

EIGHTH EUROPEAN ROTORCRAFT FORUM

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EH101 DESIGN

-
A COLLABORATIVE PROGRAMME

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1. INTRODUCTION

The EH101 is an aircraft which is being designed and developed jointly by the U.K. and Italy.

The Royal Navy and the Italian Navy have similar requirements for an aircraft to replace their Sea Kings/SH3-Ds. These requirements demand a helicopter that is significantly larger, faster and possesses a greater endurance than the Sea King. It must also operate in severe weather conditions including icing.

The companies involved (Westland Helicopters and Costruzioni Aeronautiche Giovanni Agusta) recognised that this aircraft should be attractive to markets other than pure Naval markets. A market survey conducted in 1981 indicated significant sales potential for civil and utility variants and yielded valuable customer design requirements.

The Governments and industry launched a collaborative project definition phase in June 1981. This phase lasted nine months and produced an aircraft definition to meet the requirements of the two Navies. Westland and Agusta believe that this defined aircraft also satisfies to a large extent the market survey requirements for commercial operators. Work is now proceeding to finish definition of the aircraft on the basis of an integrated development programme aimed at producing Naval, Civil and Utility variants.

2. WHY A NEW AIRCRAFT ?

The SH3-D utilised by a large number of operators world-wide was designed in 1956-1957 at an A.U.W. of approx 7400 kg. It is now operating at A.U.W.s of approx 9500 kg and will be more than thirty years old by the time that EH101 is coming into service. The Navies' requirement for a replacement aircraft can be summarised as;

- providing a weapon platform compatible with the primary (ASW and ASVW) and subsidiary role requirements (ie improved payload/range)
- providing agility appropriate to landing in severe weather within the confined space of small ships, (ie equivalent in thrust margin, yaw acceleration and control characteristics to the present smaller R.N. aircraft - LYNX)
- provide all-weather operational capability including the ability to operate in icing conditions
- provide improved performance characteristics (speed, hover, flyaway, etc)
- provide the maximum cabin volume, consistent with folding the helicopter within the Sea King folded envelope (15.84m x 5.18m high x 5.48m width)

The aim of the above Naval requirements is to arrive at a helicopter that is capable of fullfilling the Navy primary A.S.W/A.S.V.W. role, and the subsidiary roles, with greatly extended operational capability and mission availability.

Preliminary studies indicated that the resulting aircraft would be;

- 1) of similar overall dimensions to the SH3-D
- 2) of greater weight (approx 13000 kg)
- 3) of larger cabin volume (6.5m x 2.39m x 1.82m) sufficient to seat 30 passengers
- 4) of greater endurance (500 miles)

A formal market survey was therefore instigated to explore the civil and utility market potential for this class of aircraft. The results gave further requirements to be added to the naval requirements already mentioned. These include;

- the ability to carry thirty passengers over 500 n.m. range to civil certification requirements (BCAR, RAI, FAR)
- the ability to support off-shore oil rig operations (mixed passenger/freight role) at up to 300 n.m. radius of action
- cargo transportation of 5500 kg over minimum range
- high cruising speed
- vehicular access directly to the main cabin via a rear ramp door

The aim of designing a civil/utility aircraft meeting the above additional customer requirements introduces the civil certification philosophy of placing maximum emphasis on safety levels and the customer emphasis on achieving minimum life-cycle costs and maximum maintainability.

Summarising the above requirements the following features are dominant:

Naval - operational capability and mission availability

Civil/Utility - safety, low life cycle costs and maintainability

These dominant features and the particular design requirements all have to be achieved within a common aircraft configuration.

Westland and Agusta have collaborated on studies and project definition over the last eighteen months and believe that it is possible to derive the variants from a common aircraft, and that the market potential is sufficient to justify the launch of an integrated programme to develop naval, civil and utility variants.

3. DESIGN CRITERIA

In meeting these dominant design requirements within the development timescales, certain design rules and criteria emerge.

