

A New Avionics System for the EC225/725 Cougar An "ADVANCED HELICOPTER COCKPIT & AVIONICS SYSTEM"

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Symbols

ADC	Air Data Computer
ADI	Attitude Display Indicator
AHMU	Avionics & Helicopter Maintenance Unit
AHRS	Attitude and Heading Reference System
AMC	Aircraft Management Computer
AFCS	Automatic flight Control System
APM	Auto-Pilot Module
DMAP	Digital Map
DTU	Data Transfer Unit
EID	Electronic Instrument Display
EWS	Electronic Warfare System
FADEC	Full Authority Digital Engine Computer
FCP	Flight Control Panel
FDR	Flight Data Recorder
FDS	Flight Display System
FMECA	Failure Mode Effect Analysis
FMS	Flight Management System
FND	Flight and Navigation Display
HUMS	Health & Usage Monitoring Systems
HSI	Heading Sensor indicator
HMI	Human Machine Interface
IFDS	Integrated Flight & Display System
ISI	Integrated Standby Instrument
KDU	Keyboard Display Unit
LCD	Liquid Crystal Display
LRU	Line Replaceable Unit
MFDAU	Multifunction Data Acquisition Unit
NR/NF	Rotor and Free turbine speed
NVG	Night Vision Goggles
PFD	Primary Flight Display
PU	Processing Unit
RA	Radio Altimeter
RCU	Reconfiguration Management Unit
RVDT	Position Sensor
SEMA	Smart Electro-mechanic Actuator
SIU	System Interface Unit
VMS	Vehicle Monitoring System
VPU	Vibration processing Unit

Abstract

The aim of this paper is to present the so-called advanced helicopter cockpit and avionics system which is under development at Eurocopter for its new EC225/725 Cougar program.

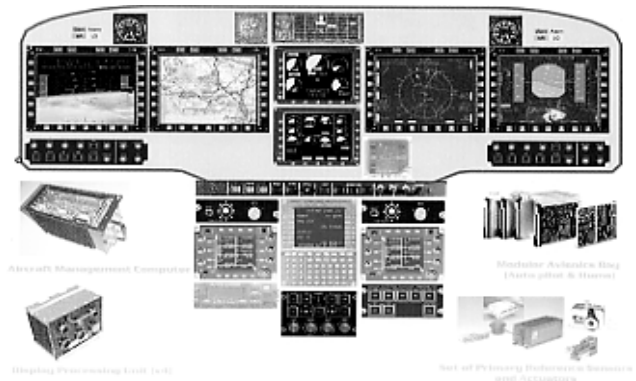


Fig 1: The ADVANCED HELICOPTER COCKPIT AND AVIONICS SYSTEM

The origin of this project takes into account the existing avionics called "Avionique Nouvelle" which are already certified on single- and twin-engine helicopters in VFR and IFR versions (see ref1) and the need to enhance them in order to cover the missions of medium heavy helicopters.

Customer requirements are at the origin of the technical improvements of operational functions but economical aspects are also a major concern inducing the use of commercial off-the-shelf products for the aeronautical market.

The architecture is built in order to enhance dependability, to facilitate maintenance and to cope with dedicated missions of such types of helicopter.

The choice of an open system architecture was one of the driving factors in the development of this new avionics. This approach allowed development of the product using COTS components not only in terms of HW but also concerning the development tools.

Another important factor is the Human Machine Interface. HMI is designed around a modern Glass Cockpit concept. Two Vehicle Management Displays, located in the central part of the front panel, and four Piloting displays, based on 6"X8" landscape format, for mission and piloting purposes, offer better mission reliability. (Fig1)

The integrated maintenance function uses the Vehicle Management System resources to gather all avionics data and to deliver a complete diagnosis at system level.

The Context

The origin of this project took into account the existing avionics which are already certified on single- and twin-engine helicopters in VFR and IFR versions. In order to cover the various missions of medium heavy helicopters the need to enhance them appeared. This new Avionics System development for the Super Puma is based on Eurocopter experience in integrated systems and was launched in 2001 after a preliminary design phase of one year.

