EUROFAR AIRFRAME AERODYNAMIC DESIGN

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Abstract

The aerodynamic airframe design performed during the EUROFAR preliminary feasibility phase is outlined in this paper.
Further to parametric studies giving a first baseline configuration, the following step consisted in refining the preliminary design of the wing. Then, several other configurations were selected for wind tunnel tests and trade-off activities. Experimental results, along with computer codes for aerodynamics and flight mechanics prediction and configuration selection, allowed the baseline refinement to be carried out. General trade-offs, such as wing location or tail and engine configuration, were conducted, followed by wing profile improvement and finally, general aircraft configuration optimization.
Using the respective experience of airplane and helicopter manufacturers involved in EUROFAR, it was possible to adapt design methods and computation codes to the tilt-rotor aircraft. Necessary additional studies are to be performed by the end of this phase or during the beginning of the following phase, in order to complete and optimize the current aerodynamic design status.

I.INTRODUCTION

EUROFAR (European Future Advanced Rotorcraft) is an association of helicopter (AEROSPATIALE-helicopter division, AGUSTA, MBB, WESTLAND) and aircraft manufacturers (AEROSPATIALE-aircraft division, CASA), aimed at the development of a civil (and eventually military) tilt-rotor. Phase 1 of this program is a three-year feasibility period, consisting in making technical investigations and evaluating the coherence of a new civil transportation system, launched within EUREKA framework.
The basic vehicle missions are mentioned hereafter:
- the commuter mission calling for a 30 pax payload, high speed cruise (at least 300kt at 25000ft), long range (600NM), category A performance capability at the All-up-Weight at 500m ISA+10°C.
- the offshore oil mission requiring a 600NM capability with 30 pax plus 300kg of mission equipment.
In addition, there are some other requirements: cost effectiveness, comfortable interior, low exterior noise level, high safety level, high performance (Ref 1).

II.SIZING PHILOSOPHY

II.1.GENERAL

The cooperation between helicopter and aircraft manufacturers during the EUROFAR preliminary phase gave the opportunity to compare the respective predesign methods when applied to the same project requirements. Generally the two approaches appeared to be similar. In particular, both were supported by parametric computer codes determining design sensitivity to the main sizing parameters and requirements.

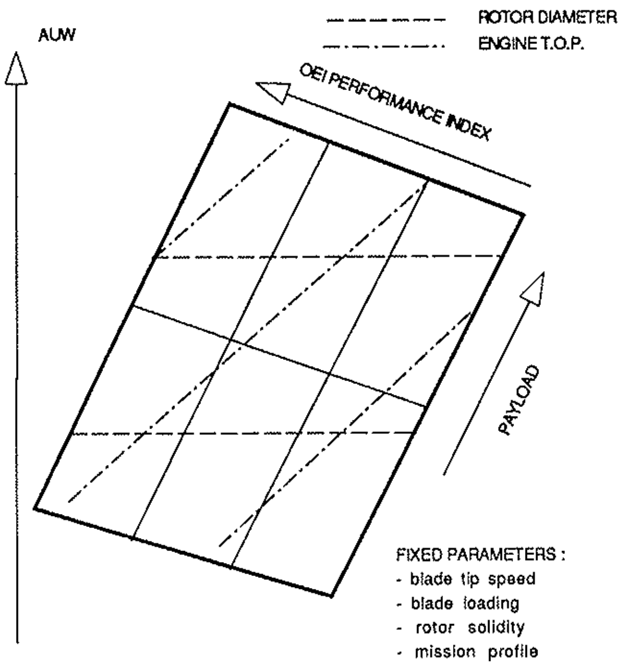

Figure 1.a : Typical helicopter sizing diagram

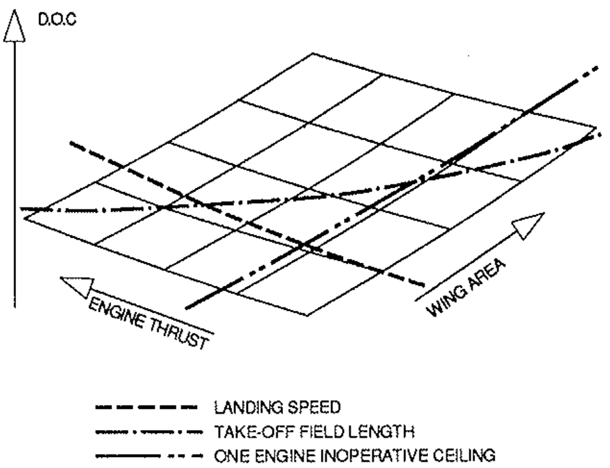

Figure 1.b : Typical airplane sizing diagram

One difference was that helicopter design, as that of any powered lift vehicle, was as a general rule orientated towards weight minimization whereas for fixed-wing aircraft DOC reduction remained the major objective.
Fig 1.a represents a typical helicopter sizing diagram which shows the All-up-Weight (AUW) sensitivity to payload and one engine inoperative (OEI) performance. It shows that for a given rotor diameter, the design AUW directly depends on the emergency power available from the candidate engine.
The aircraft design philosophy was to define wing area and engine size in order to optimize the direct operating cost directly; the aircraft had to fulfil several operational constraints: landing speed or fuel capacity generally determined the wing area and engine thrust was defined for a target take-off length (Fig 1.b).
As far as the tilt-rotor design philosophy was concerned, the wing span was directly associated with the rotor diameter, assuming sufficient given rotor tip/fuselage clearance. Rotor diameter depended on the selected disc loading and the wing area was selected to provide the best performance and a minimum realistic conversion speed. The required wing span and area defined the wing aspect ratio, which was also limited to ensure good flutter behaviour. The installed power was fixed by the OEI performance requirement (cat.A at 500m ISA+10°C). The engine super-emergency rating depended on rotor disk loading and AUW as plotted on Fig 2.

