MPC75 - THE EVOLUTION OF A NEW REGIONAL AIRLINER FOR THE LATE NINETIES

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Abstract

Within the lifespan of an aircraft type over roughly 50 years the pre-development phase is the most crucial one. During that period, before a programme launch decision based on first customer orders is taken, the project is defined technically and thus most of its later cost is determined.

For MPC 75, a new 80-130-seater family of aircraft, this interactive technical definition process shed some earlier ideas already. It has now led to a balance between technological options, operational necessities and commercial constraints.

In describing the currently reached status as well as the remaining open decisions the various influential factors affecting such a project definition process are briefly outlined. They indicate a strong trend towards minimizing technical risk and cutting cost to safeguard commercial viability in the expected competition scenario.

Aside from the product the organisation for producing it must also be established. Nowadays this usually involves international collaboration and hence proper sharing of work, cost and risk. An even more delicate process.

I. Introduction

I.1. Aircraft Life Cycle

Looking at a typical aircraft life cycle (Fig. 1), this initial phase up to Development Go-ahead covers about 5 years for a brand new design. This will be followed by the aircraft development up to certification in 4 to 5 years. Production will then pick up and hopefully run at high rate well beyond break-even point in say another 10 years. With further models, modifications, design improvements production will continue another 10 years after which product support must continue - to up-keep the last aircraft over its expected life of say 25 years. Thus one has to consider a total life cycle of about 50 years.

For any major project the feasibility and project definition phase is the most crucial one for later success. This is particularly true for a new aircraft development

The technical definition frozen at that early point in time fixes a high percentage of the necessary development and especially of the recurring production cost. Aside from technical decisions the whole business partnerships, subcontracting have their bearing on overall success.

This emphasizes the need for the careful selection of technology levels as well as inherent design adaptability to changes which definitely will happen during such a time span. Changes in economic development, airline structures, regulations are just a few to be mentioned.

Obviously, any decision taken is a risk, but that's life.

I.2. MPC 75 - History

For MPC 75, as it was originally named, the 80/100 seater project which Deutsche Airbus (then MBB) started in close cooperation with XAC from China in the mid 80's, the pre-development phase is not yet over. Over the years MPC 75 has evolved via DAA to REGIOLINER, as it is now called.

As shown in the schedule (fig. 2) this phase includes already a multitude of milestones and achievements. A necessary expansion of the partner consortium scheduled for 1991 is still to be finalized.

Due to various reasons, engine non-availability being just one, neither this nor any other new aircraft project has been launched in the 100-seat category, though market experts foresee a definite need for replacements in the near future.

Some of the evolutionary steps experienced with the MPC 75 - DAA - REGIOLINER Project during its ongoing definiton phase will be reported briefly. The changes shown (fig. 3) as to propulsion system type and location, seat capacity and hence fuselage diameter and wing size are just examples of the more obvious ones.

This process continues as long as the management allows the engineers to further fine-tune the resulting solu-

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tion until tight schedules force a design freeze shortly after the development decision.

II. Project Evolution

II.1. Market Needs - Fleet requirements

Extrapolating from existing fleets under sophisticated consideration of factors like economic developments, airport capacity, probable transportation flows and traffic growth, the experts dare to estimate the necessary number of aircraft needed to fulfil the envisaged demand. Age pattern and assumed retirement age give an idea of the share of aircraft replacement/growth (fig. 4).

The example given illustrates a recent estimate for various classes of seat capacity.

Although the larger aircraft sectors promise a much bigger turnover, Deutsche Airbus was looking for new markets not yet covered by existing Airbus types.

For our new 100-Seater-Family only two colums are of interest, but together they indicate quite a sizable market of over 2000 A/C. The majority of those will be needed to replace the old and ecologically unacceptable aircraft built in the late 60's and early 70's.

II.2. The Logical Step.

Once the market has been identified the question arises how to fill the need by derivatives or by a completely new design. Plotting seat capacity versus date of first flight for available aircraft (fig. 5) indicates a strong tendency to keep existing models in business. Although original designs dated back to the 60's, re-engining, stretching, shrinking and systems up-grading were the solutions pursued at minimum risk. But after 20 to 25 years of technological progress the question was put, whether the possible beneficial combination of several advancements would yield a product superior to any derivative solution and worth the extra effort to start from scratch.

II.3. Technology Options

The original concept (fig 6) included a large number of technology items like

- Natural laminar flow, high aspect ratio wing
- Rear-mounted propfan propulsion
- Riblets
- Aluminium-Lithium alloys
- CFRP-wing box and empennage
- Fly-by-wire flight control and
- Advanced cockpit

Some of those were dropped or changed in the evaluation and risk assessment process, as is natural progressing from studies to detailed investigations and closer to the launch date. The main yardstick has always been the overall economic effect of the feature expressed by direct operating cost changes including formula and non-formula repercussions where possible.

Aside from the customer acceptance, that is, his willingness to pay for the extra features, the second question always concerns the effect on overall cash flow for the manufacturer. An even more difficult assessment is required on how the technology item eventually will improve market penetration, market share. Those considerations must also include the technology readiness or the timing and effort to reach that goal. The latter will vary with the manufacturer's experience.

II.4. Aircraft Design Integration

Aircraft designers always search for a balanced compromise between various requirements and possible technical solutions. Sizeable technological advancements in the basic areas of aerodynamics, structures, systems and propulsion provide a variety of options to utilize those goodies. As indicated in fig. 7 some of the targets could be lower DOC, better climb and field performance, more range, lower noise and emissions or higher cabin comfort standard than offered today. The problem usually encountered is the fact, that the benefits of the total technological improvement in the end are much smaller than expected. Thus we are unable to realize all the good features to the envisaged degree. Usually this screening process takes place aside from regulations in close contact with the customers strongly influencing the requirements. The only trouble being, that they don't know what they need 20 years from now, nor do they ever have the same set of expectations. The risk remains with the designer/manufacturer who has to take the decision now and has to sell later.

