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THE EUROFAR PROGRAM: AN EUROPEAN OVERVIEW ON ADVANCED VTOL CIVIL TRANSPORTATION SYSTEM

By

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THE EUROFAR PROGRAM

An European Overview on Advanced VTOL Civil Transportation System

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ABSTRACT

This paper summarizes some European overviews on the role which could be devoted to a transportation system based on the tilt-rotor, and on the conditions of introduction of this aircraft within civil community :

As regards these issues, the Eurofar approach is based on aircraft design activities, and on studies related to marketing, infrastructure and airspace system.

1 - THE AERIAL CIVIL TRANSPORTATION SYSTEM

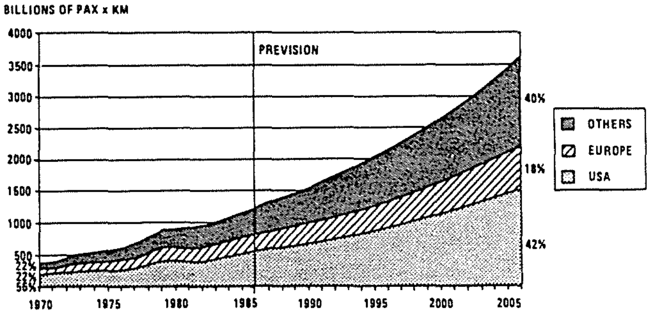
1.1 - A dramatic evolution

At the turn of the century, the transportation function will have considerable political, economic, social and cultural impacts, both in developed countries and underdeveloped areas. Within this framework, the aerial system is already facing a travel demand growth which is causing airport capacity problems and congestion effects throughout the world.

Il we consider the typical U.S. situation, the F.A.A. listed in 1988 16 major airports as "congested" i.e. having an annual cumulative delay of departure exceeding 20,000 hours. Among them the "top ten" airports saw in 1988 590,000 hours of delays which represents a loss of over 25,000 man years of labour (Ref. 1). Moreover, a dramatic increase in movements for air travel is expected in the USA with a 74 % increase in passenger and a 32 % increase in the number of jet transports by 2000, resulting in 42 airports forecast to exceed 20,000 hours of annual air carrier delays in 1998 (Ref. 2).

The same type of evolution is expected in Europe and Far-East, as a result of the political move, economic situation, new life-styles, general professional demand and finally airline deregulation. In western Europe, congestion already produces unacceptable levels of delay, inconvenience, and widespread costs. The proportion of flight delayed by more than 15 minutes almost doubled between 1986 and 1989. The cost of these delays to airline and the travelling public has been estimated at 1.5 billion $ annually. The total annual loss due to delays, inefficient routings arising from poor route structure and military airspace restrictions, non-optimal flight profiles, low ATC system productivity and other inefficiencies has been estimated at 5 billion $ (Ref. 3).

Moreover, it is forecast by European studies (fig. 1) that by the year 2000, the number of passengers will be twice today figure.



SOURCE : ICAO (USER EXCLUDED) + PREVISION

Figure 1 : Civil traffic evolution

1.2 - The V.T.O.L. aircraft role

One of the major points is that short haul transport plays an important part in congestion, consuming air slots and ground spaces. The records for 1988 current New-York traffic (three airports combined) showed that 44 % of departures carry 18 % of the passengers less than 300 miles (Ref. 1).

A similar situation exists in Europe, with, for instance, a traffic concentration within a relative reduced area, between some hubs like London, Paris, Francfort, Brussels and Amsterdam.

Therefore, considering that future problems are related to terminal operations and short haul demand, it can be anticipated that rotorcraft could play a larger role in the future, provided that a dedicated air and ground transport system could be established, but outside from the crowded airplane system and serving it.

Nevertheless, it has to be considered that the classical helicopter has up to now failed to be accepted as a regular scheduled civil transport air-vehicle. The main concerns against the helicopter are the operating cost, the environmental intrusion, and the lack of comfort, speed and range.

Therefore, a VTOL vehicle must be provided which overcomes these limitations. Studies conducted over many years in the past have shown the tilt-rotor concept to be the best solution for the mission spectrum of interest here.

European researches launched by the GARTEUR, including operators survey and parametric studies assessed the interest for the tilt-rotor aircraft (Ref. 4).

For these reasons, the Phase 1 of the Eurofar Program has been launched within the framework of the Eureka Program, with the participation of France, Germany, Spain and U.K.

2 - THE EUROFAR PHASE 1 GOALS

The Eurofar Phase 1 is a Feasibility Phase, approved as an official Eureka project during the fifth European Minister Conference in Madrid (15th September 1987). This phase started January 1988 and ended officially in December 1990.

The necessity of this phase was based on the need :

- to provide the appropriate government and public authorities with the opportunity to consider the establishment of such a new air transportation system
- to ensure that a subsequent development program could be launched with minimum technical and financial risks
- to improve the European position, when considering international activities related to advanced V.T.O.L. aircraft and future civil air transport systems
- to achieve further and more detailed substantiation of the commercial opportunities.

To reach these goals in an optimum way, the study included :

- Technology evaluation selection and integration within the pre-design of a "Baseline Aircraft", including experimental activities on critical components and systems
- Infrastructure and airspace requirements, and operational analysis
- Certification and procedural aspects
- Marketing research and economic evaluations.

Since these four elements are strongly interrelated, it was necessary to perform the Feasibility Phase within a concurrent and highly interdisciplinary study process, including the active participation of European helicopter and airplane manufacturers, research organizations and Aviation Agencies.

