P120

THE DEVELOPMENT OF A NEW LIGHT, SINGLE ENGINE HELICOPTER FAMILY

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SUMMARY

Improving the relatively modern ECUREUIL helicopter is our permanent concern. Many pre-projects were devoted to its replacement or a complementary helicopter lest they were developed by our competitors.
P120 outlines were drawn in 1984 shortly after it was realized a cooperation programme was needed to share development costs and reduce manufacturing costs.

Numerous thoughts were given to this programme since then starting from studies covering every sector of the light helicopter market, examining concepts and technologies, defining cost / development objectives, considering possible cooperations with China as a privileged partner.

This paper illustrates the design and development of P120L, the first product of a whole family, and is, in fact, a conclusion of the investigations undertaken over the last five years.

The design-to cost process was extensively applied to reach cost objectives as well as P120's main technological innovations compared to its predecessors.

INTRODUCTION

Remaining in the competition, one of the industry's permanent concern, involves improving existing products or developing new products.

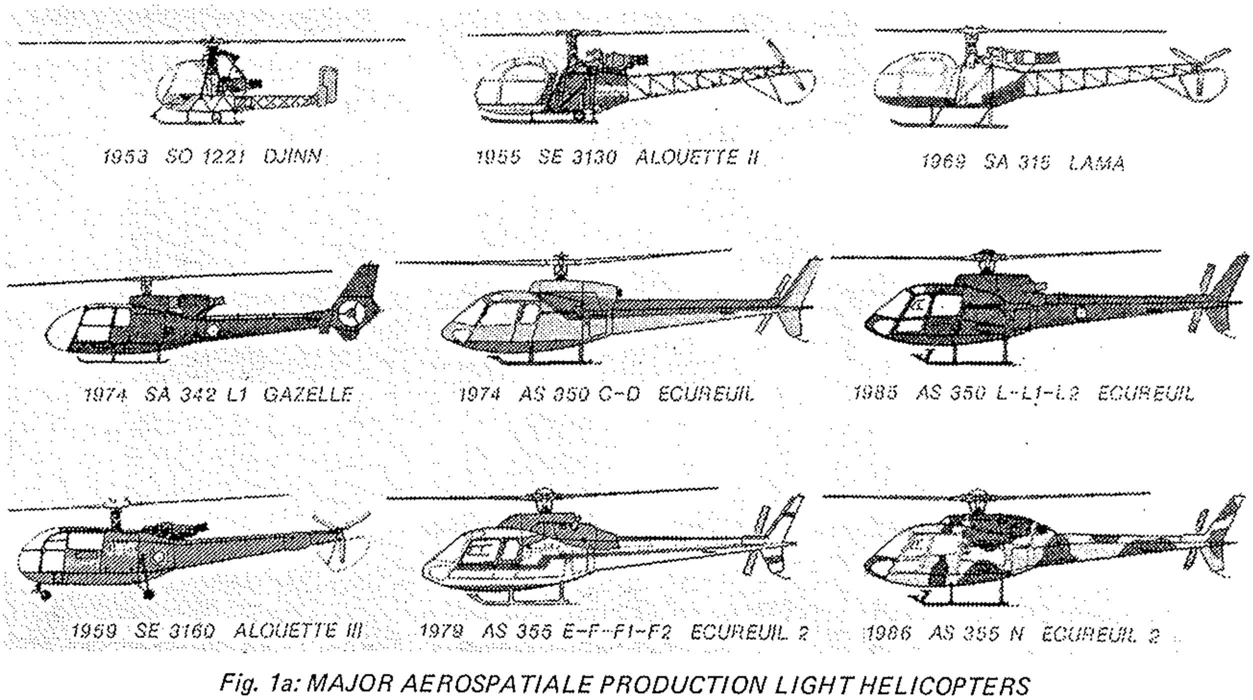


Fig. 1a: MAJOR AEROSPATIALE PRODUCTION LIGHT HELICOPTERS

The light helicopter segment, a significantly large and diverse market, was from the origin part of the Aérospatiale range. Aérospatiale's long experience of this segment is presented on Fig.1a illustrating well known missions.

Following the ALOUETTE family in the 60's and the ECUREUIL family in the 70's, Aérospatiale launched a third generation of light helicopters, P120, in cooperation with CATIC of China and Singapore Aerospace.

The challenge for the ALOUETTE family was to meet the French Army requirements as well as develop French helicopter technologies; the challenge for the ECUREUIL family was to reduce costs by a factor of 3 for civil customers; the challenge for P120 will involve meeting the current technological as well as economical requirements without compromise.

Once the appropriate market and operational surveys had been completed, it was decided to design a light, multi-purpose helicopter as well as launch a new family to replace the first generation ALOUETTE II, ALOUETTE III, LAMA and GAZELLE.

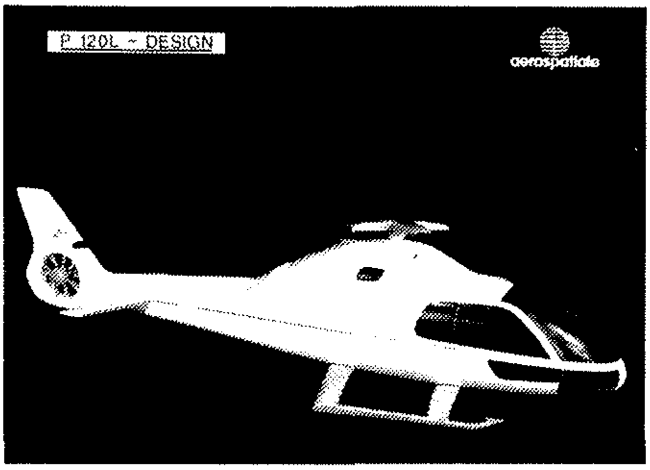


Fig. 1b: P 120L DESIGN

The application of Aérospatiale research and development technology will allow for improvements in a number of fields such as:

- Rotor technology
- Low noise fenestron tail rotor
- Human engineering and comfort
- New cockpits designed for safety
- Composite structures and crashworthiness aspects

An integrated development effort will be called for to reduce this family's development costs.