II.5. Evolutionary Decisions taken

As indicated above, some more obvious changes to the project took place a while ago. The natural laminar flow wing concept had to be dropped for reasons presented before (see ref. 1) which could be summarized as follows (see fig. 8).

The expected large drag reductions had block fuel effects which in turn promised only moderate fuel cost savings on short ranges with the risk of being nullified by structural necessities and operational limitations.

For quite other reasons the propfan was no longer pursued not even as a later retrofit. This again was not only a small weight and DOC-advantage for a new turbofan powered aircraft in the envisaged economic scenario of rather low fuel prices (fig. 9). Likewise important was the fact that a new manufacturer or consortium with a new airframe should not try to break the ground for a brand new propulsion concept. The market was not and even is not ready today to accept such re-engined derivatives from established airframers.

Last not least the steady capacity increase forced the change from a 4-abreast, which is good for up to 110 passengers, to a five abreast fuselage cross section. The latter one, opening options up to 140 seats and more into the trunkliner market on the other side must be carefully sized at its lower capacity end. About 90 seats appear to be the minimum for wing mounted engines plus full simultaneous ground vehicle access to all cabin doors and cargo holds. This ground handling requirement is one feature to shorten turn around time and thus offers the option of higher utilization. Since small jet aircraft, especially when combining other modern technology and speed are generally more expensive than their turboprop-powered competitors, carry a high financial burden, they must offer features to stretch their annual utilization to a maximum of revenue miles. Aside from short turn around times and easy servicing, the airport noise level should not impose any curfew restrictions, the field performance should open slots on smaller runways and range capability should be in line with enlarged catchment area and extra point-to-point connections.

III. Current Project Status

The technical status briefly presented here describes the project, which started as MPC 75 and is now called Regioliner within a new consortium including Aerospatiale and Alenia. Neither the consortium, the name nor the technical definition are final, although the technical changes become less obvious and less fundamental than earlier on.

III.1. Design Requirements and Objectives

Out of a long list of Design Requirements and Objectives the main items are listed (fig. 10). They cover range and capacity as well as design speeds and altitude basically defining the aircraft size and wing design. Engine thrust requirements are specified by take-off and climb performances and supplemented by rather detailed noise and emission targets covered later. Furthermore Marketing Requirements always include an improvement in Direct Operating Cost relative to competing older products. But as indicated above, the sum of all improvements targeted usually exceeds by far the total potential from technology. On top of that new technology has its price; be it modern low fuel, low noise, low emission engines or lightweight CFRP structures to mention just two.

III.2. Family Concept

The required seat capacity and range led to the definition of an aircraft family (fig. 11). Starting the production at the lower end not only fits the market, but also gives the chance to considerably enhance the structural efficiency of the higher weight, larger capacity versions.

Basic design range is set at 1500 NM for the 95 as well as for the 125 seat model. Both capacities will also be offered with extended range options of at least 2300 NM utilizing the full wing fuel volume.

III.3. Configuration and Layout

The currently established overall configuration of both capacities are shown in fig. 12 and fig. 13. Aside from the longer fuselage and the additional overwing exits there are no other apparent changes. This concept of high geometrical commonality helps to save especially in tooling and production.

Yet in order not to penalize the smaller version too much, structural components must be designed to their individual tasks. On the system side this principle usually is abandoned for the sake of better spare part commonality.

The five-abreast fuselage cross section (fig. 14) not only offers an adequate cabin width for improved passenger comfort, but at the same time enables the installation of large overhead bins with unmatched baggage volume per seat. The same is true for the cargo compartment, which furthermore will be optionally equipped with a moving carpet loading system. This will speed-up the loading and unloading with less personnel.

Cabin layouts presented (fig. 15, 16) are only examples to indicate flexibility in arrangement. The four-door solution not only enables single and two class layouts with adequate galley, toilet and stowage space, but likewise ensures quick turn around by unobstructed boarding / deboarding, cabin cleaning and galley replenishing.

This fine tuning of door positions also included the cargo hold access (fig. 17). The option of simultaneous servicing to all 6 doors with adequate space between the vehicles and especially between the vehicles and the aircraft/engine on the right hand side led to the current solution, which is acceptable around the short fuselage and good for the stretched one.

IV. Technology Status

IV.1 Targets pursued

Out of the multitude of earlier ambitious technical features the currently remaining items are summarized in fig. 18. They can be characterized by

- low drag transonic wing
- high by-pass ratio turbofan
- expanded use of composite material
- fly-by-wire control system and 2-man glass cockpit.

During the ongoing pre-development phase of our project a better understanding and assessment of possible achievements was reached especially in relation to the envisaged time frame with a first flight in, say, 1996.

IV.2 Aerodynamic Design

Based upon a solid background of Airbus experience the aerodynamic design effort centered around the new wing. Lower wing loadings and slightly lower design speeds had to be incorporated into the new wing design.

The resulting wing concept (fig. 19) features leading and trailing edge high lift devices as well as spoilers and airbrakes/lift dumpers to enhance field performance and handling qualities. After detailed investigations the Fowler flaps will be supported by a linkage system selected to minimize weight and cost. The 6° dihedral and a pronounced gull wing were selected to accomodate the large engine nacelles without installation drag penalties nor excessive landing gear length.

CFD-tools have been applied to optimize the 3D wing loft in the presence of engines, pylons, flap - support fairings and the fuselage with it's belly fairing. Nonetheless analytical methods were continously checked by numerous wind tunnel test (1000 h) with models evolving in definition and size as development work progressed (fig. 20). A major challenge were back-to-back tests with known models for which flight test results are already available. For the high speed regime design goals are achieved and validated resulting in a major step forward in aerodynamic efficiency (fig. 21). Fine tuning of wing-fuselage as well as rear-end shape will continue to keep the high standard achieved with the all new design impossible with derivative aircraft.

