NH90 AVIONICS RIG CONCEPT

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Abstract

The NH90 helicopter comprises specific avionics and mission systems for the different helicopter versions: TTH (Tactical Transport Helicopter) and NFH (NATO Frigate Helicopter). The various systems like the Flight Control System, the CORE system, and the TTH MISSION System, are developed and integrated at the EUROCOPTER premises in Marignane and Ottobrunn, whereas the NFH Mission system is developed and integrated from AGUSTA at Cascina Costa.

The Flight Controls, CORE, and TTH MISSION system integration rigs will be used for the validation of the various avionics components and subsystems, the integration of the respective systems, and the flight test support for the prototype helicopters (PT2, PT3, PT4 and PT5). These rigs are closely embedded into the set of other avionics system development tools used in this program.

Experience from other programs (as e.g. the TIGER) shows, that on a rig, original harness, avionics bay design, or cockpit layout are not essential. Whereas the ability to perform subsystem tests in parallel, or to perform equipment verification with the equipment installed in the rig, can reduce the testing time considerably.

A new rig concept has consequently been applied for the NH90 from the beginning: Emphasis is given to the adaptability of the different test needs during a system integration process. Deviation from the requirement to have a full mechanical representation of the rig in terms of cockpit design, harness, or avionics bay opens a new degree of freedom for the organisation of testing:

Rigs are made up from modules which can either be operated stand alone (for component and subsystem testing) or coupled together (for system integration). This concept is supported by the use of common test systems (ANAIS), which are tailored to this highly flexible way of integration, allowing a maximum of test automation and parallel testing. The use of special to type test equipment (STTE) can thus be limited.

Similar rig modules as used for the two main computers (CORE Management Computer and MISSION Tactical Computer) are also part of the operational software development and test on the software test benches in Ottobrunn.

As a consequence of the chosen integration and test approach, highest possible compatibility, and test portability between test means at the distributed test and integration locations are ensured.

NH90 Avionics System Description

The NH90, a helicopter in the 9 t class, is beeing developed in a quadrilateral co-operation for the armed forces of France, Italy, Germany, and the Netherlands by the companies EUROCOPTER, AGUSTA and Fokker. Two major versions are foreseen:

- the NATO Frigate Helicopter (NFH) for the navies of the 4 Governments is a helicopter with multi-mission capability equipped with 2 torpedoes or 2 anti ship missiles. A sonic system with a sonobuoy dispenser and a dipping sonar is operated by a sensor operator via his cabin console. Tactical data can be exchanged via Link 11 interface. In the cockpit, the tactical commander and the pilot have at their disposal a radar/IFF, a FLIR, and the electronic warfare system.

- the Tactical Transport Helicopter (TTH), for the Italian and French army, and the German army and airforce is able to transport up to 20 troops or a light tactical vehicle. Operation at day, night, and bad weather conditions is supported (see Fig. 1) by a piloting FLIR steered via helmet mounted sight/display, integrated (into the helmets) image intensifier tubes (IIT), an obstacle warning system (OWS, not finally decided, depending on equipment availability), a digital map generator, and a weather radar. Self protection is assured by an electronic warfare system.

Apart from some options, the Basic system is common for both helicopter versions and consists of the flight control system plus the CORE system. It is shown in a simplified diagram in Fig. 1 together with the TTH Mission System package. The integration of this avionics configuration is the major focus of this paper.

The NH90 will be fitted with a full Fly-by-Wire (FBW) Flight Control System which is composed of the Primary Flight Control System (PFCS) for basic helicopter control and stability capabilities (including the actuator loop closure), and the Automatic Flight Control System