The ADVANCED HELICOPTER COCKPIT AND AVIONICS SYSTEM is designed to assist the crew in performing Flight, Navigation, Communication and Mission management through glass cockpit displays, digital computers and associated centralised cockpit controls. It includes the following subsystems:

- Vehicle Monitoring System
- Flight Display System
- Auto-pilot
- Health & Usage Monitoring Systems
- Mission Suite for Civil Customer (Flight management) or Military Market (Digital map & Electronic warfare)
- Avionics Maintenance Ground Station

The main concern of the new glass cockpit is the ability to cope with various mission needs. For helicopters, this is a very new situation compared to commercial aircraft needs. Moreover the missions of the helicopter are in constant evolution to cover new operational use for military operations but also civil ones as the all weather helicopter.

Two types of studies have been done to cope with the customer needs and to deal with industrial aspects.

On one hand the family concept was reused when existing technology or products already existed on the latest evolution of the Dolphin Helicopter,

On the other hand it was decided to develop new building blocks that could participate to other systems or platforms .

The "Avionique Nouvelle" resources have been used and enhanced for the Autopilot and the Health and Usage Functions. For the Vehicle Monitoring System and the Flight display system new developments were launched.

Concerning the human machine interface, the standardisation of the cockpit throughout the Eurocopter product range was a main concern. This commonality already existing between all medium helicopter fleets (EC135, EC 145, EC 155 [i]) is now extended to the EC225 and EC725. This family concept for modes and controls will allow pilots to easily go from one helicopter to another one of the fleet. Moreover, the IFDS symbology concept, first applied on the Super Puma in the 1980s (now fully mature), is now enhanced according to the evolutions already validated on the NH90. The Eurocopter glass cockpit has followed during these twenty years a progressive evolution from the first IFDS on Super Puma based on 4 CRT Displays only dealing with piloting aspects then to the New Avionics approach using similar HMI for piloting purposes but extended to Vehicle Monitoring with LCD technology. Now the standardisation of 6" X 8" landscape displays based on COTS technology allows the formats for short term piloting aspects (ADI) and mid term navigation (HSI) to be included in one display with respect to existing symbology principles (Fig 2).

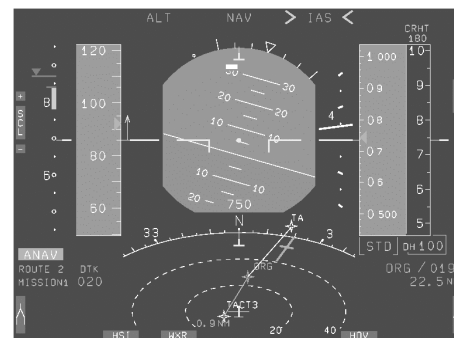


Fig 2: FND concept

This combined format common with the NH90 helicopter, called Flight and Navigation Display (FND), can also include a first limit indicator that prevents the pilot from exceeding the engine and gear box limitations. Having all the major parameters gathered in one single display, the other 6" X 8" screens are fully available for mission purpose by displaying a Weather Radar, an Infrared Camera, a Digital Map, an interactive Navigation Plan or other required data such as threats given by the Electronic Warfare System.

An open system architecture to easily customise the helicopter to the mission

The avionics of the new Super Puma has been design to cope with certification rules but also to be easily adapted to operational needs. The rapid evolution of the systems and the various mission suites that exist have required the development of basic avionics that can support existing mission equipment but also the next generation under development. To integrate these systems, in the future, with a minimum of modification of the basic avionics, some design rules have been taken into account that contribute to an open system (Fig 3). The criteria selected were the following:

-independence principle

The objective to reduce the effect of one modification to one SW layer or HW component, has been

obtained after the identification of a functional segregation. As a consequence the exchanges between functions have been reduced to high level parameters which are not affected by external modifications.

-interconnectivity principle

The goal to easily add one COTS component is achieved by using standard HW interfaces (digital; video) but also standard protocols. It allows the reception and transmission of data from/to this new element of the system with no major modification to the core system.

-modular architecture

The possibility to change, if needed, some resources by new ones that will appear on the market during the life cycle of the helicopter (display ; processing) is obtained thanks to a modular design.

