CHALLENGES IN INTERNATIONAL CO-DESIGN AND DEVELOPMENT OF A NEW FAMILY OF AIRLINERS

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Abstract

This paper is explaining the differentiating factors of the new Fairchild Dornier 728JET Family of Airliners. Differentiating here is not only limited to the design and the capabilities of the aircraft itself, but also new views to the market as well as the way how it is designed, manufactured and managed are included. General approaches to integration, project and supplier management are discussed. This shift of the scope of work has an influence on the tools being used in the design process and on the required qualifications of the design team and the individual engineer who will be touched as well.

1 Historical Background

In the 1950's, the world's airline industry went through a major revolution - commercial jetliners have been introduced like the Comet, the Boeing 707 and later the Douglas DC-8. The speed of these aircraft doubled the productivity of the airlines operating them, spelling the demise of the large turboprop airliners of that day.

Forty years later another revolution began, again involving jets. This time, it was the emergence of the small regional jet. Now it is driven more by passenger demands but again the regional jet is changing the way the airlines operate. Passengers have got used to fly in jets and it no longer matters that one or more legs of their journey may only be 250 to 300 miles with only 30 or so passengers.

This is clearly reflected in Fig. 1. In 1989, a total of 191 50-seat aircraft were ordered (worldwide) of which 100% were turboprops, only eleven year later, in 2000, 50-seat orders peaked at 445 of which 91% were jets.

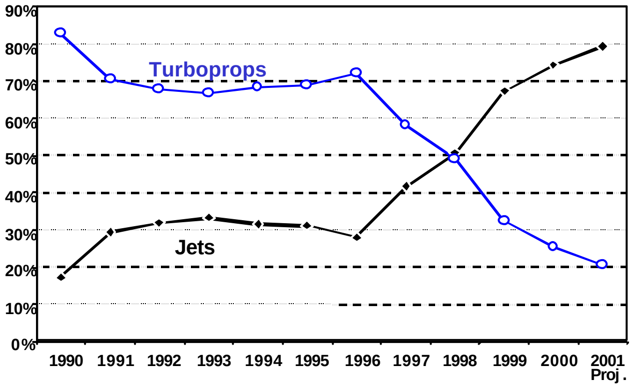

Fig. 1 Regional Aircraft Deliveries 30 – 110 Seats

2 Market Forecast and Preconditions of future Regional Airplane Success

Now today's technology has to be used to build an aircraft which not only meets the demand of the traveling public for seamless comfort to bigger airliners, but also meets the needs of the regional airline operator for high productivity in terms of range / payload capability, high reliability, reduced pilot workload and all that at competitive seat mile economics.

Therefore, the regional jet phenomenon is more evolutionary than revolutionary. So far, the first generation of so called regional jets are being used primarily to expand the role of turboprops rather than fully exploiting the capabilities of a modern regional jet airliner. They are each conversions of a former business jet fuselage or turboprop fuselage or aircraft. The capabilities of the first generation regional jets are simply being used to allow them to increase the frequency of the feed to the hub or extend the spoke to more distant secondary and tertiary airports.

However, the next generation of regional airliners will be regional airliners, not merely "regional jets." The first and most important of the new capabilities of these true small airliners is the capability to create market fragmentation. These new airliners, seating 70 to 110 passengers, can be used to serve long thin routes between a major hub and smaller market (see Fig. 2), and to serve short to medium point-to-point service between secondary cities.