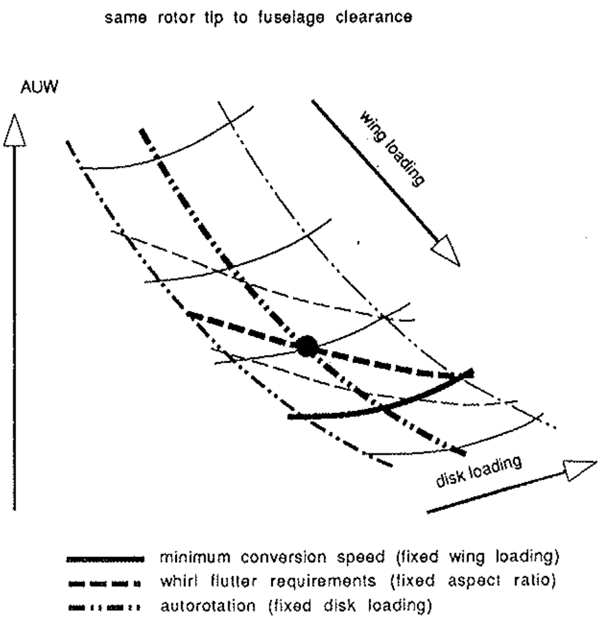

Figure 2 : Baseline sizing diagram

II.2.EUROFAR SIZING

From this comparison of sizing methods, the following philosophy was selected for EUROFAR:
- Use of modified parametric helicopter code for determination of general dimensions, weights and power ratings.
- Use of parametric fixed-wing A/C codes for wing and tail-surface sizing with respect to performance and stability requirements.

The modified helicopter code was already available in the GARTEUR study related to tilt-rotors (Ref 2).

III.PRELIMINARY BASELINE DESIGN

III.1.DESCRIPTION

The above parametric codes gave the description of a first loop vehicle with the following characteristics:
- AUW = 13650 kg
- Empty mass = 8750 kg
- Rotor diameter = 11.21 m
- Wing area = 35.2 m2
- Fuselage length = 19.4 m
- 2 engines (MCR at SL/ISA = 2570 kW)

They also gave recommandations for other aerodynamic parameters:
- thick profile for flutter free stiff wing
- inverse sweep for blade flapping protection
- full span flaps (flaperons) and large deflection to reduce conversion speed and minimize rotor/wing interaction in helicopter mode.

Further to these parametric studies, the following step consisted in performing aerodynamic trade-off studies in order to refine the preliminary wing design.
Firstly, the wing airfoil was chosen from available catalogues : NACA 43021 because of its good Clmax, low pitching moment and space to accomodate trailing edge devices.
As regards the wing planform, in order to get better understanding of the impact of the different parameters on the aerodynamic performance, drag computations were made while varying the following parameters in turn: area, aspect ratio, taper, thickness, sweep (Fig 3).
Wing area optimization in cruise flight only, at fixed altitude and fixed speed (Ref 3), led to a value of 37.5 m2 close to the one on Fig 3: 38.3 m2.
As regards low speed requirements, the problem was to extract sufficient lift from the very thick profile; the objective for Vs1g led to a wing area of about 35m2.

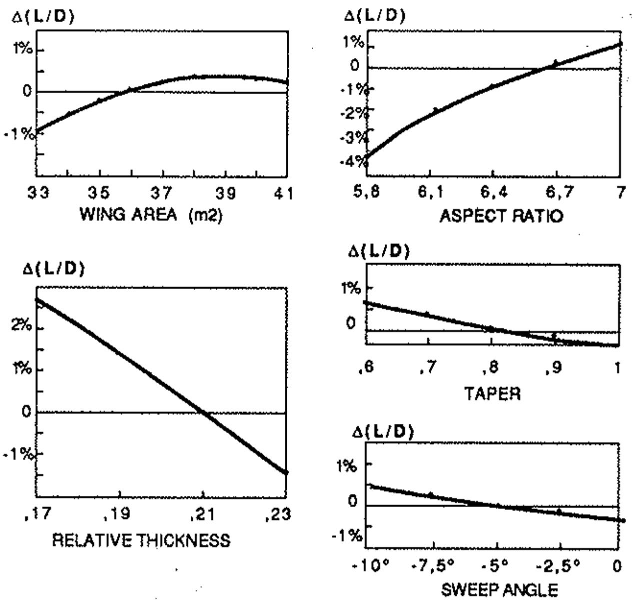

Figure 3 : Wing aerodynamics trade-offs

But, geometric parameters could not be chosen on aerodynamic considerations only; structural weight variations had also to be taken into account. Rough preliminary design formulas for aircraft wing weight gave simple guidelines to improve the aerodynamic efficiency of the wing, while keeping the structural weight constant: increased taper ratio to be exchanged with lower thickness and higher aspect ratio, keeping the baseline value for wing area (low speed requirement) and the baseline value for sweep angle (flapping clearance of the rotor). This led to selecting the following wing planform:

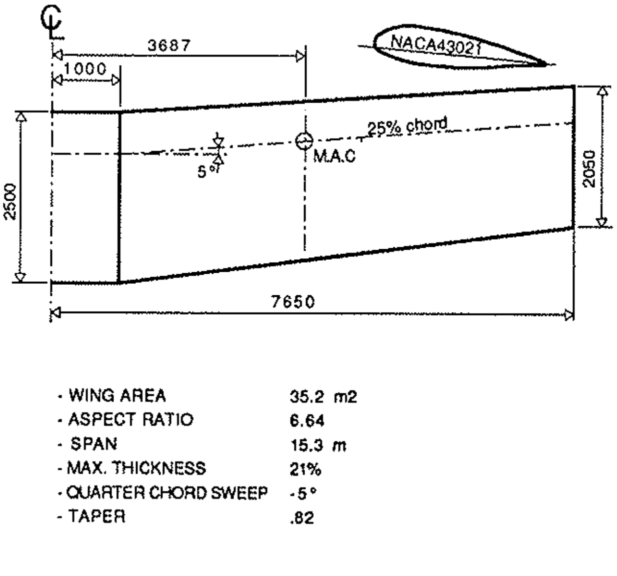

Figure 4 : Wing profile and planform

At that stage, it was absolutely necessary to make some choices (those which, a priori, appeared to be the best), to complete the first baseline description (Fig 5), i.e.:
- T-tail configuration for the empennages
- High wing/fuselage integration
- Fixed engine (only the rotor and the output gear unit were tilted).