Huge efforts will prove necessary as far as "design to cost" is concerned, using ECUREUIL as a very competitive reference, and this includes value engineering techniques, new industrial schemes, etc.

Those efforts will be borne by a cooperation team.

Since the margin is quite narrow between the market requirements, the concepts and technologies needed for performance (flight performance and also noise, safety, etc.), the regulations and the costs, every step has been very carefully thought out and detail studies were very often undertaken from the project stage.

The iterations made during the pre-project phase led to a Program Requirement Specification which main objectives are:

- low sales price and DOC (-20% compared to ECUREUIL)
- simple use and maintenance
- 5-seat, multi-purpose, comfortable helicopter able to perform many civil and military missions
- high performance i.e. faster than GAZELLE, higher than LAMA and including the latest technology
- environmental resistance
- high level of comfort, limited noise and vibration nuisance
- Aesthetically pleasant

TECHNOLOGICAL APPROACH

Aérospatiale's general research and development have thus been concentrated on P120. Pre-development studies were specifically adapted to its size and converge towards development of P120L, the first of a variant family.

The past of current technological research programmes undertaken by Aérospatiale to offer P120L every chance of success are illustrated on Fig. 2.

The main developments that helped validate concepts and technologies were undertaken either with rotor wind tunnel trials at Modane (these were later recouped with SUPER PUMA MkII developed in 1989 and DAUPHIN X380 tests), with 332 MkII tests (4-blade Spheriflex rotor developed from 1983 to 1989 and MGB technologies developed in 1987/88), with DAUPHIN tests (Composite Spheriflex rotor with inter-blade adapter developed from 1988 to 1990; X380 fuselage aerodynamics developed in 1990) or with Tiger tests (mainly with structure technologies developed in 1988/1989).

This list is not exhaustive. Research as well as the closely related development of the various helicopters included in the Aérospatiale range help optimize new as well as series aircraft.

The pre-projects undertaken for P120 size and the specific objectives listed above and costs, in particular, led to pre-developments again specifically designed and sized for P120.

The first pre-development took place in 1989 and involved testing a new generation fenestron prototype with significantly improved performance and reduced noise. Research is currently in progress to reduce noise with a non uniform phasing technique.

The second pre-development involved evaluating a V shaped stabilizer on a Fenestron ECUREUIL demonstrator model in the wind tunnel. This concept was abandoned, at a later stage, for this helicopter size after trade-off studies and optimization.

The third P120 specific pre-development involved manufacturing a new composite fenestron blade with a dual technical and economical purpose.

Finally, as new avionic instruments costs are due to come down and LCD technology, in particular, providing they meet helicopter environmental conditions, this type of technology should be adopted for P120 if it proves viable.

In conclusion, everything was done to meet the technical and economical requirements as this programme was prepared to offer a helicopter that would give Aérospatiale the technological leading edge it had gained over its competitors with ECUREUIL in the 70's.

This paper will not be limited to those aspects but will also describe innovations in other fields i.e. engines with FADEC digital fuel control

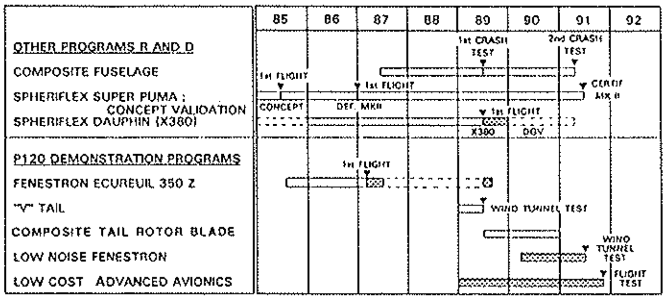


Fig. 2: P 120 ORIENTED RESEARCH AND TECHNOLOGICAL DEVELOPMENT

PROGRAMME SCHEDULE

Listening to the customers' operational needs, opening a permanent dialogue to anticipate their future requirements, improving the safety aspects, meeting increasingly demanding regulations are the industry's constant concerns leading every year to the creation of helicopter pre-projects ready for launch at the right time.

Succeeding GAZELLE and LAMA as well as launching an economical 5-seat civil helicopter is now proceeding logically after 20 years of existence and successes.

Following a 5-year preparation phase in cooperation with our Chinese and Singaporean partners, the active phase of the P120L programme started in 1989.

The programme is proceeding in accordance with the usual methodology. The present phase involves continuing the technological pre-developments described above and providing a detailed P120 definition for full scale development scheduled in the first six months of 1991.

P120 development programme is presented on Fig. 3. This is a general cooperation programme where the work is carried out by each partner in accordance with contractual sharing principles.

The definition phase based on a general specification started with the Framework Contract's signature early in 1990 and should lead to P120L launch early in 1991. This phase will help set every programme operating rule, determine the size and technology of every sub-assembly and confirm the current schedule and cost assumptions.