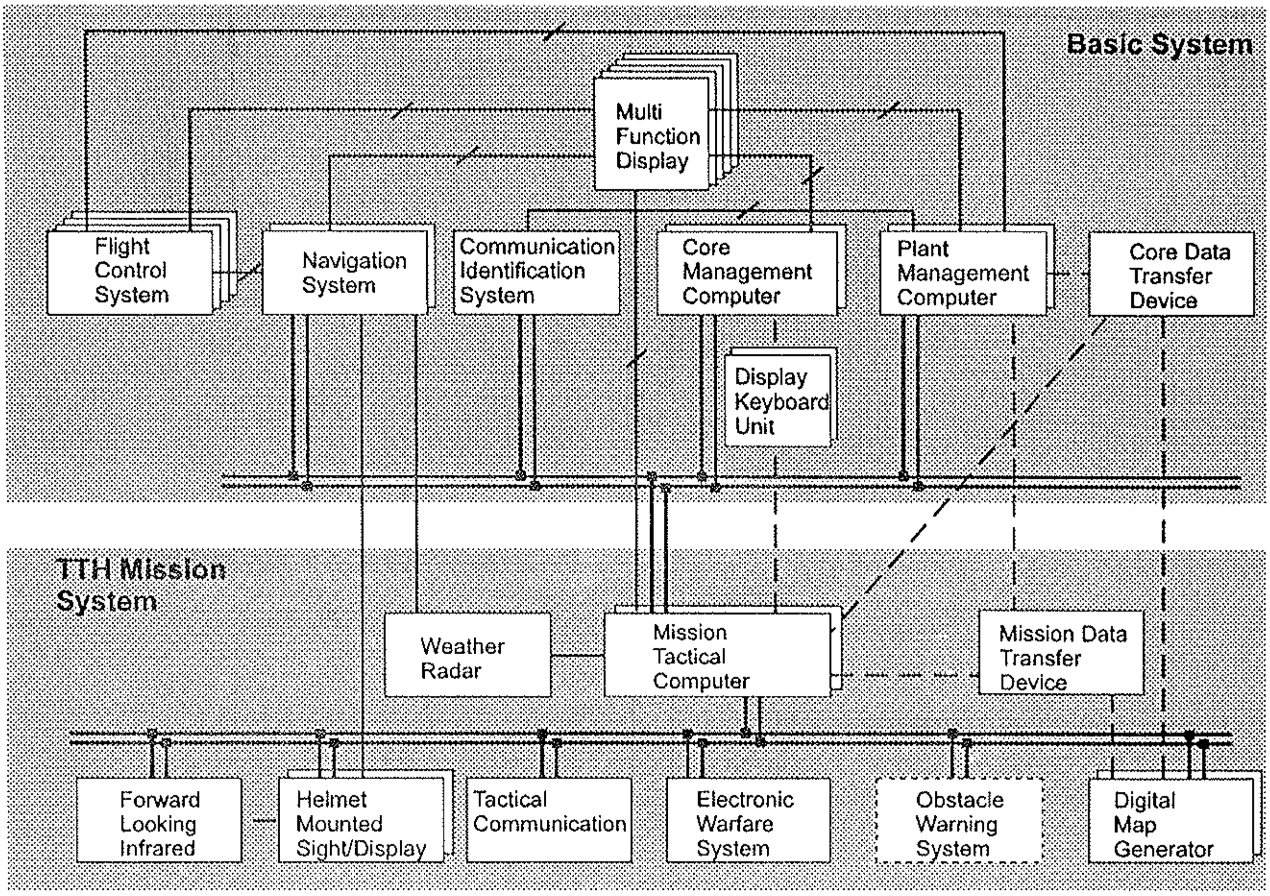

Fig. 1 Basic System and TTH Mission System (video connections not shown)

(AFCS) which provides the adequate modes of operation for the hands-off flight required by the missions.

The CORE system is designed around a dual redundant MIL Bus according to STANAG 3838. It includes 4 Multi Function colour Displays (MFDs), with provision for a 5th (used in the NFH version), and 2 (+ 2 in the NFH version) Display Keyboard Units (DKUs). The MFDs have an LCD screen with an area of 8" x 8". Each MFD has 2 video inputs (STANAG 3350) and an ARINC 453 input (not shown in Fig. 1), its own symbol generator, and is connected via ARINC 429 lines to the other MFDs and the rest of the system. The DKUs are connected via EIA 485 lines to the dual redundant Core Management Computers (CMCs) and Mission Tactical Computers (MTCs) respectively. In the TTH version, CMC and MTC use the same hardware but different software.

