-assembly and to modify its characteristics.
The following information on the part or sub-assembly are displayed:

- the TBO, SLL, OTL, equipment inspection
- the TSO, TSN
- the Remaining Time Before TBO, SLL and OTL expiration thresholds
- the « In Service Introduction date »
- the date of last overhaul
- the storage duration

- the ageing counter values
- the list of modifications embodied to the part.

The user has the possibility to issue a given Log Card for all operators in the loop and a historical Log.

4.3.3 Aircraft constitution and aircraft type break-down

These functions allow the initialisation and the updating of the aircraft configuration and the updating and follow-up, from the typical break-down for a given type of aircraft.

Therefore, they will be essentially used by the maintenance manager or the system manager. The following functions are accessible:

- initialise or update an aircraft or a component, Initialising an aircraft means indicating a typical reference break-down , initialising the general aircraft data ("In Service Introduction date", Flight hours and landing counters), assigning the Serial Numbers to all Part Numbers for the typical break-down list and filling in the data contained in the equipment Log Card, indicating an OMP identifier (Operator Maintenance Programme),
- carry out equipment installation and removal operations,
- transfer an aircraft or a sub-assembly from a ground station to another,
- obtain access to the equipment follow-up monitoring elements (TSN, TSO, Remaining Time before TBO or SLL....), directly based on the selection of an equipment item,
- add an equipment or optional equipment not initially planned.

Any sub-assembly installation and removal action will be dated, in order to preserve the consistency between an aircraft configuration and the flight parameter files.

4.3.4 Equipment follow-up

This function will be used by the maintenance manager in order to follow up movements of new equipment or of equipment returning from an overhaul or from a loan.

The user has the possibility to:

- perform updating actions further to a return from overhaul or from loan,
- carry out the updating actions further to the reception of a new part,
- issue the Equipment Log Card pertaining to a part for the interested operators,
- issue the historical Log for a part or sub-assembly,
- issue the set of parts, for a given status,
- issue the maintenance actions and give furtherance to a prolonged storage.

4.3.5 Scheduling

The purpose of this function is to allow the user to:

- create the presentation format for scheduling and planning (list of inspections to be displayed with the period range, list of the first level Part-Numbers),
- indicate the forecasted flights,
- plan and organise the maintenance actions.

All the maintenance tasks are then displayed under the form of a planning, scheduled in the following order:

- corrective maintenance (further to exceedances, pilot remarks or maintenance team remarks),
- time limits (TBO, SLL, OTL, equipment inspection),
- remaining time before TBO and SLL,
- inspections.

From this planning, the following possibilities are proposed to the user:

- select a corrective maintenance to see the list of associated incidents,
- select a "Time Limit" to see the terminal element having reached the threshold,
- select an inspection to consult the maintenance document describing it or all information concerning this task (costs, consumable items, tooling, intervention zone, ...),
- postpone or anticipate tasks, within the tolerance limits. In order to optimise his maintenance planning, the user must anticipate maintenance tasks (inspections and/or actions further to a life limit attainment) or postpone said tasks (in this case, within the associated tolerance limit).
- consult the list of Job Cards concerning the Serial Number,
- print the corresponding Job Cards with their allocation and date.

4.3.6 Job Cards follow-up

This function allows the follow-up of the Job Cards both by the maintenance personnel and the

maintenance manager. These Job Cards can come either from scheduled or unscheduled maintenance.

A Job Card can be:
- a part replacement further to a "Time Limit" attainment,
- an elementary inspection,
- a reference to a Job Card, further to incidents.

The maintenance engineer can consult the list of Job Cards allocated to him and enter the equipment removal and installation operations.
The maintenance manager can also add manually Job Cards (unscheduled maintenance) and allocate a series of Job Cards to a maintenance technician with an associated "Due Date".

4.3.7 Recommended Maintenance Programme customisation

The purpose of this function is to enable the user to customise EC Maintenance Servicing Recommendations (except Air Worthiness Directive chapter). Therefore, it allows the OMP (Operator Maintenance Programme) to be elaborated.

The following possibilities are offered:
- group or split tasks in the periodic inspections,
- extend the visit or inspection periodicity with EC agreement,
- take into account or not a non mandatory elementary visit or inspection,
- lower the TBO, OTL or SLL values, or the periodicity (or increase these values to a certain extent, in keeping with the associated tolerances),
- add information (costs, workloads, deadlines, intervention zone....).