IV.3 Propulsion Situation

In the required thrust classes of 15000 to 19000 lb a total of four candidate engine projects are studied and pursued by manufacturer groupings:

MTU/Pratt & Whitney
BMW Rolls Royce
CFM international
Allison GMA (still).

They all base their designs on some existing, proven HP core hardware, propose very similar by-pass and overall pressure ratios (fig. 22) and aim for a basic thrust class at the upper end of what Regioliner currently requires. Thus R92 at the lower end will get a down rated version. This is beneficial in terms of maintenance especially for short range operation, but causes weight and some first cost penalties.

To keep engine costs low, cycle parameters and temperatures have been chosen to best suit the cost sensitive short haul market. Nonetheless all four options promise a sizeable reduction in thrust specific fuel consumption (TSFC) of more than 10 % over engines currently available in that thrust class (fig. 23).

The environmental impact of air traffic increasingly comes under scrutiny. This already has led in some countries to emission taxes and extra charges for excessive noise. Therefore any new project conceived today must envisage the possible scenario in 20 or 30 years from now. Compliance with stage III noise rules applied today will certainly not be enough in 2020. Design targets have been established (fig. 24) for Regioliner providing noise reductions of at least 4 EPNdB below current levels for each measuring condition. Compared to current derivative aircraft this is a further substantial improvement. With the side line noise being basically a function of thrust and exhaust velocity one could either increase by-pass ratio, that is fan size and engine weight or select a long duct nacelle with mixer or both to reduce the most critical noise. Trade-offs are still under way and could affect the final engine choice taken together with the customers.

Aside from the overall reduction in fuel burn per passenger mile, environmental considerations have led the engine manufacturers to optimize mixture and burner to achieve high energy yield with low noxious content in the exhaust.

Compared to the old ICAO-rules, current aircraft already are much better than required by those rules. Yet, for any new project targets are set for even lower values. As fig. 25 indicates R92 offers further drastic reductions in unburned hydro-carbons, carbon monoxide and smoke versus F100 or MD95 with their older engines. With the current burner design one can only trade nitrogen-oxides against CO contents as demonstrated with the Tay and the JT8D values. The NO_x level could be roughly halved to about 30 % of the ICAO limit, by introducing a staged combuster, which of course has its price. However, this option will only be chosen when taxes or regulations force the operator to do so.

The new engines, some of which may not reach the production stage, are certainly one essential feature for any new aircraft in the 100-seater bracket. Thus development schedules are going to be interlinked.

IV.4 Structural Design

Structural pre-design emphasized aside from a high structural design life in hours and cycles, solutions, with low production cost, good corrosion resistance and ease of maintenance. New metallic materials have been included in the selection process which led to the exclusion of aluminium lithium as well as any metallic composite. For the envisaged application, material and production cost quickly preclude any possible weight reduction whenever the extra cost exceeds $ 600 per kilogram saved in the basic structural weight.

This ratio assumes that the material decision still can be fully integrated into the aircraft design with all its snowball effects on design weights, thrust and even wing size etc. Furthermore any material modification must lead to a benefit for the customer of about the same amount as is expected for the manufacturer. That is the lower DOC basically possible with the lighter structure must not be compensated more than 50 % by it's higher component cost.

A long in-service experience with carbon and glass fibre composites even for primary structures led to detailed studies for new structural elements. Possible weight savings were checked against various production processes, tooling concepts and material properties to find balanced solutions. Studied applications are summarized in fig. 26. For the wing box the final decision has not been taken, which indicates the high risk still involved in spite of the successful design, manufacture and static test (fatigue still running) of a full scale test box (fig. 27). The blade-stiffened monolithic wing box panels, integrated with metal and CFRP ribs and spars to a fuel-tight integral tank allow to simulate load introductions from engine pylon and flap supports along with normal air loads and the wing/fuselage joint. Average stress levels of 3.5 ‰ have been reached in the lower panel at nominal gust load

The sensitivity of cost efficient CFRP structures is represented in fig. 28. The acceptable target upper limit is given with $ 600/kg. For the actual structure, estimates still vary considerably between optimistic and realistic assumptions. With the high material cost any correction or strengthening of the CFRP structure not only decreases the number of kilograms saved (to the left), but simultaneously increases the incurred cost. Whereas the lower curve gives the effect of reduced weight savings on otherwise fixed cost the upper line includes the extra cost for manhours and material when e.g. more layers than expected are needed.

The overall weight situation of the Regioliner does not show big improvements in spite of all the assumed CFRP application. Fig. 29 gives guesstimated explanations for that result. Several items like fuselage volume and pressure, thrust/weight ratio and especially wing planform add up to increases in empty weight per passenger seat, which hardly can be compensated by new material application and engine technology.

IV.5 System Concepts

After lengthy trade-off studies and airline contacts the basic system approach for the new family just below the A320 shows strong similarity not for lack of ideas, but for the sake of commonality with the Airbus type (fig. 30).

The advanced flight deck features large displays and side stick controllers linked to integrated avionic computers of the full fly-by-wire system with mechanical back-up on two axes. The flight management is standard integral part of the autoflight system. The centralized maintenance system forseen could easily be expanded to include engine and APU health monitoring.

Design studies into the cockpit arrangement have led to ergonomic solutions with excellent visibility, 6 large CRT screens or LCD flat panels and two MCDU on the center pedestal with extra space for customer options like printer and ELS (fig. 31).