Other components of the CORE are the Navigation System (NAS) with a Landing System (VOR, MLS, DME and TACAN for the Italian and French NFH version), and two redundant Inertial Reference System (IRS) computers including each a GPS receiver. The Plant Management Computers (PMCs) manage vehicle and maintenance data, and are connected to both Data Transfer Devices (DTD) which are used for data loading and downloading. The Communication and Identification System (CIS) consists of the Intercom System, 2 V/UHF radios, an HF radio, an IFF, a Direction Finder (DF) unit, a Warning Tone Generator (WTG), and a Central Warning System (CWS). In addition to the mentioned communication devices, a tactical VHF/FM radio is part of the TTH mission system.

Avionics Development Tools and Methods

In order to ensure the harmonised and coherent NH90 Avionics system definition, software development, simulation, and integration at locations and with working groups which are sometimes more than 1000 km away from each other, a common Avionics Database System (ADBS) is the basis for these activities (see Fig. 2).

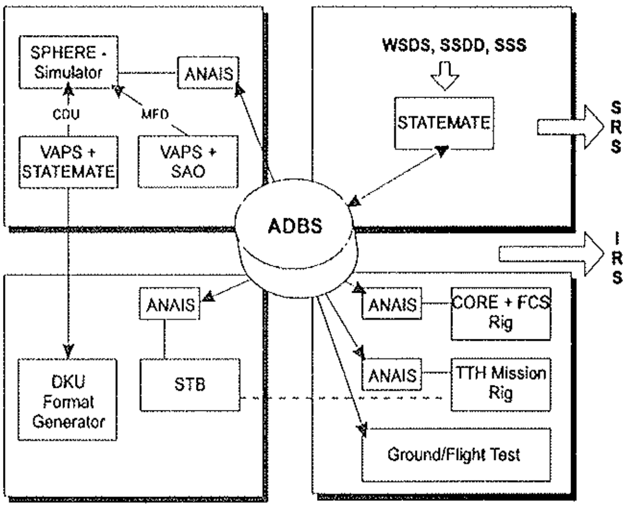

Fig. 2 NH90 Development Tools at EUROCOPTER

For system design activities, ADBS is coupled with the CASE tool STATEMATE and produces the Interface Requirement Specification (IRS), while functional design with STATEMATE results in Software Requirement Specifications (SRS).

ADBS and the EUROCOPTER test system ANAIS (Avionics Numerical and Analogue Integration System) are also linked with the other major development activities. Linkage means here, that data from ADBS (which is also used for configuration management) can be loaded automatically and used from the design, test or simulation engineer.

System simulation, DKU and MFD page simulation (with the specification tool SAO developed in the airbus program) is performed in the simulator (SPHERE) in France. CORE, TTH Mission system software and DKU format development is done at the Software Test Bench (STB) in Germany. Integration will be performed on the CORE rig in France and the TTH Mission rig in Germany.

Rig integration activities are shared in EUROCOPTER between CORE rig (CIR), FCS rig and Electrical rig (not shown in Fig. 2) in France, and the TTH MISSION System Integration rig (TIR) in Germany (see Fig. 3):

CORE, Mission system, and Flight Control System are all pre-integrated on their respective rigs, while simulating the missing interfaces. CORE and FCS rig will then be linked together to test the complete Basic system (which will be flight tested on PT3 in France).

Regarding the Basic System functions, the CIR will also support the NFH mission system rig of Agusta and PT5 (NFH) flight tests in Italy.

In a further step, on the TIR, a coupling with the software test bench of the CMC can be performed if required. The complete system will be finally checked on the helicopter prototype (PT4) which will fly in Germany.