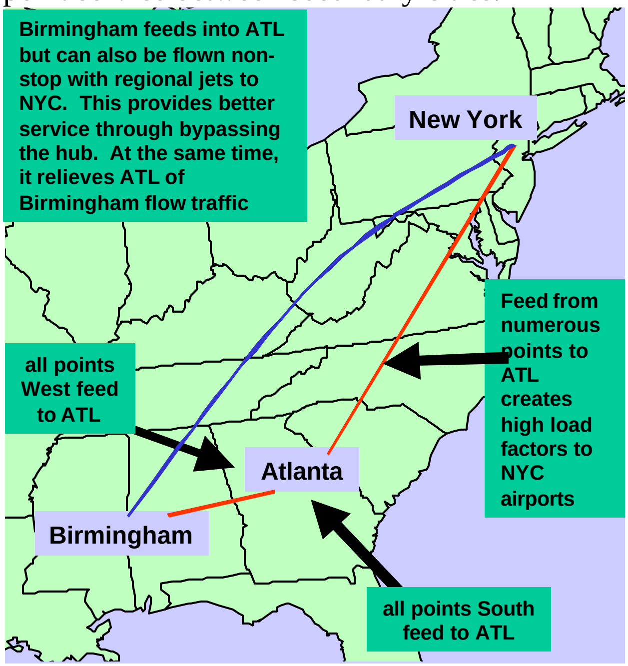

Fig. 2 Market Fragmentation – Hub Bypass and Relieve

All of this is predicated on well-built, low-cost aircraft. With regional carriers unable to fly large numbers of passengers long distances, and thus charge higher prices, the aircraft they fly have to be affordable to purchase and both reliable and economical to operate while still meeting the high standards for low noise and low emissions.

As a manufacturer, we can control the acquisition costs and, to a large extent, the operating costs of those aircraft (see Fig. 3).

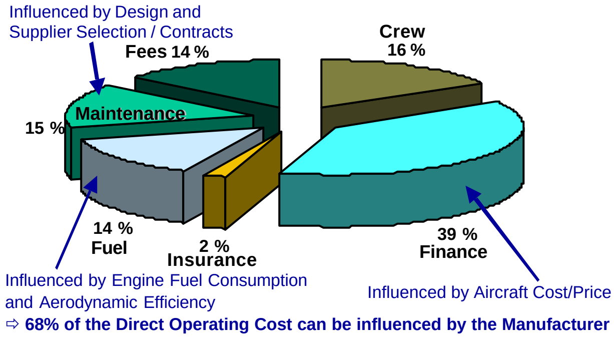

Fig. 3 Influence of the Aircraft manufacturer on the direct operating cost

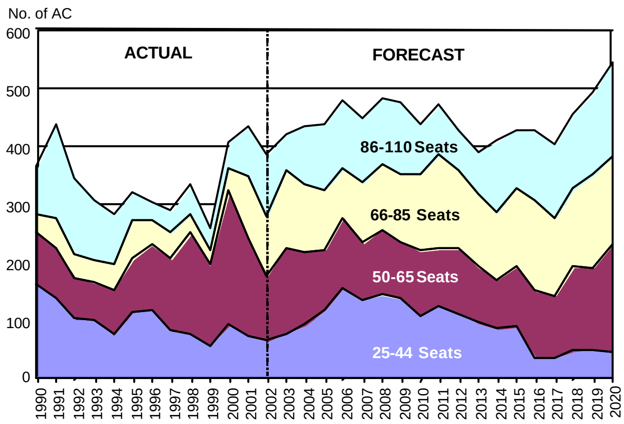

Fig. 4 Market growth by size category

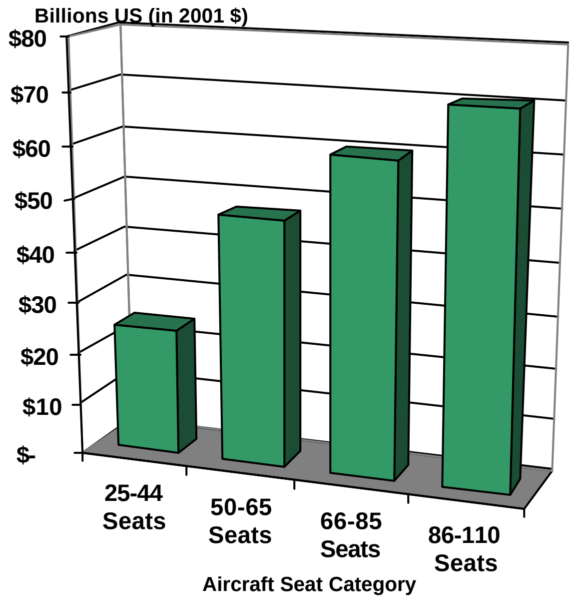

Fig. 5 Total Regional Jet Market Volume

The growing market for regional jets and regional airliners is currently projected to be around 9,100 new aircraft in the next two decades, with these aircraft falling roughly into four size categories--30 to 40 seats, 50 to 60 seats, 70 to 80 seats and 90 to 100s seats.

This is driven by both replacement of older Turboprops and capacity growth leading to a estimated total purchase volume of more than 200 Billion US$ (2001 economic conditions).

