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THE GROUND AND FLIGHT TEST PROGRAMME
FOR THE EH101

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1. Introduction

The development programme for the EH101 helicopter is designed to provide an integrated test philosophy for three variants of the helicopter viz. Naval, Civil and Utility.

The ultimate objective of the programme is to certify a Naval aircraft for the UK, a Naval aircraft for Italy, Civil aircraft for the World market and finally a Utility aircraft for both Civil and Military markets throughout the World.

This paper presents the overall ground and flight trials programmes planned to achieve the project objectives, it also indicates progress on both component and aircraft testing achieved to date.

This paper also complements Paper No.76 presented by K.G. Bannister which outlines the logic of the Naval aircraft weapons system development programme, including current progress.

The development process can be considered in three phases,

- a) Preliminary testing to provide basic information to the design teams on the feasibility of certain concepts. This activity precedes and complements the basic vehicle and system design.
- b) Rig/bench testing to demonstrate strength, durability and function of mechanical components. Complex test rigs and simulators are also provided to evaluate and integrate the sophisticated Weapons System prior to flight trials.
- c) A flight trials programme to prove and qualify both the vehicle and the complex weapon/ avionic systems.

Progress at the time of writing this paper is limited, however the opportunity will be taken during the course of the presentation to highlight progress and developments leading to first flight.

2. Preliminary Testing

2.1. "Lead In" Tests

In the early project definition phase a number of "lead in" test activities were undertaken in order to provide basic design information on new materials and processes. These tests included structural element tests of composite materials for rotor blades, tests of fasteners and bonding of composite materials for the structure.

One major feature of this phase was development of a rotor blade de-icing system using a Wessex Hack aircraft. The objective of this trial was to demonstrate the rotor blade mat heating cycle technique and to confirm the heating cycle sequences, in particular the inboard/outboard cyclic options. A series of trials were conducted which produced the fundamental design information necessary for the EH101 blade de-icing system.

Figure 1 shows the relationship between the "Lead In" tests and the full integrated programme.

YEAR	1982	1983	1984	1985	1986	1987
ICE PROTECTION	WESSEX ICING TRIAL		FINAL WESSEX ICING TRIAL			
	NGTE - INTAKE ANTI-ICING TUNNEL TEST		SLOW SPEED SIMULATION TEST		ICING TUNNEL TEST ON DEFINITIVE INTAKE ANTI-ICING	
	OB1 OSC. DE-ICING MRB TEST		OB2 OSC. DE-ICING MRB TEST			
STRUCTURE			COMP. GLAZING STRUCTURE - TESTS OF JOINTS AND GLAZING BARS			
	FASTNER TESTS. - RIVETS, BOLTS, BARREL NUTS ETC.					
			HONEYCOMB PANELS AND WINDOW INSTALLATIONS			
			COMPOSITE TAIL - TESTS OF PANELS, JOINTS, MOUNTINGS AND 1/2 SCALE STRUCTURE			
MECHANICAL COMPONENTS	TESTS OF ELASTOMERIC AND CONTROL BEARINGS		TESTS OF COMPOSITE MATERIALS & LAY UPS FOR ROTOR HUBS, BLADES & FEASIBILITY COMPONENTS			
		FLYING CONTROL SYSTEM FRICTION TESTS				
AVIONICS	ELECTRICAL COMPONENT EVALUATION TESTS					
	SYSTEM ARCHITECTURE EVALUATION FOR MIL 1553 DATA BUS					
	COMMENCED 1975	FEASIBILITY TESTS OF 270V DC SYSTEM FOR DE-ICING				

FIGURE 1 - "LEAD IN" TESTS

2.2. Avionic 'Hack Aircraft'

Another early element of the programme was the flight assessment of selected critical sensors and systems prior to the main EH101 flight programme.

As the majority of the aircraft's avionic development can be carried out independently of the specific helicopter two separate Hack aircraft programmes were undertaken.

An SH-3D 'Hack' aircraft is being used for those avionic sensors specific to the Italian Naval requirement and a Sea King for the UK specific Naval sensors.