The following alternative design trade-offs would confirm these choices or not.

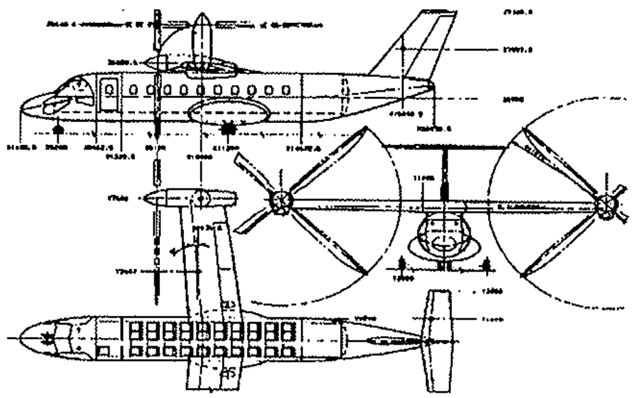

Figure 5 : Preliminary baseline configuration

III.2.ALTERNATIVE DESIGNS

Several configurations were selected for wind tunnel tests and trade-off activities. The possibilities included :
- high wing / low wing
- T-tail / low tail
- tilting engine / fixed engine

Investigations on the effects of size were made for the empennages and undercarriage sponsoons.

IV.GENERAL DESIGN TOOLS

IV.1.AERODYNAMIC COEFFICIENT PREDICTION

Contrary to helicopter pre-projects for which a preliminary drag estimation only was necessary, the study of a tilt-rotor, as that of any airplane, required a relatively complete set of data related to airframe aerodynamics as early as possible, in order to start handling qualities and performance analysis.

Therefore, until the wind tunnel test results of model 1A (see §IV.2) were available, a temporary set of aerodynamic data was established. The method used, which had been developed for coefficient prediction of transport aircraft, was based both on a theoretical analysis (lifting surface) and semi-empirical methods.

Although it was the first time that such a method was applied to a tilt-rotor airframe, the predicted coefficients later appeared to be in good accordance with the wind tunnel test results.

IV.2.WIND TUNNEL TESTS

IV.2.1.General objectives

The main purpose of the EUROFAR small scale wind tunnel tests was to provide the aerodynamic airframe coefficients requested by flight mechanics codes and in particular, those which had a definite impact on A/C trim states and dynamic stability.

Performance related measurements, such as cruise drag and maximum lift determination, were considered with a lot of reservations because of the low Reynolds and Mach numbers related to the testing conditions.

Three small scale wind tunnel models were defined:
- Model 1A: modular airframe model for force and moment measurements.
- Model 1B: powered model for measurements of rotor/airframe interactions during conversion and airplane mode.
- Model 1C: partial model to investigate rotor/wing interaction in H/C mode around hover for various flap settings and rotor/wing separations.

Due to budget limitations, model 1B was postponed until the following phase; only models 1A and 1C were thus tested during the preliminary phase.

IV.2.2.Presentation

Model 1A (Fig 6) was a complete non-powered fuselage model, in modular design (scale: 1/12.5th); its main objective was to support configuration development and stability assessment.

The model design included an internal metallic frame, to attach the balance and all the components, while the outer structure was made of fibreglass: the solid shapes were obtained by computer aided manufacturing, using the CATIA geometric definition integrated in specific numerical control machine programming.

The tests, performed at the AGUSTA wind tunnel facility, combined both configuration studies and optimization (wool tufts flow visualization and local modifications were made), with aerodynamic characterization in terms of stability; this was performed with force measurements at conventional angles of attack.

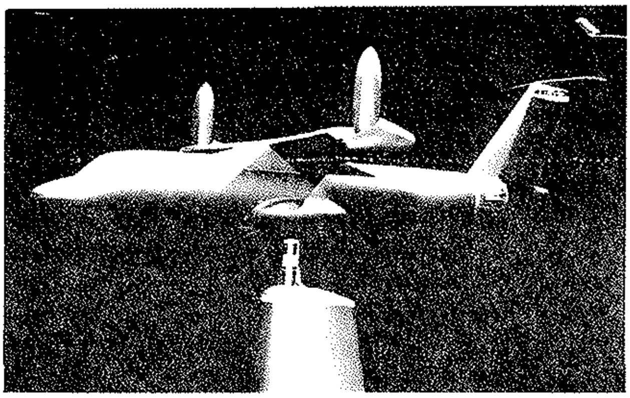

Figure 6 : Model 1A

Due to high modularity, a parametric study on main topics, such as wing positioning (low and high wing, longitudinal position, wing setting), empennage configuration and sizing (T-tail vs low tail, with two different areas for both vertical and horizontal stabilizers) was also made.
The model allowed all the proposed configurations and parameters, the variation of wing control surfaces, and nacelle tilting to be reproduced.
Other areas of interest, such as wing/fuselage attachments and integration of nacelles (complete tilting or partial tilting configuration) to the wing, were investigated through dedicated test programmes.
The results obtained were used to refine the proposed baseline configuration.

Model 1C (Fig 7) was a simplified interactional aerodynamic model, with the same scale as that of the complete model. The design included a tilting nacelle model, a wing with pressure tappings and control surfaces and a rotor model produced with a wooden fixed pitch three blade propeller.
A two-component force transducer allowed thrust and torque at the rotor to be measured, both for the isolated rotor and the rotor with the nacelle and wing: it was possible for the interference effects to be measured in different arrangements and conditions.
The tests conducted showed the very large wing download reduction obtained with a large flap deflection (60°), confirmed the 6% download assumption, and were useful for the integration of the nacelle and wing to the rotor.
A following step would include a larger scale model with intake simulation.