<u>Design Criteria</u>	<u>Requirement.</u>
- 3 engines	Safety,
- Engines with maximum separation	Maintainability
- Maximum redundancy of load path (eg blade structure, rotor hubs)	Safety,
- Maximum redundancy of system components (eg 3 hydraulic supplies, 2 alternators, 2 fuel pumps per tank, dual duplex AFCS computing)	Safety, mission availability
- Maximum use of composites for reduced weight with good fatigue properties (blades, hubs, primary structure where appropriate, etc)	Safety, operational capability, low life cycle costs
- Design for reduced pilot workload (eg high capacity digital computer capability using multiplex data bus architecture, efficient all CRT cockpit displays, etc)	Operational capability, safety
- Maximum utilisation of advanced aerodynamics (eg distributed aerofoils on blades, advanced platform tips)	Operation capability, low life cycle costs
- Maximum use of health and usage monitoring	Mission availability, safety, maintainability
- Maximum emphasis on achieving targets for weight, performance, design to cost and R & M	Availability, low life cycle costs, maintainability
- Specific modular build (eg in engines and equipped structure)	Maintainability, low life cycle costs

The achievement of these design 'aims' within the required development timescale of first flight in mid 1986 obviously dictates the technology level utilised in the aircraft. Therefore whereas such features as bearingless rotors, all plastic primary structure, fly-by-wire/light control systems etc could allow more ambitious targets to be set, they are not considered sufficiently mature to form part of the current aircraft definition. New technology for its own sake is therefore not a feature of the EH101; care has been taken to utilise the technological advances now reaching maturity for the accomplishment of the performance and life cycle targets.

4. COLLABORATIVE STRUCTURE

The purpose of this section is not to cover the total collaborative picture of all those involved in the EH101, which includes the U.K. and Italian Governments and the two Navies, but to concentrate on the Companies' engineering activity as it relates to the EH101 design.

Collaborative organisations can take one of several different forms. Previous WHL collaboration with Aerospatiale for instance involved more than one aircraft and each company had design leadership for one aircraft. The Panavia example established a central organisation with proportionate manning respecting the national contributions to the programme. Another recent example was a 50/50 partnership but with one company being chosen as design leader. The collaborative arrangement between Westlands and Agusta is a 50/50 partnership with no design leader. This presents unique problems for the two companies. Therefore in order to bring the two companies together WHL and AGUSTA set up a joint company in London called E.H. Industries (EHI). This is intended to accept the Governments contract with WHL and Agusta and to manage the project in a satisfactory manner. EHI does not have any technical authority and therefore this section concentrates on indicating how the two Companies have worked together during design definition, and how the future might look.

The aircraft definition obviously must be, and has been, jointly agreed by both Companies. This has been achieved by establishing working teams to jointly address the configuration of the aircraft and the definition of the elements of the aircraft (Fig. 1). These teams have examined the options available, assessed the technical benefits and trade offs, and jointly agreed on definitions of overall configuration, structural and mechanical definitions of fuselage, gearboxes, hubs etc and definitions of systems. Also covered were agreed positions on design targets and standards. This process has not been without its difficulties, although a good relationship and understanding has arisen in most areas. It has become obvious in some areas however that more than pure engineering judgements are involved in decisions. Some of the factors influencing the view of the companies are illustrated in Fig. 2. They include differences in language, regulations, standards, technology and even immediate history of Sea King Replacement design activity. These differences have in a few instances made it difficult to reach a joint engineering decision. However in all cases the Companies have been able to reach ultimate agreement - for the sake of the project!

For the full design and development phase now commencing a work-sharing agreement has been reached. This agreement is designed to simplify the design interfaces whilst maintaining the 50/50 work division. It does not represent the production work sharing. Within the work sharing each company will design and develop its share of the aircraft whilst respecting the previously agreed definition. The partner will keep a 'watching brief' over the design by continuation of the working teams. All information will be duplicated in both companies to allow the joint aircraft release process to be undertaken.