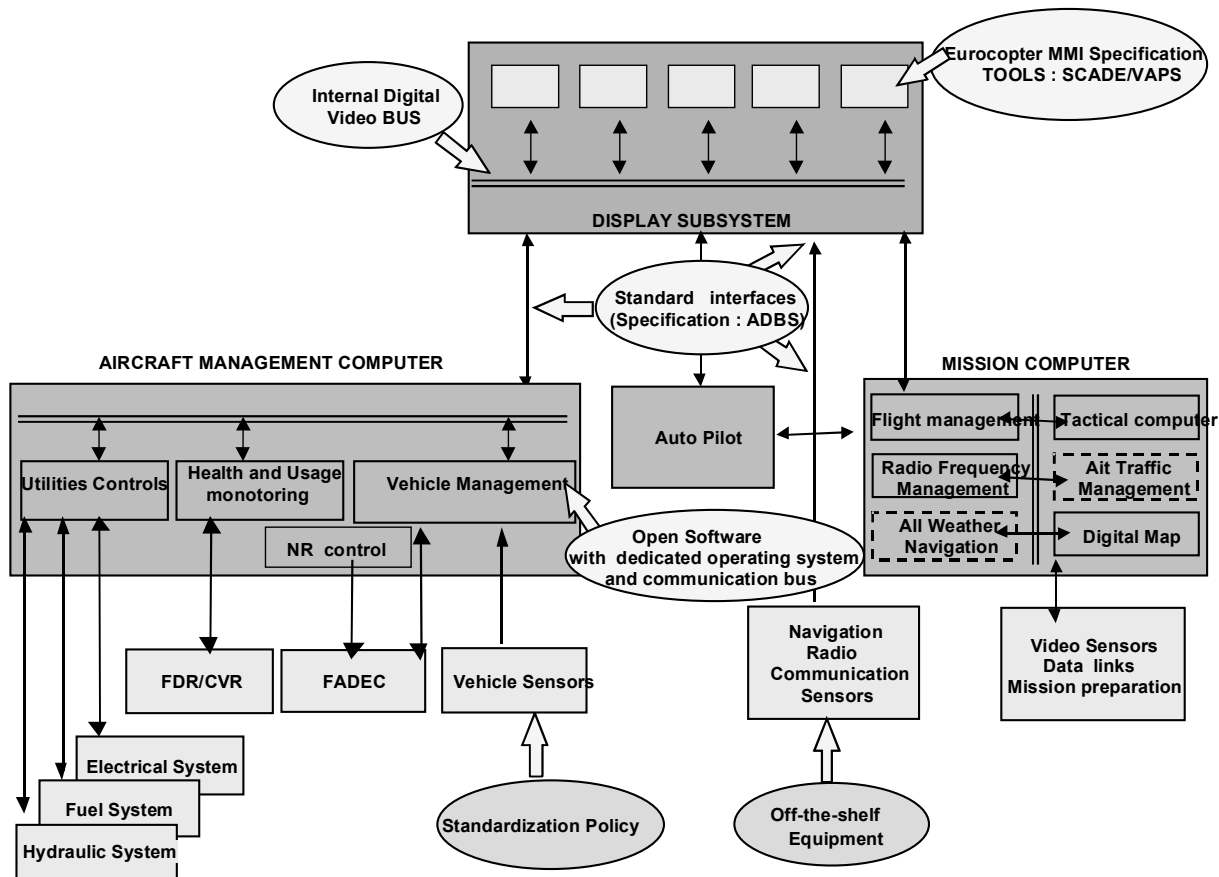


Fig 3: Functional design

-centralised maintainability concept

To easily take into account a new component, without adding specific tools to access to its failure or to configure it, specific rules have been established. Dedicated maintainability resources have been included at equipment level and the Aircraft Management Computer has been selected to be the maintenance manager of the whole avionics system.

-HMI mastered approach

The good integration of mission aspects in terms of human machine interface is driven by the adaptation of the symbology to the mission by including all additional required symbols. So, in addition to the previous architecture criteria, to master the evolutions in terms of symbology, it was decided to use Vaps and Scade as definition tools but also during all the development cycle by using their certified workshop version.

System Description

The civil certified avionics of the new Super Puma EC225 is mainly supported by three functions:

The Vehicle Monitoring System

is composed of two main items

-a duplex computer "AMC"

-two 4"X5" displays "EID"

A set of vehicle or engine sensors directly linked to the computer or through ancillary boards "SIU" complete the system.

The AMC computes the analogue inputs and the digital FADEC data to deliver on a digital link the values of the parameters to be displayed on the two EIDs or to be used by other subsystems as Autopilot or Flight Management System.