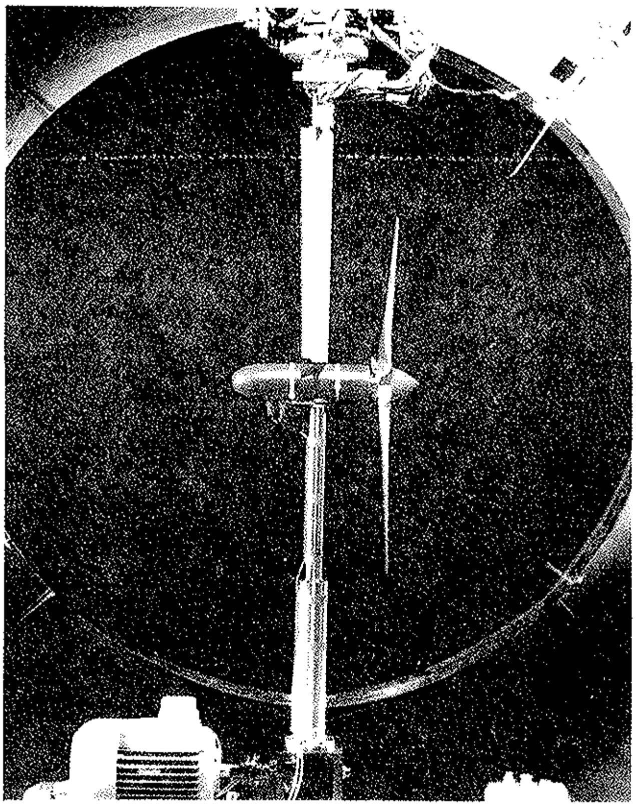

Figure 7 : Model 1C

IV.2.3.Result analysis

As stated in §IV.1, model 1A results were generally in good accordance with the predictions of the set of temporary aerodynamic data.
There were only small differences which had no major impact on A/C behaviour. In terms of lift gradient, the wing appeared to be slightly more efficient than predicted and consequently, the setting angle could be reduced. This was also true for the plain flaps selected on the model for design simplicity. However, slotted flaps were proposed for future A/C to minimize drag during conversion.
The effect of wing downwash on the horizontal stabilizer appeared to be less considerable than expected with the T-tail configuration. For the low tail configuration, this effect seemed nearly independent of airframe incidence, which remained unexplained.

IV.3.FLIGHT MECHANICS CODE

The development of a flight mechanics code adapted to tilt-rotor aircraft was necessary to support the activities related to handling qualities and control laws. To meet this objective, AEROSPATIALE helicopter code S80, was modified to incorporate specific tilt-rotor features, such as tiltable nacelles, wing flaperons and tail control surfaces. To ensure the model fidelity in the whole EUROFAR flight envelope, it was also necessary to change the rotor modelization from a simple disk actuator to a complete blade element model. The S80 was therefore coupled with AEROSPATIALE isolated rotor code R85 (Fig 8).

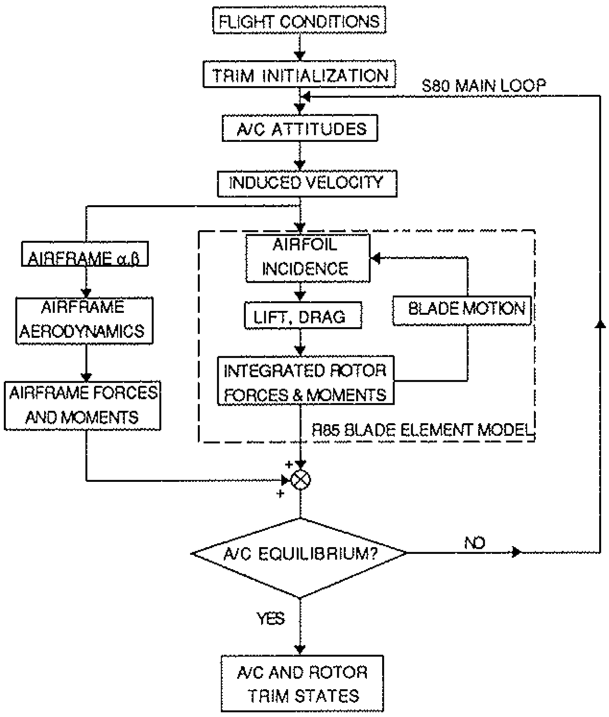

Figure 8 : S80/R85 flow chart

The disk actuator model was nevertheless kept in the S80 code as an option which could be used at low speed when the rotor inflow remained moderate.

IV.4.CONFIGURATION SELECTION CODE

Handling qualities requirements also strongly influenced configuration selection. In particular, empennage sizing, longitudinal wing position and wing sweep had to be correlated to allow the designer to adjust:
- the size and position of the required CG range
- the pivot position recommended by structural specialists.

A code which calculated optimized aircraft geometry when the three above conditions were met, was developed; more details on the methodology are given in §V.3.

V.BASELINE REFINEMENT

V.1.GENERAL TRADE-OFFS

Besides aerodynamic aspects, the complete integration of the vehicle also took account of more developed structural and dynamic studies in order to produce an improved aerodynamic design (wing planform, profile , tail sizing...).

V.1.1.Wing location (high or low)

For medium size fixed-wing aircraft, experience had proved that no configuration offered a definite advantage with respect to the other. For advanced turboliner projects, the two configurations were still proposed: low wing for SAAB 2000 and high wing for DO 328. For EUROFAR, a trade-off study, supported by wind tunnel testing of model 1A, was performed.
A preliminary analysis showed the following advantages and drawbacks of the high wing configuration.

advantages:
- sufficient clearance between pax doors and rotating blades
- easy installation of APU gear box
- no pressurized floor
- easier cable and wiring installation
- no fuselage cut-out.

drawbacks:
- worse accessibility to rotors, engines and fuel tanks
- longer landing gear track
- wing/fuselage connecting frames more heavily loaded under vertical crash loads
- two fairings for wing/fuselage connection and landing gear (however, with the low wing, it would not be possible to integrate the landing gear within the wing contour because of the forward sweep angle, which would make it necessary to install a kind of sponsoon at the wing trailing edge).