There remains other information relevant to design and development that will be jointly agreed and controlled by the formulation of a joint body with equal representation from both companies (Fig.3). It is our belief that the engineering co-operation established over the previous eighteen months demonstrates that this is a feasible proposal. The subjects to be jointly controlled include;

- Design information (loads, geometry)
- Compliance with regulations (BCAR, FAR, RAI, AVP 970)
- Design targets (weights, costs, performance, R & M)
- Standards (procedures and parts)
- Design integration
- Interface control
- Configuration control management
- Product support via an engineering data base
- Procurement specifications

5. AIRCRAFT DESCRIPTION

The aircraft is of conventional single 5-blade main rotor, single 4-blade tail rotor configuration, powered by three GENERAL ELECTRIC engines.

Leading particulars include

Length, rotors turning	22.9 m
Length, folded	15.85 m
Main rotor diameter	18.59 m
Tail rotor diameter	4.00 m
Cabin length	6.50 m
Cabin width (at floor level)	2.39 m
Cabin height (on centre line)	1.82 m
Weight (maximum)	14200 kg
Disposable load	6599 kg
Speed VNo	157 kts T.A.S. S.L. I.S.A.

The main features of the design are;

- 1) Main rotor. The main rotor hub is articulated with an elastomeric bearing carrying blade tension loads while allowing flap, lag and torsional movements. The blade is focussed at a geometrical hinge offset of 5% by a plain bearing adjacent to the elastomeric bearing. The hub is designed to provide multiple load paths wherever possible in order to provide a high degree of safety. Accordingly a composite hub supports the elastomeric bearing and carries centrifugal loads. The out-of-plane loads are carried directly into the metal core from the focussing bearing and are not normally carried by the composite hub. Centrifugally operated flapping and lagging stops are provided. Lag damping is by hydraulic dampers. The facility for manual blade folding is standard and automatic folding using an integral electric motor can be provided. Blades possess a distributed aerofoil section and swept tips and are of composite construction incorporating a de-icing mat if required.
- 2) Tail Rotor. A semi-rigid composite hub is used with elastomeric feathering bearings. The blades have a parallel planform with twist and tapering t/c ratio. Blade construction is composite with provision for anti-icing mats if required.
- 3) Transmission. The main gearbox has inputs for the two side engines which are angled in at 15° and the central aft engine which is offset to port. The gearbox is a four-stage design with an overall reduction ratio of 97.4:1. The side engines drive through a spiral bevel first stage, a spiral bevel second stage, a helical pinion/collecting wheel third stage and an epicyclic final reduction stage. The centre engine drives through a spur gear first stage and then through a spiral bevel second stage. Tail drive is via a helical take-off from the collecting wheel, through a spiral bevel stage to the output at the rear of the box.
- 4) Engine installation. The engines will be CT7-2A for civil use. They are gimbal mounted to the gearbox at the front of the engine and strut mounted to structure at the rear of the engine. Engine starting will be pneumatic from a ground-supply, an APU or by cross-bleeding between engines. Provision is made for an APU that can either power accessories directly with main rotor stopped or incorporate a stand-by generator, depending on customer needs.

Up-rated engines derived from the same family with a 20% increase in power are proposed by G.E. These will be installed for final world-wide clearance.

- 5) Controls. Conventional mechanical (rod and lever) controls are utilised from pilots and co-pilots stations to the powered jacks. Primary mixing necessary with a swash-plate control system is via a mechanical mixing unit in the cabin roof. The series actuators for AFCS inputs are of expanding link form between pilot and mixing unit and the AFCS is therefore axis dedicated. The swashplate is positioned by three P.F.C.U.s mounted on the sides of the main gearbox.

- 6) Fuselage. The fuselage is divided into four modular sections which can be separately built and equipped, as far as practical, before final assembly. These are;
- (a) forward fuselage which consists of a cockpit and an avionics bay.
 - (b) a main cabin of constant cross section 6.5 m long incorporating fuel tanks beneath the floor.
 - (c) a rear fuselage.
 - (d) a tail unit including cone, pylon and tailplane.

Two rear fuselage versions are available. A plain, low drag, version with a low upsweep angle, and a version incorporating a 2 m wide, 15° ramp door for vehicular access. The forward fuselage, main cabin and rear fuselage are of conventional metallic construction utilising skin/stringer and honeycomb panels. The tail unit is of composite construction.