It allows access to engine power check results and to various engine counters such as turbine cycles or engine operating times.

The Autopilot System

is supported by a dual/duplex architecture including:

-2 dual Computers that control the actuators directly

-2 Mode selectors, one for each pilot

The Autopilot ensures the stability augmentation and all attitude holds by using the data delivered by the primary reference system. It ensures IFR approach with radio navigation means and, coupled with the flight management system, it allows following of the selected flight plan or specific approach such as trans-down for Search and Rescue missions.

The Flight Display System

is a full glass cockpit display system built from up-to-date Active Matrix Liquid Crystal Display (AMLCD) technology. The landscape format was selected to enhance the display of video format for the mission requirement but also to reduce the height of the front panel, which is a specific helicopter constraint, to enhance external visibility. The display system is designed to cope with dual or single pilot IFR rules.

All the sensor data are concentrated in separate Processing Units, each associated to one 6"X8 " Keyboard and Display Unit, resulting in a quadruplex system which allows great Minimum Master Equipment List (MMEL) enhancement. To easily customise the radio and mission sensor set, to the customer need, a configuration table is included in the design of the multifunction displays. The software structure has been also defined according to his need to clearly identify the data flow between the equipment software and the application software by including a common data base

In addition the ADVANCED HELICOPTER COCKPIT AND AVIONICS SYSTEM is completed by a Reconfiguration Management Unit ,2 flight control panels used for the displays controls and Autopilot mode selection and the following set of back up instruments:

- a caution and warning panel
- two NR/NF indicators for the pilot and copilot
- a mechanical clock
- an Integrated Standby Instrument which gathers in one LCD Display the back up attitude, altitude and airspeed in a 2.5"X2.5" PFD format.

A simplified diagram of the architecture is provided (Fig 4)

The Mission Suite that can be either certified or qualified for military applications includes in addition:

- A full NVG Cockpit
- The Flight Management System
- The Digital Map
- The Electronic Warfare System

