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TECHNOLOGY DEVELOPMENT AND FUTURE AIRCRAFT DESIGN AS A METHODICAL CHALLENGE

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Abstract

The development of a new passenger aircraft means the integration and management of many interlinked influencing factors. For reducing the development risks as much as possible, a planned new aircraft is defined in detail and technical questions are investigated during an extensive "predevelopment" phase, before a new aircraft programme is launched. Thereby, the latest status of technology defines the baseline for big optimisation efforts.

This paper introduces main steps of technology planning, derived from visions, strategies and analysed key buying factors for future aircrafts. Facing the complexity of the product, the extreme cost of aircraft development and the transnational collaboration in the aeronautic industry, technology development and future aircraft design is an organisational and methodical challenge. The applied methods for the evaluation of new technologies and the following technology management are described and discussed.

Keywords: innovative products, aerospace engineering, market survey and evaluation, distributed product development

1. Introduction

This paper gives an overview of main methods used for creating and managing the "Research and Technology Programme" of Airbus. It starts with an introduction of the product 'aircraft' as an extremely complex technical system and a technological challenge. The second paragraph characterises the Research and Technology (R&T) and the product development process in the aeronautic industry as a consequence of the product complexity of passenger aircrafts and the transnational collaboration in Airbus as an integrated company. This clearly leads to a process- and organisational challenge. The third paragraph introduces main targets, derived from 'key buying factors' for aircrafts, visions for the next decades and their strategic impact on the R&T work. Paragraph 4 identifies technology areas which need to be directed by the R&T work for enabling Airbus to reach these targets. Thereby, some evaluation-methods to analyse the impact of new technologies on the aircraft performance are introduced. Additionally, the organisational concept for the programme launch and management is briefly described. The paper ends with a discussion on the specific requirements for methodical approaches in the R&T management and in the development work at Airbus.

2. Aircrafts as Challenging Products

Travelling with a modern passenger aircraft, everybody experiences the dimensions, the forces and the fascination of this large technical product. A passenger aircraft provides a convenient and high speed transport in the hostile environment for human life at high altitudes. Thereby, the high external temperature and pressure differences during flight create extreme requirements for the aircraft's structure and systems. Additionally, with a takeoff weight of several 100 tons (the new A380 will start with about 560 tons!) the structural stresses during takeoff and landing and the necessary performance of wheel-brakes are much higher than in formular 1 racing cars. Figure 1 shows the new Airbus A380, an aircraft for more than 550 passengers, (first flight planned for November 2004, entry into service in 2006).

Figure 1. The new Airbus A380: A 'megaliner' for more than 550 passengers.

Moreover, an aircraft is taxiing on ground up to several 10.000 km per year, which is in the yearly range of private cars. Within this high-tech structure, cabin systems provide the passenger with everything he needs to survive and to enjoy – beginning with the right air pressure and temperature, but also galleys for hot meals, washrooms, audio and video entertainment, and even internet access. Thus, an aircraft represents an entire 'survival environment' for extreme conditions, moving on ground and in the air. Obviously, aircrafts are unique products in terms of the variety of requirements, of product related processes, of technical complexity and of size. Consequently, the development of future aircrafts is a very special technological and methodical challenge.

3. R&T- and Design-Process Characteristics at Airbus

Due to the size and technical complexity of aircrafts, and the very high quality and safety standards, the design of a new aircraft is an extremely time- and cost-intensive project. Thus, the product cycles of aircrafts are measured in decades, not in years such as in the automobile industry. In order to reduce the development risks facing this complex task, a planned new aircraft is defined in every detail, and technical questions are investigated during an extensive "predevelopment" phase. Compared to the high level of knowledge on an aircraft concept (e.g. regarding most performance and production related questions) before the start of an 'aircraft programme', the product development work of a 'new design project' in the machinery industry starts on a much less elaborated and defined level. This means, the R&T work in the aeronautic industry goes quite far 'downstream' to the final product. Thereby, the latest status of technology defines the baseline for big optimisation efforts. Figure 2 shows the main stages of a typical aircraft development process. The predevelopment work in research and technology takes sometimes more than 10 years, before the product development of a new aircraft starts.

