

THE EH101 SYSTEM DEVELOPMENT - PROGRAMME UPDATE

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Executive Summary

The EH101 Project is a multi-variant helicopter development programme which encompasses two naval aircraft variants, a civil passenger transport, a commercial utility, and a tactical support aircraft. All the variants are equipped with a fully integrated Vehicle Avionic System featuring Electronic Cockpit Displays, digital Flight Control System, Computerised Aircraft Management System, and a comprehensive Comms and Navigation suite with a fully integrated mission fit to meet the specific role requirements.

Extensive test facilities are available to support the programme ranging from system benches to fully dynamic integration rigs and a total of ten development aircraft. Full simulation facilities, system performance modelling and an EMC aircraft test vehicle have also been provisioned.

To date over 5000 hours of integration testing has been carried out together with over 600 hours of flight testing on Hack and Pre-production aircraft directly associated with avionic system development.

Although the development programme is scheduled to continue into 1992, the development status of the avionic system is well advanced and the productionisation of the equipments is underway in preparation for the full production launch expected early next year.

1 Introduction

The object of this presentation is to provide an update on the status of the development of the EH101 Avionic System and is a follow-on from a previous European Rotorcraft Forum Paper (Reference A) presented in 1987 which described the evolution of the system designed for the aircraft and outlined the development concept and the facilities required to support the project.

In order to set the development status in context, background information on the project, and an overview of the EH101 avionic system has been included in this report, together with an outline of the relationships between the different aircraft variants which are being developed.

2 Background

The EH101 has been designed from the outset as a multi-purpose helicopter which contains a common core design element which is optimised for a particular task by the addition of variant specific attributes.

This relationship between the variants currently under development (with respect to the avionic system design standard) is as shown in Fig 1.

The EH101 project thus takes the form of an integrated programme which will ultimately result in the development of the following aircraft:-

- o ASW/ASST aircraft for the Royal Navy.
- o ASW/ASST aircraft for the Italian Navy.
- o Military Utility/Tactical Support Helicopter.
- o Commercial Utility Helicopter
- o Civil Passenger Transport Aircraft

3 System Commonality

3.1 General

Systems which exhibit the highest level of commonality are primarily associated with the vehicle avionics such as the Flight Control System, the Electronic Instrument System, the Aircraft Management System and the Secondary Navigation Sensors.

The all-digital Automatic Flight Control System provides the comprehensive Autostabiliser and Autopilot functions which are common to all variants plus, for the naval variants, hover trim control and cable hover modes for the Active Diving Sonar. The AFCS is a common implementation, pin configurable for each variant application.

The Electronic Instrument System consists of three Symbol Generators, three Display Mode Selectors and six 7"x 6" colour CRT Displays which provide the flight, navigation, and the engine and transmission displays. The display requirements are virtually common to all variants and, like the AFCS, the EIS is a common pin configurable system. In addition to the inherent redundancy, reversionary back-up to the EIS is provided by a small number of dedicated instruments for Baro Altitude, Airspeed, Attitude, and Magnetic Heading plus a standby

Power Systems Display Panel. The reversionary instruments are common to all variants.

The Aircraft Management System provides the basic avionic system processing for functions such as navigation, condition monitoring, performance calculations, maintenance and operator interface. The latter function is achieved by means of a multi-function Control Unit fitted at each crew station.

The application software for the AMS consists of a number of common modules which perform the common utility functions (condition monitoring, performance calcs, maintenance etc.) plus additional modules tailored to meet the requirements of the specific variant. Included in this latter category are:-

- o Military Comms Control.
- o Interface with the Mission systems.
- o Military Data Bus Control (MIL STD 1553B).
- o ARINC 429 I/O Management.
- o Military Tactical Navigation
- o Military Mission Systems status monitoring.

The AMS hardware is generically common, utilising a common range of hardware modules such as the 80286 CPUs, ARINC 429 Interface Cards, 1553B Interface Cards, Nodal Resources Modules, Power Supplies, and Box Assembly. The host of analogue interfaces with the engine, transmission and airvehicle systems are accommodated by means of two Sensor Interface Units (SIUs) which provide the analogue to digital conversion of the sensor data. For the military applications, the SIUs are separate units and the AMS is therefore a four box configuration consisting of the two SIUs and two Aircraft Management Computers, interfaced via a dual redundant MIL STD 1553B data bus. For the civil/commercial applications, where

the AMS processing task is not as comprehensive, each SIU is incorporated into a composite AMC/SIU assembly as shown in Fig 2.