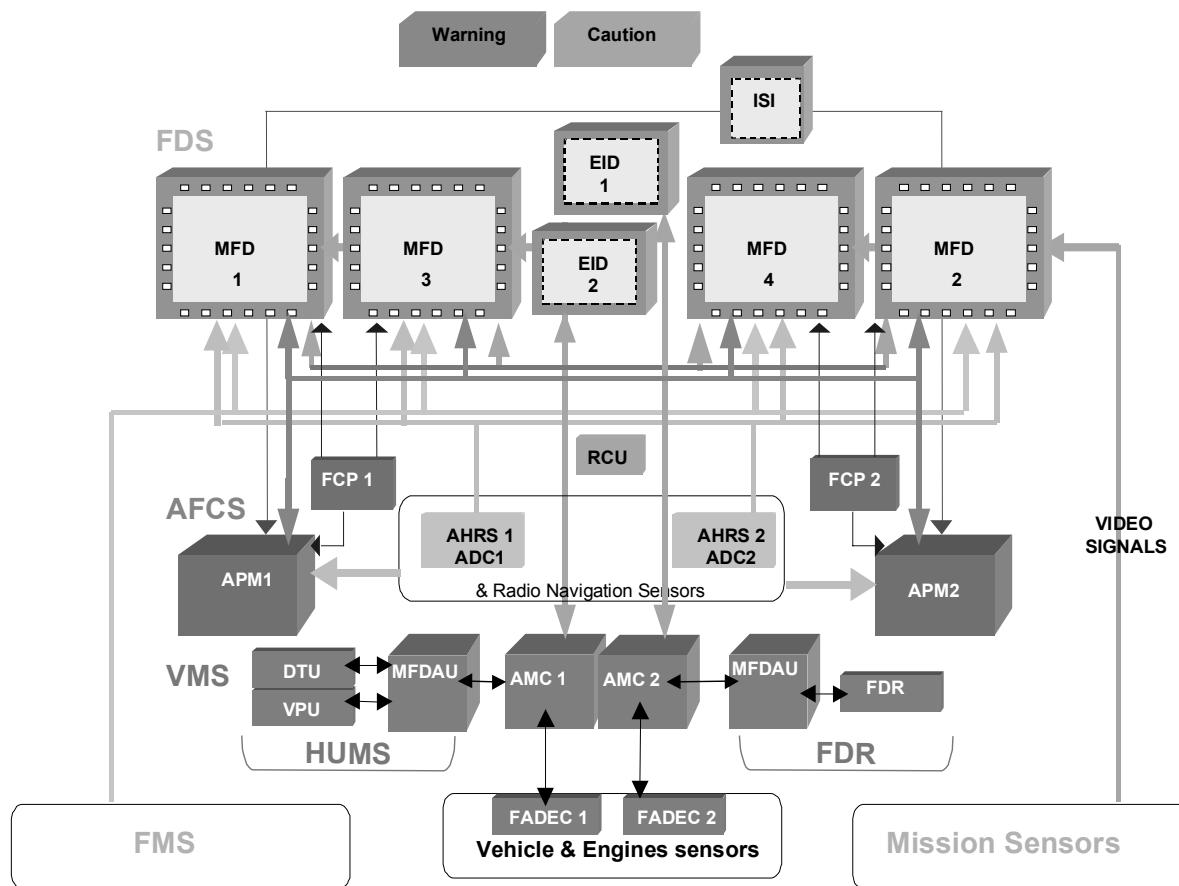


Fig 4: Architecture overview

A brand new Display System including a First Limit Indication

The Super Puma cockpit includes four 6"X8" landscape displays. These displays are controlled by four processing units, that include the primary flight and navigation parameters. These data can be presented on one format called the FND. This FND combines an Attitude indication, completed by the air data values and a heading indicator that allow display of the usual navigation data. The HSI characteristic is to be an ovoid representation that, associated with the vertical presentation of barometric and radio altitudes strips, gives an impression of 3D representation. This solution already developed in the NH 90 helicopter is particularly well adapted to the selected landscape format of the displays. To inform the pilot of the flight envelope and the engine limitations, the FND also includes the First Limit Indicator.

This information, computed by the VMS, is presented as a collective strip where the collective

values corresponding to the maximum continuous power, take-off power or transients, are marked with dedicated symbols. These values are computed thanks to the primary parameters of the engine such as engine turbine speed, torque or exhaust gas temperature. Depending on the ambient pressure and temperature, the parameter which is the closest to its limit is determined. The difference between the actual value and the limit is equivalent to a power margin that corresponds to a manoeuvrability which is presented to the pilot as a possible resource in terms of collective.

The FND is also designed to allow super imposing of the weather radar or the navigation route delivered by the Flight Management System on the HSI or sector mode. Thanks to the two displays available for each crew member the FDS allows presentation of different navigation sources on the same "half system". One can be presented on the sector or "rose" mode of the FND, the other can take place on a full page of navigation management in correlation with mission data such

as threats. To avoid conflict, the autopilot is always coupled to the active navigation source of the FND. To follow or modify their route, the crew have access to two navigation routes: one is the present one and the other is in preparation. To help the crew to select new way points, a digital map can be superimposed. A joystick for each crew member is available to allow designation of the new route.

In addition to the piloting displays, the cockpit includes, in the central part, two EIDs that are dedicated to engine and vehicle management. These displays are controlled by the Aircraft Management Computer that was first qualified in the context of another Super Puma version. This system gathers engine primary parameters, gear box oil pressures and temperatures, and hydraulic system data.

Although the VMS may appear to be a simple alternative to conventional systems, it is in fact much more, particularly for reducing crew workload and increasing safety. Thanks to its close relationship with FADEC computers, it allows display of the engine power checks during flight, and recording of the usage parameters, such as one engine inoperative phase duration. The VMS also supplies the maintenance team with various information concerning the status of the helicopter and it establishes a status of the whole avionics system.

Moreover it identifies for each flight phase, the optimal value of the rotor speed, and control it through the FADEC regulation. In case of engine failure it computes the collective value that ensure the minimum acceptable speed for the rotor during the transition phase.

The benefits of a new Autopilot

The EC 225 is equipped with a four-axis autopilot computer developed using the dual duplex architecture already certified on the EC 145 (see ref 2). This architecture allows the flight to be continued with full functions after a first failure and passivation of the second failure if any.

