THE AIRBUS / ENGINE & NACELLE MANUFACTURERS RELATIONSHIP : TOWARDS A MORE INTEGRATED, ENVIRONMENTALLY FRIENDLY ENGINEERING DESIGN

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Abstract

The lifetime of an aircraft model, from first ideas until the last aircraft is out of service, can be about 60 years. Mitigating the impact of growing traffic on environment is therefore a challenge to be faced at the same time by airframe, engine and nacelle manufacturers.

Significant progresses in terms of integrated engineering design have been made over the last 15 years at Airbus, yielding the A380. Steps are now taken to prepare the revolution needed to meet the long term environmental objectives, which will require an even more integrated, environmentally friendly engineering design.

1 Introduction

The lifetime of an aircraft model, from first ideas until the last aircraft is out of service, can be about 60 years :

- up to 10 years from first ideas to entry into service,
- 20 years or more where aircraft model is produced and operated,
- continuous operation which can exceed 30 years after end of aircraft model production.

During that time, which is longer than the majority of marriages, airframe and propulsion systems are designed, built, and fly together, transporting passengers and freight all over the world.

Furthermore, various forecasts consistently indicate a growth in world air transport of about 5% per annum over the next two decades.

As a consequence, mitigating the impact of growing traffic on environment is a challenge to be faced at the same time by airframe, engine, and nacelle manufacturers.

2 Environment within Top Level Aircraft Requirements

Even before a new aircraft concept is created, the designers are faced with a set of Top Level Aircraft Requirements (TLAR).

Those TLAR are basically established from market requirements, and environmental criteria are always present, as illustrated Fig. 1

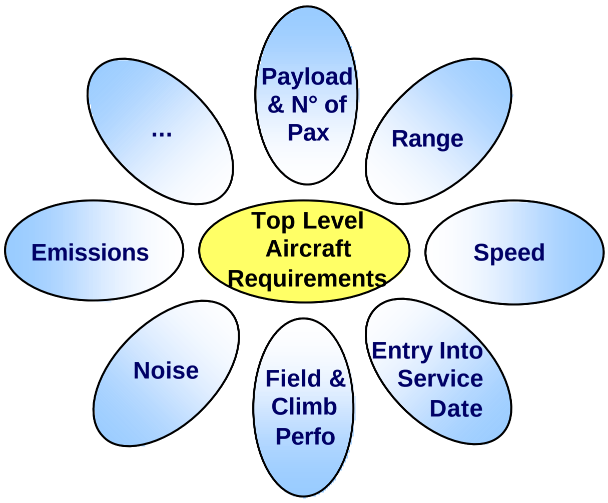

Fig.1. Typical Top Level Aircraft Requirements

External noise requirements can be expressed in different ways: margin to ICAO Chapter 3 or Chapter 4, or noise classification at certain airports (e.g. London Airports Quota Count system) to avoid curfew (QC2 or lower). The noise requirements are also defined in consideration of several, sometimes conflicting local requirements.

Emissions requirements are usually expressed in margin relative to ICAO CAEP/4 (or CAEP/6 now) for NOx, UHC and CO, or as emissions classification at certain airports (e.g. Zurich) to avoid surtaxes on aircraft landing charges.

Both Noise and Emissions requirements are always established in consideration of existing, but also expected environmental regulations, at aircraft entry into service, as well as for the life of the product.

3. Key steps in integrated engineering design optimization

In Airbus, the aircraft design process is divided in four phases, as illustrated Fig. 2

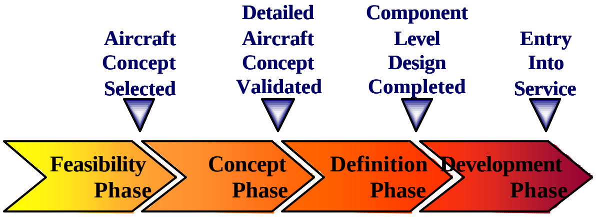

Fig.2. Airbus Aircraft Design Process Architecture

3.1 Feasibility Phase

Feasibility Phase starts when the first product ideas are captured, and ends with the selection of the Aircraft Concept.

Using TLAR such as Payload, Range and Speed, the Aircraft manufacturer first looks at technology readiness in support of the expected entry into service date. This results in the first sizing of the aircraft concept, yielding for instance aircraft weights and wing area. Take-off and Climb performance requirements are then used to issue the initial Top Level Engine Requirements (TLER) (Engine thrusts, Noise and Emissions requirements…) associated to the TLAR.