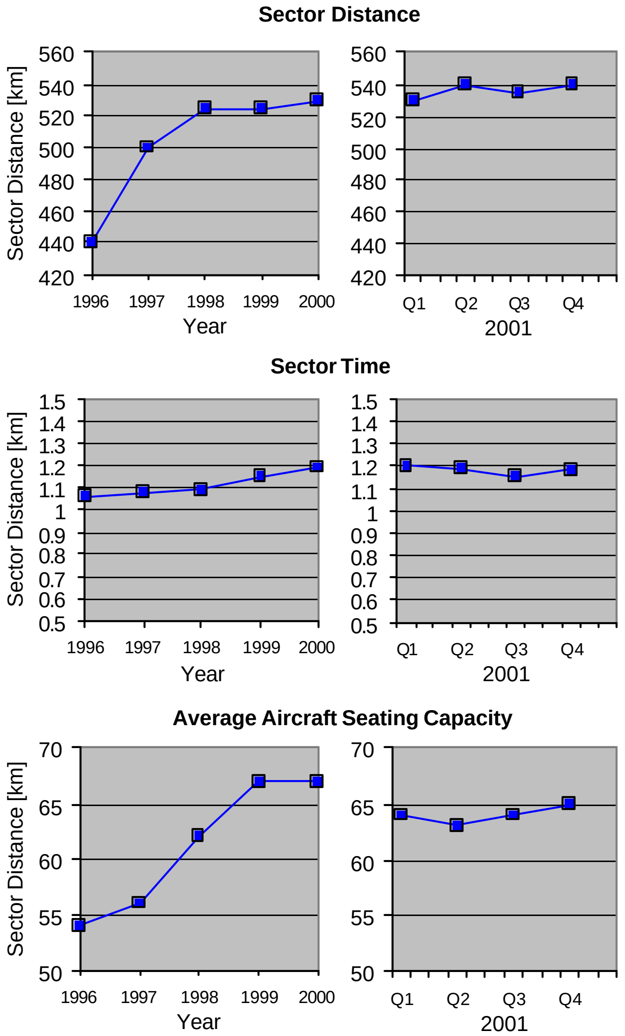

Fig. 6 Development of the regional market in Europe [2]

Fig. 6 is clearly showing some of the driving trends for the regional airline industry in Europe [2]. Average sector distance and time has been growing 20% in the last five years and the average aircraft size went up about the same amount. On top of this each airline has some special requirements for fairly long routes – be it for weekend charter operation or in their regular network.

3 Development Initiative at Fairchild Dornier

In 1998, Fairchild Dornier made the decision to develop a new family of next generation, wide body, low-wing regional airliners, creating the 728JET family of 70 to 110 seat airliners, currently the 728JET and the 928JET.

To create this new type of jet airliner with low acquisition price, low direct operating cost, seamless comfort to passengers and acceptable environmental impact to local communities, Fairchild Dornier is turning to new technologies.

As the capital cost of the aircraft has to be kept low, design and production cost of the aircraft must be kept low. A major element in reducing production cost today is extensive use of CAD/CAM - computer aided design/computer-aided manufacturing, applied not only to piece parts and components, but also to assembly. Driven mainly by cost, there is a shift from application of sophisticated technology in the in the aircraft itself to innovative design and production.

3.1 Starting from a Clean Sheet of Paper

Starting from a clean sheet of paper for the aircraft family as well as for growing the company offered several unique opportunities:

For the aircraft:

- Selection of the right cabin cross section and size.
- Selection of the right wing size and airfoil layout
- Selection of the right engine
- Selection of the right avionics package reducing pilots workload
- Application of digital design technologies
- Design for automated manufacturing
- Design for tight tolerances and long service life

For the company:

- Building up a lean company
- Relying on risk sharing partners with end item accountability allowing for fast

and flexible ramp up of resources and knowledge base

- Investment in production facility simulation and layout
- Investment in advanced production technologies

3.2 Design Decisions

As mentioned earlier, the focus has to be on mainliner comfort and performance at commuter aircraft operating cost. Fig. 7 is summarizing some key design targets [1].

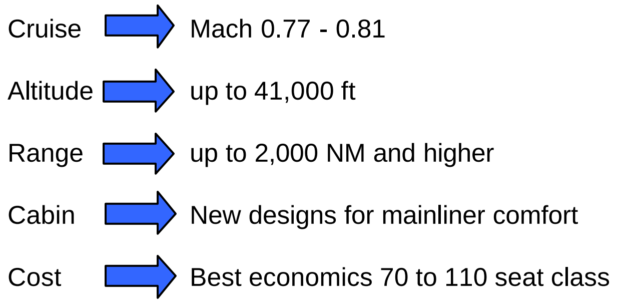

Fig. 7 Key Regional Jet Design Targets

The whole design of the 728 Family started from the cabin cross section onwards. Sensitivity studies considering mass and drag impact of different seat layouts (4- vs. 5-abreast) and diameters have been prepared.