4.3.8 Modifications management

The purpose of this function is the consultation, selection or introduction of Service Bulletins and modifications of Airworthiness Directives.

The operator can consult the list of modifications previously received and download a set of modifications transmitted by Eurocopter via PCMCIA.

The maintenance manager can also obtain the following reports:
- list of modifications to be introduced with their applicability,
- list of helicopters impacted by a particular modification.

4.4 HUMS expert

4.4.1 Usage

This function allows the expert to know the helicopter usage ranges and, consequently, the potential damaging of the various mechanical parts or sub-assemblies.

The expert can select a part to see all damage counters associated to it.

For each part, two types of data are presented: those of the considered flight and those corresponding to accumulations, either since the origin or since the last overhaul for the considered part.

The current damage, the average damage/ flight hour and the provisional damage after the next flight are presented with orange and red alarms associated to given thresholds.

4.4.2 Health

This function allows the expert to access to the engine power assurance check trend analysis and to the vibration data having activated a health alarm for a deeper analysis.

Engine Power Assurance Check

The expert can see all general parameters corresponding to the flight conditions at the time the acquisition was launched and the results of torque and temperature margins computations.

Two curves are also presented, showing the trend analysis of these two parameters on the last flights. A dotted line shows the threshold for the alarm activation.

Vibration monitoring

The expert has access to all vibration data of the flight for all monitored elements and to health indicators and their trend curve. The following sub-assemblies are monitored:
- mechanical parts (elements depending on the helicopter type, such as Main Gear Box main module, Tail Draft Shaft, Tail Gear Box)
- rotors (main rotor and tail rotor)
- engines

The ground station presents:
- on a curve form, the temporal signal, the FFT signal, the residual signal, the FFT of the residual signal,
- on a histogram way, the different health indicators and the amplitudes of the signal frequency spectrum.

For each indicator and for each element, orange and red thresholds are displayed.

For all indicators, the expert has access to a trend analysis from the last flights.

For the engine vibration monitoring, the expert has access to four graphs « N1 at normal cruise », « N2 at normal cruise », « N1 during shut down », « N2 during shut down » presenting the vibration levels in function of the engine speed.

4.4.3 Status

The expert has access to the list of alarms and failures detected during the flight in the time appearance order and the list of LRU involved in the failure with an associated probability.

5. CONCLUSION

The modular architecture of EC HUMS Avionique Nouvelle allows to meet the needs of civilian and military operators taking into account the economic constraints relative to light and medium helicopters. The Ground Station is an important part of the system as it is the only place where the crew, the maintenance team and the experts meet to make decisions about maintenance actions. The Ground Station proposed with HUMS Avionique Nouvelle offers a lot of possibilities to the customer to manage his complete helicopter fleet. EC HUMS Avionique Nouvelle has the capability of integrating new functions to remain the closest as possible to new operational requirements and new market needs .

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7. ABBREVIATION

ADC	Air Data Computer
AN	Avionique Nouvelle
ARMS	Aircraft Recording and Maintenance System
CAD	Cautions and Advisories Display
CP	Control Panel
CPDS	Center Panel Display system
CVFDR	Cockpit Voice and Flight Data Recorder
DSPM	Digital Signal Processing Module
DTU	Data Transfer Unit
EC	Eurocopter
EES	Electrostatic exhaust gas monitoring system
FADEC	Full Authorized Digital Engine Control
FFT	Fast Fourier Transform
FSR	Flight State Recognition
GSC	Ground Station Computer
HC	Helicopter
HUMS	Health and Usage Monitoring system
IDM	Inductive debris monitoring
IGB	Intermediate gear box
LRU	Line Replaceable Unit
MFDAU	Multi Function Data Acquisition Unit
MGB	Main Gearbox
MMO	Mast bending moment
MQTR	Tail rotor torque
N1	Engine gas compressor speed
N2	Free turbine speed
NR	Rotor speed
OTL	Operating Time Limit
PCMCIA	Personal Computer Memory Mard Association
QDM	Quantitative debris monitoring
SLL	Service Life Limit
TBO	Time Between Overhaul
TDS	Tail drive shaft
TGB	Tail rotor gear box
TOT	Hot section temperature
TSN	Time Since New
TSO	Time Since Overhaul
VEMD	Vehicle and Engine Multifunction Display
ZFL	Zahnradfabrik Friedrichshafen