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DEVELOPMENT AND INTEGRATION OF
THE EH101 ASW WEAPON SYSTEM

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1. INTRODUCTION

This paper describes the evaluation and development programme for the EH101 weapon system with particular emphasis on the avionic aspects, and the mission system, of the Royal Navy variant.

The paper includes a summary of the initial modelling and simulation work carried out by Westland Helicopters Limited, which established the basic weapon system parameters, and outlines the avionic system architecture which evolved from the collaborative project definition/initial development phase.

The paper also describes the development philosophy and the facilities used for development of the avionic system for the Royal Navy and other variants of the EH101.

2. INITIAL OPERATIONAL ANALYSIS

From the previous contract for WG34, the U.K. forerunner of the EH101, three Assessment Models were developed to examine the overall effectiveness of the Weapon System. These models were designated as follows:-

- o Scheduling Model
- o Tactical Model
- o System Model

The scheduling model was used to assess the overall performance of a fleet of helicopters engaged in maintaining and monitoring a sonobuoy screen around a transiting naval force during a period of submarine attack. The model provided a comparative measure and identified the trade-offs associated with parameters such as:-

- Number of aircraft
- Number of weapons
- Quantities and types of buoys
- Reliability
- Fuel load

The tactical model provided an assessment of the detection and screening capability of the system and consisted of a detailed representation of the sonics system and the associated displays. The model outlined comparative analysis of detection performance of a sonobuoy screen against a variety of submarine targets and in differing acoustic conditions.

The systems model forms the basis of the current Attack Model and was used to measure the weapon delivery accuracy within a range of tactical scenarios and acoustic environments. This model, coded in Fortran and run on a VAX 11/780 provided valuable information on the sensitivity of system parameters to splash point accuracy and identified the major sources of error inherent in the system.

In addition to supporting the operational case for the project the net output of the modelling work provided the basic design parameters for the systems being specified for the EH101.

3. SIMULATION IN THE PRELIMINARY DESIGN STAGE

RN Sea King Replacement simulation started in the Company in 1975, using a relatively simple mission system simulator to investigate how a tactical crew of 2 could handle the number of sensors and systems to be incorporated into the aircraft. It addressed navigation, passive and active sonobuoys, radar, weapons, stores and ESM. It used three side by side CRT displays, a keyboard and cursor control device for each member, and with menu options shown at the foot of the main displays. Some 400 hours of simulated sorties were flown with front line RN Sea King crews.

The main finding was that, if, as in the simulation, control and display of the data from the different sensors could be brought together so that the crew could visually correlate the various data, then it was practical to consider using a tactical crew of 2.

Other findings were:-

- a. The tactical crew should be sat side by side, as there was considerable discussion and cross-reference of items on individual displays.
- b. Each crew member required 2 displays, principally to use one as a working frame, and one as a reference.
- c. Control menus were cluttering the main displays and should be removed to a separate Control and Display unit.
- d. Control sequences should be as short and self explanatory as possible.
- e. The importance of aircraft speed in the successful engagement of submarines, when using sonobuoys as the principal acoustic sensor.

4. SUMMARY OF THE AVIONIC REQUIREMENTS

The EH101 from the outset, was conceived as a multi-variant aircraft to cater for the requirements of the RN Sea King Replacement, the Italian Navy (MMI) SH3D replacement and civil and utility variant requirements derived from a number of worldwide market surveys.

The RN and MMI requirements have been amalgamated into an aircraft specification which forms the technical basis of the contract between EHI and the joint government management organisation (IPT). The civil and utility variants are defined in specifications which also form the contractual basis for DTI and MICA funding in the UK and Italy respectively.

An overall comparison of the requirements is shown in figure 1. A high degree of commonality exists in the basic vehicle avionics system such as AFCS, "utility functions", and aircraft instrumentation (EIS) and also in the mission systems of the naval variants, however, certain other constraints were apparent which, in effect, reduced the level of commonality between variants. These were:-

- i. Interface standards - the predominant interface standards for civil and military projects is currently to ARINC and MIL STD 1553B respectively.
- ii. Customers have preferred suppliers and types of equipments in service, with the associated logistic support already established.
- iii. National procurement policy for mission systems does not allow, in some instances, common solutions to be pursued.

