Composite Materials in the Airbus A380
- From History to Future -

Jérôme PORA
Airbus, Large Aircraft Division
1 Rond Point Maurice Bellonte
31707 BLAGNAC Cedex, FRANCE

Summary

Applications of composite materials and technologies on A380 are reviewed. Also, the "lessons learned" from the existing fleet. Decision for applications of composite materials is consistent with an evolution within the Airbus family. To step into primary structure with a new technology first time requires special attention and careful preparation, including hardware tests and full-scale manufacturing demonstrators. The Material and Technology down-selection Process used by Airbus is described. Finally the remaining limitations to composite introduction on airframe, such as reliability of cost prediction, are highlighted.

1. A380 : a unique technology platform

Market pressure for a larger aircraft continues to increase. Growth, congestion, economic and environmental factors are driving the need to develop new solutions. Airbus's answer is the A380 family. Airbus forecasts a market of about 1,300 aircraft in the A380 size category over the next 20 years.

By the end of 1999, enough technical detail on the aircraft was fixed to permit the aircraft specification to be presented to potential customer airlines. This has allowed Airbus to make commercial offers since mid-2000 and launch commitments the same year. This will result in Entry Into Service (EIS) of the 555-seat, double-deck A380-800 during 1st quarter 2006, as shown in Figure 1.

As the flagship of the 21st century, the A380 will not only be the most spacious civil aircraft ever built, it will also be the most advanced - representing a unique technology platform from which all future commercial aircraft programmes will evolve.

As the programme enters its final definition phase due for completion by the end of 2001, an array of new technologies for material, processes, systems, and engines have already been developed, tested and adopted.

All technology considered for the A380 is carefully studied to determine its effects over the lifetime of the aircraft, and is proven to be fully mature and capable of delivering long-term benefits before it is selected. Each selection therefore contributes to attaining or bettering the programme targets in keeping with the basic design tenets of reliability, low seat-mile cost, passenger comfort and environmental friendliness.

A number of innovations introduced on the A380 will ensure considerable weight savings despite the aircraft's prodigious spaciousness, and countless tests run to date show that aerodynamic performance of the aircraft will also be significantly enhanced. Better aerodynamics and lower airframe weight reduce the demands placed on engines and translate into lower fuel burn, reduced emissions into the atmosphere, and lower operating costs.

An estimated 40 per cent of the aircraft's structure and components will be manufactured from the latest generation of carbon composites and advanced metallic materials, which, besides being lighter than traditional materials, offer significant advantages in terms of operational reliability, maintainability and ease of repair.

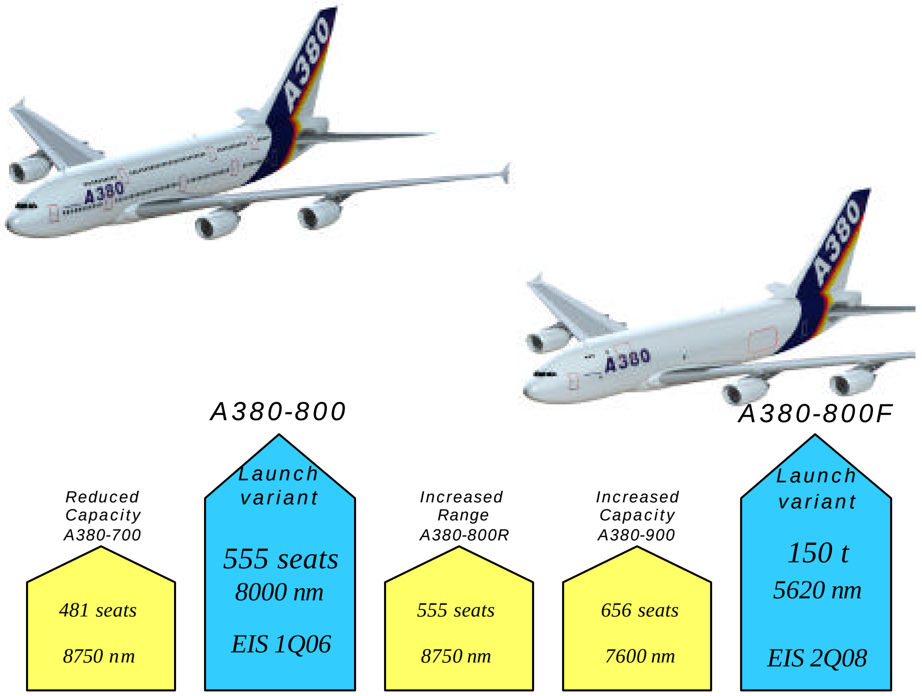

Figure 1: The A380 Family

2. The Material and Technology down-selection Process

A Material and Technology down-selection Process [1] is used at Airbus. Its goals are listed below:

- Deliver a robust structural design and mature materials and manufacturing technologies
- Prepare technical solutions which allow target weights and target costs for the airframe to be achieved
- Keep advanced technologies within the technology evolution at Airbus
- Mitigate risks from initial steps into new technologies
- Support standardisation of structural design and maintenance concepts across all Airbus programmes

In order to achieve these goals, guiding principles have been established:

- Transfer the “lessons learned” from existing Fleet into A380
- Continue Technology Evolution at Airbus
- Take benefit from earlier Airbus Programmes
- Prepare “Right First Time” for series production with demonstrators
- Establish targets for trends of technology parameters versus time

An “Initial Set of Structural Design Drivers” was established in early 1997, as shown on the schedule in Figure 2, giving guidance for a preliminary selection of alternative materials candidates for different sub-components of the airframe. The analysis of materials and manufacturing process costs was an ongoing supporting activity for the evaluation.

In-service experiences with the existing Airbus fleet were reviewed with maintenance experts from airlines. Each of the design solutions and material applications envisaged had to get approval from A380 customers with respect to inspections and repairs. Workshops with airlines are regarded as a key element of the “technology down-selection process”.

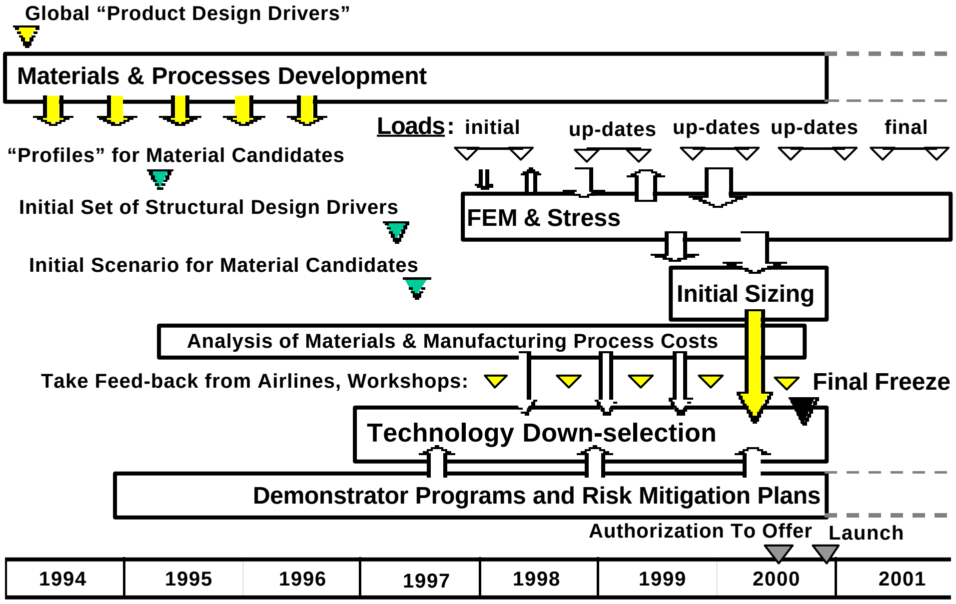

Figure 2: General Material & Technology down-selection schedule of A380

3. The A380 General Structural Design Criteria

Structural design criteria of A380 (Fig.3) highlight the "drivers" for structural design and material selection as explained below:

Aluminium materials loaded in tension are sensitive to the level of load and the type of variation of the load level. For this reason crack growth rate as well as residual strength (when the crack has developed) guides the selection of an appropriate alternative material candidate for Airbus aluminium structures.

Compression loading requires yield strength and, in combination with stability, stiffness plays an important role.

In cases where the structure is prone to damage (e.g. foreign object damage), the design requires damage-tolerant material characteristics.