3 - TECHNOLOGY AND VEHICLE DESIGN

3.1 - Requirements and design process

A main part of the work done during the Feasibility Phase was dedicated to the aircraft technical characteristics in a broad sense. Technical studies concentrated on identifying and understanding the physical fundamentals of the tilt rotor concept. The technical issues included aerodynamics, dynamics, performance, handling qualities, loads, noise and vibration. Substantial effort was spent to select the basic aircraft technologies and to work out the conceptual solutions for the various systems and subsystems and components.

Design guidelines for the European Civil Tilt-Rotor studies were developed as based on (Ref. 5) :

- The concept having been demonstrated by the U.S.A., mainly through the XV15 Program
- The available T/R basic know-how existing in the European companies and Research Agencies participating to the Eurofar Program
- The utilization of the advanced technological background coming from rotary wing and fixed wing European industries, to be applied on T/R aircraft to demonstrate and optimize the transportation system efficiency
- The specific requirements for civil application deduced from civil airworthiness codes which may be issued by relevant National / International Agencies by the end of the century, and with the hypothesis that these codes could be harmonized with the code presently in preparation in the USA by the F.A.A.
- The specifications established by Eurofar teams.

For the later, size and mission spectrum for the baseline vehicle were selected from early marketing studies (the later results supported these assumptions). The basic requirements were :

- 30 PAX + 2 pilots + 1 flight attendant
- Min 300 kts cruise speed
- High cruise altitude (about 25 000 ft)
- Range of 2 x 300 Nm (mid landing)
- Category A takeoff
- Comfort similar to modern jets
- High safety and attractiveness
- Environmental acceptability.

3.2 - Aircraft sizing and performance

Design studies conducted to a Baseline Aircraft having the following main features (Ref. 6)

- DGW = 13 650 kg
  (rooftop cat. A at 500 m ISA + 10, max. fuel capacity)
- Power plant = 2 x PW 300 TS engines
  maxi continuous SL/ISA = 3185 kW
- Cruise speed = 335 kts
  (7500 m ISA)
- Aircraft length = 22.4 m
- Wing span = 14.6 m
- Rotor diameter = 11.2 m

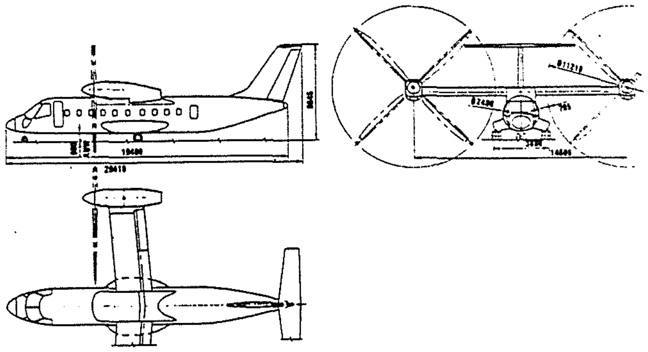


Figure 2 : Three-side Viewing

3.3 - Technology Highlights

The requirement for high performance led to technological innovations with "fresh solutions" on a broad front. The most important features are (Figure 3) :

- a four-bladed, composite gimbal rotor system with homokinetic torque transfer (via a "membrane" hub design)
- flexbeam type rotor blades with specially tailored airfoils for high performance
- composites for the wing, the fuselage and the tail-plane sub-structures
- a quadruplex fly-by-light control system with smart actuators and decentralized intelligence
- an advanced flight deck with digital avionics and flight-management system.

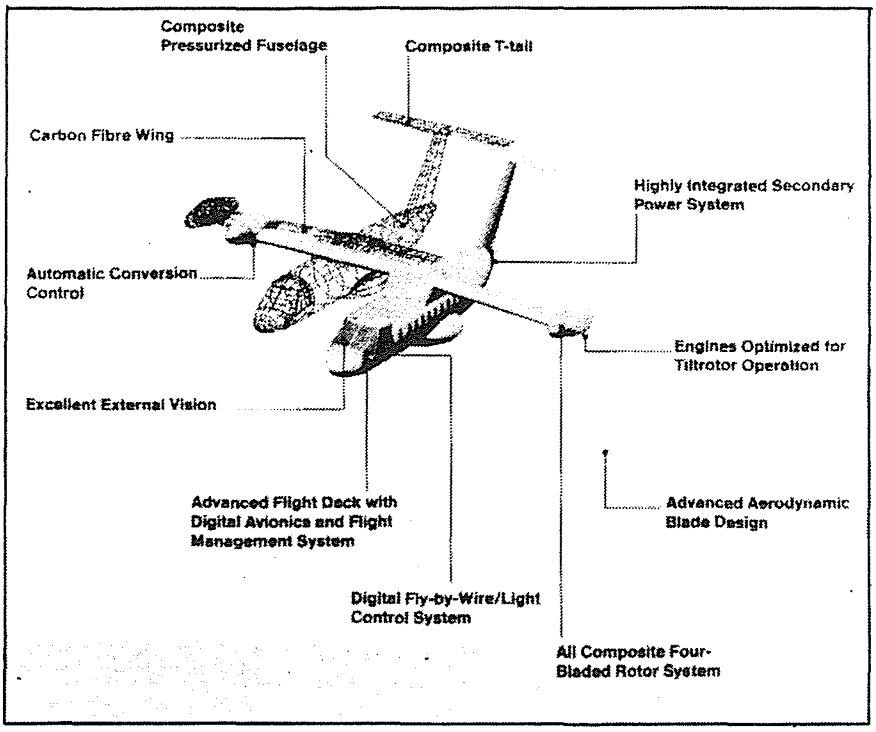


Figure 3 : Technology Highlights

The Feasibility Phase also included a comprehensive wind tunnel model testing and concept validation/ demonstration program :