The development phase which is to start without any transition will begin with the compilation of the necessary production documents followed by part manufacture, lab. tests before flight, prototype assembly and, finally, flight tests. The first flight of the first prototype has been scheduled early in 1993 and the second prototype is to fly 6 months later. The development phase will be concluded with type certification at the end of 1995 with a pre-production helicopter.

Industrialization will proceed between mid 1993 and the end of 1995 while the first helicopters are to leave the production line in the first 6 months of 1996.

. the corporate market requiring a luxurious and efficient helicopter

. the military market

This led to a multi-purpose helicopter derived from two basic versions with maximum commonality:

. the most economical version

. the high performance version

Besides, a large survey was undertaken to assess the weight of the main requirements, the operational data and even the main architectural and technological selections.

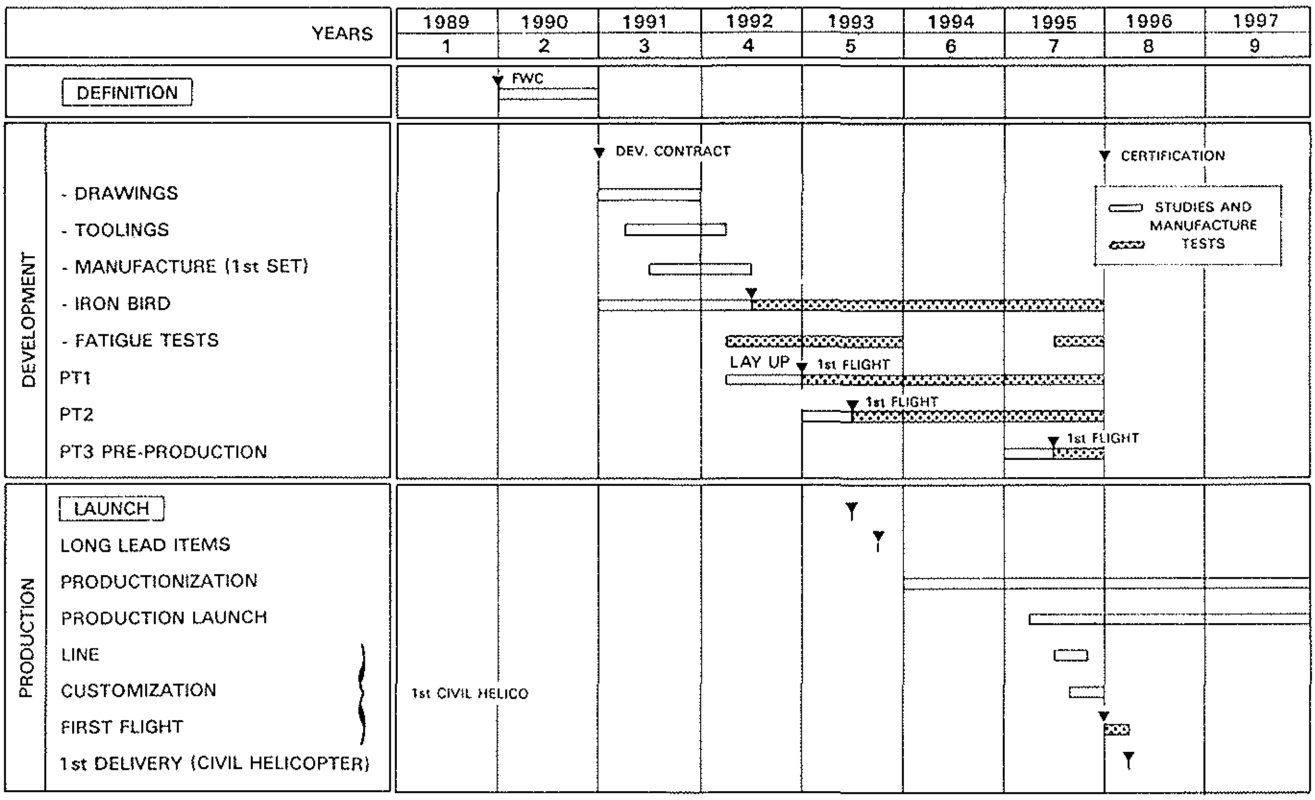


Fig. 3: P 120L - PROGRAM SCHEDULE

MISSIONS AND MAIN REQUIREMENTS: OPERATIONAL NEEDS

The P120L segment can be summarized in four main sectors of operation:

. the economical civil market i.e. transport, freight, training,

. the high performance civil market i.e. air work, sling loading etc.

The main difficulty is then the satisfactory integration of the numerous, sometimes contradictory, data gathered during this survey.

The main criteria were then translated into objective parameters and, at the end, into requirements summarized in Table 1 below :

CRITERIA	OBJECTIVE PARAMETER	REQUIREMENT
Maintainability Availability	MTBF DOC	Overall failure rate: 5.10^{-6}/FH Mission reliability: 97% for day transport VFR
Safety		Applicable safety regulation: FAR 27-25 Fail safe and damage tolerance as much as possible
Costs	Sales price DMC	Adequate 20% <350B2, engine excepted
Agility	Speed Manoeuvrability	270/275 km/h: civil and military version, clean MIL.F.83300: 35 kt cross wind
Comfort	Noise Vibrations Habitability Aesthetics	ICAO limit-4 EPNdB external <0.1g at cruise speed for passengers World population between 5th and 95th percentile
Range	Payload/range	800 km max range

TABLE 1

I would also like to give a few thoughts on aesthetics, a highly subjective criterion inserted amongst objective technical or economical parameters which obtained, suprisingly, a fairly high and probably underestimated rating because it must have been considered too rationally by those surveyed.