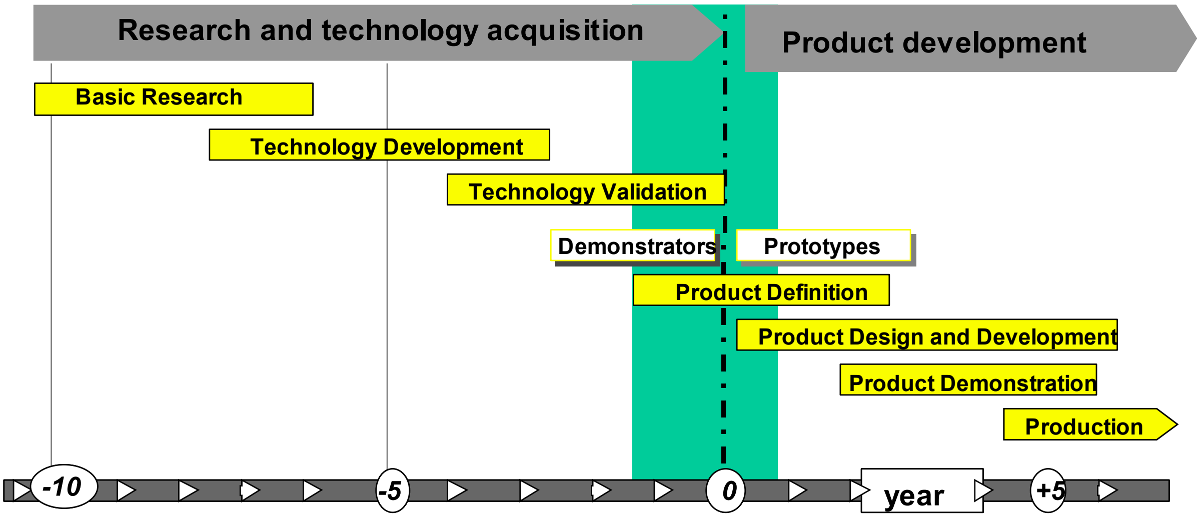

Figure 2. Research & Technology and Product Development in the Aeronautic Industry.

Balancing the various interlinked requirements, today's aircrafts (e.g. Airbus vs. Boeing single aisle aircrafts) are looking at a first glance quite similar in their overall layout. Nevertheless, by developing better solutions for every phase of the aircraft design, production and life cycle, the improved overall performance of the future aircraft and thus important competitive advantages are determined. In this regard, many important aircraft design decisions are determined by managing the current and deciding on the future technology programme.

The aeronautic industry is working very international in general (due to the high development cost and politically motivated networking with later customer countries). At Airbus, the integration of 4 European Airbus-partners from France, Germany, UK and Spain into a single company created a specific situation of international collaboration within one company, through all phases of technology and product development. Additionally, there is international cooperation and joined research with industry and universities.