As far as handling qualities were concerned, aerodynamic coefficients of both versions appeared to be similar. There was no clear indication to expect better handling qualities for one of the two configurations.
In terms of drag, considering symmetrical vertical wing positions around the fuselage axis, it was generally slightly lower on the high wing configuration than the low wing configurations (Ref 4). However, due to the fact that it was easier to integrate a low wing to the fuselage (only a Karman junction was required instead of a specific fairing over the fuselage) and we needed a larger sponsoon for the high wing, the

two configurations were considered to be equivalent.
Consequently, decisive arguments for selecting one configuration rather than the other were found as the result of the analysis of controllability in helicopter mode. With a low wing configuration, the vertical distance between the rotor plane and CG was definitely smaller than with the high wing. This reduced the control power along the pitch axis significantly. From that point of view, the pitch controllability of the low wing concept could only be acceptable when the wing was fitted with large equivalent hinge offset rotors, such as bearingless type rotors. With the selected gimballed design, the high wing configuration appeared to be the most appropriate (Fig 9).

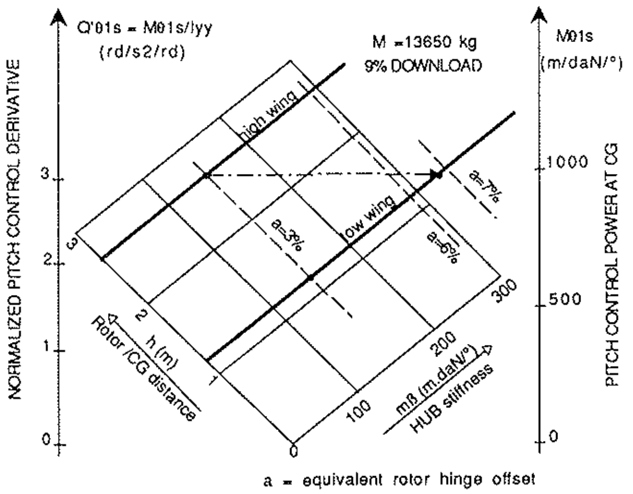

Figure 9 : Impact of wing position on pitch controllability

V.1.2.Wing planform (tapered or straight)

The first studies on operating costs showed that the fuel contribution was not so considerable as expected and rather recommended to improve acquisition cost and weight. So, in spite of a slightly lower efficiency in cruise (flat optimum on Fig 3), the constant chord wing was preferable to a tapered one, as far as weight and cost were concerned.

V.1.3.Wing thickness

Load and whirl flutter requirements led to a trade-off between structural weight and aerodynamic efficiency which was more favourable in the case of a thicker wing. Therefore, relative thickness was increased to 23% (NACA 43023).

V.1.4.Wing fairing

For the preliminary studies, a 5.5° wing setting was chosen to ensure a horizontal fuselage attitude around mid-cruise (300kt/FL250). This value led to a very large wing fairing, which appeared to disturb the airflow on the rear part of the fuselage during wind tunnel tests. Consequently, a fuselage attitude of 2.5° at the beginning of cruise was judged to be acceptable; this new hypothesis along with the slightly better lift efficiency of the wing (shown in wind tunnel tests) led to a 1.5° setting.
As mentioned above, on the high wing configuration some specific aerodynamic problems arose for the proper integration of the selected wing section (of high thickness) and given wing setting to the fuselage. In particular, the wing-body fairing had to achieve the best aerodynamic performance, i.e. attached flow at all attitudes on both wing and fuselage junctions with minimum drag, while remaining as small as possible to avoid weight penalty.
The fairing shape was designed on the basis of a 3-D CAD model developed with CATIA; this analysis was firstly made using the VSAERO panel method, and the selected modifications were then tested on the modular wind tunnel model described above.
Fig 10 shows the panel model with CP distribution for one of the candidate configurations.

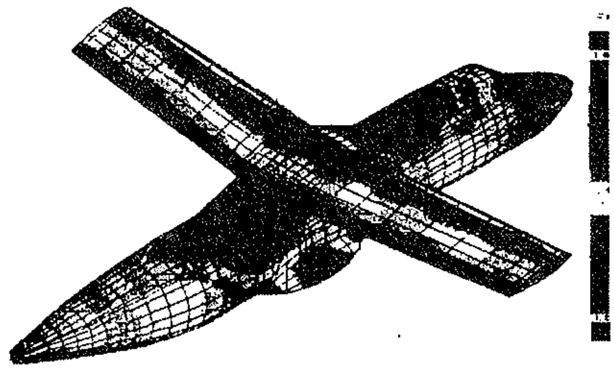

Figure 10 : CP distribution on VSAERO panel model

Fig 11 shows the wing fairing development on the wind tunnel model, obtained by adding plasticine to a basic fibreglass shape: nose and rear fairing portions were modified, and both flow visualizations and force measurements were applied to compare the solutions.

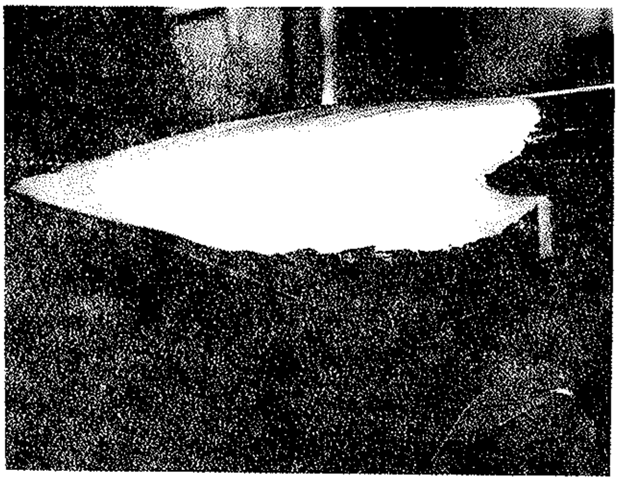

Figure 11 : Wing fairing tests

V.1.4.Engine installation (fixed or tiltable)

The main technological differences between the two concepts are summed up below.

stationary engine concept:

On the one hand, the major drawback was a more complex gear system and nacelle structure.