The navigation sensor fit reflects the differences between the requirements for accurate autonomous navigation in the military scenario and the radio navigation requirements of the civil operators. Commonality of fit is limited to the Attitude and Heading Reference System (AHRS) and Radar Altimeter.

3.2 Military Systems

The military variants which evolve from the common avionics described above are all configured around Mil Std 1553B data bus architectures. The naval aircraft, which have an extensive mission sensor fit, contain an Aircraft Avionic Bus and a Mission Avionic Bus interlinked via two Mission Computer Units (MCUs) as shown in Fig 3. The MCU hardware is generically the same as the AMCs and, together with the tactical Displays and Control Suite, are common to both naval variants. The Mission Sensor fit and the application software in the MCUs are national specific.

The military utility aircraft is integrated around a single data bus and which also accommodates the Defensive Aids suite and a surveillance radar.

The military navigation sensor suite consists of an Inertial Platform, Doppler Velocity Sensor, and Air Data System, which provide the autonomous capability, plus GPS Navstar. All the navigation sensors interface with the AFCS and EIS to provide independent sources of navigation data for system integrity purposes.

The Communication System for each military variant is a variant specific fit providing communications in the VHF, UHF, and HF Bands with additional secure speech, intercom, homing and relay facilities.

3.3 Commercial/Civil System

The civil system architecture which is being offered for Type Certification is configured using ARINC 429 interfaces as shown in Fig 4. In addition to the common systems already discussed, the civil system contains a commercial aircraft standard Comms fit, a Flight Management Computer, and an extensive Radio Navigation Suite.

An second AHRS is fitted to provide reversionary navigation capability and to provide an addition source of data to the AFCS and EIS.

4 Development Concept

The evaluation of the avionic systems reflects the integrated nature of the project in that the responsibilities are spread across international boundaries and encompass a comprehensive suite of bench tests, system rigs, integration rigs, aircraft ground and flight tests and other specialist facilities.

The development logic is shown in Fig 5. A building block approach has been used in that the equipments are evaluated individually before being integrated at sub-system and then system level using representative stimulation and emulations to exercise the equipments in a manner representative of their operation in the aircraft.

Equipment such as navigation sensors which are difficult to assess in a laboratory environment have been subject to stand-alone flight trials as part of their development programme and to provide benchmark performance datums for subsequent flight trials on pre-production aircraft as part of the integrated system.

In addition to the rig test facilities nine pre-production aircraft have been built and their contribution to the development of the avionic system is shown in Table 1. A modified Sea King Aircraft (called the Hack Aircraft) has provided a valuable and timely contribution to the flight test programme as shown in the Table.

5 Development Status

5.1 General Achievements

All the major assets required to support the avionic system development are fully commissioned and operational and to date, over 5000 hours of integration testing has been carried out together with over 600 hours of flight testing on the Hack and Pre-production aircraft directly associated with avionic system development.

The full airvehicle avionic system configuration, including AFCS, EIS, and AMS is standard fit from first flight for all aircraft from PP4 onwards

Details of the achievements and status of the airvehicle development programme are given in Reference B.

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5.2 AFCS

The initial equipment deliveries commenced in early 1988 with rig standard software. Six major software updates were originally planned but these have since been consolidated to four issues and WHL have recently taken delivery of Issue 3. This delivery standard builds upon previous issues and includes the following prime functions:-

- i) - Stabilisation in Pitch, Roll, and Yaw
- ii) - Heading Hold
- iii) - Turn Co-ordination
- iv) - Collective ASE
- v) - Baro Alt Hold, Rad Alt Hold,
- vi) - Heading Acquire, Vertical Speed Acquire.
- vii) - Approach Modes
- viii) - Navigation Modes
- vii) - Built-in Test

Each Software Issue is subject to rigorous testing prior to being flown on a pre-production aircraft. Following extensive simulation trials, AFCS development was undertaken initially on PP3 which first flew with the AFCS operative in January 1989. Work is now continuing on PP4 and PP5 leading to the assessment of the final software issue which includes Transitions, Hover Trim, Cable Hover, and Precision Point Approach. The AFCS has been operable in flight for over 200 hours which includes a total of 20 hours dedicated AFCS flying.