The autopilot drives the servo valves of the hydraulic block for all axes but also electromechanical actuators for roll and pitch control (Fig 5). This architecture enhances the authority of the autopilot by reducing the effect of a failure on one component but also enhances the dependability of the autopilot functions by maintaining control of helicopter stability and trajectory after a failure.

Moreover, new control laws have been studied to enhance operational features of the EC225 by managing, in an innovative way, the four axes. On a conventional autopilot the altitude profile is followed by managing the collective axis and the speed by controlling the pitch. This approach does

not take into account the engine power limitations and induces altitude loss during accelerations and generates continuous variations of collective value during high speed cruise. The new design takes into account the available power to generate the collective order. When the collective is close to its limit, depending on flight conditions and the engine power, the auto-pilot can transfer partially the management of the altitude on the pitch axis.

This enhancement is possible thanks to the high level of integration of the avionics system. The Vehicle Management System that elaborates the power margin values thanks to engine primary parameters, transforms this power into a collective margin before delivering it to the autopilot which uses it for the management of the pitch and collective axes and to the cockpit display for pilot use and monitoring.

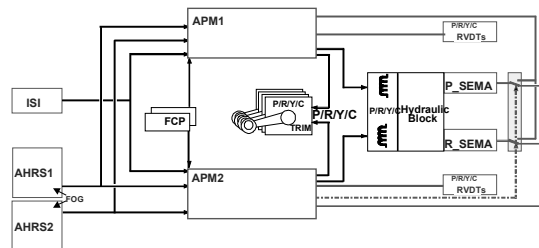


Fig 5: Autopilot architecture

A global system approach to enhance MMEL

Most of the systems take into account the preliminary hazard analysis to determine the level of redundancy and the SW development assurance levels. The ADVANCED HELICOPTER COCKPIT AND AVIONICS SYSTEM design includes in this approach the availability to reduce Direct Maintenance costs by reducing as far as possible the phase duration where the helicopter is on ground due to repair time. The analysis of the failure of each component was established at the early stages to identify the required redundancy to take off with one component failed in each subsystem. A procedure using adequate resources was identify, allowing to reduce to the minimum the impact on the number of embedded equipment items.

The dependability of the avionics has been enhanced thanks to two types of analysis.

On one hand, the use of new technology such as integrated standby instruments allows the use, by all the system, of embedded resources that were in the past only available for a dedicated function. Generally, on conventional architectures the attitude sources are composed of two AHRSs that deliver their data to the Autopilot and display system. To ensure safety aspects, an independent instrument is added to monitor the system after a failure. The ADVANCED HELICOPTER COCKPIT AND AVIONICS SYSTEM architecture includes as back up an Integrated Standby Instrument System that includes an AHRS. This instrument, which is totally independent of the system in normal flight, can be used as a third AHRS source when needed. For example in case of take-off with one AHRS failed, the ISI allows control of the data delivered by the other AHRS. Moreover in case of failure of this AHRS during the flight a reconfiguration mode allows display of the ISI attitude source on the main display. In this way, the pilot can recover a normal situation on his FND, providing a reduced workload by having all the required data up to the end of the flight in the same place as usual.

On the other hand, the use of synthetic data that can replace the primary parameters when a computer or a sensor is lost, offers the crew the opportunity to continue the flight in safe conditions by following limitations which are artificially computed thanks to work around algorithm using some hypotheses based on the reduction of the flight envelope. The first limit indicator which is a major indication for controlling the engine limitations, follows this approach. To cover the possible failure of the Aircraft Management Computer that computes the First Limit Indicator in normal conditions, a simplification of the laws that normally take into account all the engine parameters such as torque, engine turbine speed or exhaust gas temperature, has been identified. This law takes into account the mathematical model of the engine and the limitations known according to the ambient pressure and temperature. According to some hypotheses that reduce the usable power of the engine, the First Limit Indication remains available in a degraded mode after total loss of the aircraft management computer. This back-up law is embedded in the processing unit of the displays that already acquire the required parameters for other purposes. To maintain an open architecture with the criteria of functional independence explained before, the law is defined as a generic polynomial function. The constant parameters that customise this function to the helicopter type are downloaded from the AMC to the display system at power-on and saved up to the next exchange.