A tricycle undercarriage with oleo pneumatic struts is used. Single main wheels retract aft into sponsons and twin independently rotating nosewheels retract forward into the nose.

7) Aircraft Systems

(a) Electrical. Two 30/45 KVA oil spray cooled brushless generators are driven from the accessory gearbox. The generated voltage is 115/200 volt 3 phase supply connected to a star 4-wired system. Single phase 26 volt AC is supplied via transformers from the busbars when required. 28 volts D.C. is derived from the AC system by means of two 6 KW T.R.U.s. operated in a parallel configuration.

A 24 volt Nickel-Cadmium battery is provided to start the APU and provide emergency power. If there is a requirement to operate in severe icing then two 60/90 KVA generators are utilised in order to provide main rotor de-icing as well as engine intake anti-icing.

(b) Hydraulic. Three independent 3000 psi circuits are provided. In normal operation No.1 and 2 circuits are dedicated to the duplex P.F.C.U.s and No.3 circuit powers ancillaries such as landing gear retraction, wheel brakes etc. The third circuit can however feed either No.1 or 2 sides of the main servos while ancillaries are isolated. In the event of No.3 system failure, or substituting for No.1, the ancillaries can then be fed from No.2 circuit.

(c) Fuel. Three main fuel tanks each feed one main engine. Each tank is fitted with dual submerged boost pumps within a collector and an ejector system to maintain fuel in the collector at all times.

A crossfeed system using three electrically operated valves allows all collectors to feed any two engines and all engines to be fed by any collector.

Additional tanks (up to a total of 6) can be used and fuel is transferred by using the refuel/defuel system into the three main tanks.

(d) AFCS. The AFCS is a duplex digital system using multiple microprocessors in each lane. The computing is designed to operate as an in-lane monitored system which does not depend on interlane disparities for failure detection.

The AFCS provides autostabilisation (including three axis attitude hold and turn co-ordination) and autopilot functions to suit customer requirements.

The system has extensive self-test capabilities, 'transparent' operation and 'failure survival' characteristics (ie in critical areas of the AFCS first failures require no immediate pilot action and the affected function remains operative).

8) Avionic System. The avionics system architecture (civil/utility) is centred around a single Aircraft Management Computer which interfaces with the AFCS, communication/radio navigation systems and the flight instruments.

The Aircraft Management Computer performs the following functions.

- (a) Navigation - from navigation sensors with the position displayed on the control and display unit.
- (b) Flight Planning - provision for loading, storing and editing of routes and waypoints (moving or stationary). AFCS steering commands will be generated and range, time on station and distance estimates given.
- (c) Performance - information related to cruise, climb, hover, available power, fuel usage, weight and centre-of-gravity will be provided.
- (e) Aircraft Monitoring - indications will be provided of the health monitoring for component degradation using vibration sensors and oil debris monitoring. Engine performance will be monitored during normal flight regimes.
- (e) Maintenance - Usage monitoring of appropriate parameters related to fatigue lified components will reduce the life-cycle cost. Avionic status information is monitored to assist with on-condition maintenance of avionic equipment.
- (f) Check Lists - provides interactive check lists on the Control and Display unit.

A Control and Display Unit provides a means of manually inserting system control parameters and selecting modes of operation for the Aircraft Management Computer.

6. AIRCRAFT PERFORMANCE

The estimated performance of the civil aircraft is summarised as follows.

- Speed - The design VNO is 157 kts S.L. I.S.A.
VD IS 200 kts S.L. I.S.A.
- At maximum A.U.W. and 3000' I.S.A. + 20°C
V cruise is 150 kts
- Take-off - At a take-off weight of 13000 kg using CT7-2A engines
the aircraft will hover O.G.E. at S.L. I.S.A. + 19°C or
at 2300' I.S.A.
- With up-rated engines at a take-off weight of 14300 kg
hover O.G.E. will be possible at S.L. I.S.A. + 24°C.
- Engine out performance - The aircraft will be able to maintain a rate of climb of
150 ft/min with two CT7-2A engines at 1000 ft I.S.A.
+20°C at 14300 kg A.U.W. Uprated engines will improve
this performance by approximately 4000 ft.
- Payload/range - Using CT7-2A engines with normal IFR reserves of 45 min
loiter and 5% of fuel burnt, the aircraft will transport
30 passengers over a range of 500 n miles or a payload
of 3630 kg over 400 n miles.