This is why this criterion was introduced into design, with due consideration for its weight and the technical penalties it might impose.

P120 style is thus strongly personalized.

Agility and agressivity for the military versions; ruggedness and simplicity for the utility versions; fluidity and elegance for the corporate versions.

It is also important not to study each functional part i.e. cockpit, engine bay or tail rotor separately. Our current concern is to think of P120 as an entity, an industrial product where aesthetics and technical aspects are allied to optimize the product/operator equation.

ARCHITECTURE AND GENERAL CHARACTERISTICS

P120 studies are undertaken to meet various improvement requirements over the current range of helicopters of the type listed above with the prime requirement remaining low costs.

The aerodynamic characteristics are thus carefully thought out (streamlined fuselage without protrusions) while retaining a main frame offering three comfortable seats aft of the aircraft.

The cabin's volume (4.6 m^3) is large for a small helicopter and windows cover 6.4 m^2.

The cargo hold volume (2.2 m^3) helps design an avionic bay protected against electromagnetic agressions.

These volumes authorize several missions:

. Passenger transport

. Casualty evacuation

. Hoisting, etc.

and the helicopter can also be transformed into an armed version with numerous items of on-board electronic equipment.

The results of maintenance analyses were integrated very early during studies to keep the Direct Maintenance Cost low with appropriate technology, accessibility and short assembly replacement times.

Survivability is also a significant design parameter where passenger protection is guaranteed upon crash at vertical impact speeds up to 8 m/sec.

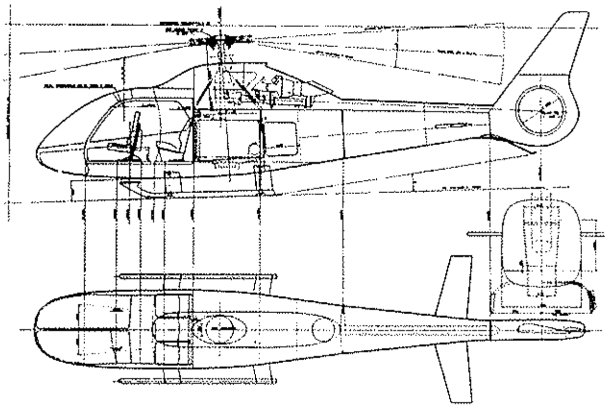


Fig. 4: P 120L - THREE VIEW DRAWING

GENERAL CHARACTERISTICS

DESIGN GROSS WEIGHT:

- Basic version: 2 T
- High performance version: 2,3 T

MAIN ROTOR:
- 4 blades
- Diameter: 10.7 m

FENESTRON TAIL ROTOR:

- 8 blades rotor
- 11 blades stator
- 850 mm diameter

ENGINES

- Take-off power from 500 to 650 kW

MAIN GEAR BOX

- Power: 500 kW
- Input speed: 6000 rpm
- Output speed: 387 rpm

VOLUME

- Cabin: 4.6 m³
- Mid cargo holds: 0.8 m³
- Aft cargo hold: 1.4 m³

CABIN FLOOR

Surface : 3 m²

FUEL TANK

Volume: 650 L

TECHNOLOGICAL CONCEPTS

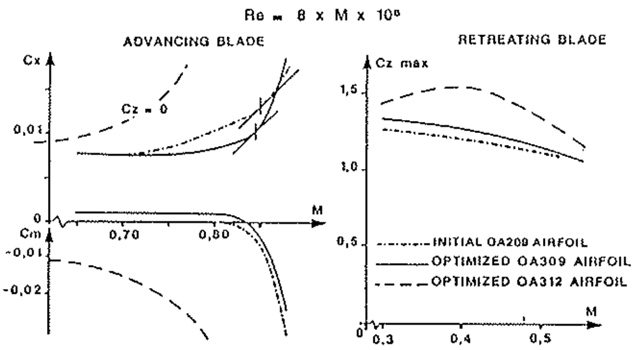
Selecting modern technologies is not an end in itself but should be the way to achieve the programme's technical and economical objectives.

Main rotor

Aerodynamics

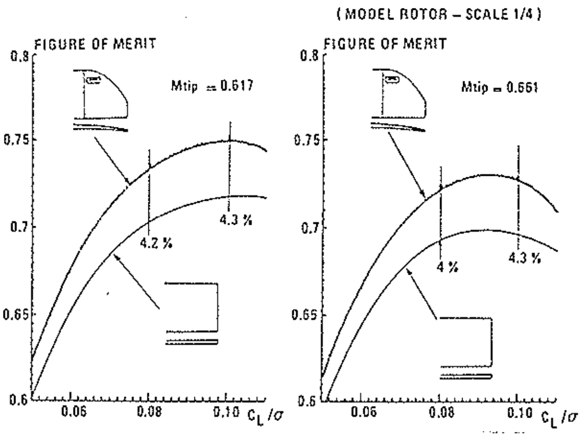
Aérospatiale and ONERA are working together to improve helicopter rotors with theoretical as well as experimental analyses and these are completed by Aérospatiale work as the new SUPER PUMA MkII (see ref. No 1) and X380 rotors are developed. Experience is thus gained in the aerodynamics, dynamics and noise reduction fields.

The definition retained for P120 is therefore the application to a 2.3 T helicopter of new airfoil (Fig. 5), planform and blade tip concepts (Fig. 6).