5.3 Electronic Instrument System

The first A Model deliveries of the EIS took place in September 1987 incorporating an initial software standard which allowed rig testing and development of the AMS/EIS interface to be carried out. Five Software

Releases were planned, each release adding further capabilities to the display symbology.

The development cycle for each software issue is shown in Fig 6. The software standard is initially defined on a CAD diagram and then assessed, in dynamic form, by aircrew and engineering specialist, on the Vision and Motion Simulator. The symbology standard is then frozen, implemented via a formal EIS update, and subjected to an in-flight evaluation.

The final formal software update (Release 5) is planned for delivery to WHL at the end of 1990 and the flight testing has revealed no significant problems in over 150 hours of flight testing on PP4, PP5, PP6 and PP8 in conditions ranging from bright sunlight to night time.

5.4 Aircraft Management System

The AMS has four formal releases scheduled for the Application Software for the military configuration and three releases for the civil/commercial version. Development work has focused on the naval versions initially, due to the scheduled arrangement of the aircraft flight programme.

Currently, Naval Release 2 is flying on PP4 and PP6 and provides the bulk of the communication, condition monitoring, and OPINT functional capabilities plus primary navigation modes. Release 3, which introduces the full area navigation function, vibration monitoring and aircraft performance calculations, will be available for flight early in 1991. Release 4 is a wash-up release designed to incorporate changes resulting from the trials on earlier releases and will form the basis of the production standard software.

The Civil AMS has been flown at release 2 on the civil aircraft PP8. Release 3 is expected in early 1991.

5.5 Navigation Sensors

The navigation sensors defined in paras 3.2 and 3.3 above were initially assessed as stand-alone sensors in the Phase 1 Hack Aircraft Trials early in 1987. Data from the IRU and Doppler Velocity Sensor was used for off-line development of the Kalman Filter algorithm which was subsequently introduced by software update to the IRU.

Over 100 hours of dedicated navigation sensor testing was undertaken on the Hack aircraft and trials were carried out over many different types of terrain and over the full aircraft flight envelope with optimum flight profiles for the trial objectives. Instrumentation facilities used for reference included Kint-theodolites (on Mod Ranges), a downward pointing airborne video camera with gyro stabilised graticule marker, surveyed waypoints and a reference Inertial Platform.

The testing and enhancements undertaken formed the baseline for the testing on the EH101 aircraft where the emphasis was placed on evaluation of navigation system performance such as in-flight alignment, Doppler error correction, Doppler/Inertial coupled performance and to assess the effects of the EH101 installation (antenna patterns, vibration, obscuration, mechanical alignment, etc.)

Sufficient testing and assessment has now been undertaken to establish confidence in the achievement of the specified performance requirements. The only major tests remaining are the overwater trials which require the aircraft to be fitted with the flotation system. These trials are scheduled for later this year.

In addition to providing data for navigation purposes, the sensors also provide the references for the EIS displays and AFCS ASE and autopilot functions. Sensor input conditioning and cross monitoring have been successfully implemented and are operational in both of these equipments.

The Air Data System for the military variants consists of a gimbed probe assembly which has to be calibrated to allow for compensation of the main rotor downwash effects over the full speed envelope. Calibration flying for the high speed case has been completed and remaining calibration flights are scheduled to commence shortly.

5.6 Air-vehicle Avionic System Status

From the above information, the development of the common airvehicle avionic equipments is clearly well advanced, with the remaining tests associated with the more advanced autopilot and area navigation functions. A similar status is apparent for the variant specific airvehicle avionic systems such as the Royal Navy comms, and the civil Comms, Weather Radar and Radio Navigation Systems. (These civil equipments are off-the-shelf items which incur minimal development risk).

In-flight operation of the integrated military and civil airvehicle avionic systems is now well established on the pre-production aircraft.

The civil variant, PP8, is currently being prepared for display at the SBAC Air Show, Farnborough. EHI, WHL and Agusta have been working closely with Certification Authorities in order to achieve Type Certification for the civil aircraft with the fully integrated avionic system fitted.