7. SPECIAL FEATURES

Summarising, the special features of EH101 include;

- 1) Large main cabin 6.5 m x 2.39 m wide x 1.82 m high. This is sufficient for thirty passengers with toilet and baggage bay in the rear fuselage. The constant cross section cabin module makes it feasible to lengthen the fuselage in the future for customers who might be space limited over shorter ranges.
- 2) Easy access to the cabin via a large 1.8 m door on the starboard side beneath the main rotor and a 1 m access door on the forward port side. Heavy loads can therefore be placed directly on the aircraft centre of gravity by fork lift truck, and the fuselage can also be divided into mixed freight/passenger roles very conveniently.
- 3) Vehicular access to cabin using the 'ramp-door' option.
- 4) Modern cockpit layout - all CRT instrument displays are being studied.
- 5) High Safety levels - Special features of the hub and main gearbox are aimed at enhanced safety by providing alternate load paths in the event of failures. Health monitoring will be an integral part of the design.

- 6) High degree of crashworthiness - the basic aircraft is estimated to meet the MIL STD 1290 80th percentile crash requirements whilst optional extras will enable the aircraft to survive the 85th percentile crash.
- 7) Low Cost - Design to cost is a specific design activity. Usage monitoring will allow operators to maximise their component lives.
- 8) High Reliability and Maintainability - Targets include a T.B.O. of 1500 hours on entry into service building to 3000 hours after 2 years with an 'on-condition' aim at maturity. An In Build Check Out System will be implemented to the avionic system design and will permit critical avionic component failures to be diagnosed, replaced and retested within planned flights.
- 9) High Performance - Performance consistent with customer requirements and appropriate to a new helicopter is available, particularly for the longer ranges.
- 10) All Weather Capability - The ability to operate continuously in icing conditions appropriate to the North Atlantic and the North Sea.

8. DEVELOPMENT PROGRAMME

The development programme depends upon a number of pre-production aircraft, the components and modules for which will be built by the company responsible in the work share, but the final assembly and flight testing being carried out by individual companies. The aircraft will be utilised for the following activities, which will be shared:-

Handling and performance assessment, dynamic component and airframe stress measurement, vibration measurement, engine integration, mechanical systems and AFCS development and type testing of the basic aircraft.

This will be supplemented by development of specific mission and weapon systems, the provision of civil and utility demonstrator aircraft to develop the variant configuration equipments and integration of the uprated engines.

The intention is to achieve temperate civil certification (CAA, RAI and FAA) by the end of 1989.

9. CONCLUSIONS

The EH101 represents a major advance in helicopter operational capabilities. This achievement has been helped considerably by the amalgamation of the two Companies engineering and managerial experiences and skills.