What airlines like to see in a new aircraft is not always what they are willing or able to pay for. Therefore detailed trade-studies are made to find an avionic solution which starts at rather low cost yet adequate performance which, if necessary, could be up-graded in capability to say CAT III A or B.

Three solutions have been analyzed as to weight, volume and cost differences (fig. 32). They also differ in redundancy and hence dispatch reliability, but the essential question remains their capability to be up-graded and the then incurred cost. Obviously the final decision can only be taken with launch customers and their preferences clarified.

V. Conclusions

The combination of advances in aerodynamics, engine, structure and system design offers a solution with clear improvements in

- fuel efficiency (15 and 30 %, fig. 33),
- operational flexibility
- passenger and servicing comfort
- payload/cargo and range improvements and
- low noise, low emissions

worth while the effort to start with an all new design. The above mentioned improvements are offered at Operating Cost levels even slightly improved over competing designs although minimal DOC were not the major target in the optimization process as outlined before (fig. 34).

While the fine tuning process will continue until design freeze the overall program timing becomes crucial.

The final picture (fig. 35), an updated version from figure 5 shown above, indicates options and ideas pursued by other aircraft manufacturers using derivatives to respond to the obvious market need in that capacity range of 90 to 130 seats.

With the replacement pressure peaking around 1995 the market share for an all new product deteriorates with every year entry-into-service is postponed and major replacement is forced into derivative solutions available in time.

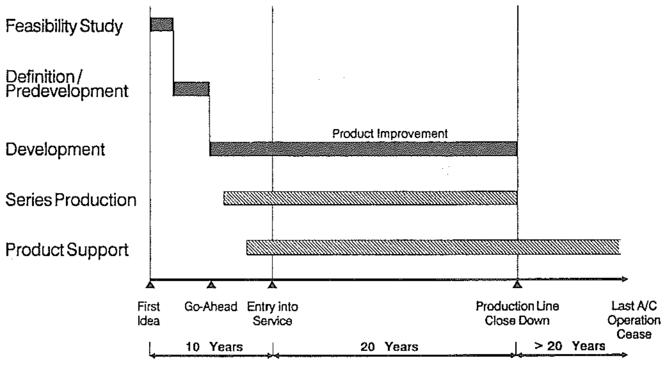
References:

[1] DGLR B. Fischer, "Projektdefinition eines Regionalflugzeuges zwischen Markt und Möglichkeiten", Paper 89-115, Annual DGLR Conference, Oct. 1989

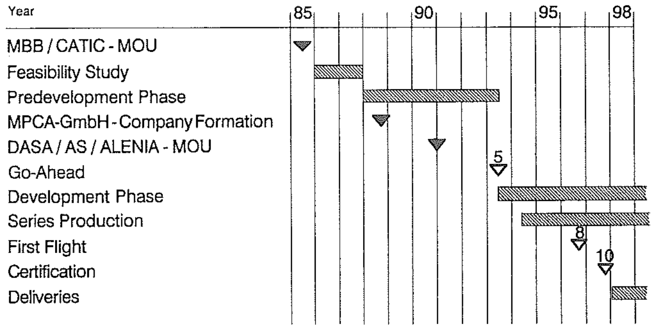
[2] AIAA B. Fischer, "Configurational Repercussions of New Technologies in the Design of a Regional Airliner", AIAA-89-2022, August 1989

Figures:

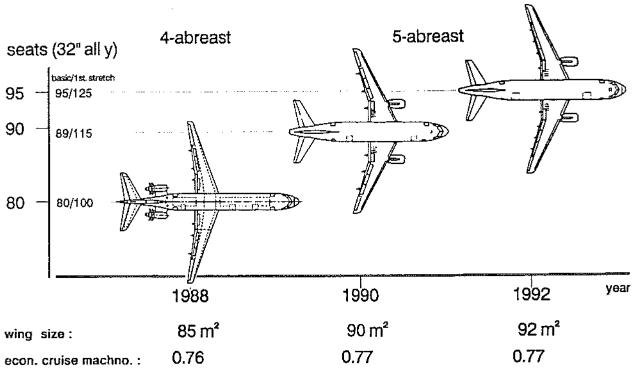
Typical Project History **Fig. 1**



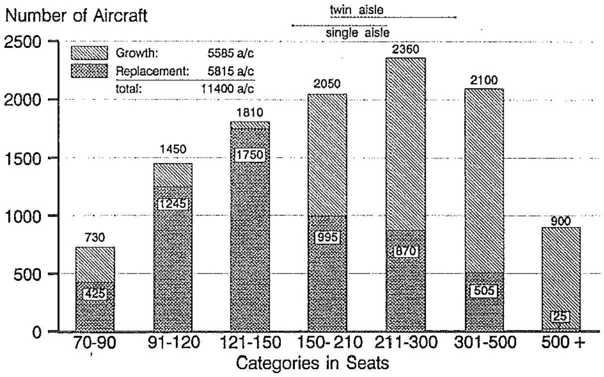
Programme Schedule - MPC75/DAA/Regioliner **Fig. 2**