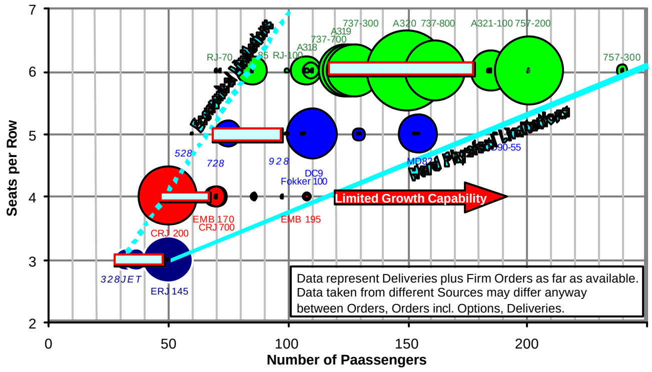

Fig. 8 Comparison of Seats per Row versus Passenger Capacity for Existing Aircraft (size of bubbles represent number of delivered aircraft)

Fig. 8 supports the decision for a 5-abreast configuration to maximize family growth potential supported by a broader existing experience base for this configuration in the respective aircraft size category. Undoubtfully the resulting bigger cross section will support the comfort aspect, which is desirable to the airlines and passengers, if not bought with higher mass or drag thus increased fuel consumption.

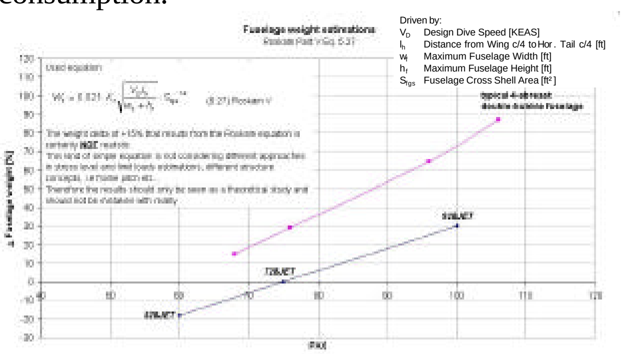

Fig. 9 Comparison of Fuselage Mass using generic design formula for typical modern 4- and 5-abreast Aircraft [3]

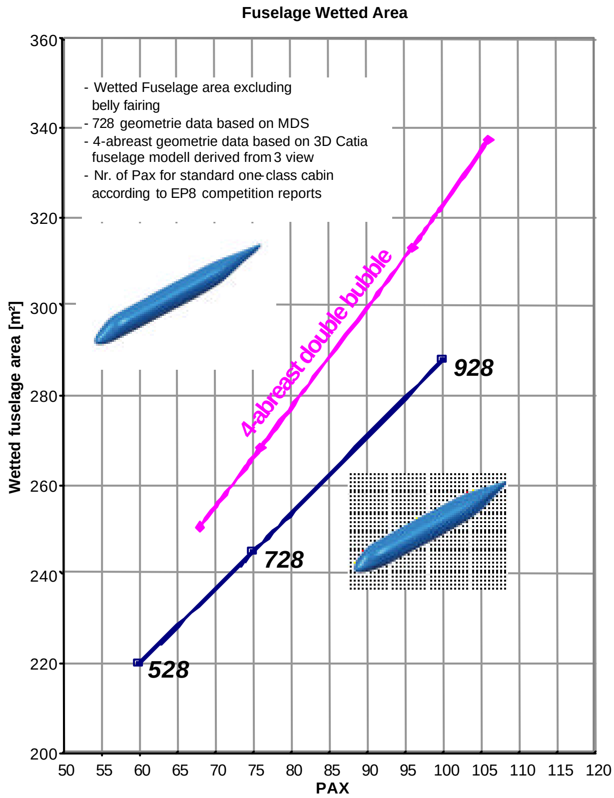

Fig. 10 Comparison of Wetted Fuselage Area for typical modern 4- and 5-abreast Aircraft [3]

A sensitivity analysis for two different families of modern regional aircraft – one 4- and the other 5-abreast for mass, fuselage wetted area and drag (see Fig. 9, Fig. 10, Fig. 11) is showing that assuming same structural design conditions the mass should come out lower as does the drag, mainly driven by the much lower wetted area, with the crossover point clearly being in the 50 seat region.