This approach allows an early assessment to enable equipment modifications to be introduced prior to the main integrated assessment and hence a potentially early equipment production launch. It also allows development to be conducted on a proven aircraft so that it is not impeded by inter-related vehicle development aspects.

Figure 2 shows the integration of the Avionics Hack aircraft with the Naval aircraft weapon system programme.

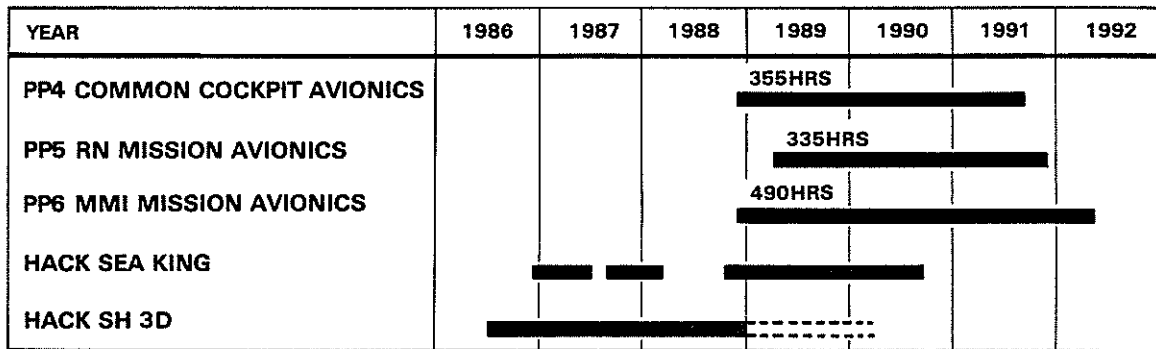


FIGURE 2 - WEAPON SYSTEM DEVELOPMENT PROGRAMME

3. Rig and Bench Testing

The rig test programme is based upon both major and minor rigs for the development and proving of both Mechanical and Electrical/ Avionic Systems.

3.1. Mechanical Systems

a) Airframe Rigs

This programme contains two major airframe rigs. The first structure is dedicated to establish the dynamic characteristics of the airframe. Should a major airframe vibration problem arise this rig will be used to evaluate and understand the mechanism and to develop a solution. In addition this structure will be used for static strength substantiation. The second airframe structure will be used for fatigue testing. This structure will cover the main rotor gearbox attachments including the airframe lift frames and their embodiment into the main cabin structure. The reaction of the rotor loads and inertia loads during landings is via the undercarriage mountings which is also included in the programme. This specimen will also be used for fatigue tests of the cargo hook attachments, rescue hoist attachments, weapon carrier fixed fittings and their structural mountings.

The Utility aircraft rear fuselage incorporates a rear ramp door and therefore static strength tests and fatigue strength tests covering this feature will be carried out on a separate test specimen.

b) Drive System Rigs

Three major rigs are available for the development and maturity testing of the transmission system.

A regenerative test rig based at Agusta as shown in Figure 3 is used in the early stages of the programme for development and fatigue testing of drive system. This rig has been designed to allow tests of the complete drive system i.e. Main, Accessory, Intermediate and Tail Gearboxes, in all combinations of engine operation (single, twin and three engines), speed and power. In the latter stages of the programme it will form a key element in maturity testing of the drive system with support from a similar rig at WHL. This aspect is described in paragraph 6. A total of 2000 hours of development testing is planned for the Agusta rig.