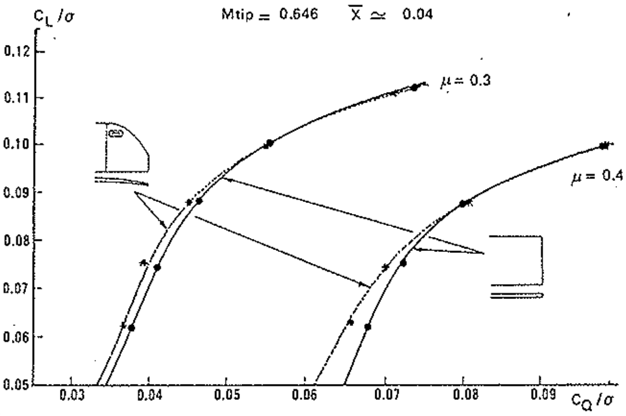


	P120L	ECUREUIL
Number of blades	4	3
Diameter	10.7 m	10.69 m
Chord	0.27 m	0.35 m
Airfoil	OA312 → 309	OA209
Twist	12	12
Tip	SPP8 Parabolic	Rectangular

Fig. 5: P 120L ROTOR - GENERAL AERODYNAMICS



HOVER PERFORMANCE COMPARISON BETWEEN SPP8 and RECTANGULAR TIP



FORWARD FLIGHT PERFORMANCE ON MODEL ROTOR (MODANE WIND TUNNEL TEST)

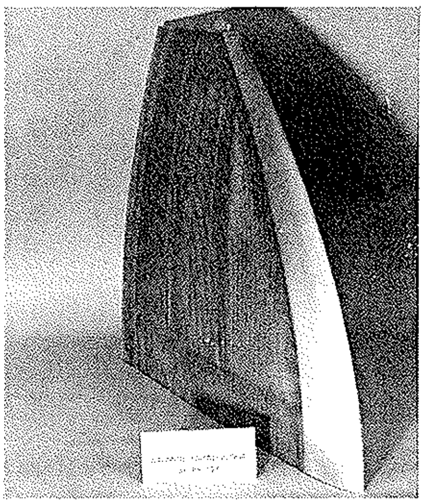


Fig. 6: P 120L ROTOR - TIP SHAPE AND AERODYNAMICS

This definition is also summarized in Figure 5.

Significant gains are obtained in terms of hover, cruise performance as well as noise reduction.

HUB TECHNOLOGY

The selections made for P120's rotor hub were also derived from the most recent developments undertaken with the SUPER PUMA Mk2 and High Speed DAUPHIN helicopters.

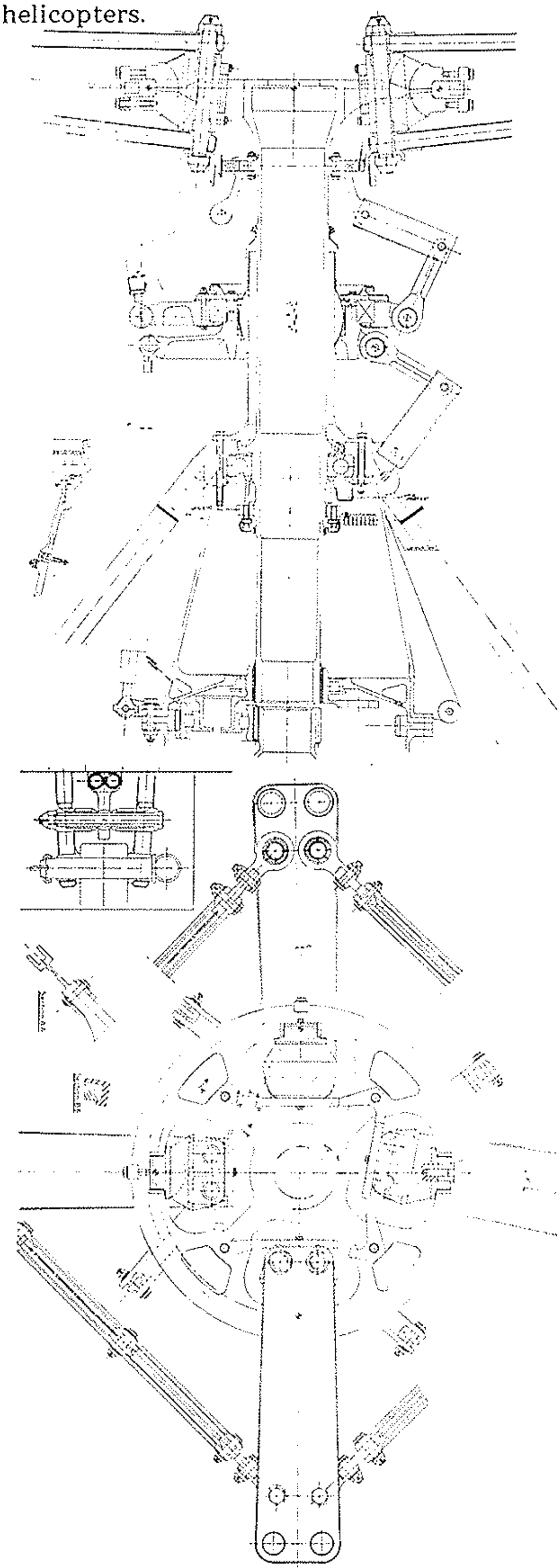


Fig. 7: P 120L - SPHERIFLEX MAIN ROTOR HUB

These two helicopters helped validate the Spheriflex hub principle where the blade is linked to the hub via a spherical thrust bearing for pitch, flap and drag.