- W.T. Model 1 :
  Configuration development model tested to support configuration selection and to produce aircraft characteristics for flight mechanics and performance (Scale 1/10)

- W.T. Model 2 :
  Isolated rotor (Scale 1/2.7 Ø = 4.2 m) tested on ground rig and in wind-tunnel to obtain rotor aerodynamics, aeroacoustics, loads and control laws in hover, conversion and cruise

- W.T. Model 3 :
  Half-span Froude scaled (1/6) model, dedicated to Rotor/Nacelle/Wing aeroelastic stability

- Composite pressurized fuselage test specimen (Ø = 2.5 m, L = 2.5 m) : dedicated to conceptual design and manufacturing assessment in the actual environment

- Pilot in the loop simulations : dedicated to control laws preliminary assessment and first evaluation of man/machine interface

- Different display models and mock-up : intended to give a comprehensive image of the tilt-rotor concept.

4 - THE CONDITIONS FOR CIVIL TILT-ROTOR

Introduction

4.1 - The main interveners

The acceptance of the tilt-rotor as a new civil transportation system is related to the positive reaction of three main interveners : the users, the operators and the "Aviation Agencies" (representing roughly speaking the "general public" interest).

The users

The users wish a convenient, well located and scheduled, cheap, safe and comfortable system of transportation.

- The vertiport localization depends on the type of commuter mission : city centre/city centre, urban area/urban area, congested hub feeder, uncongested hub. The interest of users is related to door-to-door transportation time reduction including proper connection with other systems (ground and large/long range air carrier). Typical situations have been examined by Eurofar teams

- The schedule is related for a given route, to the mean flow/peak demand with local restrictions related to environment, and economic aspects for the operators. These considerations confirmed the aircraft size choice for Eurofar (30 Pax)

- The affordable ticket price has been assessed by Marketing simulations through the "value of time saving", taking into consideration the competition of other ground and aerial systems (level of ticket price : from airplane business class to first class according to the routes).

- The safety, for non-technician people, is related to the "public image of an aircraft", with, presently, a good status for airplanes but a "psychologic reject" of the helicopter. The tilt-rotor, appearing as a classical airplane with VTOL capabilities, could have a better image than the helicopter, as already perceived.

- The tilt-rotor has a good level of comfort (Figure 4), related to aircraft architecture (correct seat pitch, galley, toilet, fuselage diameter).

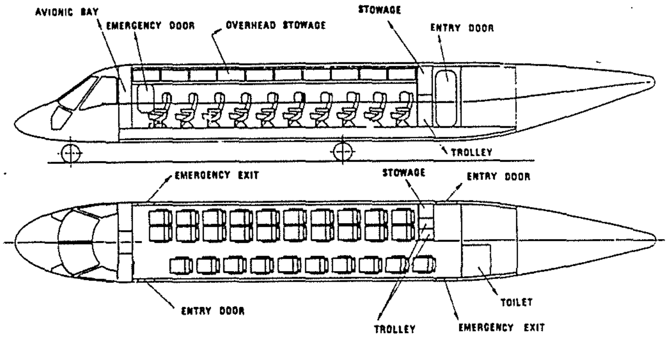


Figure 4 : Cabin internal arrangement

The high cruise speed of the aircraft (335 kts for Eurofar) reduces the practical mission time to 1 hr/1.5 hr for the greater part of the missions.

Finally, the cruise mode (representing at least 95 % of a civil mission time) gives the aircraft an acceptable vibratory level and an internal noise equivalent to turboprop airplanes, which is mainly related to the reduced rotor tip speed in cruise (Figure 5).

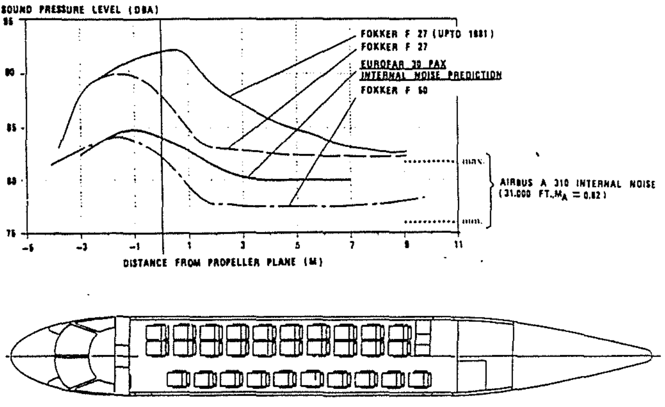


Figure 5 : Internal noise level prediction

The operators

The major problem of the return on investment for operators, has been studied through aircraft expected economics and their impact on the market, as examined within following chapters.

For the operations themselves, an important problem identified is related to MMI (Man/Machine Interface) mainly during take-off/landing when safety is crucial.

Pilot workload reduction has to be achieved through proper aircraft design features, including advanced cockpit displays, "fly-by" controls, efficient NAV/COM systems, and flight/landing aids. Proper pilot training will have also to be considered.