On the other hand, the engine installation was conventional, no special engine design was necessary, the exhaust blast was not directed to the ground and the total area subjected to turbine burst was minimized.

tiltable engine concept:

The disadvantages of this solution were a more complex shaft system, a special engine design, a reduced configuration flexibility and certification problems. The only advantages were simple cowling design, lower nacelle weight and vertical thrust from the exhaust in hover.

As far as aerodynamics were concerned, complete tilting nacelles resulted in additional drag of about 2m2 compared to the other solution in helicopter mode; this also led to higher drag in conversion, which was penalizing for performance.

So, considering all the trade-off results, the fixed engine nacelle was selected for the project.

V.1.5.Tail configuration

The crosstail had never, been considered, as it presented poor aerodynamic efficiency. The H-tail had been left out, because of weight.

From an airplane design point of view, the T- and low tail configurations could be envisaged, each of them having its own advantages and drawbacks.

Due to end-plate effects, the T-tail made it possible to have a smaller vertical tail and left the horizontal tail clear of the wing wake and downwash, which made it more efficient and hence allowed its size to be reduced, but it was heavier and subject to flutter.

From an helicopter design point of view, the rotor wake at low speed interfered with the stabilizer in low position, which might lead to questionable pitch-up attitudes during transition. A T-tail was free from interference at low speed but was immersed in rotor wake at high speed, which could also cause pitch trim problems. These characteristics were well identified on single rotor helicopters. With a side-by-side arrangement of 2 rotors, there could be significant differences. Final selection on tail layout had therefore to be based on powered model wind tunnel test results, which were to be performed in the following phase. Unexpected rotor/tail interference problems could also lead to select a completly different tail configuration, such a H-tail as on the XV15 and V22.

Until the WTT results were available, the T-tail, despite its strengthened fin to support horizontal stabilizer and possible flutter and deep stall problems, was selected as a temporary layout because of its better efficiency in cruise flight. The fact that the stabilizer was above the rotor disks in H/C mode, also led us to expect little interference in forward flight.

V.2.WING PROFILE

V.2.1.Up-dated requirements

In order to define a new airfoil specially tailored for EUROFAR, the following requirements were established:

- minimization of the profile drag and compressibility drag in the following cruise conditions:

speed (kts)	300	293	370
altitude (m)	7500	9500	7500
mach number	0.50	0.50	0.61
profile Cl	0.70	0.95	0.46

A 30% safety margin for buffet was imposed on lift coefficients.

- a 110 kt stall speed for the clean glider configuration at AUW, leading to a maximum profile lift coefficient of 1.6 (high lift device and pitching moment constraint not defined at that stage).

- a sufficiently wide cross section for the wing box which led to the following thickness and cross sectional area constraints:

wing chord = 2.4 m
maximum relative thickness = 23%
relative thickness at the front spar > 13%
relative thickness at the rear spar > 20%
relative trailing edge thickness > 0.4%
wing box cross sectional area > 0.52 m2

V.2.2.Proposed airfoil

The new airfoil was defined by ONERA (Fig 12). All the above requirements were met by calculation (wind tunnel tests in progress). Compared to the NACA 43023 profile, it provided a higher Clmax, lower drag, lower zero-lift incidence (which could also further reduce wing setting) but higher zero-lift pitching moment. However, as will be seen in the next paragraph, this last result had no influence on handling qualities and slightly affected trim drag.

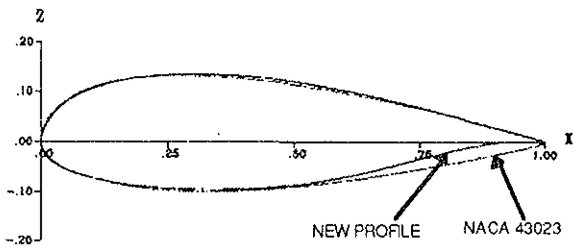

Figure 12 : New wing profile

V.3.OPTIMIZATION OF THE GENERAL A/C CONFIGURATION

The configuration selection code, already mentioned in §IV.4, was used to optimize the longitudinal wing location, the wing sweep angle and the horizontal tailplane surface, in order to obtain CG location in A/C and H/C modes in accordance with controllability and stability criteria.

V.3.1.Methodology

This method was based on the resolution of a set of three equations which correlated three degrees of freedom:
- longitudinal wing location
- horizontal tail area

which were the conventional A/C parameters, and
- wing sweep angle

which was the additional degree of freedom to solve the system.

The basic three equations used described the following conditions:
- alignment of aft handling qualities CG limit and aft loading CG in A/C mode
- equality of handling qualities and loading CG ranges in A/C mode
- alignment of pivot station and average CG location in hover mode.

The solution might be unsatisfactory for structural reasons (sweep angle too high) or installation reasons (wing too far aft) which might deteriorate weight and cost. The code was thus also capable of taking account of additional parameters:
- rotor effects : combination of vertical hub inplane forces and pitching moments due to longitudinal flapping
- pivot station variations
- difference between the two forward CG limits if the CG range equality condition was given up
- empennage aspect ratio.

Figure 13 is an illustration of the different steps of calculations, pointing out the different parameter displacements.