In addition, differences exist, particularly between military and commercial variants, which reflect the different operational scenarios, (i.e. EMC, Tempest, N.B.C. etc).

	MMI	RN	CIVIL	UTILITY	
				MIL	COM.
ELECTRICAL SYSTEM					
2 x 90KVA		*	*		
2 x 45KVA	*			*	*
AIRCRAFT MANAGEMENT FUNCTIONS					
MILITARY	*	*		*	
CIVIL			*		●
FLIGHT CONTROL SYSTEM	*	*	*	●	*
COCKPIT DISPLAY REQUIREMENTS	*	*	*	*	*
NAVIGATION REQUIREMENTS					
AUTONOMOUS	●	*		●	
RADIO NAV			●		*
COMMS. REQUIREMENTS					
MILITARY	*	*			
CIVIL			*		●

	MMI	RN
TACTICAL DISPLAYS AND CONTROLS	C	C
MISSION SENSORS		
SONICS	-	N
SONAR	N	-
RADAR	C	C
ESM	C	C
ECM	N	-
S.B. HOMING	-	N
ASM	N	
SMS	C	C
MISSION COMPUTING	N	N

C = HIGH LEVEL OF COMMONALITY
N = NATIONAL SPECIFIC

(* = HIGH DEGREE OF COMMONALITY)

FIG.1 COMPARISON OF REQUIREMENTS

From the analysis of the requirements and following the initial system design activity a relationship was established between variants which formed the basis of the development programme. This is shown in Figure 2, together with the relationship to the development aircraft in the EH101 programme.

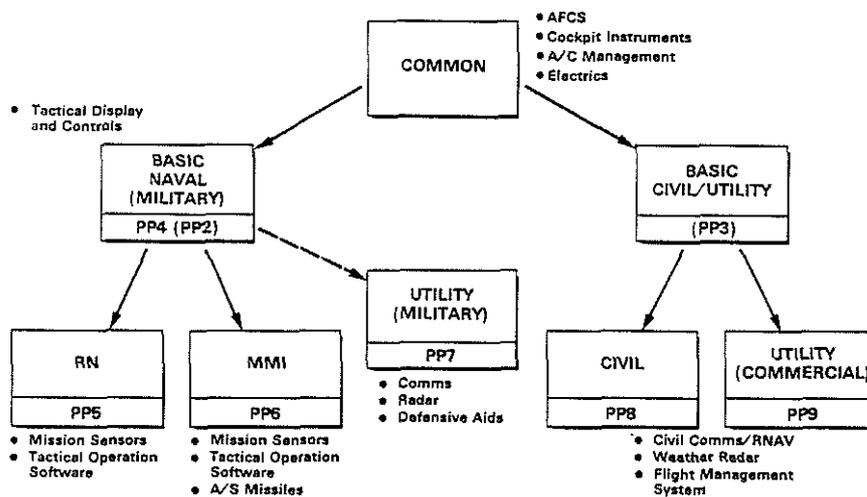


FIG.2 VARIANT RELATIONSHIP

5. SYSTEM ARCHITECTURE (NAVAL VARIANTS)

5.1 Aircraft Avionics

The aircraft avionic system is configured around a dual redundant MIL STD 1553B data bus controlled by two Aircraft Management Computers (AMC) (active/standby), which also perform navigation processing, Health and Usage Monitoring (HUM) calculations and status monitoring and operator interface functions. For the latter function, the man-machine interface is provided by means of a Common Control Unit at each crew station interfaced to AMCs via the MIL STD 1553B data bus. Engine and transmission data is supplied from the two Sensor Interface Units via the MIL STD 1553B data bus and navigation data is provided from the navigation sensors directly via ARINC 429 interfaces.

The Aircraft Management System (AMS) is also linked to the Electronic Instrument System to provide engine and transmission, navigation, and cautionary warning information. The all-digital flight control system, providing auto stabiliser and auto pilot functions is connected directly to the navigation sensors and other dedicated sensors, (Vertical Gyros, Yaw Rate Gyros, Air Data System, Accelerometers etc.,) with an interface to the AMS primarily for autopilot steering commands and status and Built-in-Test information.