Corrosion prevention is another important criterion to be considered for the selection of materials & processes, especially in the bilge area of the fuselage, which may be exposed to aggressive agents resulting from different sources.

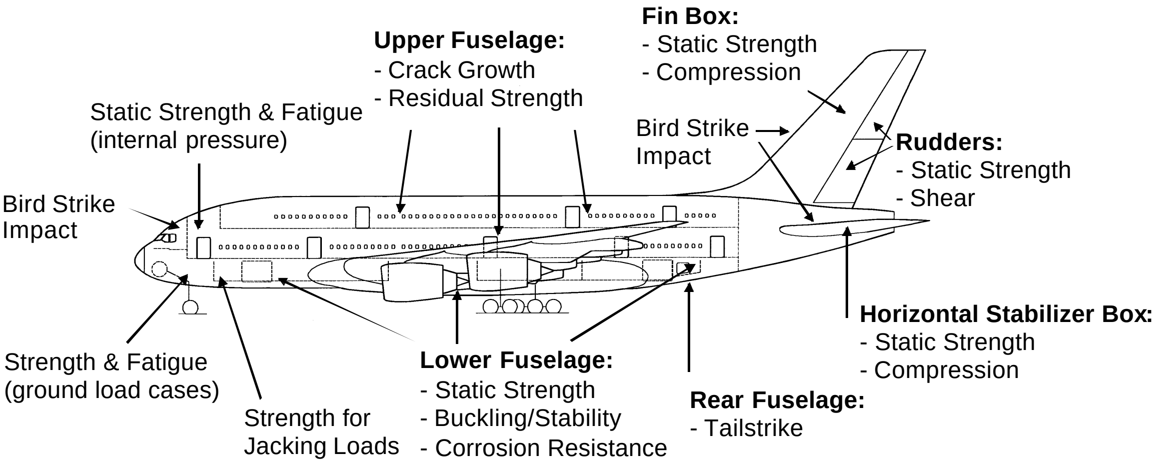

Figure 3: General structural design criteria for fuselage and tailplane of A380

The down-selection process is in essence a learning process, which deliver step-wise refinements of the "initial scenarios for material candidates". Compared to the "initial set of structural design drivers" described above, progress is characterised through better knowledge about loads and load paths as well as stress distribution and elastic deformations. As an example, detailed FEM-model analysis for the connection between the frames and the central section has shown that the choice of a Carbon Fibre Reinforced Plastic (CFRP) central section has reduced significantly the local bending effects at the foot frames due to the increase of central section bending stiffness.

4. Material and Technology developments for A380

Part of the goal is to select the most appropriate material for the specific application, which would lead to the lightest possible structure. For this purpose, composite materials are good competitors, and their use is foreseen on many areas of the airframe. The weight aspect might be in contradiction to another goal: to standardise material applications across the aircraft or the major assemblies: wing, fuselage…. Standardisation plays an important role in manufacture and maintenance over the aircraft's life. So a common understanding of design drivers and maintenance requirements is needed. In parallel, production cost investigations and purchasing activities are also necessary. Thus, material selection is not only driven by structural design criteria.

Figure 4 displays major advanced material candidates, being reviewed on the A3XX project during years the last four years. The material characteristics are in harmony with the above design drivers [2], [3].