This principle helps minimize hub size as well as dynamic loads and also offers excellent handling qualities (see ref. No 2).

The provision of inter-blade adapters on the High Speed DAUPHIN helps simplify part design for a better arrangement and reduction of static loads.

Hub integration on the SUPER PUMA Mk2 helps reduce weight and does away with the problems the mast/hub link might raise.

As far as the blades are concerned, the most recent developments undertaken with AS 332 Mk2 and X380 have shown the advantages of parabolic tips, a low cost manufacturing technology developed to meet the requirements.

The BMR concept is being evaluated as an alternative solution. The final selection will take every technical, economical and industrial aspect into consideration for the best advantage of the P120 programme.

MAIN ROTOR BLADE

P120 main rotor blade is characterized by an advanced aerodynamic definition

The technical definition is the result of a specific effort made to minimize development, manufacture and operating costs.

A number of technological selections were thus validated from 1988 with preliminary tests e.g. single operation moulding with extensive automation of spar manufacture, tip integration or the manufacture of complex foam parts cast in situ.

The high blade elongation (radius/chord = 19.8) called for very efficient composite materials to reach the necessary characteristics (torsional rigidity, 3 Ω forces and moment on rotor head).

Furthermore, the best weight/blade inertial compromise was sought to give the rotor the required handling qualities in autorotation, in particular, which is a basic quality for light, single engine helicopters.

It must finally be noted that blade design will benefit from Aérospatiale's experience in the composite blade field i.e.:

- Low maintenance cost
- Unlimited service life
- Satisfactory environmental resistance
- Repair capabilities
- Blade-by-blade interchangeability

FENESTRON TAIL ROTOR

Aérospatiale has developed the fenestron as an alternate solution to the conventional exposed tail rotor for light and medium size helicopters up to 6 tons.

The fenestron consists of a small fan housed in a shroud topped by a large vertical fin designed to unload the rotor in cruise and to provide directional stability of the airframe. As a consequence:

- Safety is improved by the shroud protecting the rotor from strikes with obstacles on the ground
- Survivability is improved by the large fin unloading the rotor in cruise
- The dynamic blade stress levels remain low, even at high speed.

From the time it was first installed on a GAZELLE helicopter in 1968, Aérospatiale has gained considerable fenestron in-service experience with over 3.7 million hours flown by GAZELLES and DAUPHINS.

The concept matured over the years with extensive research in the field of aerodynamics and acoustics to improve power efficiency as well as reduce external noise.

Considerable progresses have also been made in the field of technology with the introduction of composite materials, the simplification of the original design and the manufacturing process applied to reduce weight as well as production and maintenance costs.

Why had this choice not been made for the ECUREUIL helicopter launched after GAZELLE and DAUPHIN? Precisely because the technology did not allow then reaching the cost objectives that had been set.

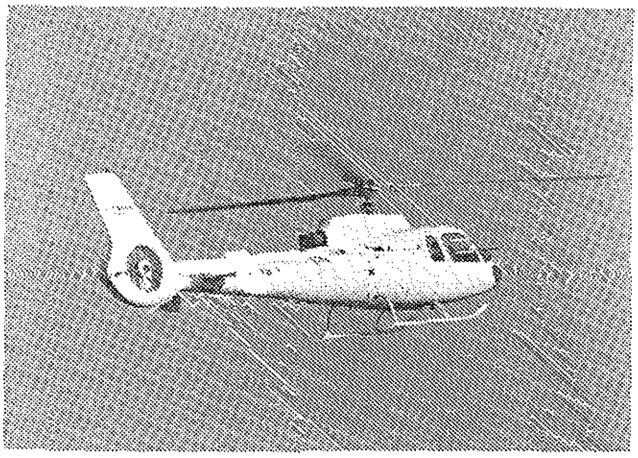


Fig. 8: ECUREUIL EXPERIMENTAL FENESTRON

In 1987, Aérospatiale flew an experimental fenestron equipped with advanced airfoils and stator blades on an AS 350 Z helicopter. This 0.9 m diameter fenestron was designed to replace the 2-blade, 1.86 m diameter teetering tail rotor provided on the production ECUREUIL with the same power efficiency but a much higher max. thrust capability (see ref. No 3). The advanced fenestron offered a 30% figure of merit improvement over the teetering rotor which had first generation NACA 0012 airfoils and non twisted blades. Fin blockage was thought to amount to 7% thrust. It was demonstrated that with less than half the teetering rotor's diameter, fenestron required the same amount of power in hover and offered a 50% max. thrust capability increase.

Fenestron also offers numerous operational advantages in terms of manoeuvrability, survivability (translation flight and landing are possible after a fenestron loss) and stability.

FENESTRON NOISE

Particular attention was paid to noise as the experimental fenestron was designed for the AS 350 Z helicopter. Rotor/stator interactions were significantly reduced with the stator blades supporting the tail gear box and replacing the large support structure used in previous fenestron designs. Compared to the first generation SA 341 GAZELLE fenestron, rotational noise was reduced by as much as -4.5 dBA to -10.8 dBA for the same power level.

Comparative measurements made in the near field around the tail rotor showed that the noise generated by the fenestron was lower than or equal to, depending on azimuth, that generated by the 2-blade teetering rotor provided on the production ECUREUIL.

Fenestron's rotational noise was -0.5 dBA to -8.5 dBA lower than that of the teetering rotor in the most severe ICAO noise certification conditions i.e. take-off and high speed fly-over.