The navigation system consists of an Inertial Reference Unit, Attitude and Heading Reference System, Radar Altimeter, Doppler Velocity Sensor and Air Data System. Primary autonomous navigation

mode is Doppler/Inertial, with the other sensors providing various levels of degraded reversionary navigation. Integrated GPS navstar equipment will eventually be fitted to both naval variants.

Reversionary instrumentation is provided by dedicated instruments for Air Speed, Baro. Altitude, Attitude and Compass indications plus a Standby Power System Display.

The Communication System channel selection/frequency control logic is contained within the AMS with dedicated Station Boxes for mode/volume controls at each crew station.

5.2 Mission System

A similar arrangement for the mission system architecture is employed. The two Mission Computer Units provide the active/standby control of a MIL STD 1553B data bus which interfaces to the mission sensors, and tactical display units. The mission computers provide the control logic for the sensors which in turn provide target data for assimilation into the mission data base. This information is processed and formatted into tactical situation and tote displays and output via the bus to the waveform generators for display on the cabin or cockpit mission displays. Radar and sonics video is also interfaced via CCIR video channels to the waveform generators.

Other mission systems include the Stores Management System for control of the torpedoes, light and heavy stores, and a Mission Recorder for direct recording of the sonics video, plus the tactical data base and crew audio.

The aircraft and mission systems are linked via a MIL STD 1553B interface to the aircraft bus in each mission computer, i.e. the mission computers are Remote Terminals on the aircraft bus and Bus Controllers on the Mission Bus. The overall system is shown in Figure 3.

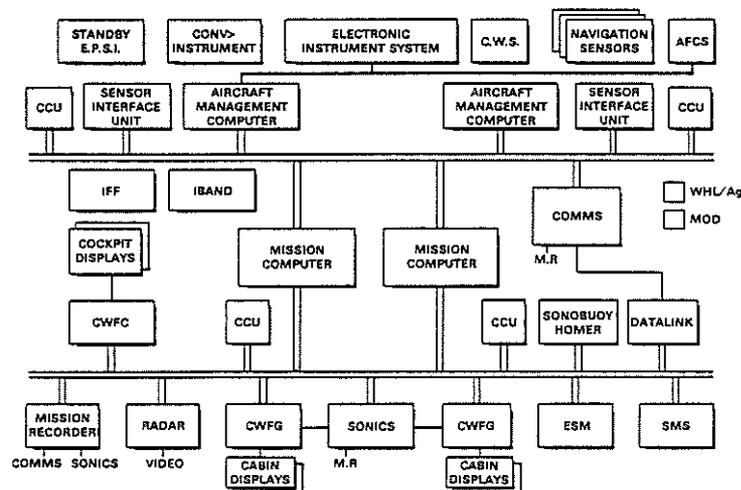


FIG.3 SIMPLIFIED SYSTEM ARCHITECTURE

5.3 Responsibilities

The collaborative workshare agreement requires that the common avionic system procurement responsibility is shared equally between Westland and Agusta. National specific equipments for the Royal Navy variant are a combination of Government Furnished Equipment and Westland procured items. These responsibilities are shown in Figure 3.

6. DESIGN PROVING - THE ROLE OF THE SIMULATOR

Since the concept of a three man crew is fundamental to the Naval EH101 operation, simulation has played a major role in the design and development activities to date. Currently, three simulators are operational at Yeovil.

- o The Cockpit Simulator - with vision and motion capability
- o Flight Dynamics Simulator
- and o The Cabin Mission Simulator

The three simulators are capable of operation individually or in linked mode - typically Cockpit/Flight Dynamics Simulator for pilot in the loop handling and control assessment, and cockpit/cabin for full crew assessment.

Initial evaluations principally addressed the man machine interface, looking at acceptability and operability testing, i.e. reach panel layout, seats, and visibility. Whilst most of these items are normally addressed first in a mock up, it is soon apparent when tried in an operating cockpit, while the pilot is conducting flight tasks, that mock up assessments can only be a preliminary guide.

An early problem identified was the difficulty in adequately displaying engine parameters from three engines using conventional instruments, particularly as it was required to show actual torque margins. Another problem was the multiplicity of Warnings and Cautions required in an aircraft weapon system of this complexity. These problems become significant factors in the subsequent decision to introduce an Electronic Instrument System.