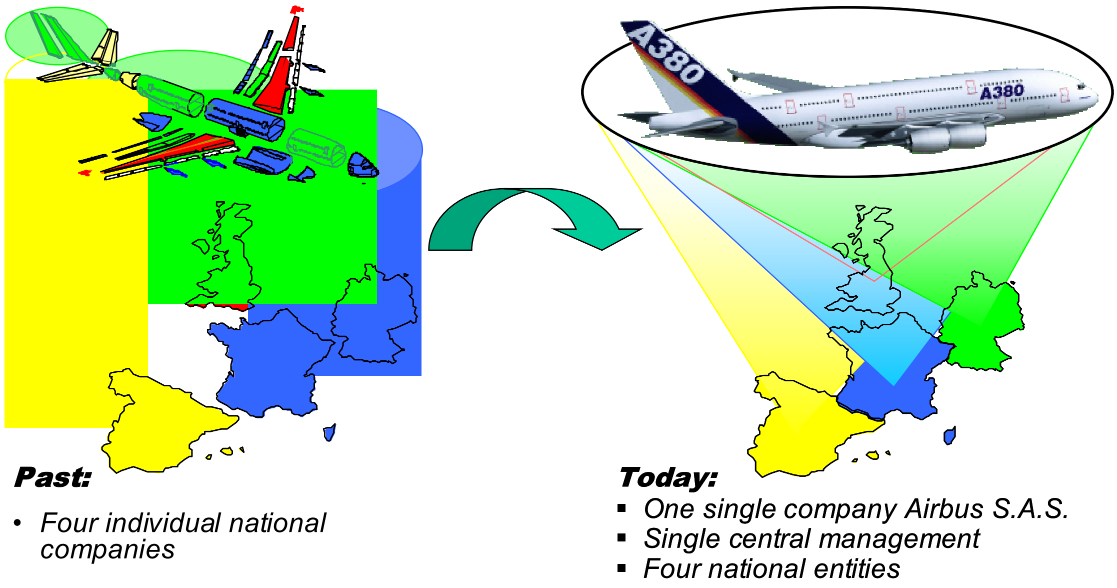

Figure 3. Airbus integrated company.

Today, Airbus Engineering is working as a transnational organisation with collaboration of engineers in joined Centres of Competence (CoC, disciplinary oriented) and Engineering Integration Centres (EIC, component oriented). In order to avoid double technology development activities, a distribution of main competencies was agreed within Airbus, which is directed to maximise synergies and development efficiency.

Table 1. Main Competencies distribution within Airbus.

Airbus Deutschland	Airbus France	Airbus UK	Airbus Spain	Airbus Central
Fuselage General	Cockpit	Wing (General)	HTP	
VTP	Centre Section	Landing Gears		
Cabin	Propulsion	Fuel System	Rear Fuselage	
Cargo	Flight Controls		Belly Fairing	
High Lift/Hydraulics	Avionics			
Low Speed Aerodynamics	Electricity	High Speed Aerodynamics		
Cabin Systems/Air Cond.				
APU A400M			APU all a/c except A400M	
Flutter				General Management
In Flight Loads		Ground Loads		Customer Interfaces
A/C Pre-flight Performance	LS & HS Performance Tools			
Ground Vibration Testing	Iron Bird		HTP Test Specimen	Flight Tests
	Flight Test Means			
Metallic Standard Design	Hard Metal Design	Metal Heavily Loaded Design	Composite Technology Management	DOA (Airworthiness)
Surface Treatment	Paint			Safety
Fatigue Tests	Static Tests			

4. Targets and Strategy Process

The enormous financial engagement calls for an intensive target and product strategy process, in order to meet the societies' and airlines' requirements of the next decades. Thereby, a closed contact to the later customers is essential. Airline surveys reveal the importance of key buying factors, as shown in figure 4.

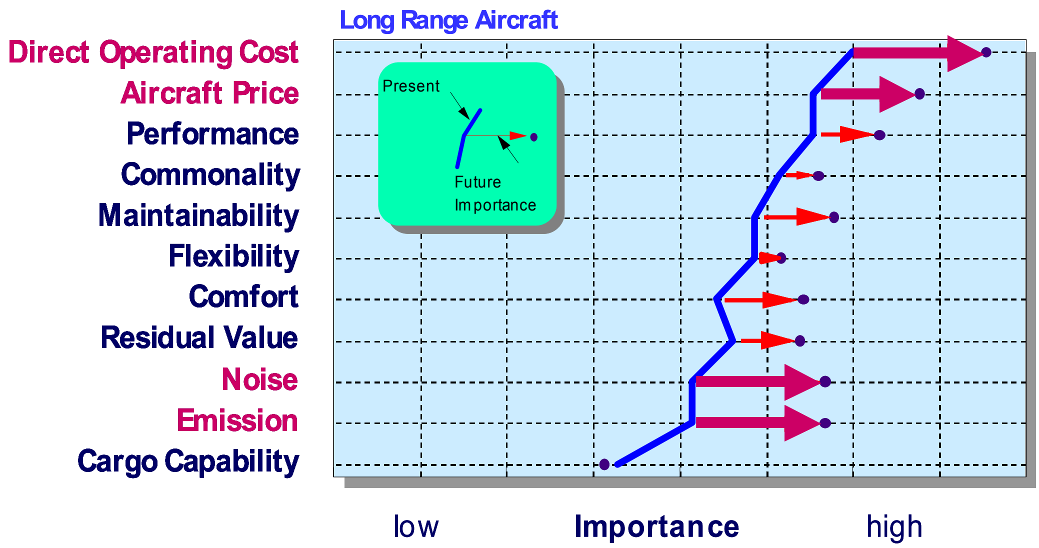

Figure 4. Results from airline surveys indicate present and future importance of key buying factors (example).