It appears obviously that a civil tilt-rotor development will have to include intensive piloted simulations and demonstrator aircraft flights, with the active participation of potential operators. Successful and promissing preliminary piloted simulations were conducted during Eurofar Phase 1 (Figure 6). They were mainly devoted to the assessment of the aircraft control laws, but they gave also valuable informations on symbology, cockpit architecture and more generally M.M.I. problems. Therefore, it is intended to conduct, during Eurofar Phase 2, piloted simulations using an optimized cockpit, in actual environment. These simulation compaigns related to typical civil operations will have to include operators participation.

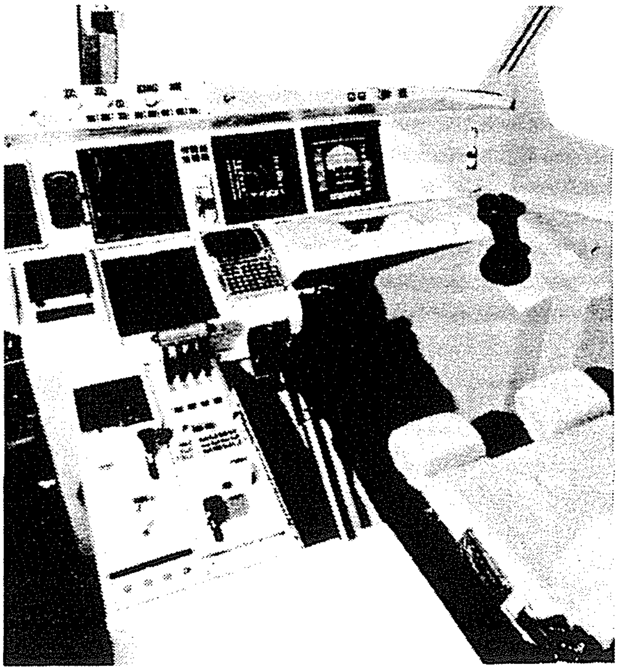


Figure 6 : Toulouse Epopée
Flight simulator cabin

The aviations agencies

These agencies acting on an International/National/Local basis prepare and issue regulations related to the aircraft airworthiness and operating rules. They take also charge of infrastructure and aerial system management.

There is presently no airworthiness regulation for the tilt-rotor. So, the Eurofar design activities were mainly based on the FAA Interim Criteria for Powered Lift Transport Category Aircraft (Part XX). This code is an interim set of rules and is not specific to tilt rotors but covers other types of powered lift aircraft. Due to this level of generality a considerable amount of interpretation is necessary. For this purpose, FAR Part 29 (Helicopters) and FAR Part 25 (fixed wing airplanes) should be used.
The other airworthiness requirement which should be referred to is JAR 25 for large fixed wing aircraft, which exists but in a different form to FAR Part 25.
There is no JAR for helicopters. The only other national helicopter code, apart from FAR is BCAR 29.

Some other applicable documents are related to proposed rules for turboshaft engine rotor burst protection, and to structural requirements for pressurized cabins and compartments in transport category airplanes.

For the operating rules, FAR Part 121 - Domestic, Flag and Supplemental Air Carriers and Commercial Operators of Large Aircraft, FAR Part 135 - Air taxi Operators and Commercial Operators - should be used. These are US operating rules only and are not applicable in Europe. The European operating rules are presently a complex set of national standards, applicable within individual states and are not transferable. The European Authorities, acting within the JAR system are moving towards the US methodology, but could well deviate from the US rules.
Therefore the European situation cannot be used as a design guide, and the decision to work with the US rules should be taken with full knowledge of the situation.

4.2 - The critical issues

To secure acceptance of the tilt-rotor civil introduction, it will be necessary to evaluate critical issues related to transportation system cost/efficiency, safety and environmental impact.

Cost efficiency

The cost/efficiency is not only related to the aircraft, according to the usual aeronautical process (D.O.C., return on investment ...), but is also dealing with the global transportation system, including for instance the infrastructure cost. The efficiency has to be appreciated through the economic impact of the T/R introduction in terms of transportation function entrancement (including for instance the help to solve large airports congestion and air carrier utilization).
This wide and very complex approach started during Eurofar Phase 1 and will have to be pursued during the following phase.

Safety

During Eurofar Phase 1, it has been considered that safety must be a leading activity. It was stated that by introducing hazard assessment as a design tool and by considering the overall transportation system, i.e. taking into account the safety of the operational procedures, it should be possible to meet both the regulatory and the customer's needs.

The main aircraft design features related to safety enhancement include :

- A stationary engine concept limiting the effect of engine rotor burst, and providing a larger margin in case of roll instability near the ground
- A connecting shaft between the two nacelles
- In each nacelle a mechanical actuator, driven by two hydraulic motors, with a redundant ball spindle arrangement and an electrical back up drive system
- A flight control system based on a quadruple redundancy
- A redundant hydraulic system with three independant circuits
- A pressure fuel system with crossfeed capability
- An electrical power distribution to equipments achieved via new technology breakers (a single failure has no consequence, a double failure lets a safe flight, a triple failure lets a safe landing)
- Finally a One Engine Inoperative rooftop categorie A capability, up to 4,100 feet at the maximum VTOL design wheight (13 650 kg) (Figure 7).