In terms of operability, it is probably true to say that all of the systems on the various panels in the cockpit, have been changed at least twice in the simulator. Simulator changes do involve expenditure, but the cost is significantly less than changing actual hardware, or living with a problem, throughout the life of an aircraft.

All the simulators have been changed in line with the development of the aircraft and indeed it is this continual change which comprises the major task e.g. introduction of EIS and the development of the formats to be used. Indeed the major problem for any design and development simulator is configuration control and this is

particularly the case where a number of variants are being developed in parallel. A recommendation for future projects would be to bring the simulators within the actual aircraft and systems configuration control, whilst at the same time permitting identifiable modules for experimental purposes.

Whilst the mission systems simulator has been used in the same manner for acceptability and operability assessments, it has also been a significant stimulus in both providing the vehicle for ideas, and more importantly in promoting the requirement definition, in that it is impossible to realistically simulate a system or function without a full definition. In other words it has forced design decisions earlier than would normally be the case. Admittedly some of these decisions may be incorrect, but if the programme is correctly scheduled, modifications can be made and more importantly, the inherent problem has been exposed.

It should also be appreciated that the simulator is the first place all the systems are integrated, in terms of what the crew see, and what they control, and this is a most significant step in the design of any modern integrated system. In consequence the simulator becomes the proving ground for the interfaces i.e. is the correct item of information available at the particular display or system. Similarly it is a platform for ensuring consistency of control and display techniques and philosophies, many of which have been designed by different engineers, or in some cases different companies.

The linked Cockpit/Mission simulators have permitted confirmation of the crew structure concepts. These tests have again used current frontline Naval crews, and the fifth series of trials are imminent with three crews each flying some eight sorties in various scenarios. The results of the trials will be fed back into the design of the next mission system application software baseline.

During 1986 use of the cockpit simulator by teams from the U.K. and Italian test agencies resulted in many changes - the majority of them minor - which have now been incorporated into the vehicle and simulator design, but the exercise also highlighted the difficulties inherent in maintaining a common design between aircraft variants and associated roles.

The cockpit simulator has been invaluable in supporting demonstration and discussions with the Civil Certification Authorities (CAA, RAI and FAA) addressing aspects such as Display Concepts and Handling of Emergencies.

One of the most significant tasks undertaken so far is the assessment of the ASE control laws and characterisation of the autopilot modes. This has necessitated the addition of vision and motion facilities to the cockpit simulator plus detailed modelling of the AFCS, the aircraft flight characteristics, (including a finite blade element model running in real time), and the engines. The ability to 'fly' the project pilots, flight test engineers and system designers together in a controlled and repeatable environment has proved of immense value and has more than offset the cost of setting up the facility.

7. THE DEVELOPMENT LOGIC

The development of the avionic system and, to outline the facilities available to support the development are outlined below.

The development logic is shown in figure 4, and is the inverse of the "top-down" approach used to define the design requirements, in that the equipments are tested individually and gradually built up into sub-systems and ultimately, a complete system, with extensive testing applied at each stage.

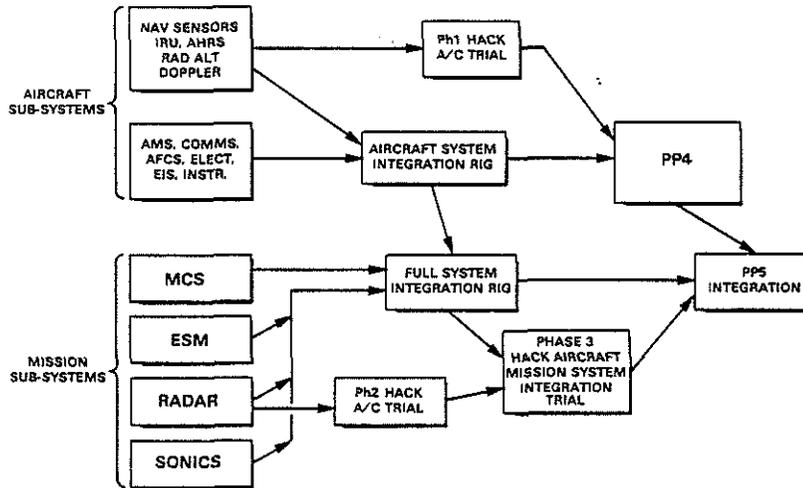


FIG.4 DEVELOPMENT LOGIC

7.1 Vehicle Avionics

Using this approach, the navigation sensors, following acceptance and proving tests at the respective suppliers, are assessed individually as 'stand-alone' equipments on the Sea King Hack Aircraft.