Particular attention has to be given to identify drivers for research and technology targets. According to those studies, which are the performance targets to be reached in the next 20 years? This question is discussed on various platforms of the aeronautic industry, such as the 'Group of Personalities' (GOP) with the CEOs of main aeronautic companies. These targets are condensed in the common objectives of the 'Vision 2020' of the European Union [see e.g. 1]:

- Cheaper and passenger friendly air travel
    - Average cost of air travel reduced by 30%
    - Improved passenger comfort
- Reduction of atmospheric emissions
    - Reduce CO_2 emissions by 50%, NOx by 80%
- Reduction of noise
    - Reduce perceived noise level by 50%
- Enhanced safety and security
    - Reduce aircraft accident rate by factor of 5
- Increased capacity and reduction of delays
    - Aviation system throughput to 16 million flights per year
    - Less than 1% of all flights exceeding 15 minutes delay

By which R&T strategy can Airbus reach these targets? Looking back on the history of passenger transport aviation, the typical technology driven step changes become visible: From propeller to jet engines, from non pressure-controlled to pressure-controlled cabins, from mechanical transfer of steering signals by cables to "fly by wire" etc. Following all these step changes, there was an incremental improvement of performance based on the existing technologies (see figure 5).

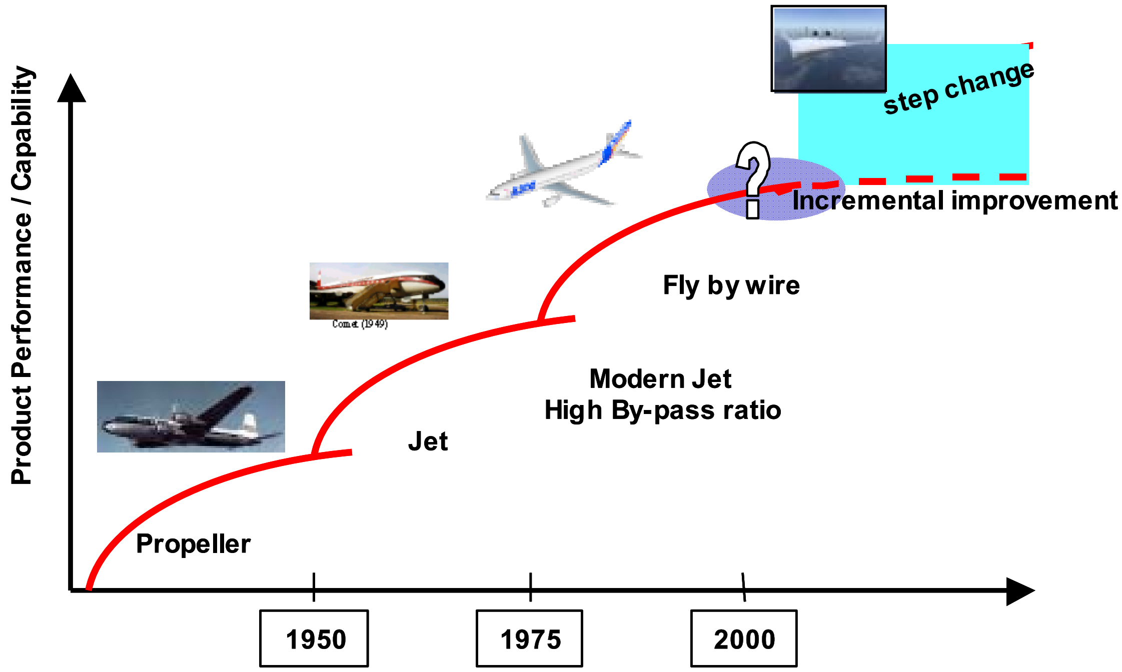

Figure 5. Product performance and capabilities growing over the decades by step changes and incremental improvements.

Currently, we are again in a phase of incremental improvements regarding the overall performance of civil aircrafts. The strategy of Airbus is to protect this incremental improvement while preparing step changes in technology and innovation by R&T work.