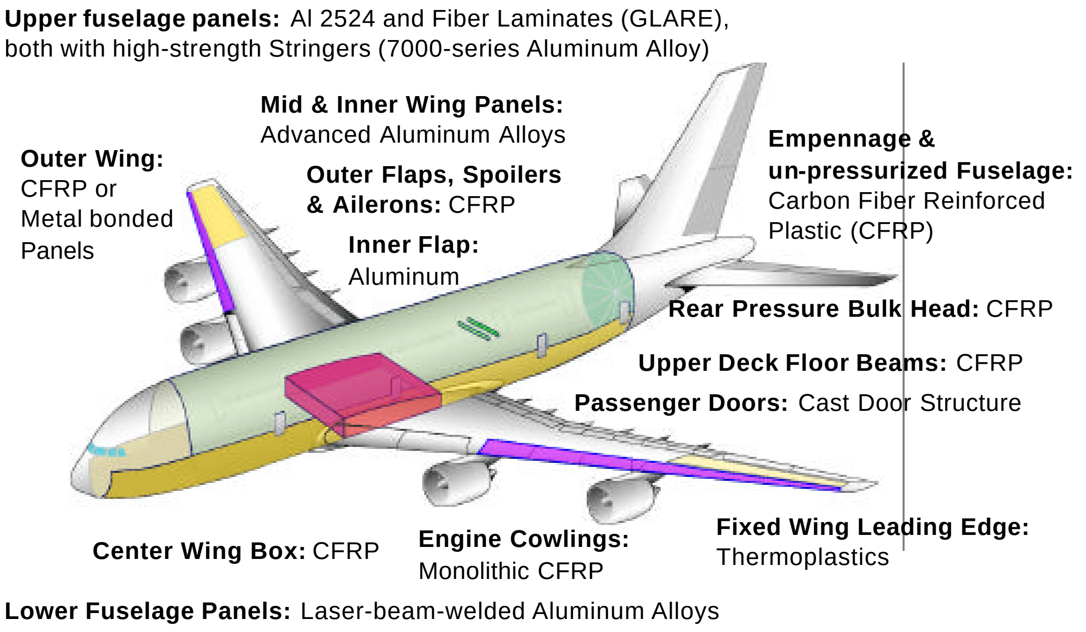

Figure 4: Major advanced material candidates reviewed for A380

5. Continuous Composite Material and Technology evolution at Airbus, and benefit from earlier Airbus Programmes

Inaugural use of a new technology shall proceed step by step, building on experience with earlier Airbus products, as shown in Figure 5 for composites. The behaviour of structures in service depends not only on material performance, but also on design solutions and manufacturing capabilities. A learning process has to be established for new technologies, which allows for optimisation of materials and processes, increasing areas of application versus time.

Due to their mechanical behaviours, design criteria are different for metallic and composite structures. Numerous years of successful experiences at designing metal structure cannot be directly transferred to composite structures. First, composite materials are not isotropic like most metallic alloys. Second, the initiation and growth of damage and the failure modes are more difficult to predict analytically on composites. Due to these complications, the best practices are fully understood only by those engineers that are experienced at designing composite structures. For A380, Airbus benefits from earlier programmes because it was the first manufacturer to make extensive use of composites on large transport commercial aircraft. The A310 was the first production aircraft to have a composite fin box; the A320 was the first aircraft to go into production with an all-composite tail; about 13% by weight of the wing on the A340 is composed of composite materials and the A340/500-600 has CFRP keel beams.

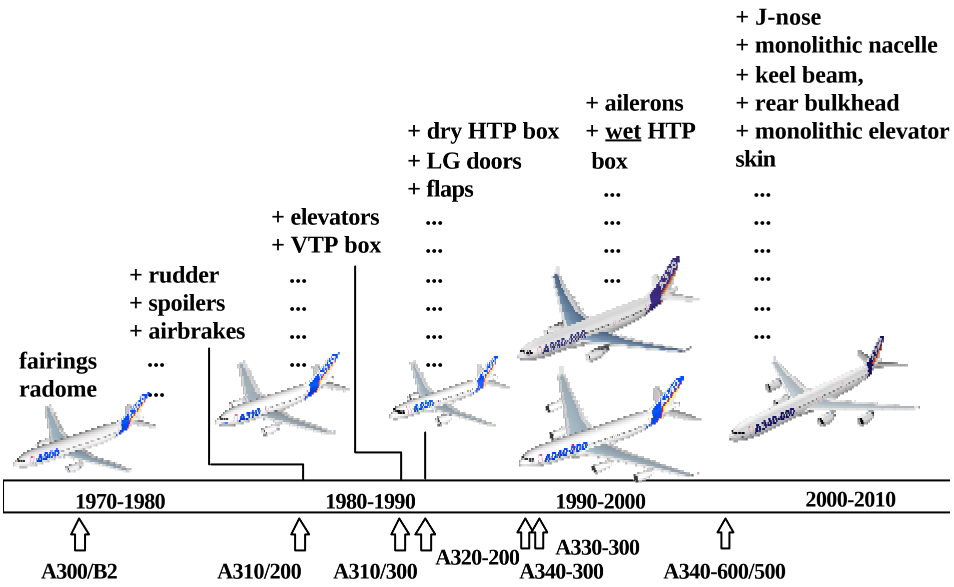

Figure 5: Evolution of composite material applications at Airbus
(HTP: Horizontal Tail Plane, VTP: Vertical Tail Plane, LG: Landing Gear)

6. A380 composite material applications

The A380 composite material applications are shown on figures 7 and 8.