The other vehicle avionic equipments which are essentially processor based rather than sensors, are subject to intensive sub-system testing, again as 'stand-alone' sub-systems prior to being integrated as a complete package with the navigation sensors. This is the configuration which is then flown on PP4. Since the majority of the equipment, except comms, are common to both Naval variants then the results of this work can be used by Agusta to support the overall development of the MMI variant.

7.2 Mission Avionics

A similar concept applies to the RN Mission System. The mission sensors, which are Government Furnished Equipment, will have already been subjected to development trials as 'stand-alone' systems by the respective suppliers and the appropriate technical authorities within the Ministry of Defence. Further trials on the radar, as a 'stand-alone' system are planned as part of the Hack Aircraft phase 2 programme.

The mission computer, and the tactical displays and controls which form the 'core' of the mission system are tested individually and then integrated on the Systems Integration Rig prior to the introduction of the mission sensors. Initially it will be possible to integrate the mission system independently from the vehicle avionic system by emulation of the vehicle avionic interface, since the system architecture was designed to provide a certain degree of isolation, in order to enhance the level of commonality achieved between variants. This configuration of mission equipments will be evaluated on the Phase 3 Hack Aircraft trials.

The total system is then fully integrated on the rig in the configuration representative of the RN pre-production aircraft PP5, prior to commencement of the flight trial.

All the mission system work is specific to the RN variant and has minimal read-across to the work being carried out to support the MMI mission system development at Agusta.

In summary, although there is only one RN configured aircraft in the development programme capable of carrying out total systems proving it will be fully supported by a representative system integration rig and by two other instrumented aircraft, PP4 and the Sea King Hack, with the capability of evaluating and developing the vehicle and mission systems respectively.

8. DEVELOPMENT FACILITIES

In addition to the simulators already mentioned, the facilities being used at Westland to support the RN avionic system development consist of six prime elements:

- o Bench and Sub-System Rigs
- o Integration Rigs
- o Avionic Airframe Rig
- o Hack Aircraft
- o Pre-production Aircraft
- and o System Modelling

8.1 Bench and Sub-System Rigs

The bench and sub-system rigs are shown in figure 5. These facilities vary from the simplest form of a cable harness and Special-to-Type-Test Equipment to complete assemblies of major sub-systems such as comms, AFCS and EIS containing emulations of

airframe and is built to the same wiring standard with additional built in monitoring and recording facilities.