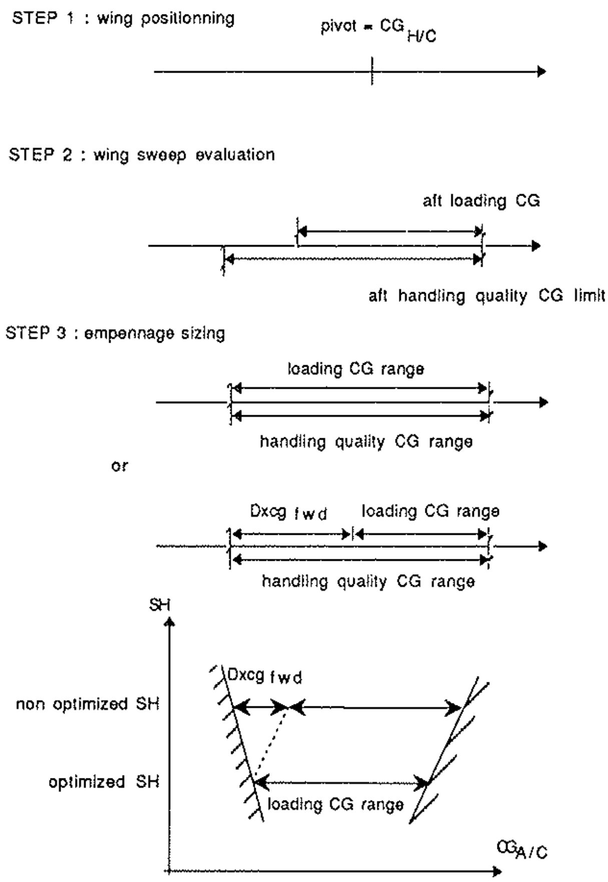

Figure 13 : Configuration optimization process

V.3.2.Design criteria

Loading CG ranges in H/C and A/C modes were supposed to be equal to 24% of the mean aerodynamic chord (MAC). The handling qualities CG limits were defined as follows:

- forward limit : demonstration of stall speed in A/C mode with a 0° flap deflection
- aft limit : maneuver limit, evaluated for the rigid aircraft in cruise conditions, considering rotor effects.

Indeed, the maneuver point was strongly influenced by the destabilizing rotor H-forces and moments in cruise flight which were incorporated into the parametric model. Force and moment derivatives with respect to shaft angle of attack were pre-computed with isolated blade element model R85.

H-forces depended on rotor advance ratio and consequently grew with altitude when the equivalent airspeed remained constant. Rotor moments mainly depended on hub flapping stiffness and free flapping response to the shaft angle-of-attack or pitch rate. As the magnitude of free flapping response also increased with advance ratio, the destabilizing effect of rotor hub moments also increased with altitude.

The net effect on the respective positions of the neutral and maneuver points is presented on Fig 14.

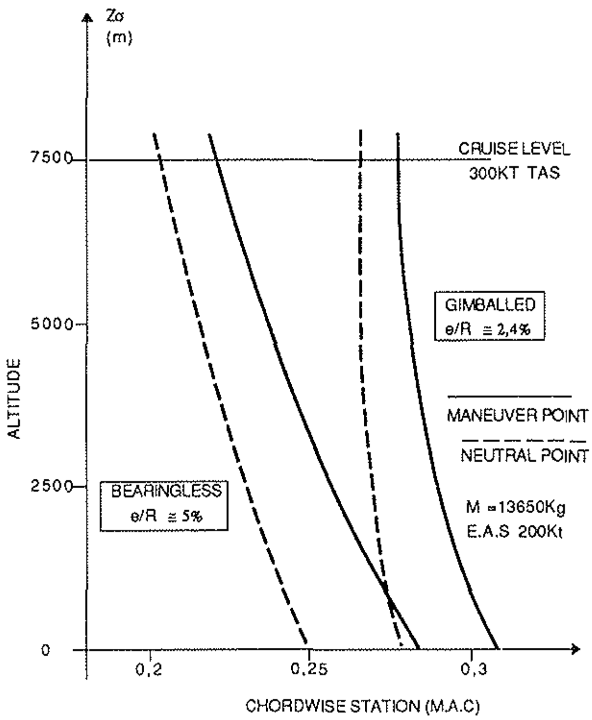

Figure 14 : Influence of altitude on pitch stability

V.3.3.New baseline definition

The first conclusion was that the optimal sweep from the handling qualities point of view (the empennage area was then minimized) was about -13° (Fig 15). But, for structural and manufacturing reasons, it seemed preferable to stay close to -5°, which led to 30% more tail area.

In addition, any forward movement of the pivot along the wing tip chord led to a tailplane area reduction (e.g. a 5% tip chord shift induced a 6% tailplane area reduction). But, as this forward movement was impossible from a technological point of view, the lowest nominal value of 45% wing tip chord pivot position was maintained.

With bearingless rotors, the destabilizing effect increased more rapidly, versus altitude, than with the low hinge offset design (Fig 14). Consequently, as far as pitch stability was concerned, a low hinge offset rotor design seemed preferable.

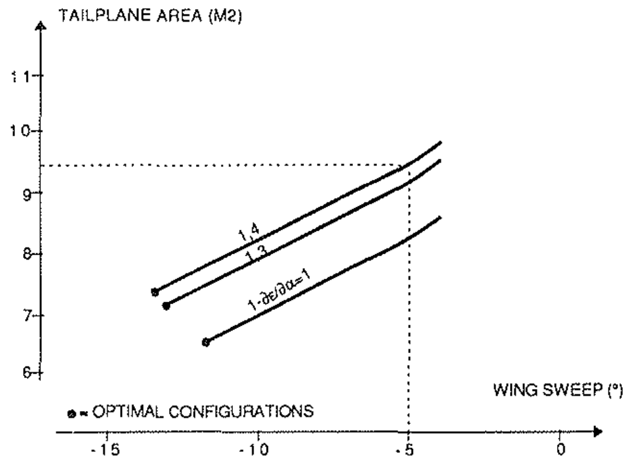

Figure 15 : Influence of sweep angle on empennage sizing

The presence of the wing upwash on the rotor increased H-forces proportionaly to coefficient $(1-\partial\varepsilon/\partial\alpha)$, where $\partial\varepsilon/\partial\alpha$ was the upwash gradient. Computed estimations gave $1.3 < 1-\partial\varepsilon/\partial\alpha < 1.4$ and the highest value was considered. So an upwash increase from 0% to 40% generated a 15% increase of the empennage area.

Finally, a tailplane aspect ratio increase from 4.5 to 6 generated 11% decrease of the tail area.