The A380 will be the first aircraft ever to boast a CFRP (Carbon Fibre Reinforced Plastic) composite central wing box, representing a weight saving of up to one and a half tonnes compared to the most advanced aluminium alloys. On A380 the centre wing box will weigh around 8.8 tonnes, of which 5.3 tonnes is composite materials. The main challenge is the wing root joint, where composite components could be up to 45 mm thick. For this specific application, Airbus will reap a large benefit from the A340-600 CFRP keel beams, 16 metres long and 23 mm thick, each of which carries a force of 450 tonnes.

A monolithic CFRP design has also been adopted for the fin box and rudder, as well as the horizontal stabiliser and elevators as on previous programmes. Here the main challenge becomes the size of the components. The size of the CFRP Horizontal Tail Plane is close to the size of A320 wings. As for the centre wing box, the size of the components justifies the intensive use of Automated Tape Laying (ATL) technology.

Furthermore, the upper deck floor beams and the rear pressure bulkhead will be made of CFRP. For this last component, different technologies are tested such as Resin Film Infusion (RFI) and Automated Fibre Placement (AFP).

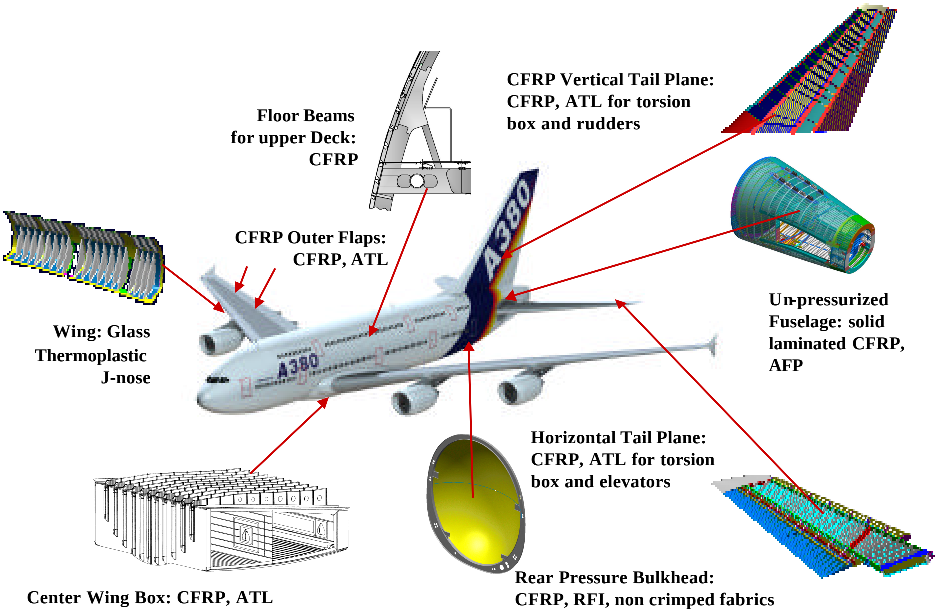

Figure 6: Major monolithic CFRP and Thermoplastic applications.