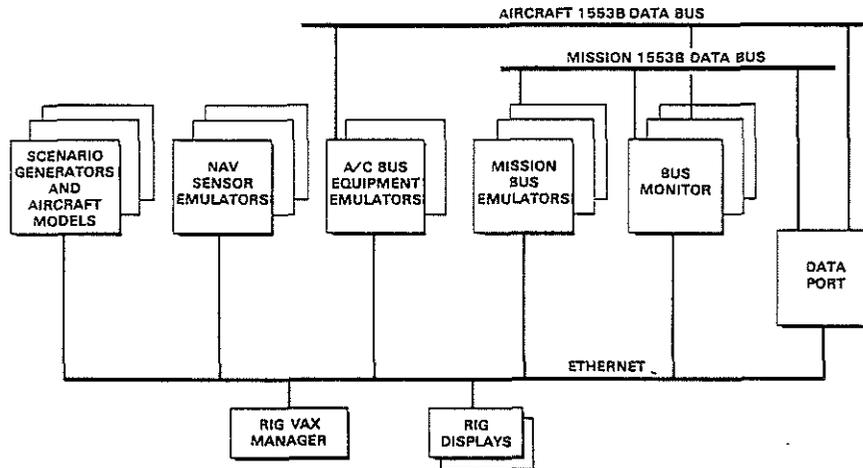


FIG.6 INTEGRATION RIG

8.3 The Avionic Airframe Rig

The objective of this rig is to minimise the utilisation of an aircraft from the flying programme for the EMC, avionic and other testing activities which require a fully representative structure, wiring and installations. The rig takes the form of a non-flight cleared airframe with representative mechanical components and structures and wired to the full RN standard. This will allow realistic EMC, TEMPEST, antenna alignment tests, etc. to be carried out without using valuable time on a flying prototype where the results would be affected by the host of instrumentation wiring. The rig is also a valuable tool for other assessments such as:-

- o Maintainability Demonstration
- o Environmental Control System Testing
- o Compass interference
- o Antenna Coupling

8.4 Hack Aircraft

The Sea King Hack Aircraft was conceived as an early test bed for evaluation and development of avionic equipments on the EH101.

The trial with this aircraft is a three phased exercise:-

- Phase 1 - Navigation Sensor Evaluation
- Phase 2 - Radar Development
- Phase 3 - Integrated Mission System Evaluation

The aircraft XZ570 is a Mark 2 Sea King with the following major modification as shown in Figure 7.

- o Incorporation of two side mounted beams which support a radar platform complete with radome and fairing
- o Airframe mods and dampers to allow the beams to be attached at the weapon hard points
- o Extensions to the aft cabin floor area
- o Additional window on the port side
- o Extensive weight saving mods

In addition, racking and consoles have been introduced for installation of the equipments and associated instrumentation facilities (MODAS plus HDDR's, AVR's, ADR, mini-ranger etc). A Downward Airborne Video Equipment provides indication to the crew and video recordings of the terrain overflow and the aircraft positional datum.

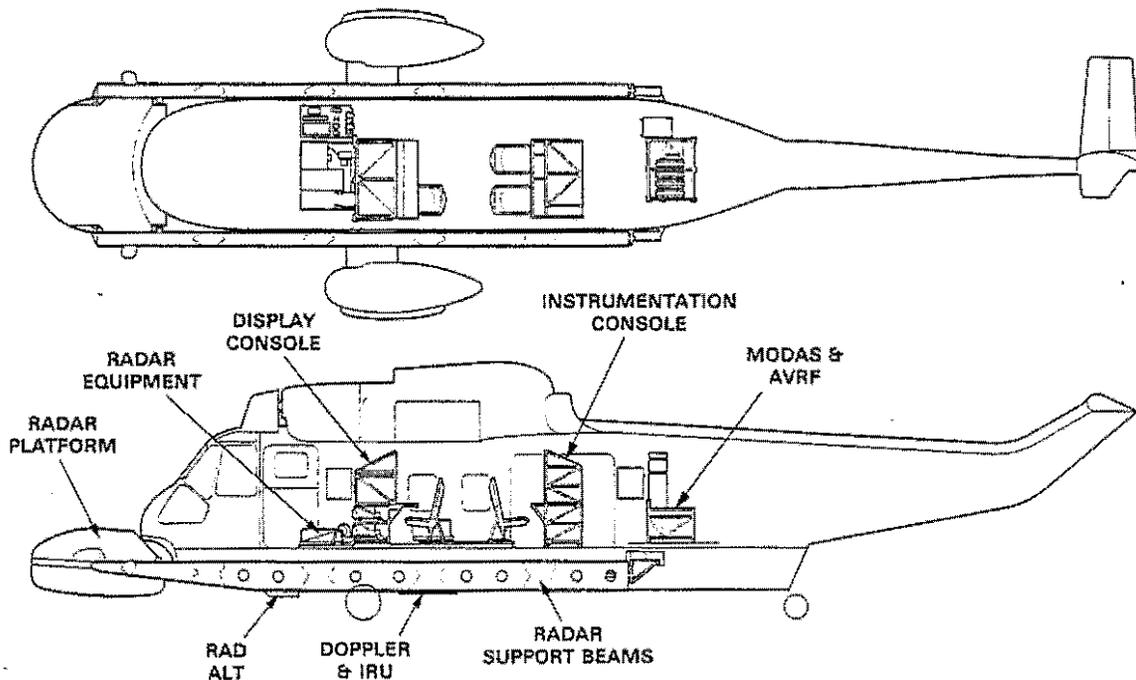


FIG. 7 HACK AIRCRAFT

This aircraft has provided vital test data some two years in advance of the prime avionic trials on the EH101 aircraft.