At this stage, the engine manufacturers are provided with the TLAR and TLER, and discussions relative to the potential new "child" are initiated.

Different propulsion systems concepts are considered, varying technology level, as well as cycle architecture (bypass ratio and overall pressure ratio).

Fig. 3 illustrates the multi-dimensional aspect of the trade-off studies which are conducted during the Feasibility Phase.

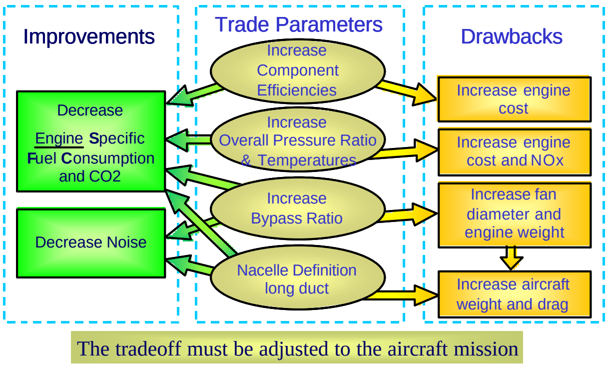

Fig. 3. Multi-dimensional Engineering design optimization

As far as noise is concerned, a key asset to proper optimization is understanding the relative weight of noise sources for the product considered, based upon General Acoustic Database provided by engine manufacturers. This understanding, shared between airframe, engine and nacelle manufacturers, allow to select the most promising architecture, as well as the most appropriate noise reduction technologies. The relative weight of noise sources for A380 are indicated Fig. 4

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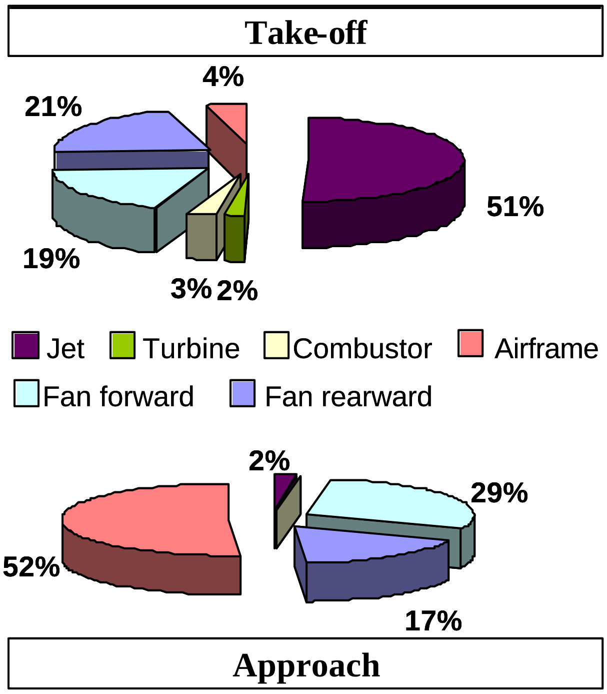

Fig. 4. Relative weight of noise sources on A380

Based on the TLAR and TLER, all the major architectural choices are made jointly during the Feasibility Phase.

For instance, Fig. 5 illustrates the magnitude of the performance and noise trade-offs that were considered for A380. The final propulsion system fan diameter selection was made based upon external noise requirements, as well as minimum fuel burn, hence CO_2.

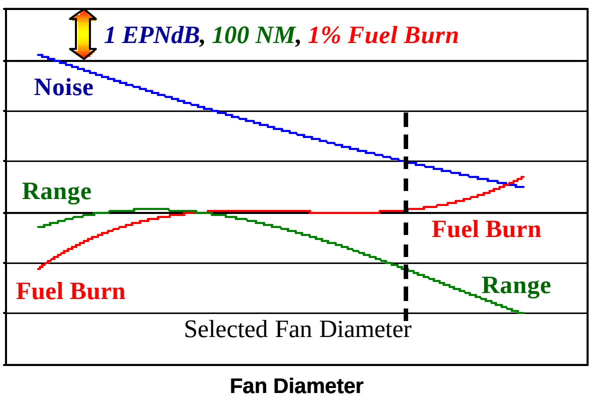

Fig. 5. Propulsion System Fan diameter trade-offs for A380

Last but not least, the aircraft concept is resized according to the architectural choices made, yielding an Aircraft Concept (including Propulsion System) selection.
The "child" is born, the TLAR and TLER being its "Certificate of Birth".