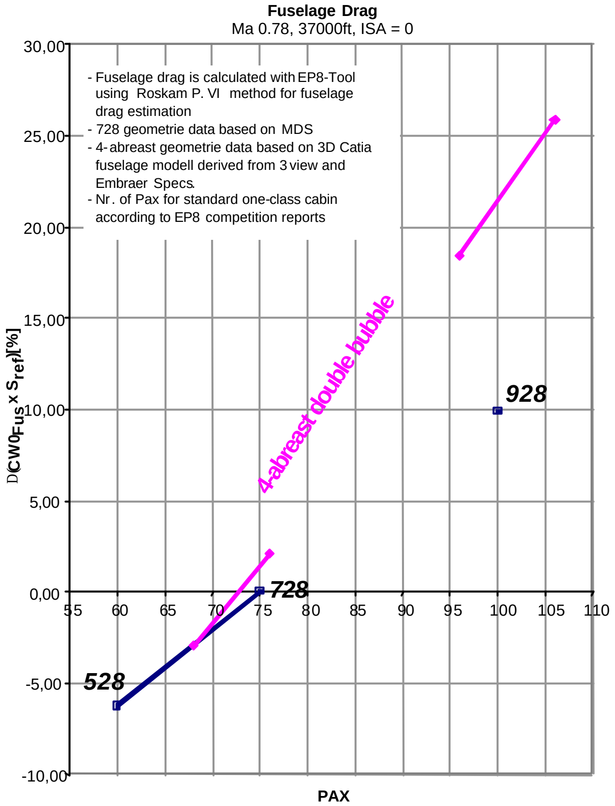

Fig. 11 Comparison of Fuselage Drag for typical modern 4- and 5-abreast Aircraft [3]

Other important parameters are baggage space, turn around times and performance (field and mission). On-board baggage volume is essential for business class passengers whereas sufficient underfloor space for checked baggage is needed for essential for hub feeder services – especially in a transcontinental environment.

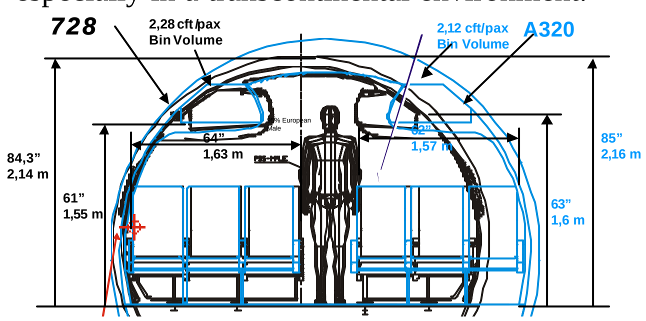

Fig. 12 Cross section comparison of 728 and A320

As the cross section comparison between the 728/928 and the Airbus A 320 Family shows (Fig. 12), the design goal of superior passenger comfort has been met by offering equivalent standing height, similar head clearance, slightly wider seats and more overhead bin volume per passenger.

The other airline requirements beyond customer comfort are related to smooth and efficient operation starting with quick turn around times, competitive field performance and mission range capability.

Ground handling is greatly improved by moving to a wing mounted design allowing accessibility to the rear cabin by full size doors and the additional aft cargo bay. This and the shorter fuselage coming with the four-abreast configuration reduces turn around times to the order of 20 minutes.