5. Building and Managing the R&T Programme

Research and Technology intends to support every phase of the product life cycle by providing innovative "high tech" solutions, in terms of innovative materials, components, designs, systems, tools, methods and processes. For approaching the above mentioned performance targets, key drivers can be identified, which define fields for research activities. Figure 6 shows, by which means the performance targets are approached in the transnational company. Obviously, many identified technology areas are competencies of several Airbus sites, which demonstrates the synergies of transnational collaboration in R&T. Figure 6 also gives an impression of the range and diversity of the Airbus R&T programme. For example, research and technology development is directed on innovative materials and manufacturing technologies, the design of all aircraft structures, alternative energy generation (e.g. by fuel cells), new aircraft configurations or new system concepts, but also enabling technologies such as new methods and design tools e.g. for requirement engineering or simulation tools and virtual and augmented reality tools for design, manufacturing and maintenance.

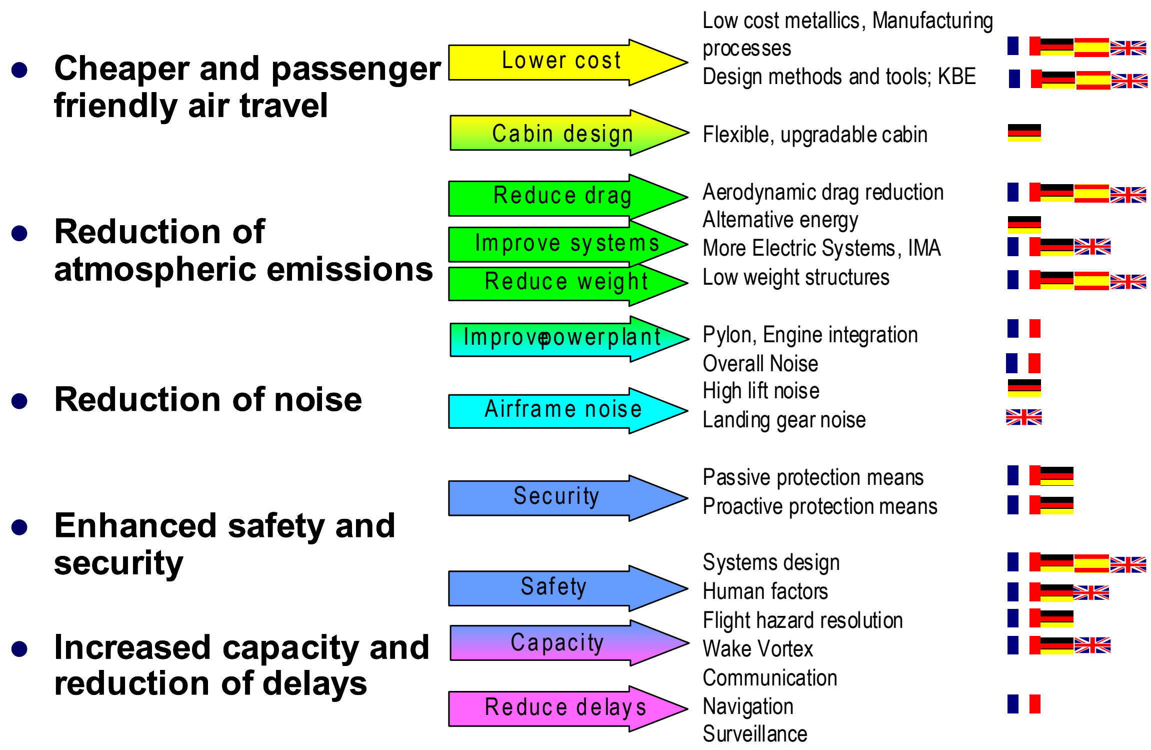

Figure 6. Implementation of the Vision 2020 by R&T at Airbus.

An important step for the creation of the R&T programme is the analysis and decision, which technologies are likely to contribute to these targets, and which effect these contributions will have in terms of customer (Airline) and manufacturer (Airbus) value. Customer value is composed by the dimensions 'economics', 'key buying factors' and 'Airline profitability'. The dominant factor for the customer is the direct operating costs (DOC) of the aircraft. Figure 7 shows main influences on the DOCs, which are the cash direct operating cost, the ownership costs, the maintenance and the crew costs.