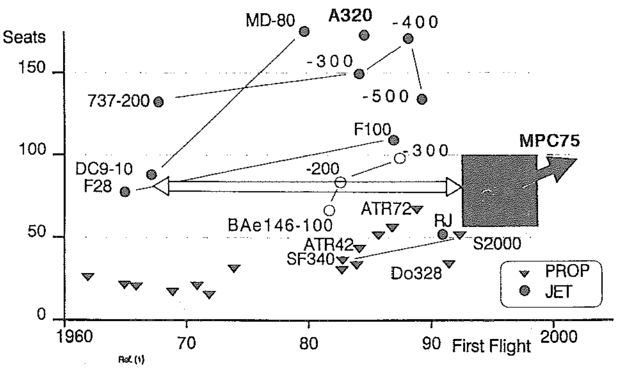
Project Evolution **Fig. 3**



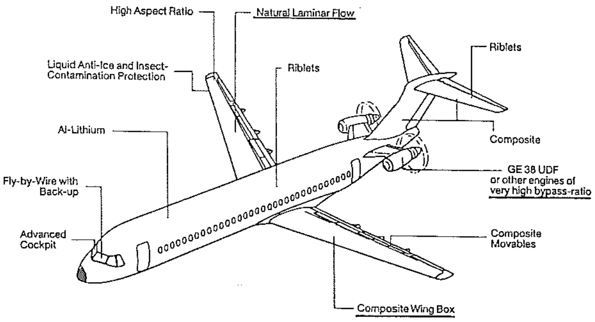
Market Needs (1992-2011) **Fig. 4**



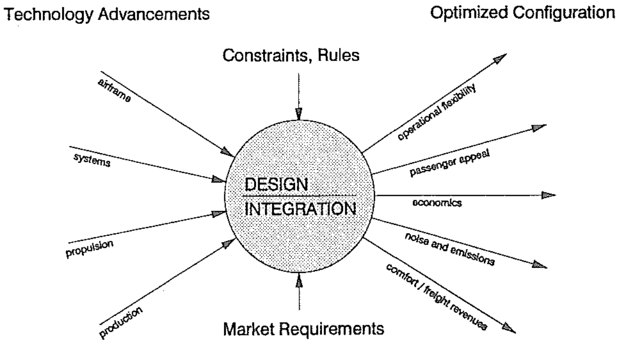
The Logical Step **Fig. 5**



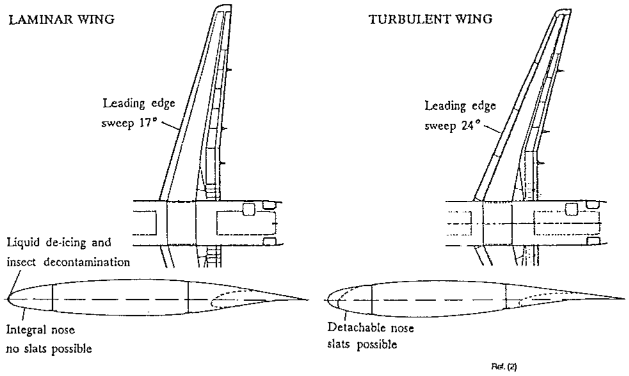
Advanced Technology Options **Fig. 6**



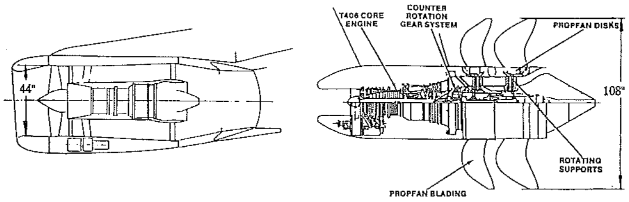
Factors influencing Aircraft Design **Fig. 7**



Wing Design Features **Fig. 8**



Propfan vs. Turbofan Propulsion System **Fig. 9**



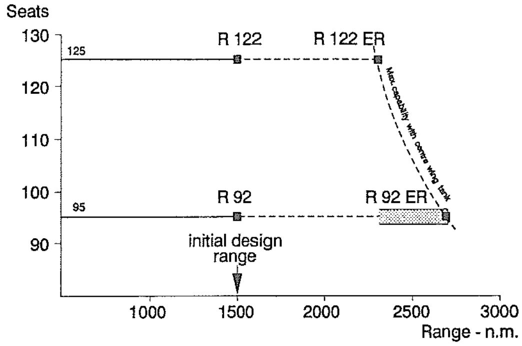
Installed T.O. thrust M = 0.2, ISA, SL	9200 lbf	+ 38 %	12700 lbf
Cruise thrust M = o.75, 35 K	2420 lbf		2450 lbf
Cruise SFC	0.64 lb/lbf/h	- 20 %	0.51 lb/lbf/h
Propulsion weight incl. nacelle	3630 lb	+ 20 %	4350 lb
incl. pylon	4020 lb	+ 38 %	5560 lb

Ref. (2)

Design Requirements and Objectives **Fig. 10**

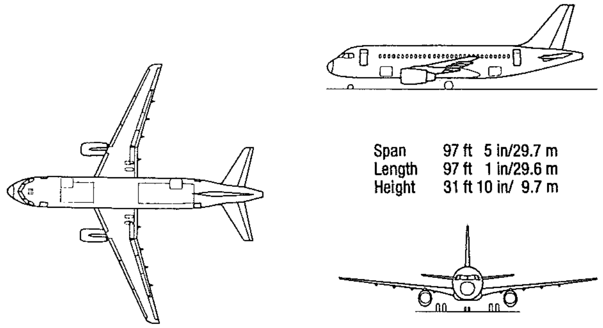
Mission	95/125 seats at 32" Pitch, comfort level better than MD80 1500 n.m. range with full payload Mach 0.77 cruise speed Extended range capability up to 2300 n.m.
Performance	Cruise altitude - Initial 35000 ft./Max. 39000 ft. FAR take-off distance at SL, ISA, MTOW - 5000 ft. ≤130 kt. approach speed
Ecology	Noise better than "John Wayne" limits (4dB below Stage III) Emission - 50% of ICAO levels in NOx
Economy	Seat-mile costs better than present-day 100 seater