5.7 Mission Avionic Systems

The core elements of the mission system are the Mission Computers, Waveform Generators (CWUs) and Common Control Units (CCUs). The MCU application software for the Royal Navy has three scheduled software releases and the sequence of events for proving each release is shown in Fig 6. The MCS rig contains representative CWUs and CCUs to enable integration of the core systems to be undertaken prior to delivery. Further

integration against emulators and eventually at system level on the Full System Integration Rig is then carried out followed by flight trials on the Hack and, ultimately, PP5. To date, the second formal release has been flown successfully on PP5 and the design standard for the third release has been assessed on the simulator and will be available later this year for rig testing.

The mission sensors for the Royal navy have all now been subject to extensive integration testing and were operational from first flight of PP5 in October 1989. Over 200 hours of development flying of the mission system on PP5 and the Hack Phase 3 trials have been achieved to date.

6 Development Issues

The objective of the Paper was to provide an update on the development status of the system and not to consider the details of the issues encountered along the way. However, for completeness some comment on the types of issues which have had to be addressed is appropriate.

The most significant issue which has occurred in a small number of instances is associated with maintaining adequate reserves of processor throughput and spare capacity to meet the in-service growth requirements whilst maintaining satisfactory system response times and acceptable degrees of data latency. Advances in technology over the timescales of the project has been of benefit and enhanced components have provided satisfactory solutions together with some reassessment of the processing requirements. Rigorous specification definition and continuous monitoring of the computing and software attributes of the equipment under development have been essential activities in the management of these system attributes.

Achievement of specified weight budgets has also incurred some effort for several suppliers. Major emphasis was placed on equipment weight during

the tendering and selection phase and the quoted weight figures in the suppliers responses were made contractual. Suppliers have had some difficulty in maintaining these weight budgets and controlling the trend in weight growth through the equipment development phase.

In order to undertake comprehensive integration testing, proprietary bus test equipment was found to be inadequate and special facilities had to be developed to monitor and analyse data generated during time dependent functional testing such as navigation alignment, initialisation, built-in test routines etc. These tests, which can take several minutes to complete, can generate over 1.0 Gbyte of data.

In general, the problems associated with system integration have been of a minor nature and have mainly been satisfied by changes introduced in subsequent software issues. A number of interim software issues have been introduced in the AMS, AFCS, and EIS as part of the system development programme. There has been virtually no system integration problems discovered on flight trials due to the extensive integration tests carried out on the rigs to investigate system operation and to underwrite flight clearance. Most of the issues arising from the flight tests have related directly to sensor operational performance associated with the EH101 airvehicle installation which cannot be fully assessed on rigs or hack aircraft.

The operation of the Mil Std 1553B Data Bus in the military variants has proved extremely reliable and trouble free. During integrated system testing and throughout a six hour continuous test the bus has demonstrated error free characteristics.

7 Conclusions

This Paper has described the avionic development programme and the current status of the avionic system trials. Of the nine pre-production aircraft, eight aircraft have already flown and five of these were equipped with the fully integrated avionic system from first flight. The majority of the avionic development tasks are complete and the thrust of the work is now aimed towards productionisation and achievement of a level of maturity and reliability commensurate with this new generation helicopter project.

8 References

Ref A: Development of the EH101 System.

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Paper No 76, European Rotorcraft Forum, Sept 1987

Ref B: EH101 Development

B J Main, Westland Helicopters, UK.