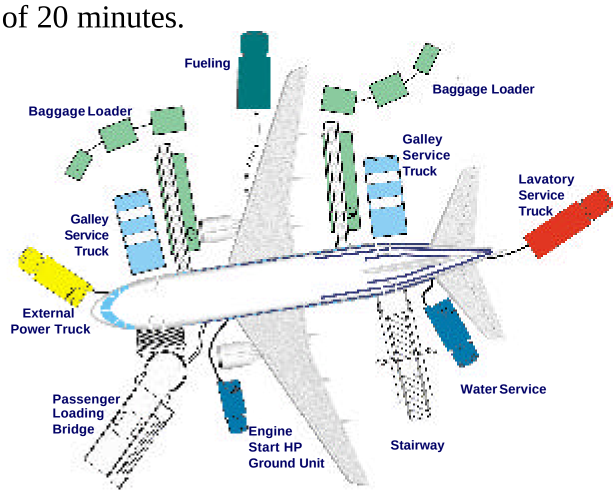

Fig. 13 Ground handling and accessibility

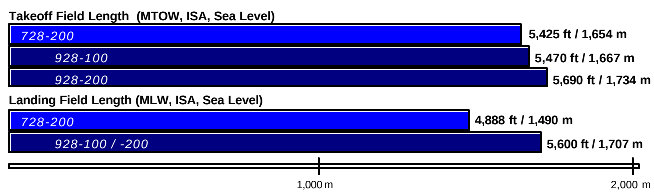

Fig. 14 728 and 928 Airfield Performance

Excellent field performance for 728 and 928 ensuring operation in and out of short airfields (Fig. 14) and superior payload/range performance supports the operators wish to develop new long and thin routes (Fig. 15). The competitive comparison is based on Fairchild-Dornier's methodology using standardised layouts and mission assumptions to harmonise the competing aircraft.

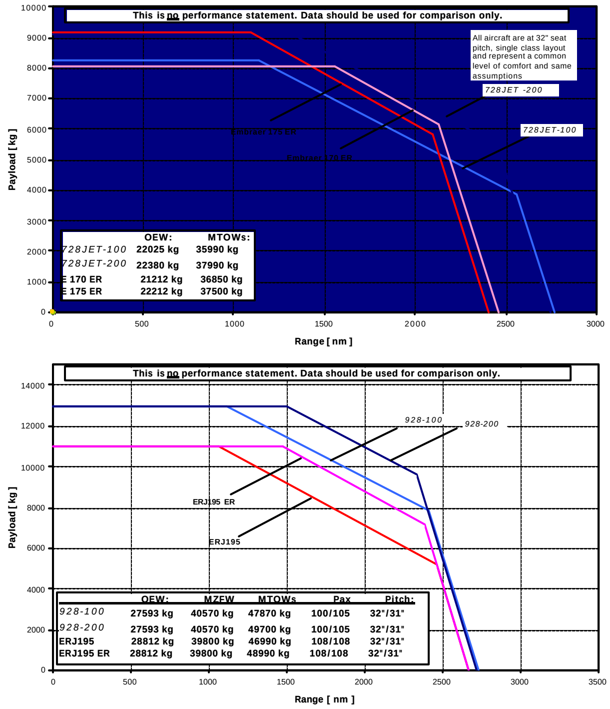

Fig. 15 728 and 928 Mission Performance

3.3 System Technology

Fig. 16 Most modern Cockpit Concept with highly integrated utility management system for reduced workload, increased flexibility and optimized maintenance

For system development, new regional jets need lightweight fly-by-wire systems and highly integrated avionics and utility management systems. These systems not only provide greater control, but also provide a combination of pilot workload reduction, weight reduction and low maintenance, which relate directly to cost savings.

In order to keep development risk low, the digital fly-by wire systems for the 728JET are being "test flown" in an "Iron Bird." This is a full-scale test rig designed physically to allow engineers to "fly" the 728JET systems in a variety of required profiles with actual hardware long before the aircraft is actually build and ready to fly. It can be coupled to the “Engineering Simulator” for closed loop testing of the Flight Control System. This Device was not only used starting in a very early program phase for handling quality testing and system design support but also as an Integrated Avionic Test Bench for checkout of the system and the software as part of the safety of flight and certification evaluations.

Fig. 17 Horizontal and vertical tail on the Iron bird with actuators, simulated surfaces and artificial load system

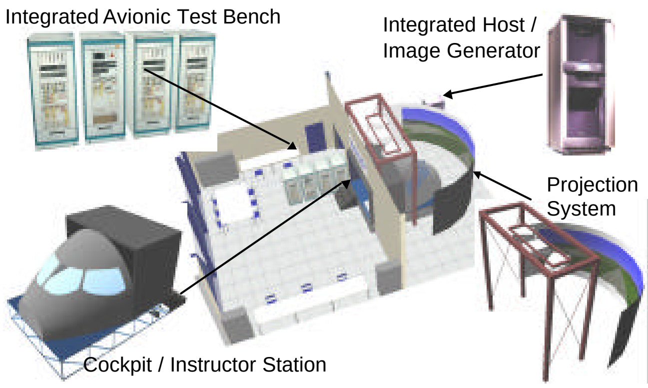

Fig. 18 Engineering Simulator with integrated Avionics test Bench

Along with the Iron Bird, a Digital Mock-Up is used, a CATIA-based visualization and integration program which allows the design of the aircraft in virtual reality. By using computer link-ups, this allows us to coordinate the design efforts being undertaken by a worldwide network of partners/suppliers.