During the Feasibility Phase, TLAR are revisited on a regular basis in order to make sure the overall aircraft product is properly sized. Safety however is, and will remain paramount, and cannot be compromised.

3.2 Concept Phase

Concept Phase starts when Aircraft Concept is selected, and ends with the validation of the detailed Aircraft Concept.

During the Concept Phase, integrated engineering design optimization continues, and new choices are jointly made, such as engine mounting system. Integrated Finite Element Models of engine, nacelle, engine mounts concepts, pylon concepts and wing are elaborated, and behavior under the various loading conditions(Fan blade out event, Take-off rotation…) is evaluated.

For instance, engine backbone bending is evaluated for the different engine mounts and pylon concepts, as illustrated Fig. 6.

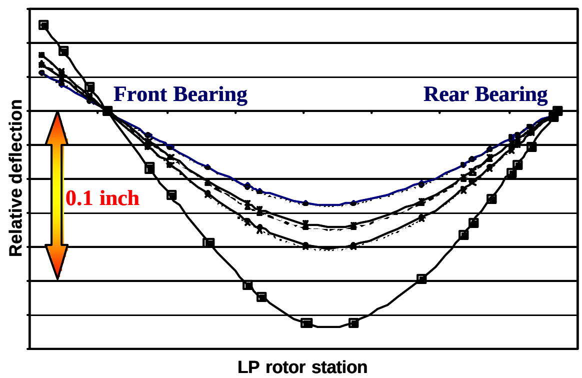

Fig. 6. Engine backbone bending for different engine mounts / pylon concepts

That information is then used to perform trade-off studies in terms of weight (Engine, Nacelle, Pylon, and ultimately overall aircraft), performance (Performance retention, Engine

Specific Fuel Consumption, and ultimately overall aircraft fuel burn or CO_2), operability (Surge margin), and economics (Recurring Costs, Direct Operating Costs).

Many other choices are made jointly in a similar way during the concept Phase, until the detailed Aircraft Concept is validated.

After the Feasibility and the Concept Phases, almost all the integrated engineering design choices have been made, and validated.

3.3 Definition and development phases

Definition Phase starts when the detailed Aircraft Concept is validated, and ends with the completion of the Component Level design.

Development Phase starts when the Component Level design is completed, and ends with the entry into service of the aircraft product, when the "child" graduates.

Through the Definition and Development Phases, the focus changes from "guaranteeing an optimized integrated engineering design" to "guaranteeing the product overall quality and maturity at entry into service". That latter aspect, although crucial, is not discussed in this paper.

A major enabler to proper integrated engineering design is the existence of mature, honed multi-disciplinary processes, known to the different stakeholders, and covering structural, aerodynamics and systems integration, as well as performance and environment aspects.

We are not yet there, but significant progresses have been made in this regard over the last 15 years, as illustrated in the first part of this paper. Improved Airbus/Engine Manufacturer/Nacelle Manufacturer integrated, environmentally friendly engineering design, together with technological progress allow today to contemplate an A380 that will not be noisier than its predecessors, although up to 100% heavier, as illustrated Fig. 7

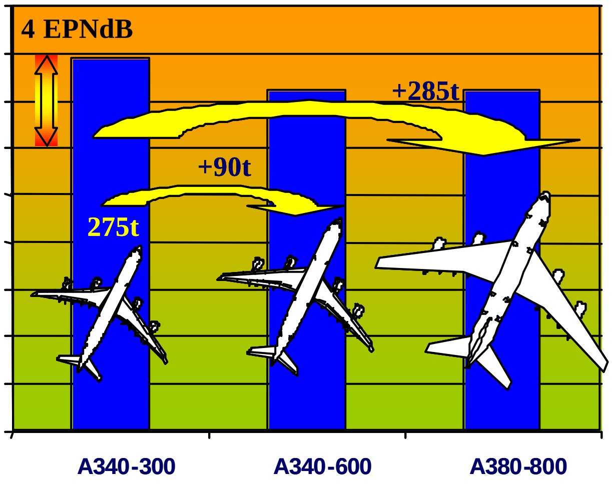

Fig. 7. A380 Take-off Noise relative to its predecessors

4. In-service Product Engineering support

Some aircraft models are very long lived, as discussed earlier, being in service sometimes for 50 years.