Paper III.2.1 European Rotorcraft Forum, Sept 1990

1.3.1.8

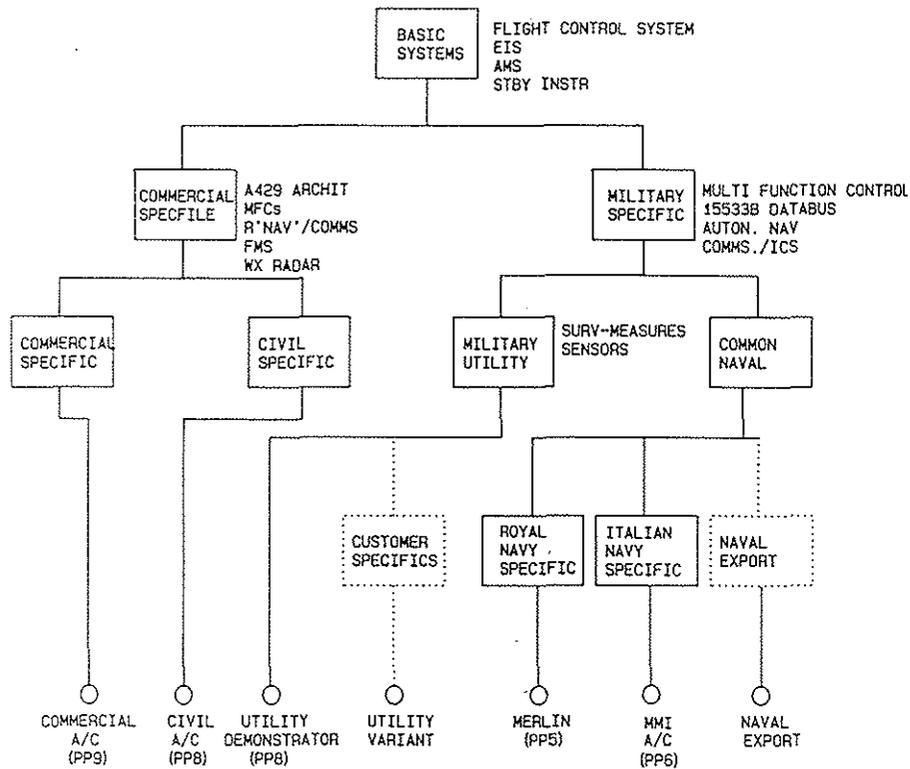


FIGURE 1 SYSTEM DESIGN CONCEPT

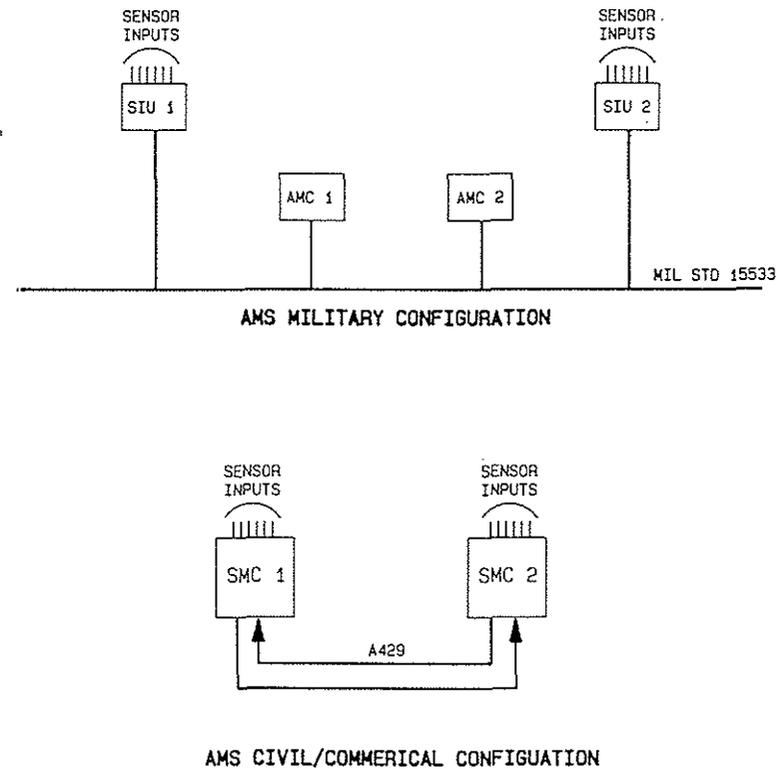


FIGURE 2 AIRCRAFT MANAGEMENT SYSTEM CONFIGURATIONS

1.3.1.9

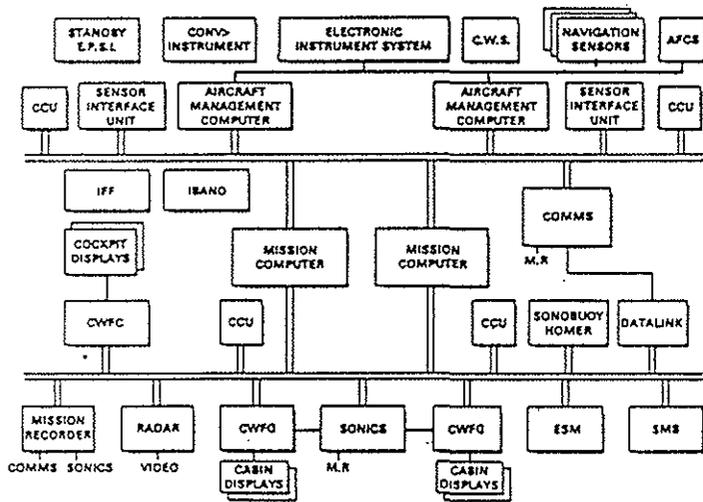


FIG 3 NAVAL ARCHITECTURE

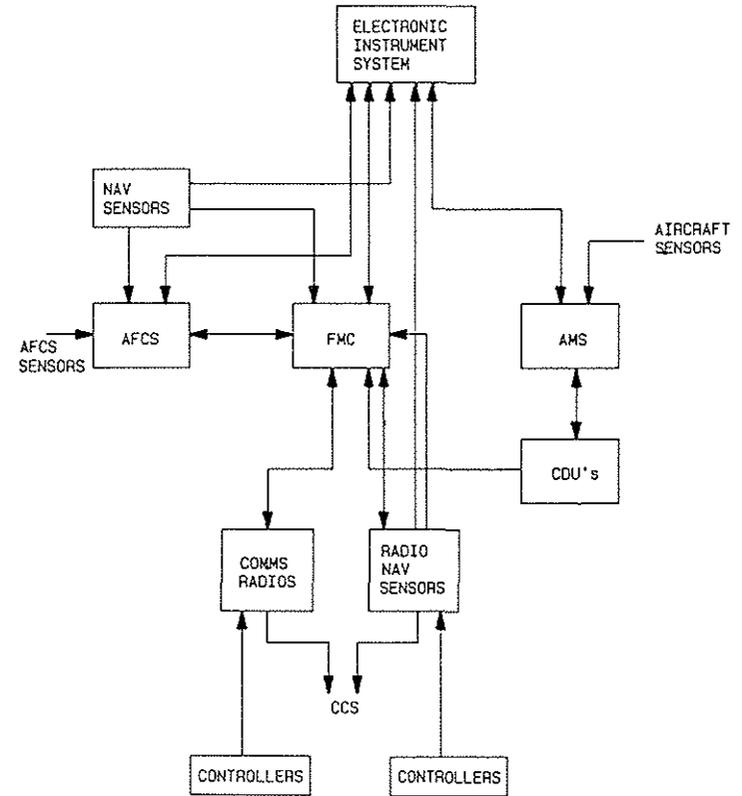


FIG 4 CIVIL ARCHITECTURE