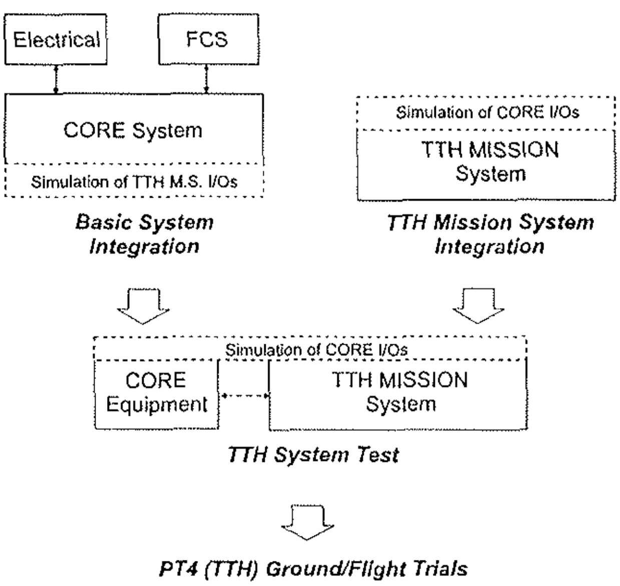

Fig. 3 TTH Avionics Integration

Such a distributed rig concept is well adapted to the present modern avionics system: Interfaces between CORE and mission systems are well defined and limited in number. Most functional chains have only minor influence on others.

System Integration - EUROCOPTER Experience

Before going into details of the EUROCOPTER NH90 rig concept, some experiences from the TIGER program (see also Ref. 1 and Ref. 2.) and other programs, as e.g. SUPER PUMA, which has been taken into account, shall be discussed.

Requirements for the integration of an avionics system are primarily determined from the complexity of the system itself, but an influence resulting from budgetary restrictions, workshare considerations (especially in a multinational program as the NH90), and usually a very tough time planning can also not be neglected. These factors have determined some of our technical choices which have finally led to the new EUROCOPTER rig concept:

Integration Time Schedule

Very short time scales, short loops of software modifications and bug fixes after a new software version has been released for the first time, characterise the demanding task of rig integration. These constraints have to be taken into account already during the conception of the rig test means:

A typical integration cycle for a new software version of the TIGER basic computers (which is normally accompanied with upgrades of symbology and changes of other equipment software) lasts about 3 months until flight clearance is given. During this time, typically 3 software releases (pre-tested on the STB) will be issued and must be integrated on the rig, with each new release taking into account the results from previous testing. Integration under these conditions is performed by a very well experienced team of test engineers, with semi- automatic test procedures and the possibility to test in parallel as far as possible. A good configuration management is essential.

Reporting Tool

During the TIGER development a tool, based on ORACLE, for the reporting and allocation of problems has been introduced. The same tool will be used for the NH90. All parties in EUROCOPTER which are involved in NH90 system development, software development, integration, and flight testing are connected to this database, i.e. everybody has real time access to all known problems and can introduce his remarks. For software development this is a major means of handling and configuration management of software problems.

Rig Harness

The TIGER rig harness is directly derived from the respective functional wiring diagrams of the original helicopter prototype. As done for other rigs (see e.g. Ref. 3) a lot of care has been taken to use the original cable types, the original routing, to have the original cable length and the original mounting locations for all avionics equipment.

Nevertheless, usually all major equipment whose interfaces are subject to a test are installed in patch panel racks and connected to the rig harness via extension cable of about 12 m length. *We never had any problems with such long connections.* This is certainly due to the fact, that almost all signals in a modern avionics system are digital and thereby difficult to disturb and tolerant to slightly reduced voltage levels. In the NH90 program, the use of original cable length is therefore no longer an important design criteria for EUROCOPTER rigs.

Use of STTE

The use of expensive Special to Type Test Equipment (STTE) will be very limited during the NH90 integration. TIGER experience has proven, that many STTE arrived very late (sometimes even after the equipment has been successfully integrated and flight tested) and could therefore not be used for an equipment or subsystem incoming inspection. In addition, each equipment supplier used its own test system and user interface for the STTE which made its operation difficult.