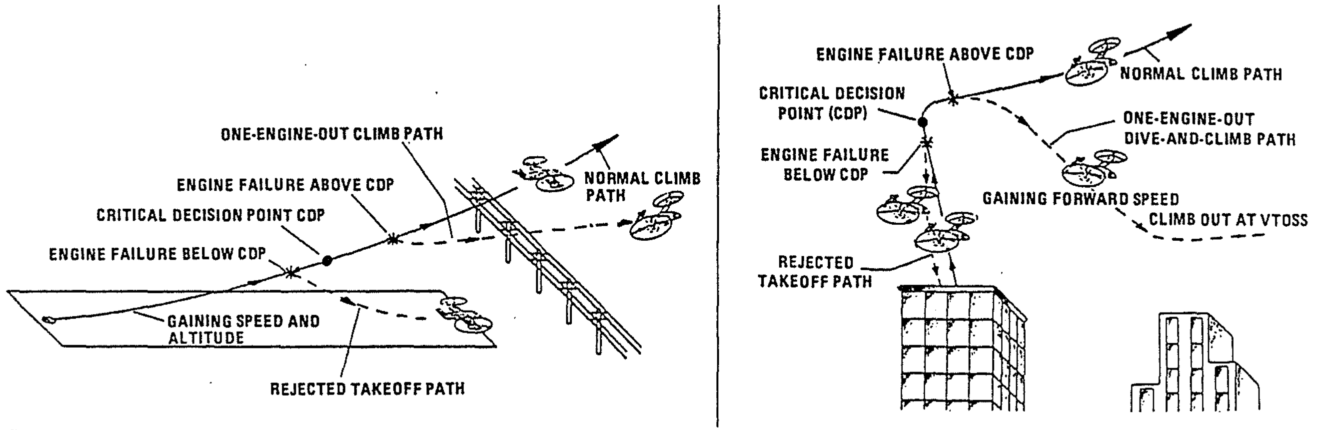


Figure 7 : Cat. A take-off (one engine inoperative)

Environment

It has been recognized that the environment (mainly external noise) was, as for the helicopter, an important element against a "free utilization" of the tilt-rotor.
The noise abatement could be conducted either through aircraft design features and through adapted operational procedures.

For the aircraft, the rotor aeroacoustic source treatement is achieved through blade tailoring and tip speed reduction in airplane mode. It has been demonstrated that the tilt-rotor does not exhibit specific problems, having the same acoustic level, as good equivalent helicopters or airplanes, when used in corresponding modes, according to current regulations specifications (Figure 8).

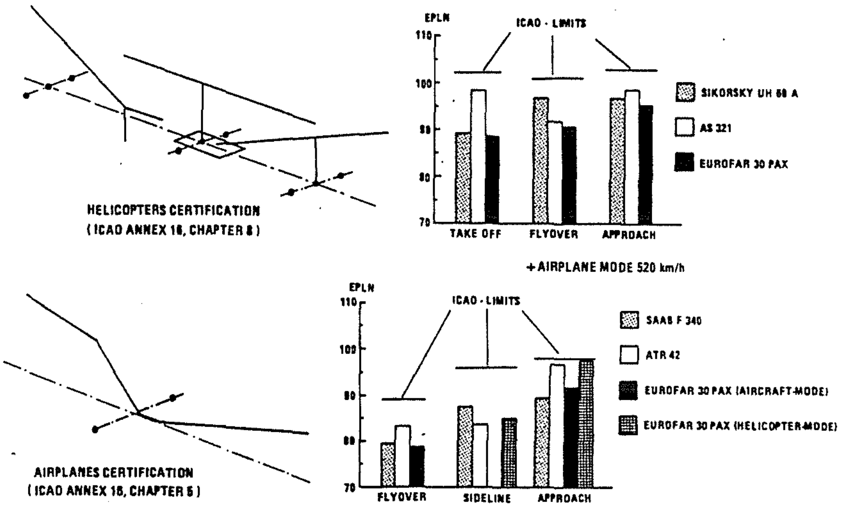


Figure 8 : Noise levels ICAO conditions

However, strong research actions will be needed to comply with local noise limits which are generally significantly below certification criteria.

For the operational procedures an environmental justification for a vertiport would depend largely upon superimposition of the anticipated noise footprint upon the surrounding area.

In this regard, the longer that tilt-rotor can be kept at altitude before necessarily commencing descent or, conversely, the sooner it can climb out to an uncontentious altitude, the better.

Steep approach/take-off gives the tilt-rotor the unique capability to reduce dramatically the cumulative noise footprint, as regards current turboprop airplanes. (Figure 9). The practical achievement of such steep trajectories will have to be assessed using piloted simulations and demonstrator aircraft.

Comparison of noise protection Area II of Eurofar with the noise Protection Area II of an airport with fixed wing traffic.
(noise protection Area II : 67 dB (A) $\leq L_{EQ} \leq$ 75 dB (A)).

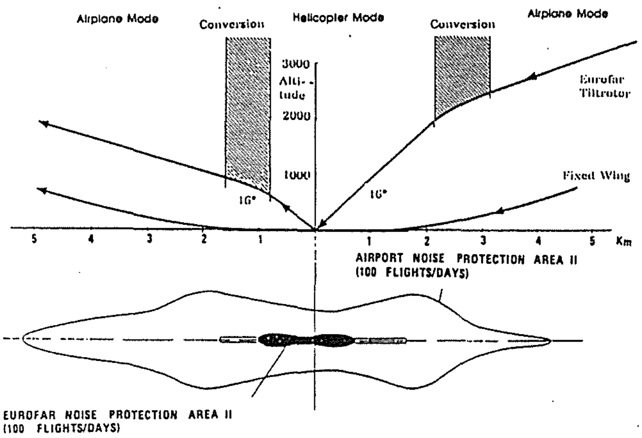


Figure 9 : Comparison of noise protection areas

5 - THE CIVIL TILT-ROTOR UTILIZATION

5.1 - Vertiports and ground infrastructure

The optimum location for a vertiport is undoubtedly in close proximity of the potential demand.
The closer, the better. Indeed, an original maketing concept for the civil tilt-rotor was its theoretical door-to-door capability, made possible by its versatile flight characteristics.