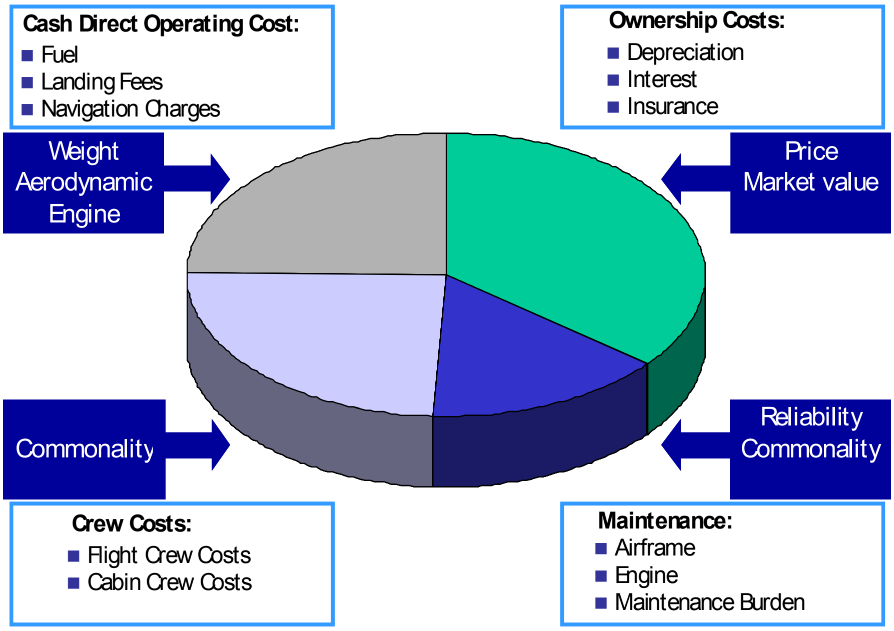

Figure 7. Direct operating cost for passenger aircrafts – with influencing factors.

Further customer factors are the mentioned 'key buying factors' (see figure 4) and the prognosis of the airline's profitability. The technologies impact on the manufacturers value is based on the non recurrent (e.g. development costs, NRC) and recurrent costs (e.g. production costs, RC), the planned production rate and the business forecast. Figure 8 shows how the customer and manufacturer value are captured in a vector, which should illustrate an improvement for both the customer's and the manufacturer's side.