FIG. 1 COLLABORATIVE STRUCTURE

50/50 PARTNERSHIP - NO DESIGN LEADER

THEREFORE

JOINT WORKING TEAMS

- CONFIGURATION/INTERFACE
- WEIGHTS AND PERFORMANCE
- R & M
- DESIGN TO COST



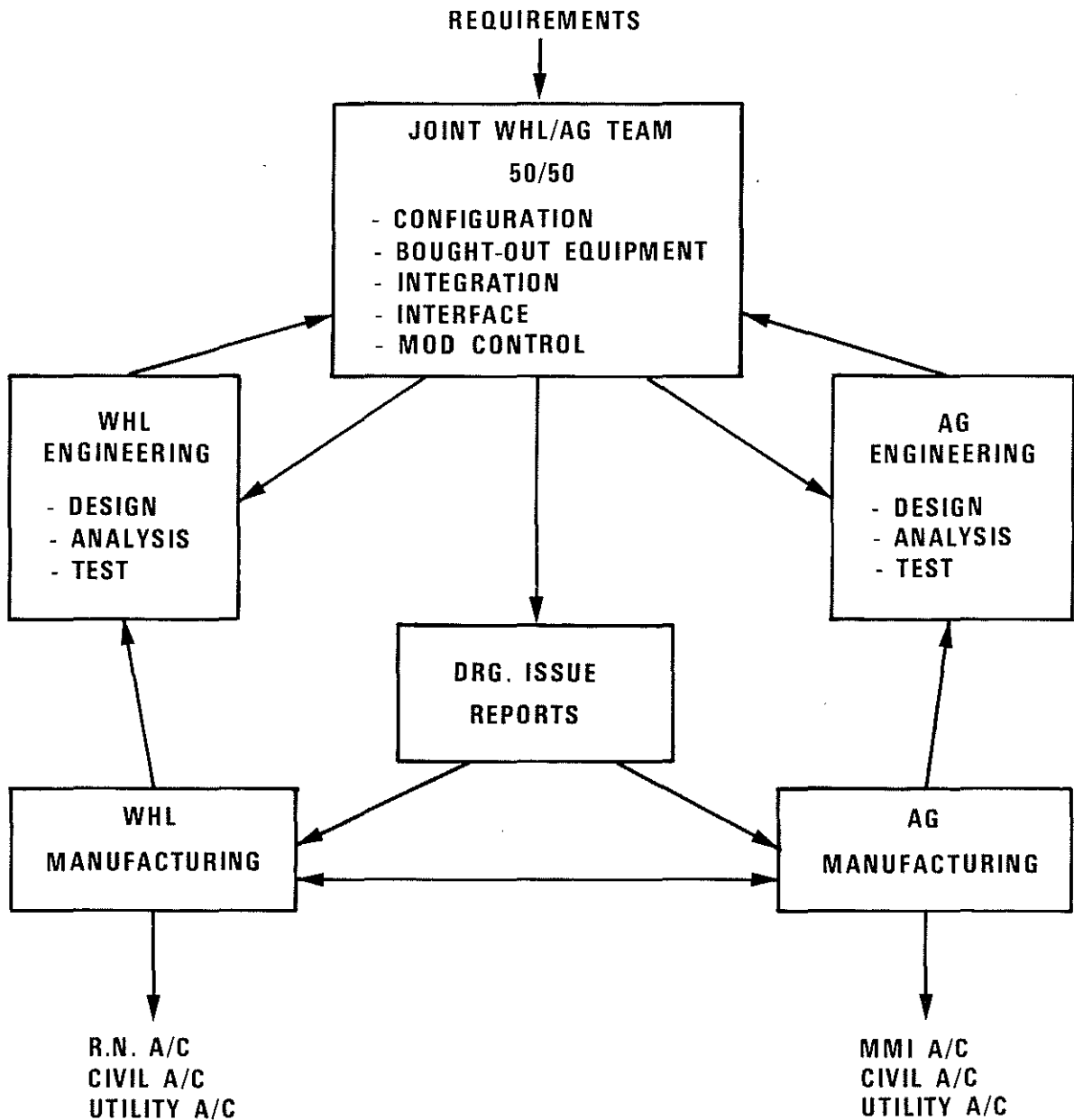
**Controlling and
setting
design targets**

- STRUCTURE
- ROTORS
- TRANSMISSION
- SYSTEMS (ELECTRICAL, HYDRAULIC, FUEL etc.)
- COMMON AVIONICS
- MISSION EQUIPMENT
- E.M.C.
- AFCS/FLYING QUALITIES
- FATIGUE
- DYNAMICS
- AERODYNAMICS
- STANDARDS (DRAWING, MATERIAL, PROCESSES, PARTS)
- QUALITY
- PRODUCT SUPPORT

FIG. 2 FACTORS EFFECTING ENGINEERING DECISIONS

<u>U.K.</u>	<u>LICENSE BUILD</u>	<u>ITALY</u>
S58, SH3-D		CH47, SH3-D, HH3-F, AB212, AB206, AB205, AB204, AB412
	<u>ORIGINAL DESIGN</u>	
WASP, LYNX, W30		A109, A129(DEV)
	<u>LANGUAGE</u>	
English		Italian
	<u>REGULATIONS</u>	
AvP25 AvP970 BCAR		No equivalent U.S.A. military specs. utilised FAR/RAI
	<u>STANDARDS</u>	
B.S., DEF. STAN.		U.S.A. MIL. STDS.
	<u>TECHNOLOGY</u>	
Conformal gears Semi-Rigid hub		Epicyclic gears Elastomeric articulated hub
	<u>FATIGUE</u>	
Block programme loading		Constant amplitude tests
	<u>SEA KING REPLACEMENT</u>	
WG34 Programme		No previous equivalent programme