These particularities could be widely accommodated by virtue of the dramatically reduced space (and cost) required for its operational infrastructure compared with that of more conventional aircraft. A single pad VFR vertiport together with its essential structures and functions may be contained within a space not greater than 2 acres (8 000 sqm), whilst an IFR double pad with comprehensive logistical support and high intensity activity needs occupy not more than 10 acres (40 000 sqm).

An illustrative comparison is achieved with classical airport (like Munich new airport) covering 3 700 acres (14 800 000 sqm), giving a ground occupancy ratio about 370/1 with large vertiport.

Considering an annual passenger capacity around 14 Millions for the airport and 600 000 for the vertiport (15 Pax x 40,000 movements representing around 100 movements/day), it finally appears that a large airport represents 1 passenger/year/sqm against 15 passengers/year/sqm for a vertiport.

However, apart from the likelihood that urban land will be both scarce and costly, the vertiport operability will arise, like for airports, from environmental objection and lack of obstruction-free airspace around infrastructures.

The issuance of operational regulations giving the tilt-rotor the ability to execute steep operational approaches will bear heavily upon the success of its acceptance.

In seeking to minimize environmental impact, Eurofar examined typical vertiport geographical location, including coordination/connection with ground transportation systems.

Finally, for feeder-line services and regional hub/spoke missions, Eurofar demonstrated that provisions regarding ground and airspace could easily be dedicated to vertiport terminals within large airports.

5.2 - Airspace system

Eurofar examined the vertiport airspace with the obstacle clearances and the related surfaces for VFR/non precision approach and departure (primary approach and departure, transitional surface).

Also comprehensively examined was the important problem of the IFR/precision instrument approach, with the approach/departure surface slope presently lowered to 10 % (5.7°), which is considered as an approcah without difficulty for an average pilot.

Such a restrictive application to an urban vertiport would render it fundamentally unpracticable. Eurofar considered that the use of new systems like MLS gave the technical opportunity to perform steeper approaches (Figure 10) whose practical affordability will have to be assessed by piloted simulations in realistic environment, during the Eurofar Phase 2.

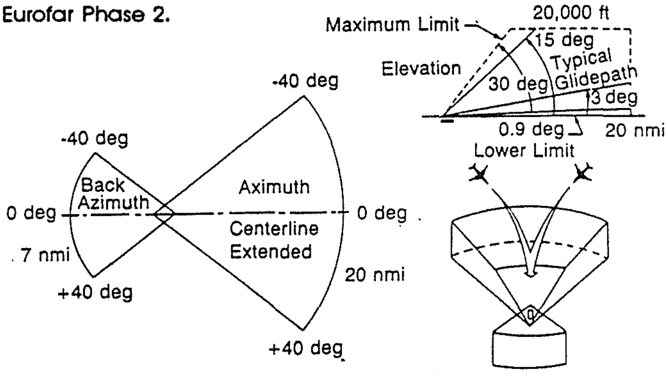


Figure 10 : M.L.S. spatial coverage capability

The concept of tilt-rotor performance, coupled with dedicated vertiport infrastructure, envisages substantial independance from the potential debilitations which beset integration with conventional air traffic. The achievement of such desired independence hinges upon formulation of discrete procedures and establishment of specific airspace tailored to the performance capabilities of tilt-rotor so as not to conflict with other demands upon Air Traffic Control but rather to seek practicable extension of the system.
The following elements are proposed (Figure 11)

- Institution of circumscribed terminals of controlled airspace at low altitude above the ground for rotortraffic only, to include one or more entry/exit.

- Institution of controlled rotorways assigned to rotorcraft traffic at low altitude (and, if necessary limited airspeed) for the connection of the abovementioned terminals with the existing controlled airspace.

- Institution of navigational data for transition from the existing controlled airspace to the newly conceived rotorways directed to or coming from new terminals

- Institution of low altitude, short distance VFR corridors linking, when practicable, non IFR equipped vertiports.

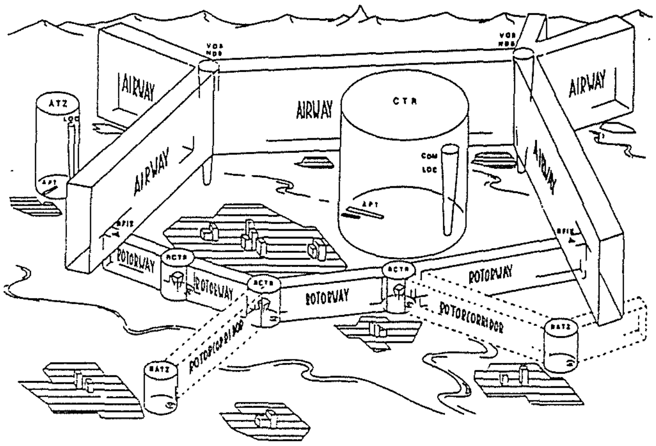


Figure 11 : Low level rotor controlled airspace proposal

6 - THE TRANSPORTATION SYSTEM INTRODUCTION

THE CIVIL MARKETING ISSUES

6.1 - The worldwide civil tilt-rotor market

Eurofar has adapted to the tilt-rotor market study an advanced simulation model called "Systems Dynamics" describing the aeronautical market in an economical homogeneous area as the result of the general economical situation in this area (Ref. 5). This method takes care of a large number of parameters (technical, regular, economical, financial, social) leading to the market establishment and evolution.