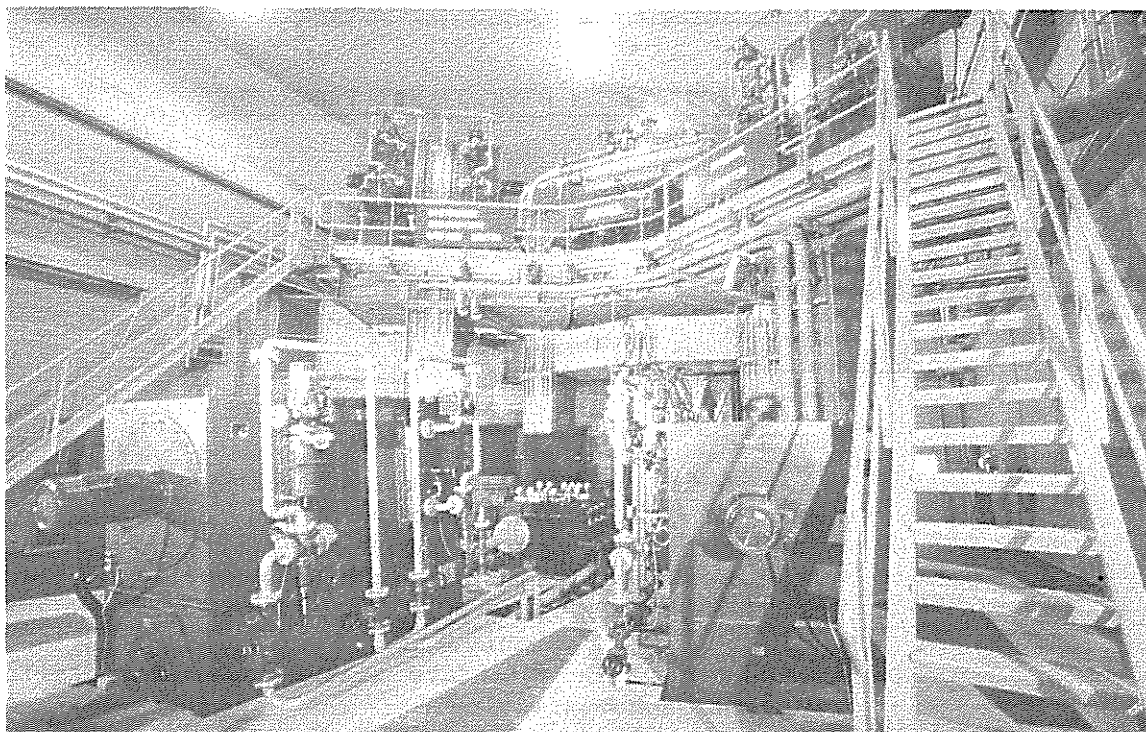


FIGURE 3 - GEARBOX TEST RIG

A rotor rig (Iron Bird) is also provided for the development of the total drive system including engine installations, rotor and controls.

A full test instrumentation system allows for collection of all significant parameters covering stresses, temperature, pressures, vibration etc., both in real time via a telemetry system and with on-board recording.

During the early phase of the programme this rig consists of an iron structure onto which is attached an aircraft representative raft, rear fuselage and pylon as can be seen in Figure 4. This approach being followed in order to commence transmission testing ahead of airframe construction and to give clearance to the pre-production aircraft.



FIGURE 4 - ROTOR RIG

Later in the programme this rig will be extensively modified into a ground test vehicle (GTV) to be totally representative of an airframe in order to provide the correct dynamic environment for the drive system. This approach is necessary in order to ensure the vibration environment and structural deflections are fully representative of the flying aircraft. It is in this mode of operation that the drive system ground certification tests, necessary to comply with MIL-Spec- Def. Stan 970 and Civil Regulations, will be conducted. A total of 1775 hours is anticipated. On completion of this basic drive system development and certification testing this rig will be used for maturity testing.

c) Minor Rig Testing

Numerous other mechanical rig tests are planned in order to demonstrate strength, functioning and integrity. See Figure 5.