Thus, during the TIGER integration, standard STTE functions (as e.g. the evaluation of a built in test (BIT)), have been replaced by rig test system means. In fact, because of the high sophisticated rig test environment, such tests have sometimes been even more efficient than tests performed with the original STTE. As a consequence, in the NH90 program STTE will be only used for tests of very specific interfaces like e.g. the stimulation of optical or radar sensors.

Automatic Testing

Due to the many man machine interfaces of a modern avionics system as in the TIGER and the NH90 with their "glass cockpits", 100% test automatisation is very limited. Nearly each system test requires e.g. the pressing of a button or the verification of information on a display. Fully automatic testing is only possible (with affordable means) if these MMI interfaces are not in the loop. It is therefore typically performed at software test bench level.

Nevertheless, as in the TIGER, the NH90 test system will ease as much as possible the test engineers work by providing inputs and results on request in engineering units, and by automatic printing of test reports.

Rig Test Systems

During the integration of the TIGER avionics system, different test systems had been in use. Flexibility, on-line modification of tests, and the possibility for parallel testing of different system functions are the major requirements of the integration team.

Due to the avionics system architecture, where most functions have only very little influence on each other such a test concept is possible. E.g. the test of the FLIR and HMS/D functions has no influence on the weather radar or the communications. Ideally it should be possible that various test engineers work independently and with their own test systems. For complex system tests, including e.g. a helicopter model, the coupling of these small test systems to "one" powerful machine should be possible. As will be explained in the next chapters, this is exactly what the EUROCOPTER test system ANAIS is able to do.

EUROCOPTER Rig Concept

The basic technical requirements for all integration rigs resulting from the requirements derived in the preceding chapters, can be summarised in the following way:

Rigs have to support several kinds of development test activities:

- Incoming inspection of equipment (replacing STTEs),
- Subsystem integration,
- System integration,
- Ground and flight tests support.

Rigs must be designed so as:

- to allow parallel testing
  - of several subsystems,
  - of one subsystem and testing of a main system function (Navigation, Communications, ...),
  - of several system functions,
- to be easily and quickly reconfigured according to the requested testing activities,
- to be cost optimised.

To meet these demanding requirements for NH90 integration rigs, a **modular** approach has been chosen as the new EUROCOPTER rig concept. The avionics system is divided in functional sets (which correspond in general to the major subsystems). Each functional set is installed and operated in one integration rig module. Integration rigs are thus composed of rig modules:

INTEGRATION RIG = Σ MODULES

The main features of a rig module are:

- Each module has its own mechanical structure and wiring.
- Each module can be operated stand-alone. In that configuration, the main integration tasks which are performed are incoming inspections, integration, ground and flight testing support of the subsystems.
- Each module can be coupled together with other modules. In that configuration, the main integration tasks which are performed are partial and complete system integration, ground and flight test support. It has to be noted that the module will be coupled only to those modules required for the specific test. Other modules which do not contribute to this test are available for other testing activities.