8.5 PP Aircraft

As shown in the development logic, PP4 and PP5 are the prime contributors to the RN development programme, and provide approximately 650 flying hours of avionic related testing.

PP1 and PP2 will also provide data on the vehicle dynamics which will be used to validate the flight dynamics model incorporated in the simulator and PP3 will also provide additional clearance data on the flight control system, since the AFCS is a common equipment.

Information will also be available from the development testing performed by Agusta in Italy, particularly with respect to navigation and other AMS functions.

8.6 System Modelling

Evolving from the initial operational analysis work, an Attack Model has been developed to provide an indication of the overall system effectiveness of the RN EH101 Weapon System. In addition, computer based test-harnesses have been developed to provide comparative performance evaluation of sub-modules of the system such as the the Navigation System and Tracking Algorithms.

The modelling work has been carried out by Westland Systems Assessment Limited under contract to Westland.

The prime elements of the Attack Model, as show in Figure 8 include:

- o Navigation system
- o Aircraft model
- o Crew Tactical Logic
- o Sonics System
- o Tactical Environment
- o Attach Tracker
- and o Weapon Ballistics

The model is used to determine the sensitivity of specific parameters within the system on overall kill probability.

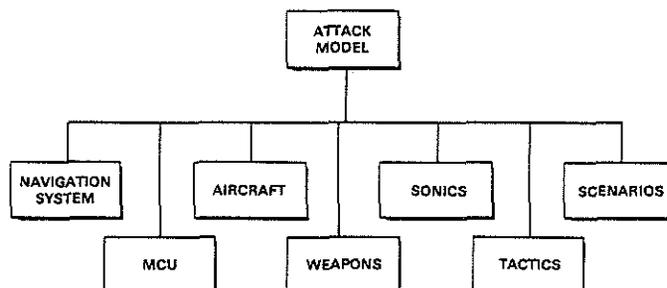


FIG.8 THE ATTACK MODEL

The scope of the model embraces an ASW scenario from the point of initial detection of the target to the weapon splash point using specific active and passive buoys for target localisation.

The relationship between the aircraft development programme and the modelling work is very interactive in that the model can provide bench mark indications of required performance whilst the rig, simulator and aircraft trials can be used to validate elements of the model.

Enhancements to the model and modelling support to the trials will be continuing activities throughout the development programme.

9. TRIALS PROGRAMME

Following initial deliveries of equipment, the sub-system and bench rig programme has commenced the build up leading to integration rig testing in early 1988.

The Hack Aircraft Phase 1 trials of the Inertial Reference Unit, AHRS, Radar Altimeter and Doppler were completed in May and the aircraft is now laid up in preparation for the radar trials in September.

The pacing items in the avionic programme is the development of the application software for the major equipments, and a scheduled series of software updates will occur during the development programme, plus the inevitable 'fixes' and experimental changes, subject, of course, to the appropriate configuration control procedures!

These major equipments, for the RN programme, first fly on PP4 and PP5 following the initial flying and proving of the air vehicle and systems in the earlier PP aircraft. The prime objective is to develop PP5 to a standard suitable for CA Release trials, which will include overall performance assessment on instrumented ranges against calibrated targets in a defined environment.

10. CONCLUDING REMARKS

This paper has provided an overview of the programme and facilities for the development of the EH101 Weapon System. The total programme is a very complex and interactive activity and any one of the aspects mentioned in this report could well be the subject of a paper in its own right.

The EH101 system represents a significant step forward in helicopter avionic technology. The integrated system architecture and inherent difficulties of assessing performance of individual elements in an unpredictable airborne and tactical environment requires the use of extensive and specialised test and support facilities. Evidence of satisfactory performance cannot be obtained simply by clocking up flying hours but by the application of a structured development programme commencing with the initial activities at individual suppliers through to the final flight test sortie with comprehensive and well defined testing at each stage.