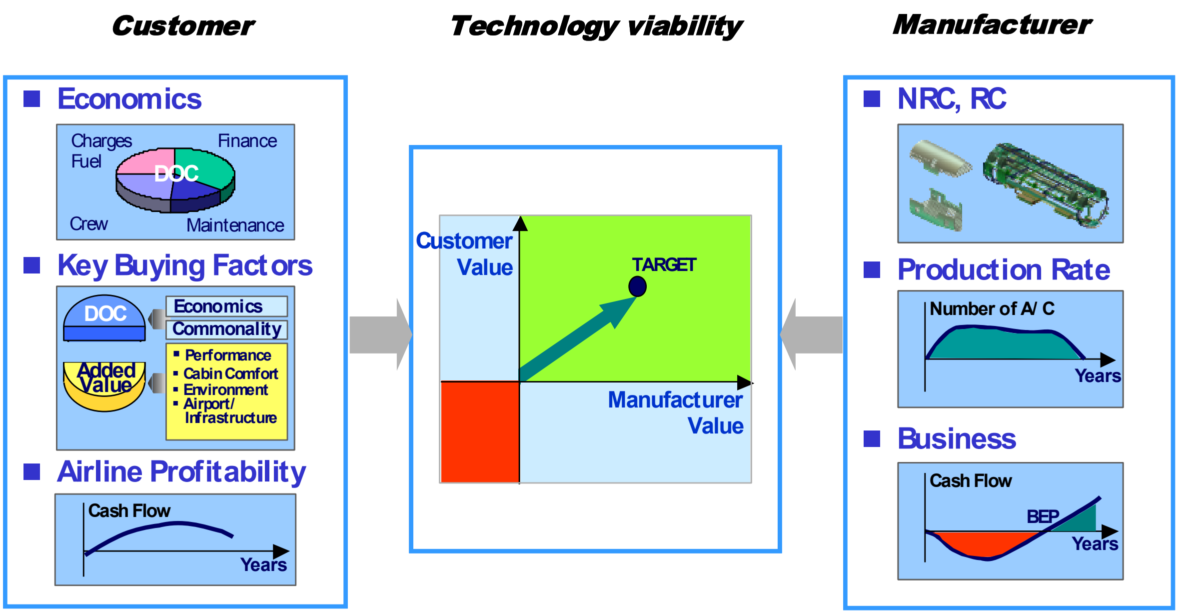

Figure 8.Customer <u>and</u> manufacturer oriented technology evaluation is an important input for a successful overall technology strategy (NRC: Non Recurrent Cost, e.g. development cost; RC: Recurrent Cost, e.g. production cost).

This technological and economical evaluation requires specific and detailed knowledge on the interrelations of factors in the complex system "aircraft". In the aeronautic industry, the knowledge on interrelations of factors is very detailed and validated compared to other industries, such as printing presses. At Airbus, a specialized evaluation department supports the decision making process on technologies by evaluation studies. Thereby, a common approach is to base the evaluation on an existing 'reference aircraft', for which a huge set of reference data is available. The following analysis of a technology requires a multi-dimensional approach and is supported by specific IT-tools, which are also developed within R&T. For the evaluation, the new technology is applied to the existing aircraft and the effect on performance, weight, systems impact, flight physics or engines is analysed. Figure 9 shows the principal approach of the technical evaluation.

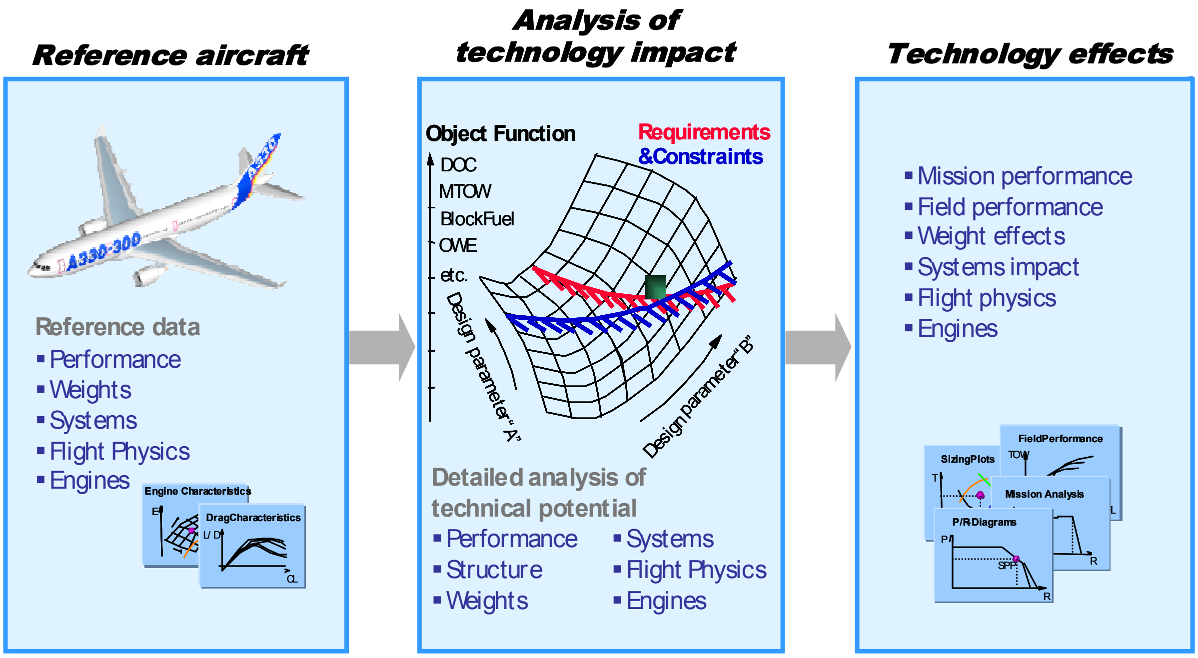

Figure 9. Technical evaluation of a new technology's impact on a reference aircraft.