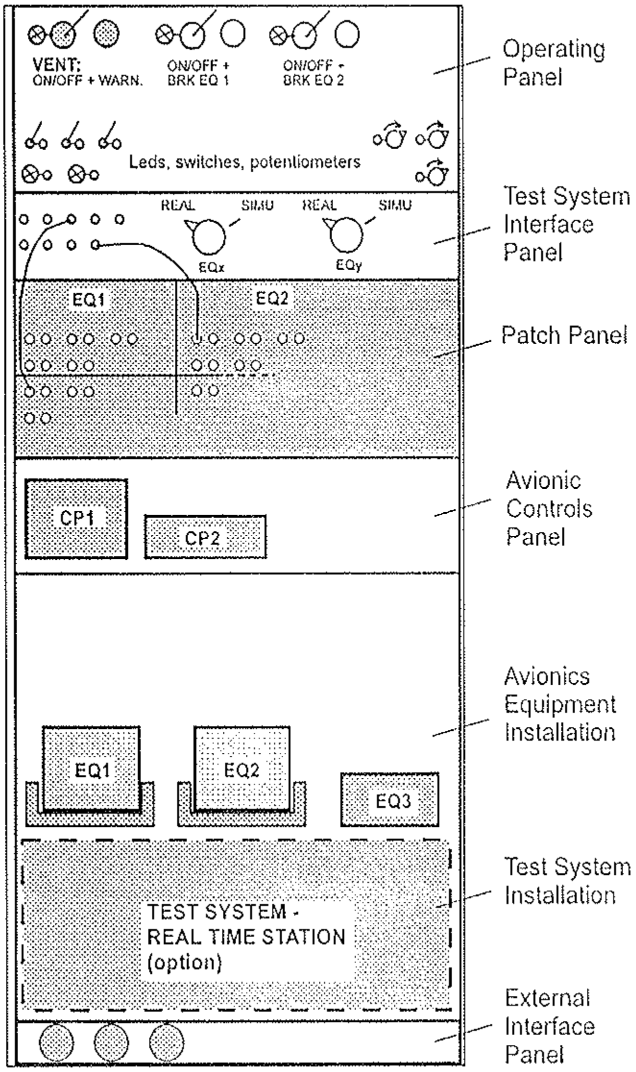

Fig. 4 General Layout of a Rig Module

That new rig concept allows the different combinations for parallel testing required above.

With regard to costs, another benefit of prime importance resulting from this modular approach, is to have commonalty between the various test benches: E.g. the Management Modules (MGM) of the Software Test benches (STBs) used for hardware/software integration of the CMCs are identical to those for the MTCs, they are duplicated at the CIR and the TIR system integration rigs.

Module Description

The main components of each Rig Module) are installed in a 19" standard rack (see Fig. 4). For the rack wiring, the Installation Definition Drawings (IDD) of the prototype helicopter are taken as the basis.

- An Operating Panel: It provides the main operating controls of the module (Power supply, ventilation) and some auxiliary test facilities (LED's, switches, ..).
- A Test System Interface Panel: It gives access to all interfaces of the Test System. Connections to the Patch Panel are usually made to measure and record signals of interest.
- A Patch Panel: It gives access to avionics signals for monitoring and stimulation purposes. Compared to break out boxes (see Ref. 3) used from others, this has the advantage of being a fixed installation with signals clearly arranged.
- Avionics Control Panels (if part of subsystem)
- Avionics equipment installation provision: mounting trays and connectors, ventilation.
- Test System - Real Time Station (VME crates) connected to the test system interface panel: ANAIS, see below
- An External Interface Panel: It is the interface with other rig modules.

EUROCOPTER's major NH90 Avionics Rigs

The CORE Rig is used for the development testing of the NH90 CORE System. Its main tasks are:

- Integration of the CORE System in TTH and NFH configurations, national customisations included,
- Support ground and flight tests of prototype aircraft (PT3, PT4, PT5).

The CIR is composed of 6 rig modules:

1. COCKPIT Module: fitted with the Control and Display subsystem. Avionics Controls and Displays (MFDs, DKUs, ...) are installed in a simplified helicopter instrument panel. Other avionics equipment are located in 19" standard racks.
2. MGM1 Module: fitted with one of the redundant CMCs
3. MGM2 Module: fitted with the other CMC
4. NAV Module: fitted with the Navigation Subsystem
5. PLANT Module: fitted with the Plant Management subsystem
6. COMM Module: fitted with the Communication and Identification Subsystem

Fig. 5 represents a block diagram of the CORE Integration Rig, showing the various rig modules and their connection principles to build up a system rig.