Some of which are:-

Main and Tail Rotor Blade Fatigue Tests

Main and Tail Rotor Hub Fatigue Tests

Fuel System Tests

Hydraulic System Tests

Undercarriage Tests

Flight Control Systems Tests

YEAR	1986	1987	1988	1989	1990	1991
MAIN BLADE TAIL BLADE	STATIC & FATIGUE STRENGTH TESTS, EFFECTS OF DE-ICING, ANTI-ICING, ENVIRONMENTAL DEGRADATION, LIGHTNING STRIKE					
MAIN ROTOR HUB TAIL ROTOR HUB CONTROLS	STATIC & FATIGUE STRENGTH TESTS & EFFECTS OF ENVIRONMENTAL DEGRADATION ENDURANCE TESTS OF ELASTOMERIC BEARINGS, DAMPER, BLADE FOLD & ARTICULATIONS					
FUEL SYSTEM	TESTS ON FUEL SYSTEMS RIG TO PROVE PERFORMANCE OF EACH VARIANTS FUEL SYSTEM ENVIRONMENTAL & ENDURANCE TESTS CRASHWORTHINESS TESTS					
HYDRAULIC SYSTEM & FLYING CONTROLS	FLIGHT CL TESTS, PERFORMANCE TESTS, CLIMATIC TESTS, ENDURANCE TESTS					
UNDERCARRIAGE	SUPPLIER DROP TESTS TESTS ON A/C DROP TEST VEHICLE TO CHECK ASSYMETRIC SHIPBORNE LANDINGS RETRACTION & STEERING TESTS STATIC & FATIGUE STRENGTH TESTS					

FIGURE 5 - MECHANICAL COMPONENT TESTS

3.2. Avionic/Electrical Systems

The avionic and electrical test programme utilises a suite of rigs of varying complexity which are used to establish confidence in individual equipment operation right through to total system integration. The rigs are categorised as follows:-

a) Bench Rig

Assemblies of simple cable harnesses, power supplies, and special-to-type test equipment for acceptance tests and other off-line support tasks.

b) Sub-System Rigs

Required for testing assemblies of major equipments, and associated integration. Included in this category are:-

AFCS Rig
Aircraft Management System Rig
Electrical Rig

c) Major Rigs

Required for system proving of configurations representative of the aircraft build. The rigs in this category include:-

- Full System Integration Rig (Naval)
- Civil Aircraft Integration Rig
- Avionic Airframe Rig

These rigs include the stimulations and emulations to enable full function testing to be carried out in a dynamic and coherent way.

4. Flight Trials

The flight programme is based upon nine pre-production aircraft together with two avionic hack aircraft. (See Figure 6).