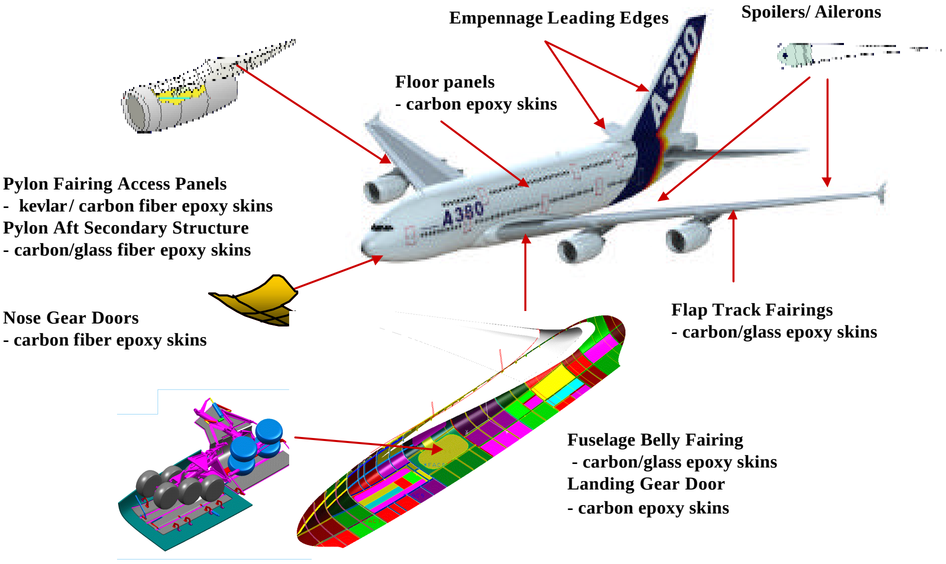

Figure 7: Major honeycomb applications.

The fixed wing leading edge will be manufactured from thermoplastics, and secondary bracketry in the fuselage (serving, for example, to hold the interior trim) is also likely to be made of thermoplastics. The fixed leading edge (wing-J-nose) in thermoplastics aims at weight and cost savings. This technology has been developed for A340-600, demonstrating weight saving, ease of manufacture, improved damage tolerance, and improved inspectability and reparability when compared to the previous A340 metallic D-nose.

Further applications of thermoplastics are under investigation, such as for the ribs in the fixed leading edges of the vertical and horizontal stabilisers.
The choice of CFRP for movable surfaces on the wing trailing edge is regarded to be state-of-the-art. The use of Resin Transfer Moulding (RTM) is foreseen for movable-surface hinges and ribs, when the shape of the components is difficult to obtain using conventional technologies.
As shown below, testing of full-scale demonstrators has created confidence in structural design solutions and application of these new technologies.

7. Full-scale demonstrators and technology choices for A380

Top target for a commercial aircraft serial production must be “Right First Time”. To come to this target requires simulation of manufacturing processes in a plant environment, not in laboratories. The test articles should be of equivalent size and surface curvature. Also stiffening elements and local reinforcements at load introductions should be demonstrated in tooling and manufacturing processes, representing a real structure at full scale, not a generic structure.
The selection of composite technologies is also linked to cost studies. One of the big benefits of expected with composite structures on A380 will be the possibility to reduce composite costs using design and manufacturing techniques that reduce the number of parts and joints.
The size of the A380 components becomes a key-parameter in the technology choice. As an example, demonstrators of A380 Horizontal Tailplane composite torsion box and full-scale CFRP rear bulkhead are shown below.

Figure 8: A380 Horizontal Tailplane composite torsion box demonstrator
(Automated Tape Laying)

Manufacturing of larger parts has been limited in the past by the size of existing autoclaves. But nowadays very large autoclaves are available, and the two real deterrents for the manufacturing of very large parts have been:

- The access to all areas of the lay-up tool,
- The limited shop-life of the composite prepregs used for CFRP primary structures.

It is obvious that automation is a key-issue to develop A380 composite applications.