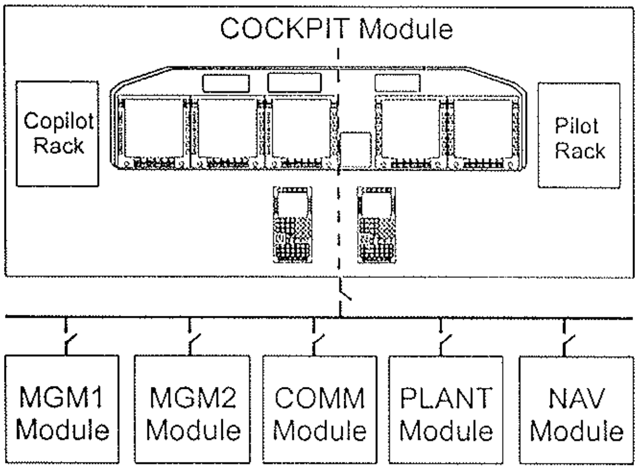

Fig. 5 Block Diagram of the CORE Integration Rig

Furthermore, the CIR can be coupled with two other integration rigs located in the same integration hall:

The Electrical Rig supports the integration of the complete Electrical System, from the generators to the AC/DC distribution. The test objective of a coupling with the CIR is mainly to check the behaviour of the CORE System in the different electrical modes, especially during mode transitions.

The FCS Rig supports the integration of the Flight Control System, a Fly-by-Wire System. The test objective of this coupling is to verify data exchanges either in open loop or in closed loop (guidance tests).

In a first stage, rigs will be coupled two by two, then in a second stage the three rigs will be coupled together.

The TTH Mission System Rig is used for the integration of the TTH Mission System in Germany.

The TIR consists of:

1. FLIR-HMS/D Module where the HMS/D sensors are installed and which can also be used for the standalone integration of the FLIR and the HMS/D subsystem.
2. MGM1Module: fitted with one of the redundant MTCs
3. MGM2 Module: fitted with the other MTC
4. EWS Module: fitted with the EWS subsystem
5. WXR Module: fitted with the Weather Radar
6. DMG Module: fitted with the DMG
7. OWS Module: fitted with the OWS

The TIR can be connected to the STB for the CMC and the MTC. Connection to the COMM module used for CIS pre-integration and operation of the Tactical Communication Subsystem will also be possible.

ANAIS Test System

Due to experience in avionics testing gained in programs like TIGER and SUPER PUMA, capabilities expected from an ideal test system have been well identified. Backed from this experience, the EUROCOPTER test system, ANAIS, has been tailored exactly to these typical needs of an avionics system integration. It is not only used for the NH90 but will also be used for future programs.

Main Features

ANAIS is a generic tool to be used for the following applications during the development of the NH90 program (compare also Fig. 2):

- SW development on Software Test Benches (STBs) for CMC, MTC and FCS computers,
- MMI and system validation on the SPHERE simulator,
- Subsystem/System integration on CIR, TIR and FCS rig,
- Ground and flight test support on rigs,
- Training on simulators (future use).

These multiple use capabilities allow to minimise development costs, to support a unique tool on each test site, to minimise time to build up a new Test System according to user's needs and to reuse components for future applications.

The main characteristics for avionics data management with ANAIS are:

- Data monitoring: real-time display either in raw formats or in engineering units, real-time data graphing,
- Stimulation of avionics data during test execution,
- Simulation of missing equipment, helicopter environment, helicopter model, ...
- Data recording and off-line analysis,
- Off line test definition and on-line test modification (during test execution),
- Connection with other avionics development tools: Avionics Data Base (ADBS), Control laws specification (SAO), MMI definition (SAO), ...

The electrical interfaces which are supported by ANAIS are:

- Discrete and analogue Inputs/Outputs,
- ARINC 429,
- STANAG 3838,
- Serial lines: EIA 485, EIA 422, ...
- Interface to graphic workstations (Silicon Graphics).

Exchanges between several rigs can be performed regarding avionics data definitions and test descriptions. These features allows the distribution of tests during the NH90 development between the different rigs e.g. between STBs and integration rigs.

An easy and flexible coupling of two or more Test Systems is also possible. By that way, if required for special tests, a very high performance tool can be obtained:

- Small Test Systems can be used for Subsystem integration and coupled together for System integration to get a big Test System,
- Data exchanges can be checked between two avionics systems integrated on two separate rigs by coupling their Test Systems. The unique time base allows to time-correlate parameters of different avionics systems. That capability will be used e.g. to perform open loop and closed loop tests of the CORE System coupled with the FCS System.