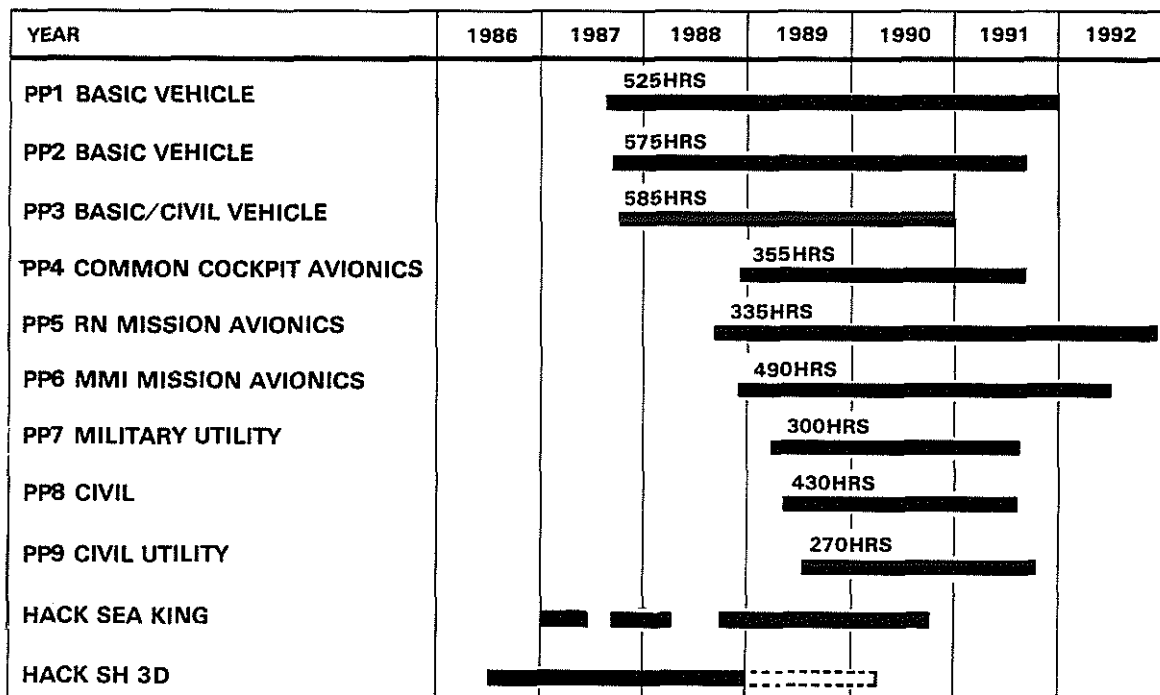


FIGURE 6 - FLIGHT PROGRAMME

These nine aircraft are grouped as follows:-

Two aircraft for the basic airworthiness, one of which is used for icing trials.

Two aircraft for specific civil variant activities including transmission type testing and climatic trials (excluding icing trials).

One aircraft for common (RN and MMI) operational equipment development.

One aircraft dedicated to the RN specific mission equipment.

One aircraft dedicated to the MMI specific mission equipment.

Two aircraft for the development of the Utility variant.

The total estimated flying shared between the nine aircraft is 3900 hours over an elapsed period of 5 years.

The targeted average flying rates per month range from a maximum of 16 on the later Civil aircraft to a minimum of 10 on the RN mission system and Utility aircraft.

The first two aircraft (PP1 and PP2) are primarily associated with basic airworthiness clearance of the vehicle.

Testing will concentrate on flight envelope exploration, Rotor and Airframe Stress Data Gathering, Engine Integration, Flight and Basic Aircraft Handling and Performance Assessment.

The first aircraft will also be used for icing trials and preliminary ship interface trials.

The third and eighth aircraft (PP3 and PP8) are primarily associated with testing associated with the Civil variant activities including integration of the higher power GE CT-6 engine. Initially PP3 will concentrate on the development of the production automatic flight control system as PP1 and PP2 will initially fly with a proprietary system (LN 400).

Hot and High climatic trials will also be concentrated on these two aircraft.

Aircraft 4 will concentrate on development of the Common Naval avionics fit and will be the prime vehicle for the full development of the flight control system.

Aircraft 5 and 6 will concentrate on the integration of national specific naval weapon systems PP5 for the Royal Navy and PP6 for the Italian Navy (MMI).

Aircraft 7 and 9 will be dedicated to the development of the differences associated with the Utility aircraft configuration. Testing will include handling, rotor and airframe stress measurements, performance measurements and Utility aircraft variant specifics.

On completion of the Naval programmes, aircraft will be delivered to the National Military Test Agencies for CA release testing prior to aircraft entering operational service. However throughout the course of the programme both Military and Civil test agencies will be given access to the trials aircraft for evaluation purposes.

5. Major Project Milestone Objectives

YEAR	1986	1987	1988	1989	1990	1991	1992	1993
FIRST RUN ROTOR RIG	▼							
FIRST FLIGHT PP1		▼						
TEMPERATE CIVIL CERTIFICATION					▼			
TEMPERATE UTILITY CERTIFICATION (CIVIL & MILITARY)						▼		
FULL CLIMATIC CERTIFICATION (CIVIL & MILITARY)							▼	
RN INTERIM CA RELEASE (SWITCH ON ONLY)							▼	
MMI INTERIM CA RELEASE (SWITCH ON ONLY)								▼
RN CA RELEASE								▼
MMI CA RELEASE								▼

FIGURE 7 - MAJOR PROJECT MILESTONES

The major project milestones (Figure 7) are as follows:-

First run of the rotor rig achieved in October 1986.

First flight of the prototype aircraft scheduled for last quarter of 1987.