Family Concept - Regioliner **Fig. 11**



General Arrangement - R 92

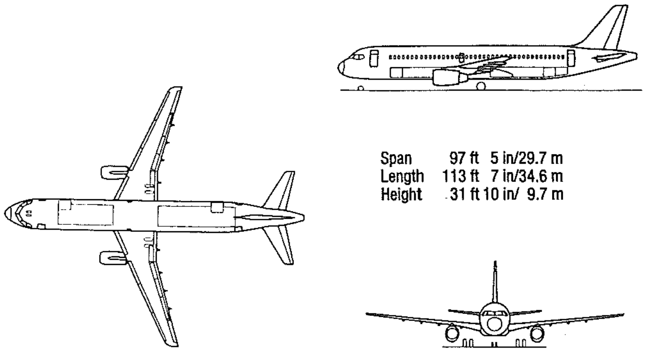
Fig. 12



Span	97 ft 5 in/29.7 m
Length	97 ft 1 in/29.6 m
Height	31 ft 10 in/ 9.7 m

General Arrangement - R 122

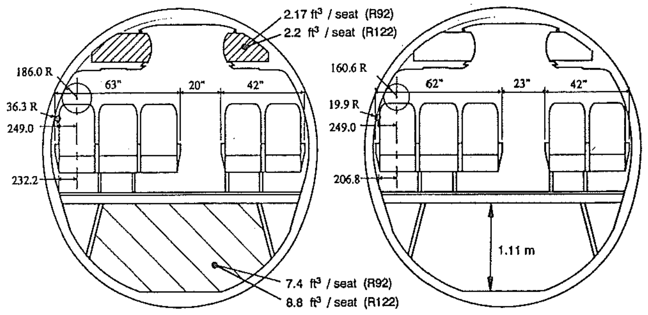
Fig. 13



Span	97 ft 5 in/29.7 m
Length	113 ft 7 in/34.6 m
Height	31 ft 10 in/ 9.7 m

Cross Section

Fig. 14



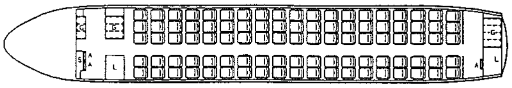
Standard layout

Optional layout
reduced clearances, 62" triple seat, 23" aisle

Cabin Layout - All Tourist

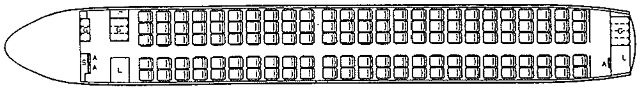
Fig. 15

R 92 95 seats



32 inch pitch

R 122 125 seats

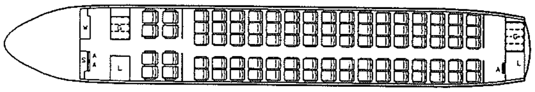


32 inch pitch

Cabin Layout - Mixed Class

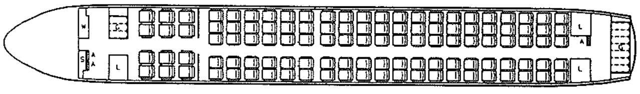
Fig. 16

88 seats



R 92 8 First class 36 inch pitch — 80 Economy class 32 inch pitch

112 seats



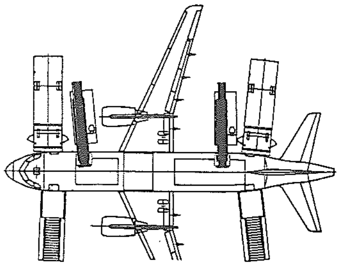
R 122 12 First class 36 inch pitch — 100 Economy class 32 inch pitch

Accessibility/Serviceability

Fig. 17

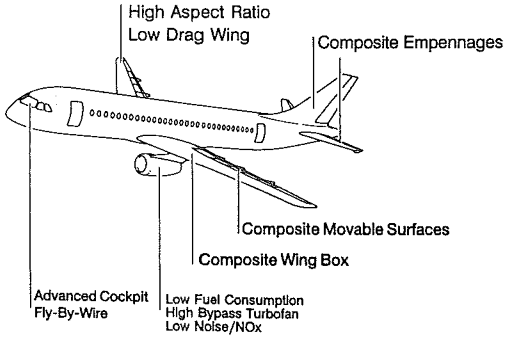
- Passenger and service doors at front and rear end
- Integral airstairs available as an option
- Separation of servicing activities from passenger embarkation/disembarkation
- Ease of galley servicing and cabin reconfiguration
- Good accessibility for servicing activities
- Centralised Maintenance System (CMS) for rapid troubleshooting
- Ease of on-line maintenance

Full main base turnround in 25 minutes



Technology Targets Pursued

Fig. 18

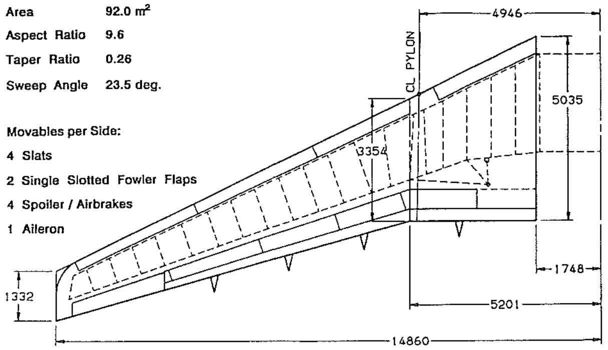


Wing Concept

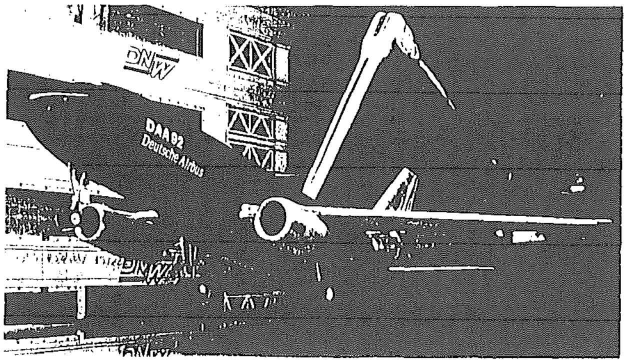
Fig. 19

Area	92.0 m²
Aspect Ratio	9.6
Taper Ratio	0.26
Sweep Angle	23.5 deg.