3.4 Design Technology

The whole aircraft design and integration has been performed in a 3-dimensional Digital Mock-up Unit (DMU) in CATIA. Not only the designers at Fairchild Dornier used this tool but all supplier-partners as well. Therefore the complete aircraft integration could be done digitally. Based on that model a clash investigation could be performed and the product structure has been developed. This product structure is linked to a SAP R3 system controlling all procurement and production processes.

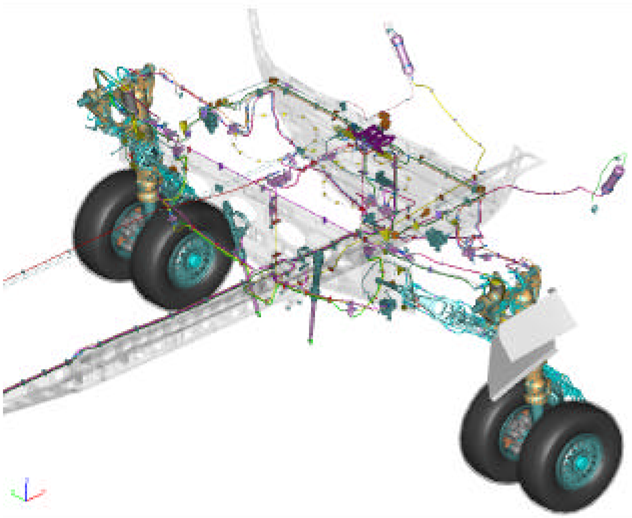

Fig. 19 Main Landing Gear in Digital Mock-up

3.5 Production Technology

The design of the whole assembly factory and the production process was digitally designed in parallel to the design of the aircraft using the 3-dimensional aircraft models in a special simulation environment, which not only allows the geometric layout of jigs but also helps to investigate assembly processes and simulate flow times step by step.

New production methods include flexible tooling for mixed-model manufacturing, computer controlled micro-precision assembly jigs and smart automation.

Fairchild Dornier now has in Oberpfaffenhofen one of the newest riveting robots in the world, made by Brötje. The Brötje riveter is fully automated including drilling holes, sealing, riveting, shaving and quality control as an integrated process for up to 10 rivets per minute with in-process quality inspection.

Fig. 20 728 Family Fuselage Automated Riveter

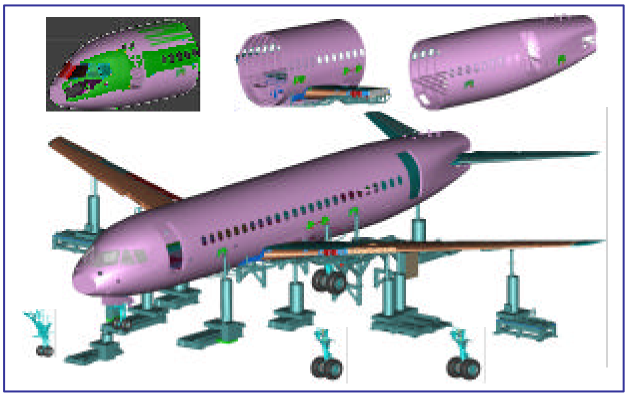

Fig. 21 728 Family Final Assembly Tool Design

Doing so it is joining skin-panel sub-assemblies into lower and upper half-shells that will, in turn, form the aircraft's passenger cabin during final assembly. The whole fuselage production concept is based on preassembled pieces moved on precision tooling designed to be flexible used for all pieces of all family members until it reached the final assembled stage.

A very similar philosophy is applied in the final assembly line where the 0,01 mm tooling precision allows 0.4 mm tolerance for major structural parts thus basically eliminating the need for shims even on the first prototypes.

Fig. 22 728 Family Prototype Final Assembly Line

4 Shifting the Work further into the Supply Base

In this framework the scope of work for the company, the design team and for individual engineers is changing. In former times the prime manufacturer used to do all the detailed design for new products and developed new technologies until they could be applied to new production aircraft. Now this is partially shifted to suppliers building up centers of excellence and becoming risk sharing partners. Instead of delivering parts build to drawings they deliver systems or subsystems designed by themselves.