Temperate certification of Civil aircraft September 1990.

Temperate certification of Utility aircraft (Civil and Military) March 1991.

Full climatic certification of Civil and Utility aircraft September 1991.

Royal Naval aircraft interim CA release (switch on only) February 1992.

Italian Naval aircraft interim CA release (switch on only) August 1992.

Full CA release Royal Naval aircraft February 1993.

Full CA release Italian Naval aircraft April 1993.

6. Maturity Plan

6.1. The EH101 Integrated Development and Certification programme recognises the need to achieve early maturity. Civil operations require a greater rate of increase of TBO (time between overhaul) and Reliability than the Military operation and therefore the programme objectives are based around these requirements with the Military specification objectives benefiting from the early Civil activities.

YEAR		1989	1990	1991	1992	1993	1994	1995	1996	1997
MILESTONES			INITIAL CIVIL CERT		INITIAL NAVAL REL					
OBJECTIVES			1000HRS TBO		1000HRS CONFIRMED	NAVAL SPEC REQ 1000HRS		2000HRS TBO		NAVAL SPEC REQ 3000HRS TBO 2000HRS MTBR
WORK TO SUPPORT INITIAL TBO OF 1000HRS		TRANS RIGS 3200HRS → DEV A/C FLYING 2600HRS → GTV 500HRS →								
MATURITY RIG TESTS	GTV	-----				-----				
	Ag TR	-----				-----				
MATURITY RIG TESTS	WHL TR	-----				-----				
		-----				-----				
MATURITY FLYING	PP8			REMOVAL UNSCHEDULED						
	PP9			500HRS	1500HRS	1000HRS				
				1000HRS		2000HRS				

FIGURE 8 - MATURITY PLAN

6.2. Objectives - (Refer to Programme Plan, Figure 8)

a) Civil

To achieve a TBO of 1000 hours at initial certification, to confirm this within one and a half years and to achieve a TBO of 2000 hours approximately four years after certification.

i.e. 1000 hours TBO by last quarter of 1990
2000 hours TBO by end of 1994

b) Military

To achieve a TBO of 1000 hours and MTBR of 800 hours one year after initial release and a TBO of 3000 hours and MTBR of 2000 hours five years after initial release.

i.e. 1000 hours TBO by first quarter of 1993
3000 hours TBO by first quarter of 1997

6.3. Scope of Programme

a) The first target is a TBO of 1000 hours at time of Civil certification. This is achieved on the basis of:

- . the flight testing achieved on the nine pre-production aircraft
- . the ground testing on Iron Bird and the GTV
- . extended running on two transmission rigs, 2000 hours at Agusta and 1200 hours at WHL

b) The maturity plan is then based on the following elements:-

- . A flight programme of 3000 hours each on pre-production aircraft PP8 and PP9, when they have finished their Type Tests and other tasks.

The programme is based on the following logics:

- a) 6000 hours total flying on 2 aircraft
 - b) 2 premature removals of transmission
 - c) Flying rate of up to 1000 hours per year
 - d) Achieving 1000 hours on one transmission by the initial naval certification date and 2000 hours on one transmission within three years.
- . Extension of flying on pre-production aircraft (PP3) to enable life extension improvement modifications to be flown and assessed.
 - . Extension of the GTV programme to 1200 hours beyond the development phase to improve MTBR and to prove any modifications found necessary.
 - . Transmission rigs at Agusta and WHL with allowance for 4700 hours shared between them.
 - . System and sub-system testing on the major aircraft systems affecting reliability, such as hydraulics, fuel, electrical, controls and avionics.
 - . Health and Usage monitoring activity - this makes use of various HUM techniques to protect and monitor the aircraft systems against failure and to monitor wear trends.

This work is necessary in the development phase to support the initial certification objectives and will be extended during the maturity phase to gain further experience on:

- a) the drive system
- b) the structure
- c) the complete helicopter

Defect and R&M analysis.