To sum up the previous conclusions, assuming an upwash gradient of 0.4, a low hinge offset rotor design, a -5° wing sweep and an empennage aspect ratio of 6, the following refined baseline was proposed:

	preliminary baseline	refined baseline
sweep	-5°	-5°
wing station	10.13 m	9.90 m
$1-\partial\varepsilon/\partial\alpha$	1.0	1.4
tail arm	10.44 m	10.66 m
tail area	7.0 m2	9.5 m2
tail aspect ratio	4.5	6.0

The new baseline A/C is presented on Fig 16, with the above wing geometry; the refined cockpit shape, new sponsoons and engine design can be noted.

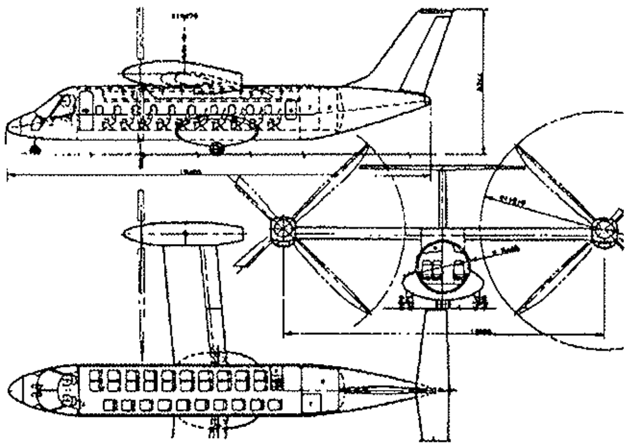

Figure 16 : Refined baseline configuration

Fig 17 presents the handling qualities limits in A/C mode. The effect of non optimal sweep is clearly shown: the handling qualities CG range is 2.7 times larger than the requested loading CG range.

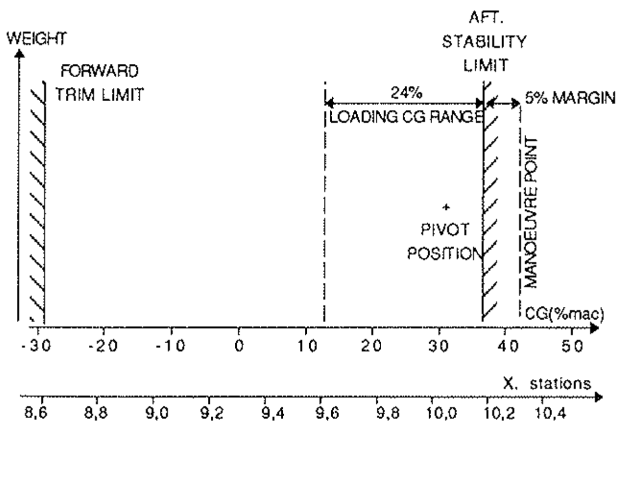

Figure 17 : Handling qualities limits in aircraft mode

VI.COMPLETION OF THE PRELIMINARY PHASE

VI.1.SYNTHESIS OF PRESENT RESULTS

Using the respective experience of airplane and helicopter manufacturers involved in EUROFAR, it was possible to adapt design methods and computation codes to the tilt-rotor aircraft. The aerodynamic airframe characteristics predicted for the baseline were generally confirmed by model 1A wind tunnel tests.

Once entered into flight mechanics codes, such as AEROSPATIALE S80, the set of aerodynamic data led to very consistent results both for trim and dynamic behaviour when compared to published data relative to the XV15 and V22. This demonstrated the general validity of the methods used in EUROFAR design, although further refinements would probably be incorporated after completion of model 2 (isolated rotor) and model 1B (powered model) wind tunnel tests.

VI.2.FURTHER STUDIES

In order to complete and to optimize the current aerodynamic design status, additional studies are necessary:

- Rotor/airframe interactions

An experimental investigation in a large V/STOL facility on powered model 1B is proposed. The scale is planned to be larger than that of model 1A. Rotors will only be Froude-scaled as this is sufficient to analyse rotor/airframe interactions and this avoids the complexity associated with Mach-scaling.

Testing will concentrate on aerodynamic interactional phenomena both at local level (rotor/wing) and on global effects (tail surfaces efficiency), in the most relevant flight conditions.

- Aeroelastic phenomena

Aeroelastic tests are planned for the end of this phase (model 3) to analyse rotor stability and whirl flutter.

- Flaperon definition

The current plain flap design selected for model 1A definition, for simplicity reasons, is not optimum in terms of lift/drag characteristics. A single slotted flap would be much more efficient and is proposed for the final baseline configuration. The aerodynamic definition of such a flap requires a specific study, to be performed during the following phase.

- Flight control laws

An advanced fly-by-wire or fly-by-light control system is foreseen for EUROFAR. Presently, the study of flight control laws is in progress. According to the results, some slight aerodynamic configuration changes might be required. A typical example related to this is the strongly divergent dutch roll mode (Fig 18), predicted for the natural A/C in cruise conditions (300kt TAS, FL250). The need to modify the fin design will depend on the control law and system architecture design.

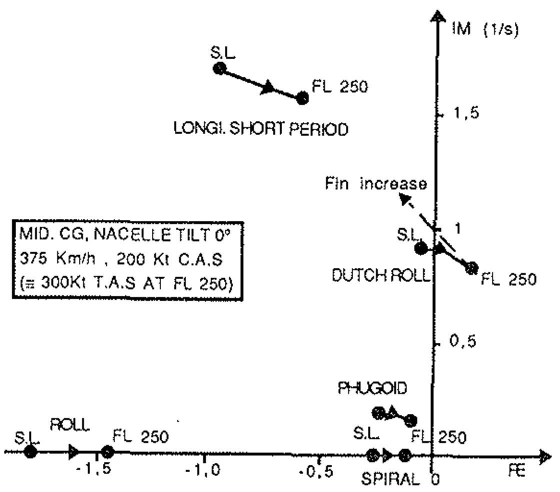

Figure 18 : Open loop eigen modes

- Piloted simulations

A real time model was developed in order to perform pilot-in-the-loop simulation tests before the end of this preliminary phase. These piloted simulations will be used to validate the fly-by-wire control laws previously developed.

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