Since the teetering rotor has fewer blades and its rotation is slower than fenestron, its noise spectrum includes more harmonics at low frequencies.

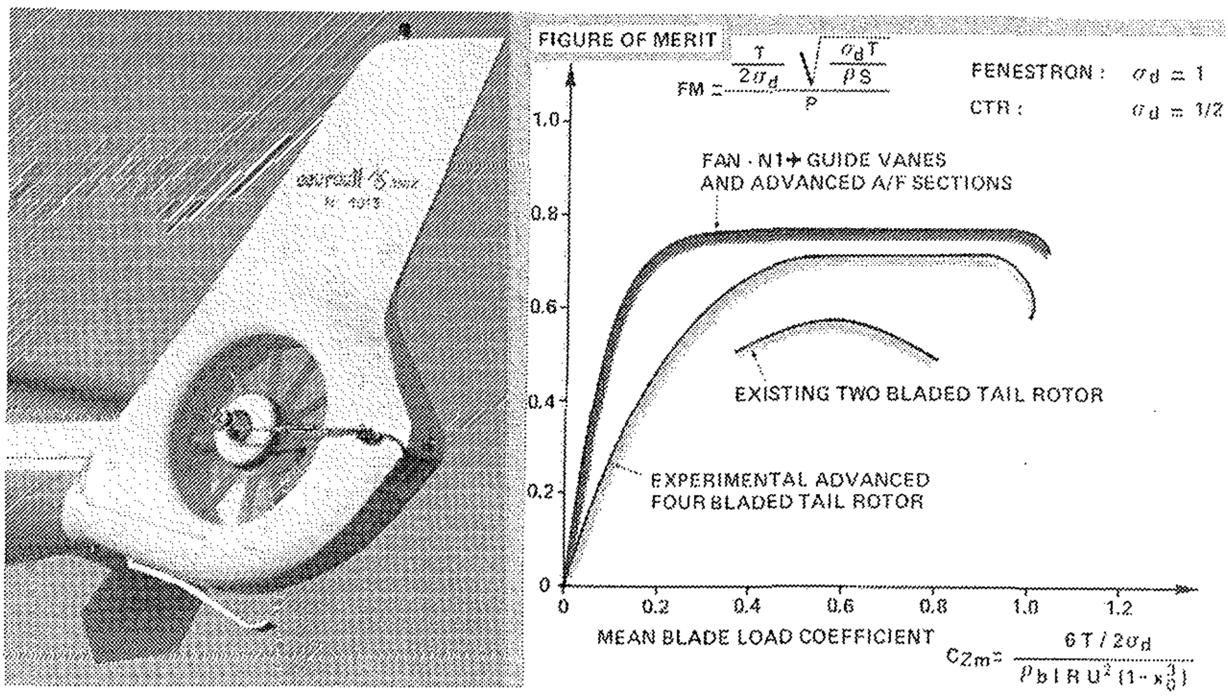


Fig. 9: TAIL ROTOR EFFICIENCY

Although fenestron radiates less acoustic energy than the conventional tail rotor, this energy is concentrated in a small number of pure tones at high frequencies which emerge from the overall helicopter noise spectrum and give a characteristic high pitch sound offensive to human ears.

Research is currently under way at Aérospatiale to modify the fenestron's acoustic signature with non uniform phasing of the fan blades. Preliminary calculations have shown that proper phase blade modulation theoretically could reduce pure tones emergence at the blade's passage frequency by as much as -3 dBA as acoustic energy is spread to lateral frequencies.

Since high frequency sounds absorption is higher in the atmosphere, fenestron's acoustic detectability is low compared to the teetering rotor. Once detected however, the fenestron equipped helicopter is identified more readily. A conventional helicopter approaching will first reveal itself by its tail rotor noise while a fenestron equipped helicopter might come closer before its main rotor's rotational noise is detected.

As every rotor, fenestrons can be made quieter by lowering tip speed and blade loading at the expense of increased blade area and tail gear box output torque. The weight and cost penalty incurred are a matter of design compromise as is tail rotor diameter sizing with respect to hover performance.

FENESTRON TECHNOLOGY

A technology demonstration programme was initiated in 1986 to develop a low cost/high performance fenestron for light helicopters.

The third generation fenestron flight tested on the AS 350 Z ECUREUIL helicopter included two new design features:

- Aerodynamic efficiency improved with stator blades downstream of the rotor
- Control loads reduced with a longer distance between the two blade bearings

Successfully ground and flight tested in 1987, this design marking a significant advance over the second generation DAUPHIN N1 fenestron is now available for the P120 light helicopter programme.

STRUCTURE

The technologies retained for the structure are adapted to meet the specifications with a low cost and maintenance price.

Titanium is used as plates at engine deck level only. Aluminium alloys are commonly used, mainly as stamped plates. Only the tail boom is a Nomex/aluminium skin sandwich.

Composite materials are used when imposed in the manufacture of complex geometry components i.e. canopy, fenestron and landing gear.

Special attention was paid in the fenestron demonstrator programme to the simplification of the manufacturing process where the structure was made of two half shells, including the tunnel, bonded and riveted together with quite a significant reduction in the number of parts and manufacturing time. A glass/Nomex/Kevlar sandwich structure was selected rather than the carbon fiber used in the AS 365 N1 fenestron to reduce material costs.

Every one of these elements contributed to the reduction in total costs, a driving factor in the design of this helicopter class, and also led to a significant weight reduction compared to an equivalent metal construction.