The relationship in this global community working simultaneously on the same program linked by digital design tools is changing and the focus of management is shifted more to integration, project and supplier management.

From a contractual and organizational point of view this requires very well defined interfaces and work shares, focusing on a minimized number of supplier, ideally only one for each complete system or component including system installations (like hydraulic and fuel lines and actuators for the wing).

The unavoidable changes in a developmental process must be covered contractually in advance to the extend, that changes as part of the design evolution are free of charge, unless loftlines or loads are changed for product improvement reasons.

The statement of work must contain all the design and integration work for a particular system with a minimum amount of required interfaces. If it is not defined that clearly, the

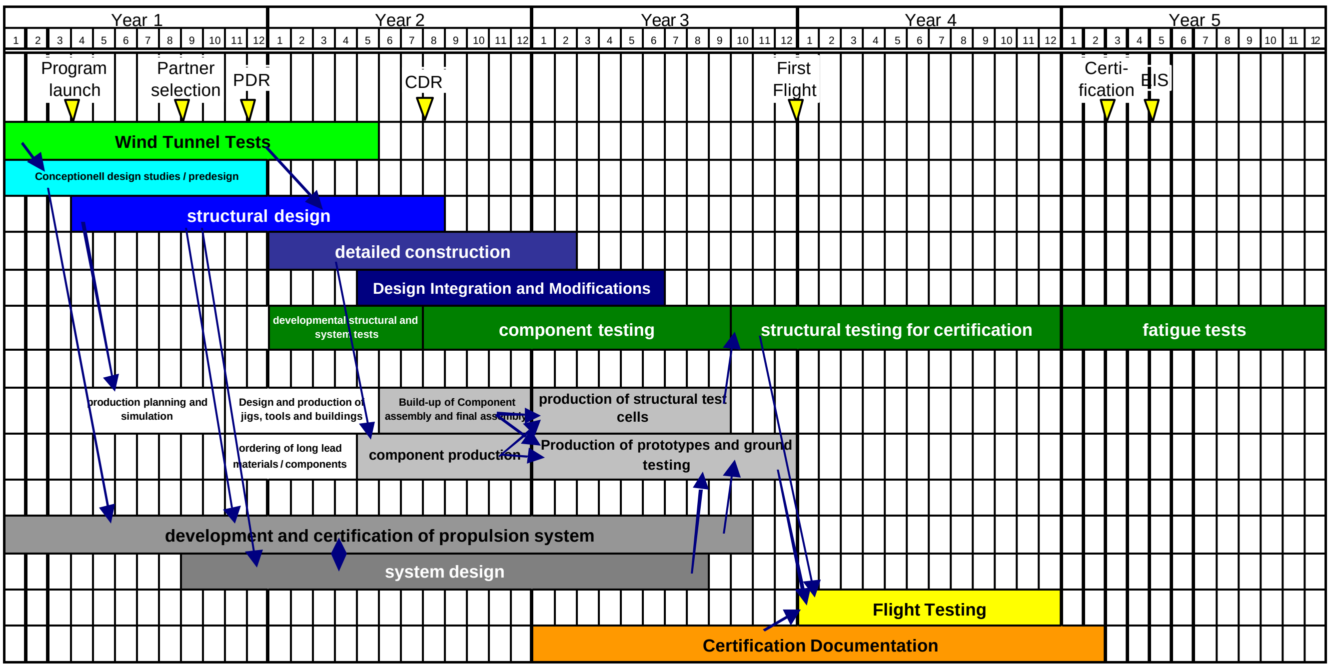

Fig. 23 Typical program schedule with parallel development path and interdependencies

supplier management gets very difficult and the OEM in the end will always be forced to jump in with its own resources to cover issues left open by one of the suppliers – often starting from a disadvantaged point by not having a complete set of system descriptions or certification documents.

For the individual engineer this means the need of a detailed technical background is still very big – maybe even growing – since the groups get smaller but the responsibility of an individual is getting bigger. Additionally management skills are now needed at the working level, where very often the collaboration with supplier partners is being handled. In this environment only a team – internally and with external partners – can be successful.

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[2] Performance January – December 2001, *Regional International. Journal of the European Regions Airline Association, April 2002*, ERA Directorate, 2002

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