FIG.3 CONTROL STRUCTURE



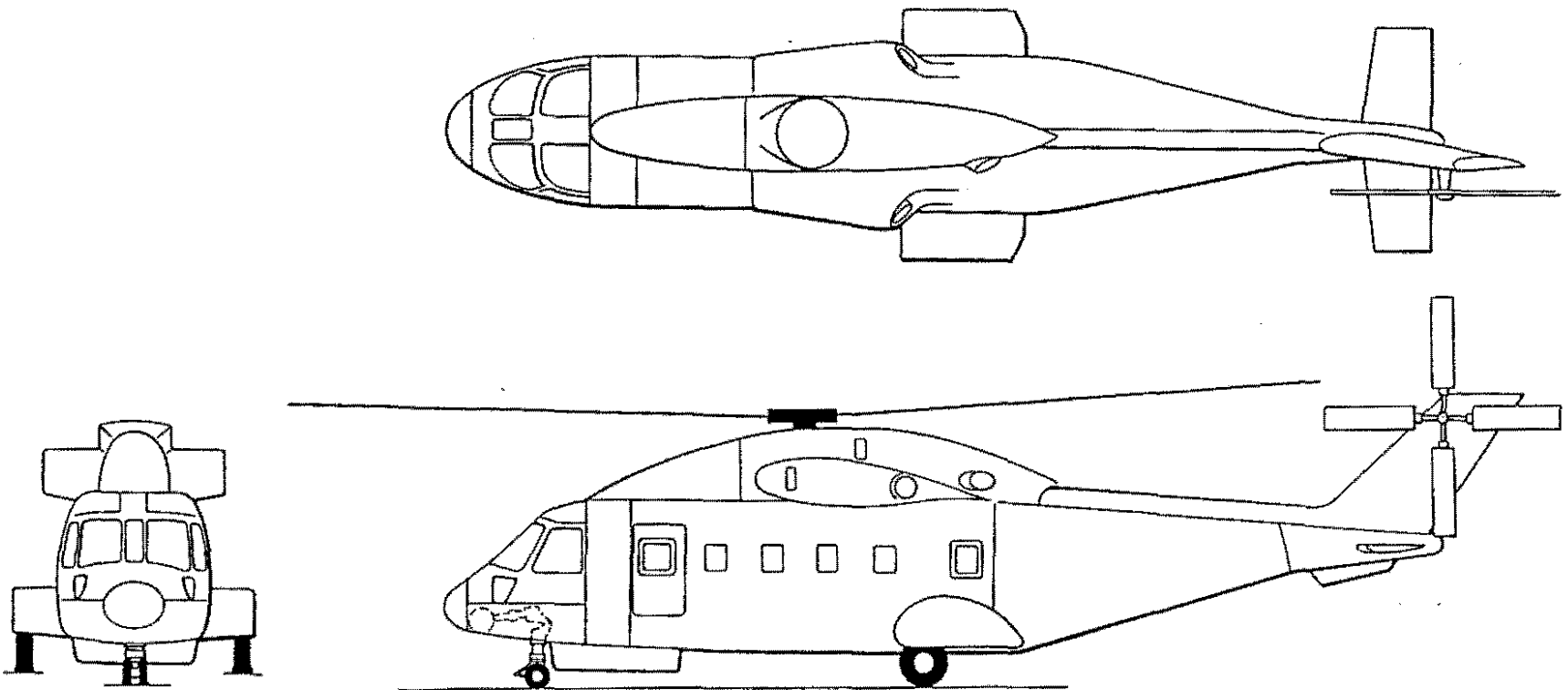


FIG.4 G.A. OF AIRCRAFT