As a consequence, opportunities for product improvement as far as environment is concerned can present themselves. A good example is the entry into service of CFM56-5B Double Annular Combustor in 1995 on A320, offering about 30% lower NOx than mid 90's state of the art, seven years after A320 entry into service.
In addition, evolution of environmental regulations can sometimes lead to a product upgrade.
In that case, the overall integrated, environmentally friendly engineering design needs to be started again, involving Aircraft, Engine and Nacelle Manufacturer.

The design space is more constrained since it is a product upgrade, and not a brand new design. But the basic process is identical.

Although ICAO Stage 4 Noise requirements only apply to aircraft models to be certified after 2006, and not to current models, Airbus and CFM have jointly decided to introduce a noise improvement package on A321/CFM56-5B/P, even though it is not mandated.

Fig. 8 illustrates the configuration of a CFM56-5B/P fitted with that noise improvement package.

Fig. 8. CFM56-5B/P with noise improvement package

A321 noise margin relative to ICAO Stage 3 is increased by more than 3 EPNdB by this noise improvement package; the improved product, which has received its new Type Certificate in April 2004, meets ICAO Stage 4 requirements.

Engineering relationship between Aircraft, Engine and Nacelle manufacturers continue for the whole life of the product, not unlike parents which, sometimes, support their children during the key events of their life.

5. Long term vision : facing the challenges of future environmentally objectives

In Europe, a group of personalities have shared their views for the future of air transport in their 2001 report "European Aeronautics – a vision for 2020" [1], illustrating the growing environmental awareness. In order to mitigate the environmental effect of a predicted 3-fold increase in air transport by 2020, drastic emissions and noise targets were defined.

For instance, as emissions are concerned, the following targets were set:

- 20% reduction in CO_2 emissions (or fuel burn) by 2020
- 80% reduction in NO_x emissions relative to ICAO CAEP/2 by 2020.

Those high level goals were interpreted by the Advisory Council for Aerospace Research in Europe (ACARE), and communicated through the Strategic Research Agenda.

The external noise targets were translated as –10 dB per aircraft operation.

As illustrated Fig. 9 for noise, those objectives are so challenging, that they will not be met simply by technological evolution.

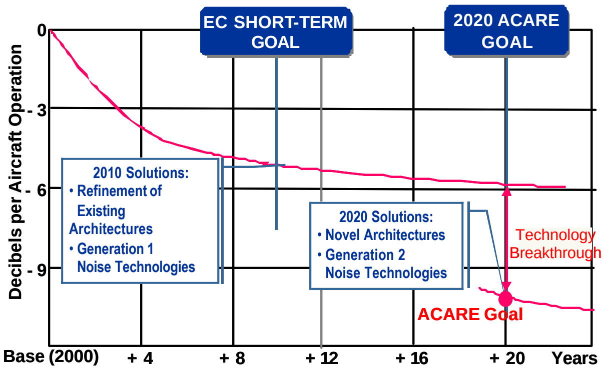

Fig. 9. Long Term Noise Reduction Objectives & Technology Paths

A revolution is indeed needed to meet the assigned long term objectives.

Within Airbus, future product concepts have been created to stimulate engineering design innovation, and identify technology gaps [2].

The Proactive Green concept challenges the designers to offer the minimum affordable impact of aviation operations and manufacturing on the environment; Fig. 10 illustrates one of the resulting potential aircraft configuration.

Fig. 10. One potential Proactive Green configuration

That potential aircraft configuration has been elaborated to benefit from noise shielding. Several other Proactive Green configurations exist, with many engineering unknowns, one of them being the current lack of real understanding of the impact of emissions on our environment.
The only way to really succeed in facing the long term environmental challenges, is for the aeronautics industry to move towards an even more integrated, environmentally friendly engineering design, fully opening the design space, identifying the technology and design processes gaps, and having the Aircraft, Engine and Nacelle manufacturers resolve those issues together.

6. Conclusion

As for all long term ties, the engineering relationships between Airbus, Engine and Nacelle Manufacturers are sometimes difficult.

Two key elements can be kept in mind to help solve those transient difficulties. The first one is to always keep focus on the ultimate customer satisfaction. And the other one is to look back and realize that a more integrated, environmentally friendly engineering design paves the way towards setting new standards.

References

[1] *Strategic Research Agenda from Advisory Council for Aeronautic Research in Europe*. October 2002 in: www.acare4europe.org

[2] Vigneron Y. *Commercial Aircraft for the 21st century – A380 and beyond*. AIAA / ICAS International Air & Space Symposium and Exposition, 14-17 July 2003, Dayton OH.