This activity makes use of the intensive flying to analyse and develop R&M techniques based on the flying on PP8 and PP9 and will supplement the mainstream activity coming from service aircraft under the Integrated Support Plan.

Investigation of Damage Tolerance.

In addition to the TBO programme a programme of work is included to demonstrate the Damage Tolerance of certain key components with the objective of fatigue life improvement.

Concluding Remarks

It is considered that the Military objective of achieving 3000 hours TBO by 1997 will best be demonstrated by in-service experience as by that time the transmission will be effectively 'on-condition' with the airworthiness protection given by the Health and Usage monitoring package which by then will be reasonably well proved.

7. Climatic Clearance

The aircraft is designed to cover the climatic temperature range - 55°C to 50°C and for flight in severe icing conditions. The overall plan is shown in Figure 9.

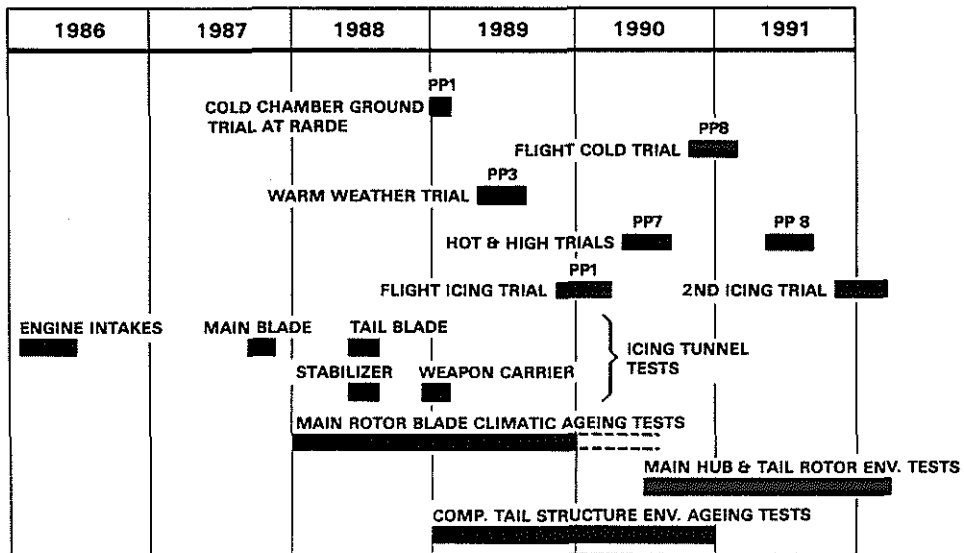


FIGURE 9 - CLIMATIC TEST PLAN

7.1. Cold Clearance

In order to develop and demonstrate cold temperature clearance all individual items of equipment will be subjected to rig testing.

However in order to demonstrate the capability of the complete vehicle two major trials are planned.

A cold chamber test at RARDE Chertsey UK where the complete aircraft will be cold soaked and operated at temperatures as low as - 55°C. In this chamber (rotor blades removed) it is possible to assess aircraft systems functions which include:-

- APU and Engine Starting
- Transmission Operation
- Fuel, Hydraulics and Control System Operation
- Rotor Head Operation including Blade Folding
- Undercarriage Operation
- Tail Folding
- Maintainability

This trial is planned early in the programme in order to highlight problem areas.

This early trial will be followed by a full cold weather trial to assess, in particular, mechanical systems operation and flight characteristics in cold dense air.

7.2. Hot Clearance

High temperature and altitude clearance will be achieved by three trials. The first trial will be an early warm weather trial to provide basic information on systems cooling, handling and performance characteristics. The results of this trial will be used to provide the basic information for initial Civil aircraft temperate certification.

Two full trials will be conducted on aircraft PP8 Civil and PP7 Utility in order to provide the basic data required for Civil Certification.

7.3. Icing Clearance

The overall plan for the development of the aircraft in icing conditions is progressing and certain aspects of the testing are complete. These include:-

- . The preliminary main rotor blade de-icing trials using a Wessex test vehicle.
- . Engine intake anti-icing trials at RAE Pyestock, these trials were used to determine the amount of distribution of heating required to keep the intakes free from ice.
- . Slow speed simulation tests of the side engine intake under low speed hover and sideways flight conditions.