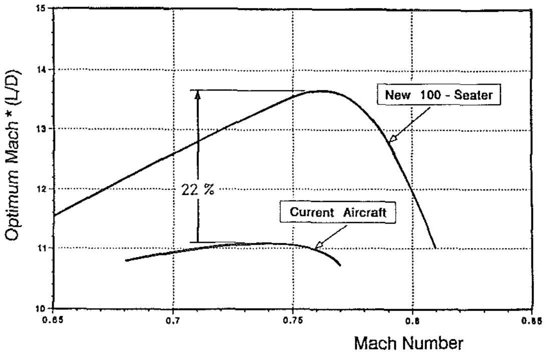
Movables per Side:
4 Slats
2 Single Slotted Fowler Flaps
4 Spoiler / Airbrakes
1 Aileron



Wind Tunnel Programme Fig. 20

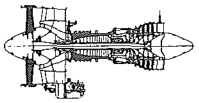


Achievements Fig. 21

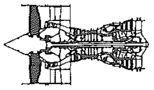


Engine Options Fig. 22

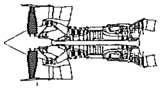
Allison GMA 3014
- 14,000 - 19,000 lb SLST
- Fan diameter 55 in.
- Compressor based on T406



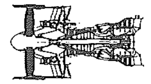
CFM International CFM 88
- 15,000-20,000 lb SLST
- Fan diameter 55 in.
- Compressor based on M88



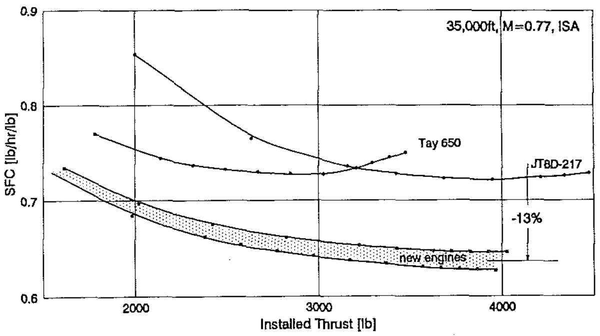
BMW Rolls-Royce BR715
- 14,000 - 20,000 lb SLST
- Fan diameter 53 in.
- Compressor based on V2500



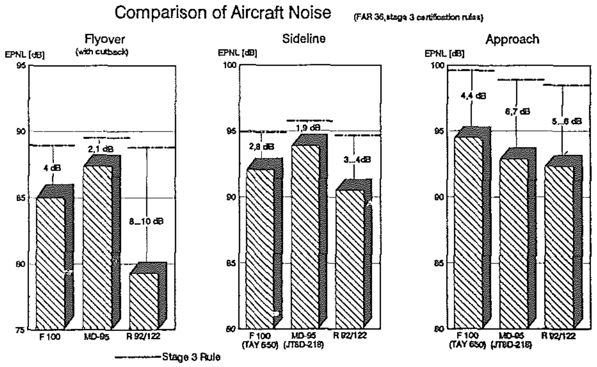
MTU/Pratt & Whitney RTF-180
- 15,000-20,500 lb SLST
- Fan diameter 52 in.
- Compressor based on EJ200



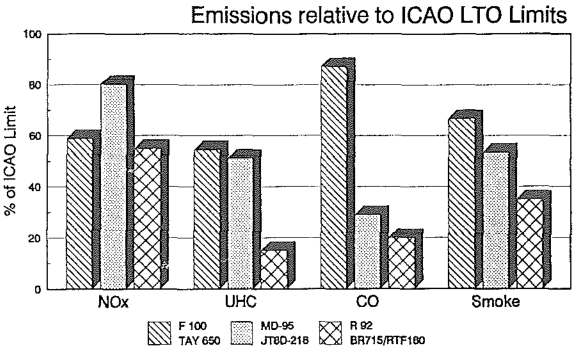
SFC Improvements Fig. 23



Noise Fig. 24



Emissions Fig. 25



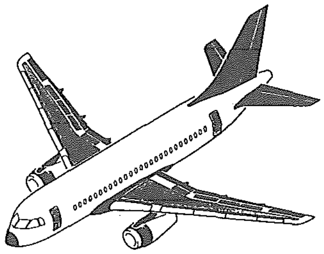
Composite Application Fig. 26

Further to composite material applications shown, major additional components include:

- Landing gear doors
- Floor panels

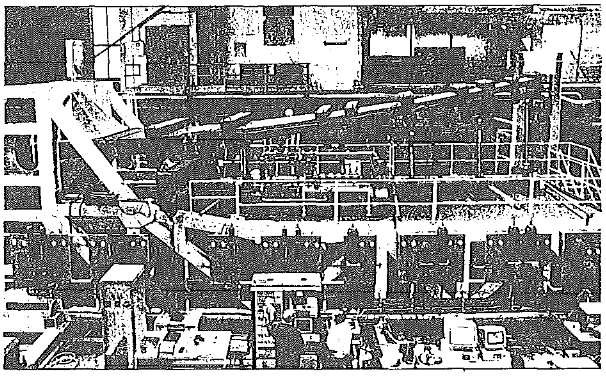
▇ Confirmed

▨ Confirmation pending

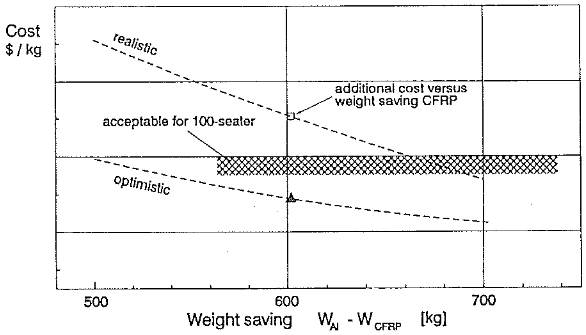


Extensive use of advanced composite materials saves approximately 20% weight over conventional metallic components