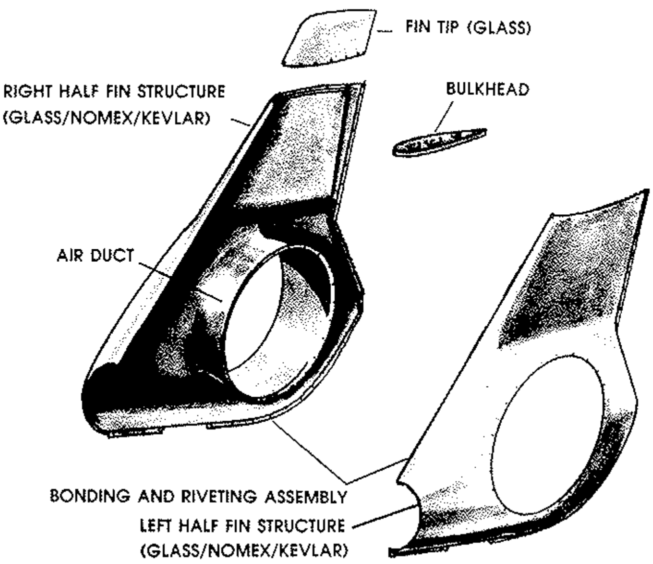


Fig. 10: EXPERIMENTAL FENESTRON STRUCTURE TECHNOLOGY

ENGINE

The basic P120 helicopter's turbine engine will include a full-authority, digital engine control (FADEC) system provided this technology is available.

This control technology allows best using the turbine performance over the entire flight envelope of a modern helicopter.

The following functions are available with maximum accuracy:

. Engine transients control and fast acceleration/deceleration, in particular

. Power chain stability control

. Engine thermal protection

. Rotor drive system protection (engine and helicopter reduction gears) .

Furthermore, the digital control computer helps diagnose system failures, offers improved data to the pilot and improves the maintenance diagnostic.

Other maintenance aiding functions such as installed engine performance control or engine cycle consumption calculation can also be integrated in the FADEC system.

Aérospatiale's considerable experience of digital engine control system will help integrate this system on P120.

AVIONICS

The multiplication and increased complexity of the functions and data made available to the crew, in real or delayed time, in a fixed volume cockpit has led the manufacturers to adopt multi-function displays (MFDs).

These displays were developed with CRT technology by Aérospatiale on the DAUPHIN and SUPER PUMA Mk2 helicopters but their cost is not compatible with that of light helicopter because of size and functional requirements.

The objectives as far as P120 instruments are concerned were to find the best compromise between technical, human engineering, safety aspects and modern, economical technology.

As far as human engineering aspects are concerned, the intention is to improve the vehicle's management function to:

. ease the crew's workload

. enrich the data displayed

. ease failure diagnostics

. avoid cluttering the instrument panel

As far as modern technologies are concerned, the intention is to:

. modernize the instrument panel

. adopt a technology authorizing data multiplexing (active matrix LCDs)

. retain a modularity concept

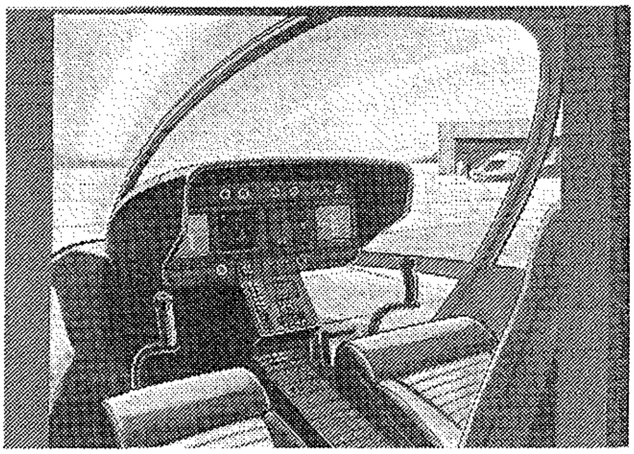


Fig. 11: P 120L - COCKPIT

Finally, it is also intended to keep the costs as competitive as possible.
A technological development initiated in 1989 started with a feasibility evaluation phase followed by mock-ups and symbology as well as modes and controls simulations.

The main selections were:

. Architecture: 2 multi-function displays

. Technology: Active matrix LCDs

. Basic functions:
- Parameters monitoring
- Piloting instruments

Efforts thus need to be made in the development of light helicopter instrument functions and a demonstrator is to fly with those instruments at the end of 1991.

DEVELOPMENT ORGANIZATION

A general idea of the P120L objectives has so far been given and the technical approach of their completion has been explained but the question still needs to be asked whether these objectives are economically realistic? The ECUREUIL designers also asked themselves this question and we know how successful the result was.

Our technological adventure will prove successful if every participant believes in its success.

An operational group type organization integrating design, processing, purchasing, design-to-cost analysis, testing and manufacturing functions has been adopted to minimize internal interfaces. This also applies between partners thus limiting energy losses related to data losses and conflicts. These tasks will be the cooperation team's responsibility.

CONCLUSION

P120L will include Aérospatiale's most advanced light helicopter technologies.

The programme will be undertaken with the intention not to jeopardize performance, costs or, above all, the helicopter's success with the operators.

The challenge will be proved a success because the safety factors have been emphasized thanks to the fenestron and optimum pilot/helicopter interface. Performances will be met with an advanced aerodynamic design and an empty weight minimized by material selections.

The operational aspects such as reliability and maintainability will be optimized with a permanent concern for these criteria and extreme design care.

P120L will be the first of a new single engine, light helicopter generation.

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