The decision making on technology projects in the new integrated, transnational company is organized according to a defined process. In this process, 'Technology Area Groups' for different disciplines, such as systems or structure, which are chaired by 'Chief Technologists', are responsible for the approval of proposed technology projects. The launch and the management of the running projects is the responsibility of the transnational R&T Programme Management. In a cascade of reporting levels and by a reviewing system in a 'work breakdown structure', several hundred projects are managed and controlled.

At the R&T Management of Airbus, modern innovation management methods [see e.g. 2] are applied, such as Technology Roadmaps for each significant technologies or key technology. In principle, a roadmap visualizes the maturity levels and time frames of different R&T projects and the route to a planned application product together with important milestones. Figure 10 shows at the left side as an example a simplified roadmap for metallic fuselage manufacturing technologies, in particular the laser beam welding of stringers on fuselage panels, shown on the right side. This technology is applied to the new A318 and the new A380, Airbus was awarded by the 'Innovation Award of the German Industry' for the development of this technology.

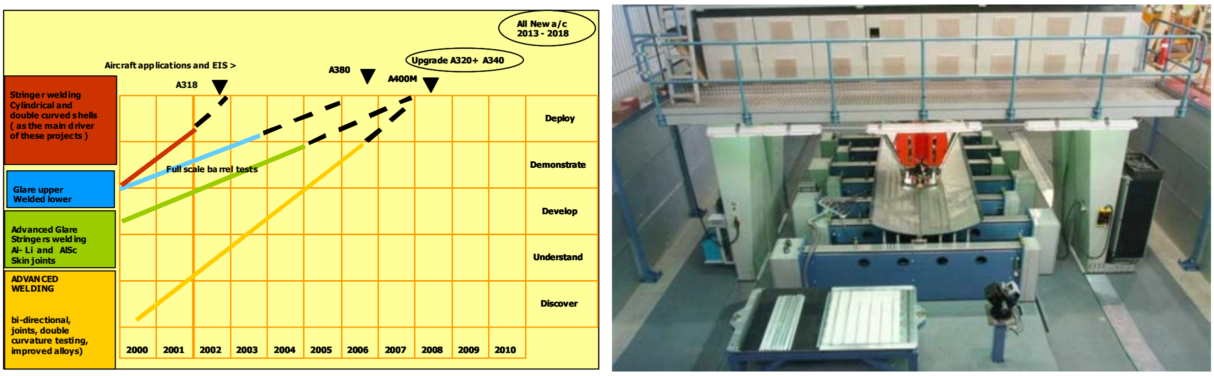

Figure 10. Simplified technology roadmap for metallic fuselage structures and production machine for fuselage panels by laser beam welding.

The high cost of technology development in the aeronautic industry calls for a support by government funding. At Airbus, R&T-work is supported by European, national and regional programmes. The organisation of the application processes with different constraints and conditions at the different sites, together with the transnational alignment of the overall process, creates an additional challenge for the R&T management.

6. Discussion

The challenge of R&T managing at Airbus lies in the combination of the high number of different projects, the variety of technologies, the complexity of product processes, the transnational collaboration between four partners with different cultures, and the complex funding processes.

These challenges require specific methodical and systematic approaches for the various analysis and decision steps in the set up of new technology projects, and in the management of the R&T programme. Based on sufficient methods and processes, R&T has to answer determining questions, for example:

- Which aircraft will answer the multiple challenges of the next decade?
- Which aircraft configurations, evolutionary or revolutionary, will offer the opportunities to meet these challenges?
- Which is the best selection of concepts and technologies that Airbus should be preparing in order to face all launching assumptions?

Facing the impact of successful R&T work on the later aircraft performance and the company's success, the importance of the quality of R&T management becomes obvious. Even different to other engineering design environments in many aspects, methods and tools developed in the aerospace industry (such as FMEA by the NASA or CATIA CAD by Dassault) were often at the front edge of methodical development in engineering [3, 4]. This makes the aerospace industry to an interesting scout for future trends in engineering design work.

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