The studies mainly included :

- A geographical segmentation : USA, Europe, "Asia 1" (industrialized countries), rest of the world (Figure 12).

  The larger market (40 %) is located in the USA and is mainly related to aerial congestion problems.

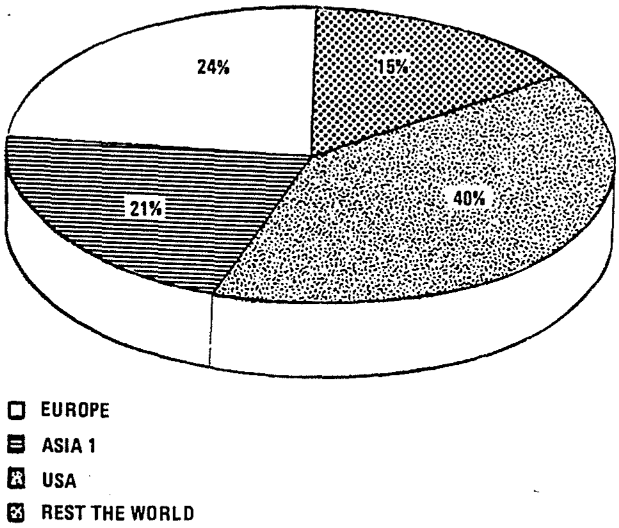


Figure 12 : 30 Pax civil T/R world market

- A mission segmentation : The largest market is related to commuter missions, including mainly urban area/urban area and hub feeder missions (Figure 13)

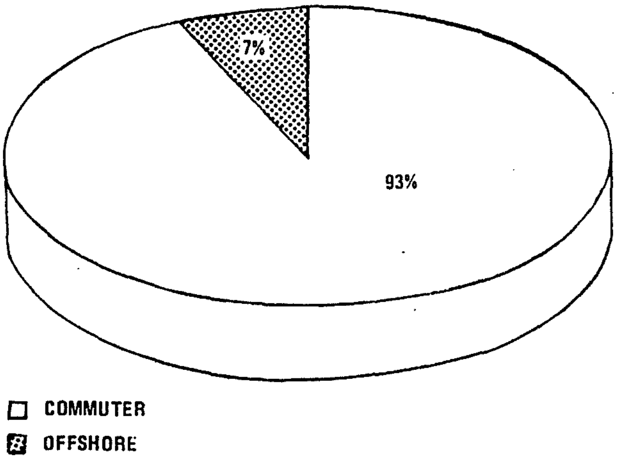


Figure 13 : 30 Pax T/R world market mission segmentation

- An aircraft size segmentation : The study included 19 Pax, 25 pax, 30 Pax, 50 Pax and 75 Pax aircraft. The 30 Pax aircraft achieves the best simultaneous penetration on the commuter and offshore markets.

6.2 - The operators and the tilt-rotor economics sensitivity

One of the most important parameter is the D.O.C. A basic range for this parameter is between 20 US cents/NM x seat and 25 US cents/NM x seat, for a 30 Pax tilt-rotor.
Simulation results suggest that the commuter market is extremely sensitive to a variation of D.O.C. value, especially in the case of a reduction of this parameter for US and European market (Figure 14).

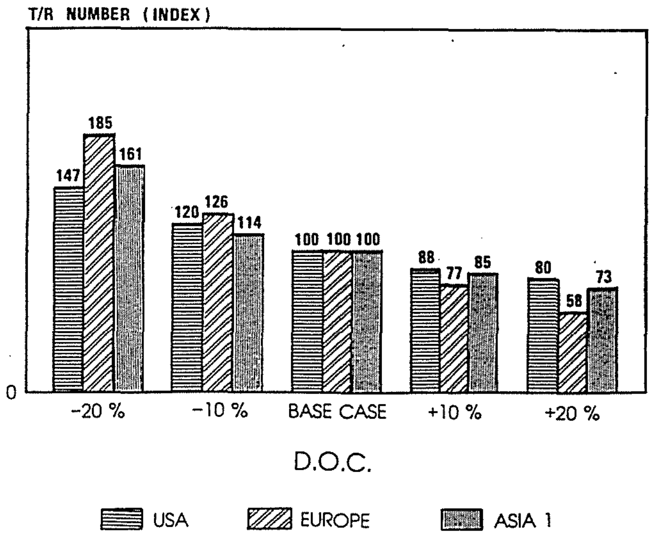


Figure 14 : Effect of direct operating cost
Eurofar 30 Pax commuter 2000 - 2012

The offshore market is absolutely not sensitive to the value of D.O.C., due to the competitiveness of the tilt-rotor for long-range missions as compared to the helicopter.

6.3 - The users and the transportation system attributes

The most important parameters is the V.T.S. (value of time saved) which represents the additional ticket fees that passengers are ready to pay to gain one hour for the door-to-door transportation (the basis being full economic ticket price for commuter and seat cost for offshore).