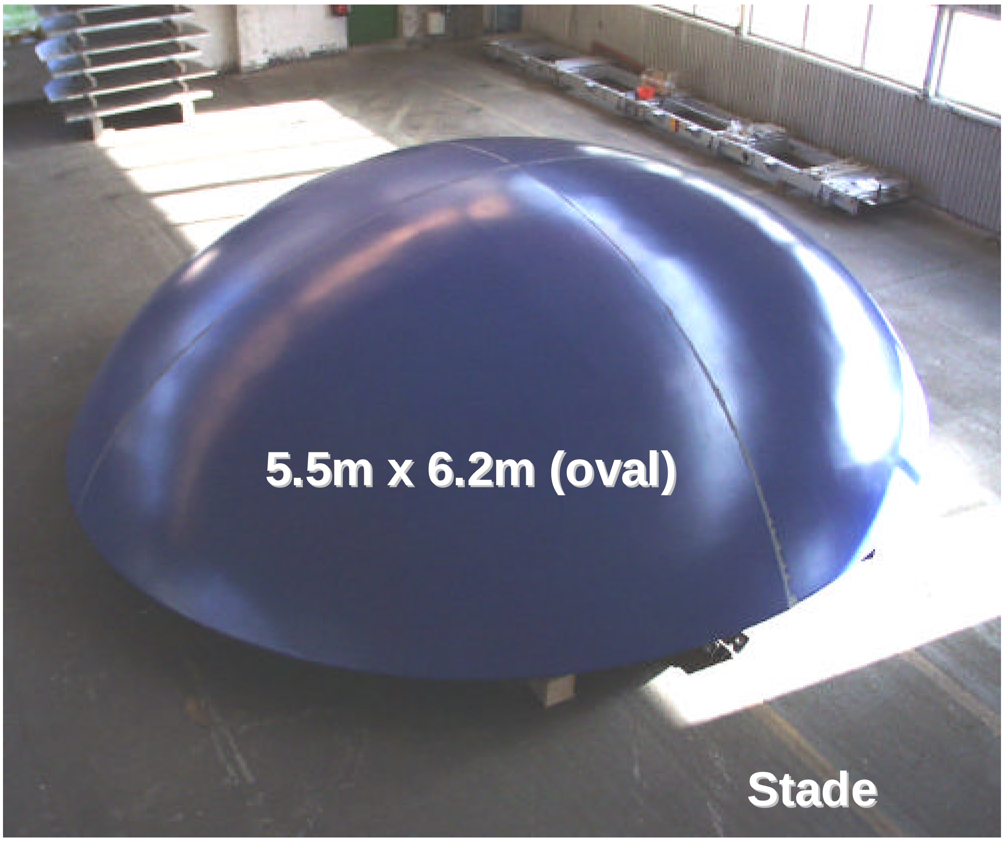

Figure 9: Full-scale CFRP rear bulkhead demonstrator
(Resin Film Infusion)

Studies related to CFRP applications for panels of the aft fuselage and the tail-cone are a good illustration of this size effect. They are outlined below. As an alternative to hand-lay-up, two automated lay-up processes are available: Automated Fibre Placement (AFP) and Automated Tape Laying (ATL). AFP is as mature as ATL. Instead of placing a pre-impregnated unidirectional tape (80 to 300mm wide), AFP machines work with up to 32 tows, placing them in a 150mm wide strip in one shoot. Each of these tows consists of a number of pre-impregnated fibres. Standard tapes with smaller width can also replace the tows. The numerical controlled head of the AFP machine has a placement & cutting device for each of the tows, which enable the machine to achieve minimum gaps/over-laps in the lay-up and to follow very complex contours. These features deliver a proper fiber placement even on strongly double-curved surfaces of moulds, where ATL would fail because of unacceptable gaps/overlaps or, because the tape-layer would fail to give sufficient pressure all across the tape to be placed.

The comparison of alternative manufacturing processes for the envisaged application for fuselage panels takes into account the following parameters: potential fiber orientation optimization and complexity of geometry. Multi-axial stressing of these panels requires little optimization of fiber orientation. Thus fabrics, tapes and tows fulfil the structural design requirements. Complexity of geometry is related to double-curvature of the fuselage outer contour. Without additional panel joints, ATL fails to place the tapes properly. As shown in

Figure 10, both hand-lay-up and AFP are feasible. The final selection has to incorporate cost comparisons and quality aspects.

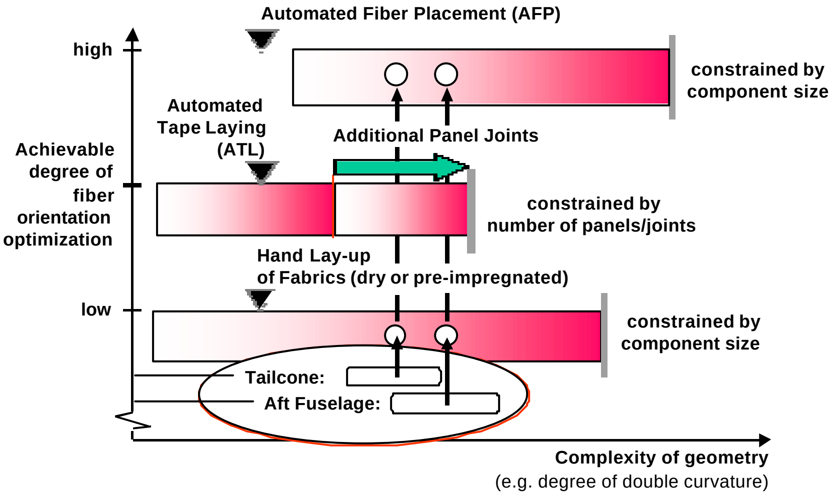

Figure 10: Comparison of different manufacturing technologies for CFRP fuselage panels

8. Motivation and limitation to composite applications

Commercial aircraft manufacturers have continuously increased composite applications for primary structures. This evolution has been presented for the existing Airbus fleet as well as for the new A380-800.