- . Oscillating blade tests using a composite main blade section fitted with specimen heater mats.

Outstanding work in rig facilities include:-

- . Oscillating blade test using anti-iced tail rotor blade.
- . Ice accretion tests on weapon carriage release unit, stabiliser and radome.
- . Tail plane de-icing and anti-icing tunnel tests.

These trials culminate in a vehicle icing trial which will be conducted on aircraft PP1 during the Winter of 1989/1990, the objective being to develop the ice protection systems and to conduct a general assessment of the aircraft in natural icing and snow conditions.

It is estimated that this full icing trial will have to be followed by at least one other trial in order to develop and improve modifications/changes resulting from the first trial.

8. Progress

Rig testing to establish initial strength and provide a 50 hour flight clearance on all major mechanical items is well advanced. Most major components have already demonstrated at least a 50 hour flight clearance capability.

Rotor Rig testing commenced in October 1986 and to date over 50 hours of drive system testing has been achieved. (See Figure 10).

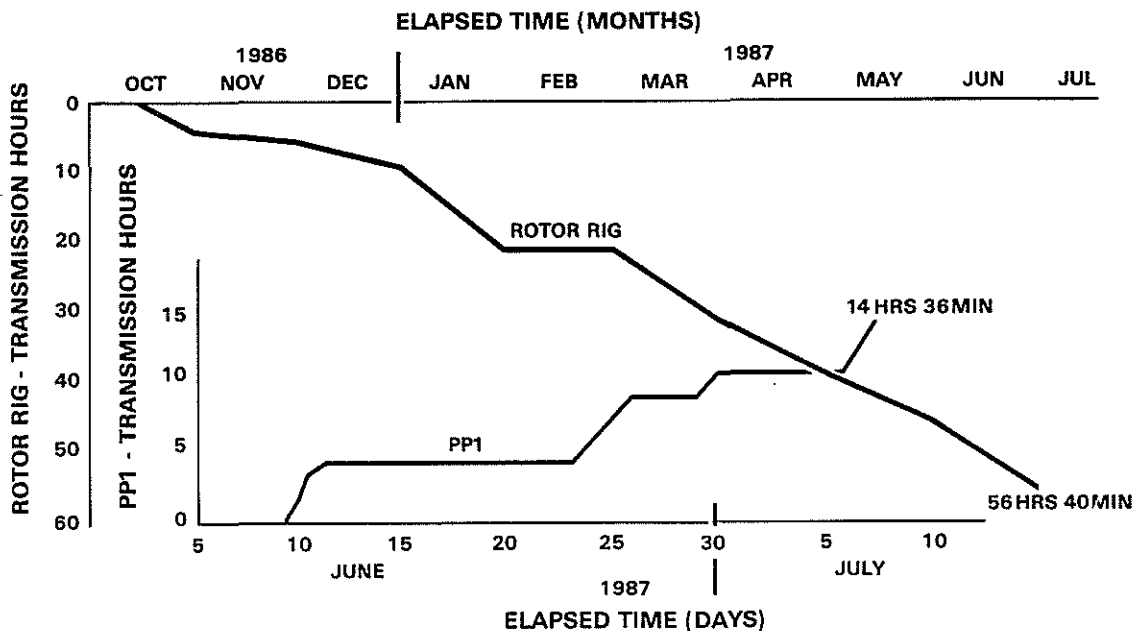


FIGURE 10 - TRANSMISSION TESTING PROGRESS

Fuel System rig testing is well underway and the early flight standard system has demonstrated flightworthiness capability.

The first pre-production aircraft commenced its 25 hour pre-flight ground testing activity on the 9th June 1987. The majority of this pre-flight programme is associated with demonstration of freedom from ground resonance. This programme has been completed with satisfactory results.

Preparation for first flight is well advanced.