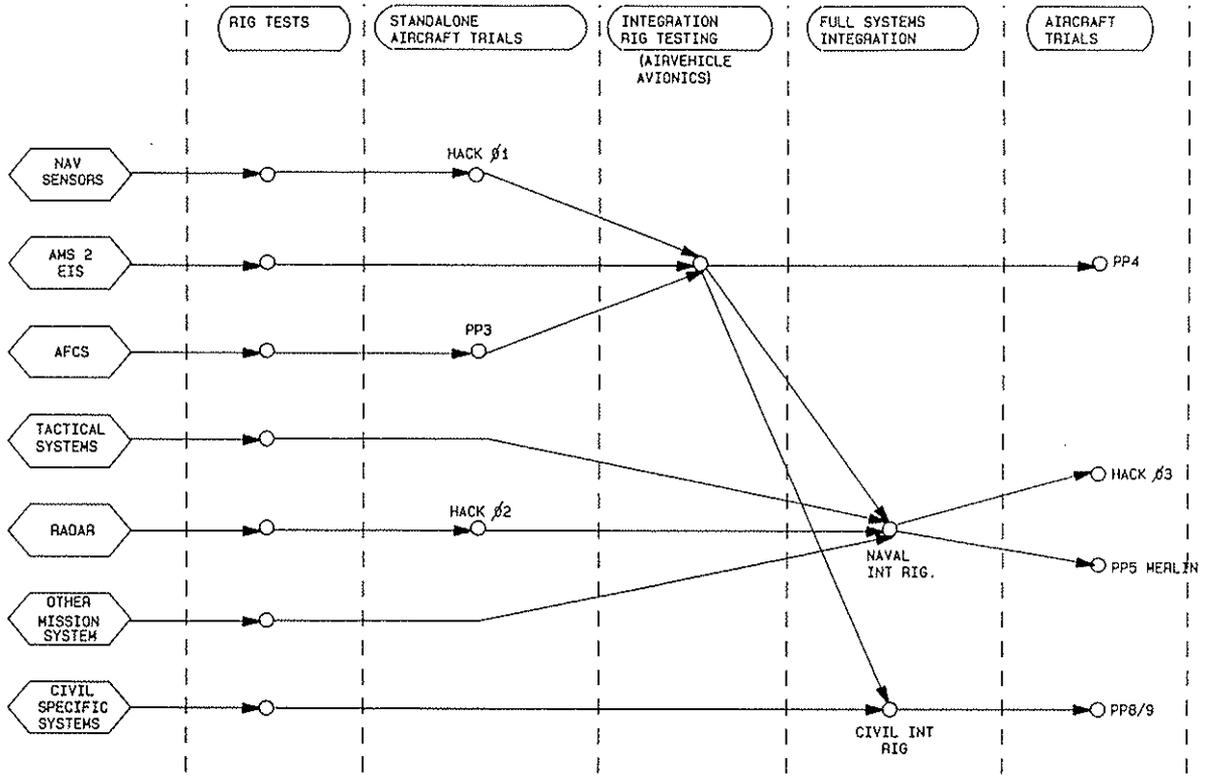


FIGURE 5 DEVELOPMENT LOGIC

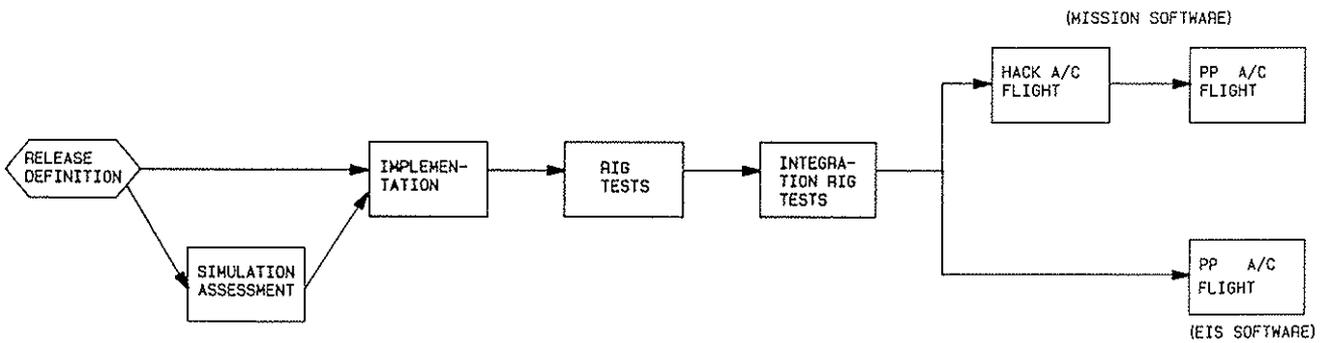


FIG 6 MCS AND EIS SOFTWARE DEVELOPMENT CYCLE

AIRCRAFT	CONFIGURATION	AVIONC FLIGHT HOURS	TASKS
PP3	CIVIL AIRVEHICLE WITH AFCS	60	AFCS DEVELOPMENT (ASE AND AUTOPILOT)
PP4	COMMON NAVAL AVIONICS	43	AMS, EIS, NAV & AIR VEHICLE SYSTEM INTEGRATION
PP5	ROYAL NAVY VARIANT	67	MISSION SYSTEM EVAL & FULL SYSTEM INTEGRATION
PP6	MMI VARIANT	70	MMI SYSTEM EVALUATION
PP7	MILITARY UTILITY	8	UTILITY AVIONIC INTEGRATION
PP8	CIVIL SYSTEM	15	CIVIL SYSTEMS INTEGRATION
HACK AIRCRAFT			
PHASE 1	NAV SENSORS (STAND ALONE)	60	NAV SENSOR EVALUATION
PHASE 2	RADAR/NAV	120	RADAR & FURTHER NAV SENSOR TRIALS
PHASE 3	RN MISSION SYSTEM	143	RN MISSION SENSOR & INTEGRATION EVALUATION

TABLE 1 AIRCRAFT SYSTEM DEVELOPMENT