A centralised Maintenance concept

The ADVANCED HELICOPTER COCKPIT AND AVIONICS SYSTEM includes an integrated maintenance function. For Maintenance purposes, the FDS system acts as a data concentrator for all the primary flight display sensors (all radio navigation sensors, AHRS, ADC and also Autopilot). The VMS acts as the data concentrator for all vehicle and engine sensors including FADEC. The maintenance manager is the AMC. The diagram (Fig 6) shows the general principle.

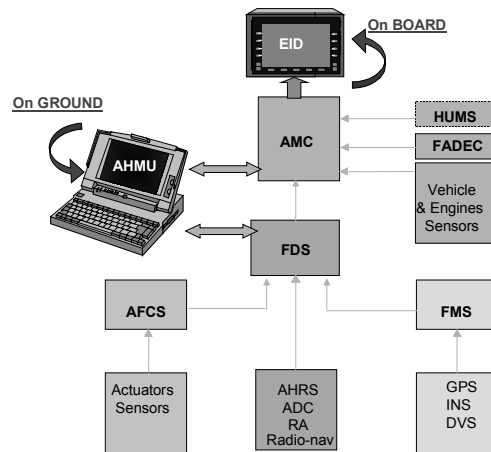


Fig 6: Maintenance concept

When a failure is detected by a subsystem the context data is recorded in the subsystem and a report is delivered to the AMC. The report can be displayed on ground on the EID. A ground station called AHMU (Avionics and Helicopter Maintenance Unit) can be linked on ground to a dedicated helicopter connector and allows direct access to each subsystem through digital serial links. In this way, the maintenance team can obtain a detailed report including the context of the failure .

This ground station composed of a hardened laptop including dedicated interface resources participates also in vehicle maintenance by including some health and usage functions such as rotor tuning.

During the flight, all the failures are detected and recorded including their contexts (date, other parameter values) by each subsystem after suitable filtering. The subsystem which has detected a failure sends, according to a predefined sequence, the relevant test code to the AMC. All the test codes received by the AMC are recorded. A filtering process is then performed by the VMS to determine if the failure is intermittent or permanent, to count the occurrence for intermittent failures and to assign a date to the failure.

In operational mode during flight the AMC delivers an identification of the LRU failed to the EID, if it is localised with a good level of confidence (this level of confidence is stated according to FMECA analysis which indicates for each test whether it concerns one LRU or more).

On ground, in stand alone maintenance mode, the VMS delivers on request the list of the tests which have detected a failure (localised or not) and the list of LRUs which are probably involved.

On ground, in ground tool mode, every subsystem acts separately and delivers, on AHMU request, all the recorded events, parameters and data linked to the failures. These data are downloaded and displayed on the ground tool.

A development supported by COTS tools

To master the development of the main critical issues and to enhance the reactivity during the bench tests or flight tests it has been decided to set up a methodology based on the use of automatic coding tools (see ref 3). The Autopilot of the recent Dolphin was already developed with a tool called SCADE, level A certified, to describe the laws and logic. This tool, well adapted also to defining modes and controls, has been used to define the activation of the symbols of the piloting displays. Concerning the symbols themselves, the VAPS tool used for definition was recently certified level B on the VMS system of the Super Puma for the Swiss Army. The experience of this first certification using QCG (qualified code generator of VAPS) was a confirmation of the interest in terms of time saving. The decision was taken to continue in this direction and the SW activities have been launched to use it for a level A application.

Conclusion

Result of the customers needs analysis and of a deep technical synthesis the ADVANCED HELICOPTER COCKPIT AND AVIONICS SYSTEM is now under ground tests . After the first flight planned mid of 2002, one year will be necessary to obtain the certification of the EC225.

Next year, the operational evaluation of the military version EC725 by the French army for its Search and Rescue mission will be an important milestone to show the great flexibility of this new avionics system.

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About the author

Sup'Aéro Engineer from ENSAE (High School for Aeronautics and Space in Toulouse , France), Serge GERMANETTI born in Marseille in 1959 joined Eurocopter in 1984. He participated in research programs to apply Higher Harmonic Control on Helicopter and contributed to the development of the New Avionics on the new Eurocopter fleet (EC135 ; Dolphin; Astar ;Twinstar). In the past, in charge of the avionics on the EC120, he his now at the head of development of the avionics for the Super Puma helicopter

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[i] EC120 EC135 EC145 EC155 EC225 EC725 NH90 are helicopters of the Eurocopter fleet