ANAIS ARCHITECTURE

ANAIS is based on standard hardware and basic software off the shelf components. ANAIS can be divided into four major items (see Fig. 6):

- Real Time Station,
- Execution Workstations,
- Preparation Workstations,
- Relational Database.

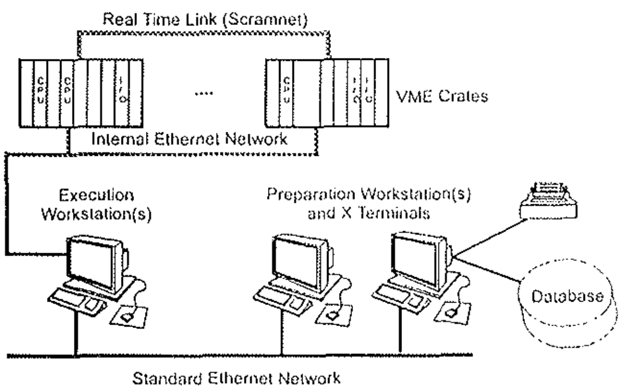

Fig. 6 ANAIS Architecture

The **Real Time Station** can be equipped with a set of VME interface boards according to bench needs (STANAG 3838, ARINC 429, ...), one CPU board (Power PC) to manage the interface boards, and at least one CPU board (Power PC) for data computing. If more than one VME crates are required (e.g. for a system test), they can be connected together via SCRAMNET (optical link).

All dispatching and scheduling problems for running multiple models in a multiprocessor environment are automatically managed by ANAIS, removing test engineers from the tedious tasks of model management.

Avionics frames can be simulated by using the avionics frame description provided in the avionics database (ADBS). Computing models may be written by test engineers either in C or in FORTRAN.

The **Execution Workstation(s)**, providing the user interface, consists of one or several Sun workstations. These workstations are connected to the VME crates via an internal Ethernet network and interconnected by a standard Ethernet network.

It is used by test engineers to control test execution: Display in engineering units, real-time data graphing, graphic stimulation are embedded in fully customisable windows on the Sun graphic interface. Graphic items may be shared on different screens used simultaneously, thus increasing display's area. It can be also used for test preparation.

The **Preparation Workstation(s)** consist of one or several Sun workstations connected to the standard Ethernet network and is optional. It is used by test engineers to prepare tests and to perform off line analysis by means of graphic forms.

The **Relational Database** is used to store avionics data definitions and test descriptions. Different versions of the Relational Database can be available at the same time, allowing equipment testing in different releases or configurations on the same rig.

Characteristic performance figures of ANAIS are:

- Precise time-stamp: 1 μs accuracy
- Up to 15 VME crates can be linked
- Up to 15 CPUs (Power PC)
- Sustains maximum data rate on each I/O,
- Up to 50 graphic displays, 2 Hz refresh rate,
- Up to 20 curves, 50 Hz refresh rate.

Conclusion

The new EUROCOPTER rig concept is characterised by its modular design. Common modules can be reused for different integration applications (as e.g. software integration, equipment, subsystem and system testing, simulation), thus leading to a high flexibility in testing and to a remarkable cost reduction. Rigs will also take over tasks which have been performed in the past from STTEs.

The high performance test system ANAIS can be tailored to the different needs of all users. It provides a unique user interface and eases test data exchange for all applications.

Through the connection with the common avionics database ADBS, the integration means are closely embedded into the avionics development tool environment.

References

Ref. 1 H. Gölzenleuchter, L. Dietl, Test and Integration Concept for complex Helicopter Avionic Systems, 17th EUROPEAN Rotorcraft Forum, Paper 91-16.1, Sept. 1991

Ref. 2 H. Gölzenleuchter, P. Erismann, TIGER Avionic Integration, 19th EUROPEAN Rotorcraft Forum, Paper F2-1, Sept 1993

Ref. 3 T. Bauer, The AH-64D Longbow Apache Hot Bench, AHS 50th Annual Forum, 1994, p. 779-795