In the basic distribution adopted for the commuter, it is considered that 40 % of the travellers would not accept to pay more than 1/6 US$ for 1 hour time saving and only 40 % are willing to pay more than 30 US$ for one hour time saving (mainly business travellers). Variance of the value of time saving around the base case indicate that, when the value of time saving is increased by 10 %, then the potential commuter market is changing with the same rate (Figure 15).
The offshore market is absolutely not affected by a variation of this parameter.

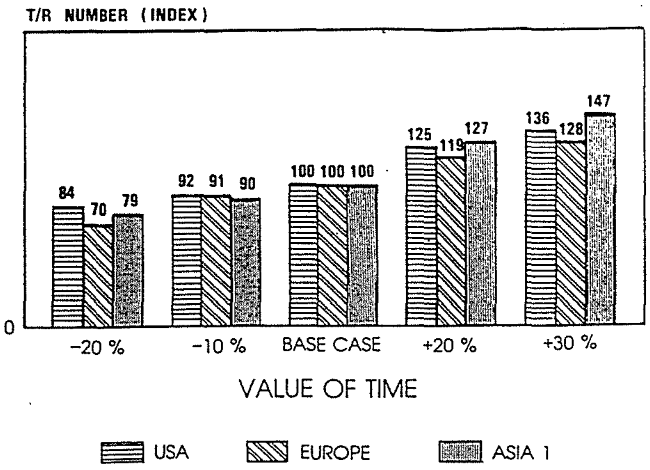


Figure 15 : Effect of value of time saving
Eurofar 30 Pax commuter 2000 - 2012

6.4 - The resistance to tilt-rotor establishment

The evaluation of this phenomena is very difficult and has been summarized through the airport and vertiport development time.

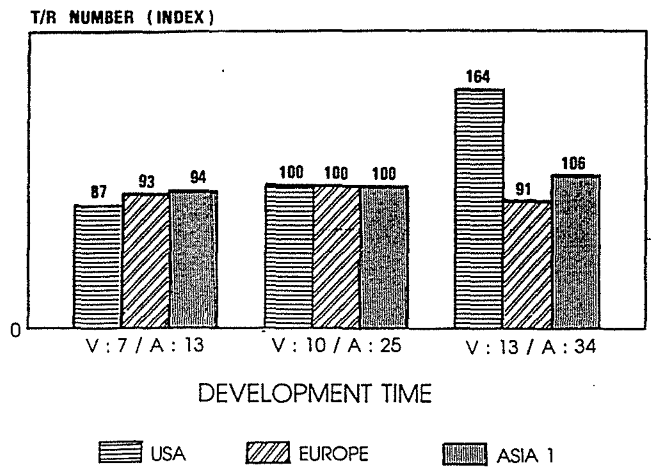
These ratios reflect the environmental pressure : the stronger, the pressure, the longer it takes for planners to develop and build airports and vertiports. On the opposite the stronger the market demand (including congestion problems related to airplanes utilization), the shorter it takes to develop vertiports.

Three scenarios are shower there (Figure 16).

- The base case (25 years to develop and build an airport in 2010, 10 years for a vertiport)
- Smaller development time for both airport and vertiport (13 years for an airport, 7 years for a vertiport in 2010)
- Increased development time for both airport and vertiport (34 years for an aiport and 13 years for a vertiport)

On the (Figure 16) the evaluation of the market for the tilt-rotor covers the years 2000 to 2012 (12 years). This period of time explain why the market is not so much reduced by a reduction of the time to develop airport and vertiport. It appears indeed that the airport capacity would not be so much changed in the year 2000 - 2010 if it takes less time to build new runways or terminals.

Contrarily, if the development time for building new airports is increased from 25 years to 34 years, then the likely congested situation of airports in the USA during the years 2000 - 2010 would worsen, creating a likely increasing demand for tilt-rotor, even if vertiport development time is increased from 10 to 13 years.



BASE IS V : 10 / A : 25

Figure 16 : Variance of airport and vertiport development time Eurofar 30 Pax 2000 - 2012

Concluding remarks and recommendations

- Three years of wide ranging activities conducted at the European scale, by several major aeronautical companies of this continent indicated that a new civil transportation system based on the utilization of the tilt-rotor was basically feasible. The general conditions for its successful worldwide introduction and development were determined ; therefore, future ways of action serving the public general interest were defined.

- The basic philosophy of the Eurofar program, dedicated not only to technical studies on the tilt-rotor aircraft but also to the global evaluation of a new civil transportation system has been fully assessed, and will be followed in the future, with the active cooperation of helicopter and airplane manufacturers, research agencies, National/ International Aviation agencies and operators.

- It has been demonstrated that the European industry can be confident in its capability to design a high performance tilt-rotor aircraft. However, the achievement of high goals related to the system cost/efficiency, safety and environmental issues, will need continuous research actions, on an international basis, including intensive piloted simulations and demonstrator aircraft, prior to any decision of program launching

- Civil operational success is strongly related to the establishment of vertiports, appropriate airspace system and advanced air traffic control specifically dedicated to rotorcraft with special procedures allowed by tilt-rotor high characteristics and advanced approach aids systems, with enhanced safety and acceptable environmental intrusion.

- Finally, it was considered that the other efforts related to the enhancement of airplane civil utilization, through economics (short-haul transport, large jet carrier) and through speed (2nd supersonic generation and hypersonic future aircraft) could be largely negated by terminal and airspace congestion.

Consequently, the relevant authorities are seriously recommended to consider the tilt-rotor as a necessary ingredient of the future civil transportation system. Therefore it should be introduced within long-term plans taking advantage of National/International incentive policy

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