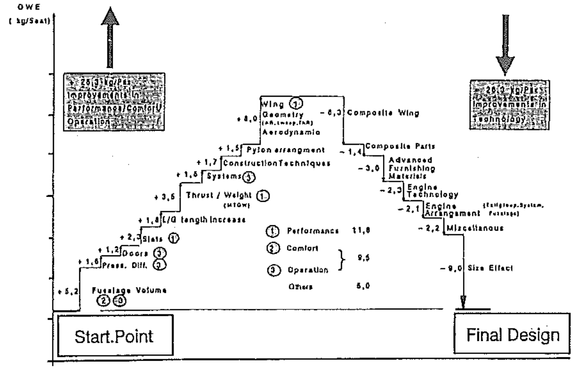
CFRP Wing Box Test Fig. 27



CFRP/Aluminium Wing Box Cost Comparison Fig. 28

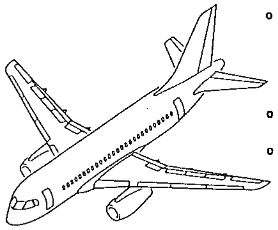


Weight Situation Fig. 29

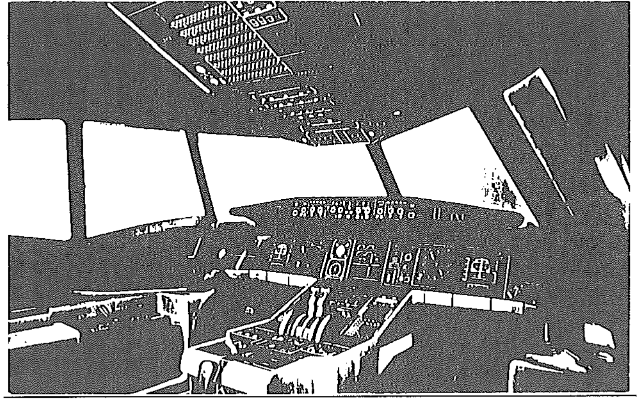


System Concepts Pursued Fig. 30

- o High Commonality with Airbus family
- o Target: Crew cross-qualification A320
- o Advanced Flight Deck
- o Large LCD displays (flat panel)
- o Side-Stick controllers
- o Integrated Avionics computer cabinets with line replaceable units
- o Flight Management System Standard- Integral part of Auto-flight System
- o Fly-by-computer/Fly-by-wire
- o 2 axes mechanical Back-up
- o Engine and APU health monitoring
- o Centralized Maintenance System
- o "Smart probes" for simplified air data system
- o Cabin Intercommunication Data System



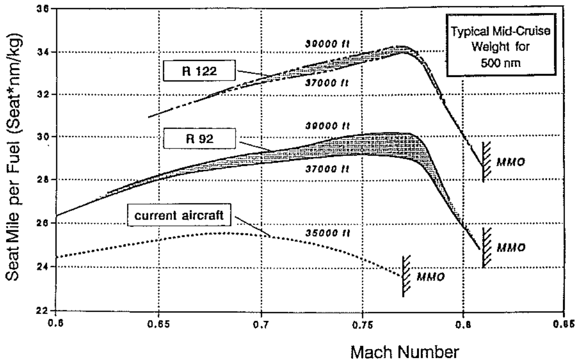
Cockpit Layout Fig. 31



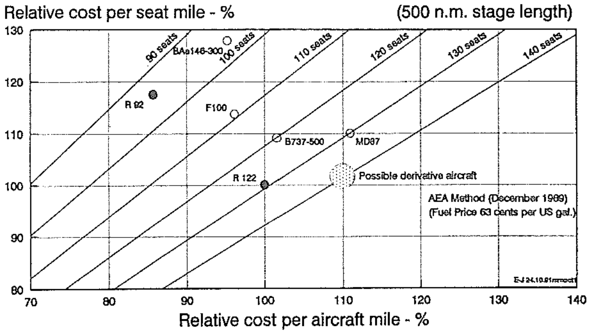
Avionic Options Fig. 32

		General Aviation	Transport Aircraft ARINC 600 LRU Avionics	Transport Aircraft ARINC 600/650 Integrated Modular Avionics
Reference Aircraft		DO 328, Canadair RJ, Saab	A 320/ F 100 Type	B 777 / Future Aircraft
Operational Functions		CAT III A Limited Flight Management (area navigation only) No BFE sensors	CAT III B Full Flight Management (vertical modes incl.) BFE sensors (ARINC)	CAT III B Full Flight Management (vertical modes incl.) BFE sensors (ARINC)
Growth Capability		Low	Medium	High
Weight	Cockpit	base	+220 Kg	+200 Kg
	E/E bay	base		
	Installation	base		
Volume	ATA 22/31	base	+40 MCU	as base
	ATA 23/34	base	+45 MCU	+25 MCU
Reliability (system MTBF)		90h	90-100h	175h
Unconfirmed removal ratio		0.4	0.4	0.6-0.9
Dispatch Reliability		low	medium	high
Maintenance Cost		high	medium	low
Customer Handling		Commuter Standard	Airline Standard	Airline Standard
Acceptance	Airline Operator	bad	good	good
	Commuter Operator	good	low	low

Fuel Economy Fig. 33



Operating Costs Fig. 34



Competition Scenario Fig. 35