On one hand weight saving is regarded to be the major motivation for composite applications, on the other hand composite component costs have to be reduced down to the level known from conventional metal structures. This can only be achieved through changes in materials and manufacturing processes. An example for potential application of Automated Fiber Placement (AFP) has been briefly presented.

It is one of the most challenging tasks in aircraft development to achieve maturity of materials and manufacturing technologies in time for the programme launch. Technology preparation takes place mainly before programme launch milestone. At this point in time the Knowledge about Cost of a new technology is on a poor level [4]. In general, suppliers offer more advanced or new materials at higher cost compared to existing materials. Years after initial introduction, prices tend to go down because production volume increases, allowing the supplier to recover initial investments.

However, commercial aircraft manufacturers have to target cost reductions, even when more expensive materials like composites, are introduced.

As said before, the size of A380 components will generate the possibility to design huge composite parts, reducing the assembly costs and increasing the volume of materials to be produced [5]. With the help of automation, it is expected to overcome some of the existing size constraints, and to get a reduction effect on the cost of composite structures to reach a more competitive cost situation when compared to metallic structures. This scenario is presented in figure 11.

9. Conclusion

Evaluation of advanced or new technologies needs to look at the aircraft as an entity. Scenarios, differing in materials and/or areas of application, can help to find the “best compromise”. Decision on application must target “best match of materials characteristics with design drivers and best match of materials choice with manufacturing technology". For A380, Airbus benefits from earlier programmes because Airbus was the first manufacturer to make extensive use of composites on large transport commercial aircraft. The A380 will also be the first aircraft ever to boast a CFRP (Carbon Fibre Reinforced Plastic) composite central wing box.

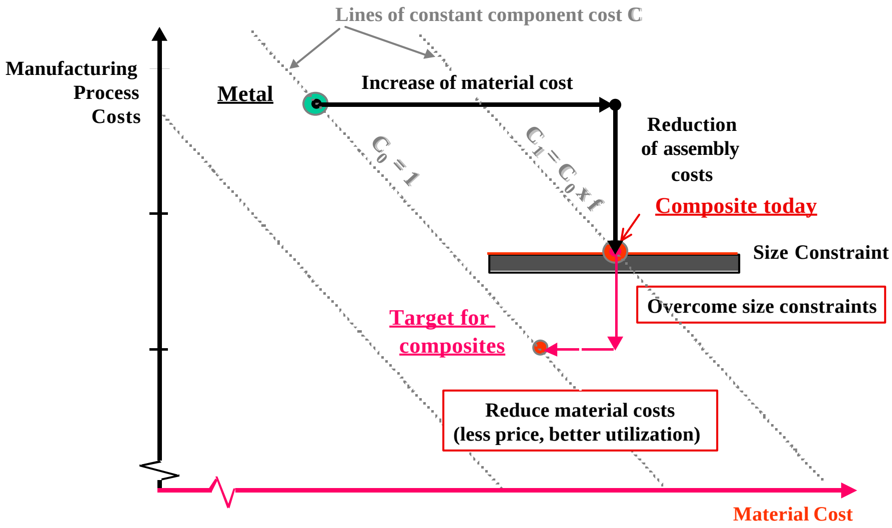

Figure 11: Status and targets for Cost of Composite Structures

But composite materials and technologies must contribute to competitive aircraft performance at affordable costs. On A380 advanced manufacturing technologies such as Automated Fibre Placement, Automated Tape Laying, Resin Film Infusion and Resin Transfer Moulding are expected to contribute to cost reductions in composite manufacture. Finally, the size of A380 components will generate the possibility to design huge composite parts, reducing the assembly costs and increasing the volume of materials to be produced, moving A380 one step further in the development by Airbus of composite applications on airframes.

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