CARISMA_FR_TN

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CARISMA:
Aircraft Cabin and Cabin Systems Refurbishing,
Optimization of Technical Processes

Final Report

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19. Abstract This Technical Note summarizes the results of the research project CARISMA. The project started in October 2008 and was split in five Work Packages. WP 1 provided the regulatory requirements towards obtaining DOA as well as the process chain of activities within the future completion center. WP 2 delivered a forecast of cabin modification scenarios that will be undertaken for the next 20 years, as well as an updatable EXCEL tool useful for own calculations. WP 3 investigated the implications of carrying out independent cabin conversions, based on two study cases. WP 4 delivered an overview of the tools required in a completion center. WP 5 analyzed the financial implications of the vision Completion Center. As an overall conclusion, ELAN should invest in the vision Completion Center, first of all due to the actual highly competitive market context. The strategy towards achieving this should be carefully selected. CARISMA serves this purpose, with its scientific view.		
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19. Kurzfassung Diese Technische Niederschrift fast die Ergebnisse des Forschungsprojektes CARISMA zusammen. Das Projekt startete in Oktober 2008 und wurde auf 5 Arbeitspakete verteilt. AP 1 untersucht sowohl die Vorschriften für DOA, als auch die Prozesskette von Aktivitäten in dem zukünftigen „Completion Center". AP 2 liefert als Forschungsergebnis eine Marktstudie, die gegenwärtige und zukünftige Trends auf dem Gebiet der Kabinenumrüstungen zeigt. AP 3 untersucht die Schwierigkeiten, auf die man trifft, wenn selbstständige Kabinenumrüstungen durchgeführt werden. AP 4 liefert einen Überblick über die Werkzeuge, die in einem „Completion Center" notwendig sind. AP 5 untersucht finanzielle Auswirkungen der Vision „Completion Center". Als Fazit, sollte ELAN die Entscheidung treffen, in diese Vision zu investieren, als erstes wegen der Marktbedingungen. Die Strategie das Ziel zu erreichen, soll sorgfältig ausgewählt werden. CARISMA unterstützt die Auswahl der richtigen Strategie durch zusätzliche wissenschaftlich-systematische Betrachtungen.		
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Abstract

This report summarizes the results of the research project CARISMA. CARISMA was undertaken jointly by ELAN GmbH and Hamburg University of Applied Sciences, through Hamburg Innovation GmbH. The aim was to support ELAN GmbH towards the vision Completion Center, by providing an unbiased outside view and practical scientific approaches of problem solving in aeronautical engineering. The project was divided into 5 Work Packages. WP 1 provided the regulatory requirements towards obtaining DOA as well as the process chain of activities within the future completion center. WP 2 delivered a forecast of cabin modification scenarios that will be undertaken for the next 20 years, as well as an updatable EXCEL tool useful for own calculations. WP 3 investigated the implications of carrying out independent cabin conversions, based on two study cases. WP 4 delivered an overview of the tools required in a completion center. WP 5 analyzed the financial implications of the vision Completion Center. Most of these topics have been approached by ELAN engineers in parallel to the university input. The approaches were however different, while the results were similar. As an overall conclusion, ELAN should invest in the vision Completion Center, first due to the actual highly competitive market context. This should be however done gradually, by starting with small projects and by gaining new capabilities.

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List of Abbreviations

ACMG	Air Cargo Management Group
ACJ	Airbus Corporate Jetliner
AMC	Acceptable Means of Compliance
BBJ	Boeing Business Jet
BC	Business Class
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CC	Completion Center
CCS	Change Control Sheet
CIDS	Cabin Intercommunication Data System
CM	Configuration Management
CS	Certification Specification
CVE	Compliance Verification Engineer
DOA	Design Organization Approval
DOM	Design Organization Manual
DSM	Design Structure Matrix
DVE	Design Verification Engineer
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
ERP	Enterprise Resource Planning
FC	First Class
ICAO	International Civil Aviation Organization
IFE	In-Flight Entertainment
JAA	Joint Aviation Authorities
JAR	Joint Aviation Requirements
LCC	Low Cost Carrier
LOOP	List of Open Points
MA	Employee (Mitarbeiter)
MOD	Modification
MP	Modification Proposal
OfA	Office of Airworthiness
PDA	Personal Digital Assistant
PL	Project Leader
PLM	Product Lifecycle Management
PSU	Passenger Service Units
QM	Quality Management
RFC	Request for Change
ROI	Return on Investment
ROR	Rate of Return
RPK	Revenue Passenger Kilometers

TC	Type Certificate
SB	Service Bulletin
STC	Supplemental Type Certificate
SWOT	Strengths Weaknesses Opportunities Threats
VIP	Very Important Person
WP	Work Package
WPSS	Work Package Subcontracting Specification
WTM	Work Transformation Matrix

1 Introduction

This report gathers the results of the CARISMA Project. The project was initiated in October 2008 from the need of academic research on a topic that, at that time, seemed to become more and more important: gaining the capability to perform Airbus-independent cabin conversion projects.

This topic was split into five work packages:
WP 1: Identification of the Process Chain Cabin Conversion
WP 2: Market Research Completion Center
WP 3: Analysis of the Process Chain Cabin Conversion
WP 4: Research, Analysis and Evaluation of Tools
WP 5: Planning of a Business Case Completion Center

Indeed, following the results throughout the two years research period, it was asserted, from the side of both partners, that the vision completion center represents a key strategy for the future of CCO department. ELAN researched the topic also on its own, parallel to the university input. Therefore the results of CARISMA come as a research supplement, which sometimes may be not accurate enough from a technical point of view, but brings an academic view that often proved original.

2 WP 1: Identification of the Process Chain Cabin Conversion

2.1 Objectives

The first Work Package had, as a main goal, the identification of the processes inside a Completion Center delivering complete or partial conversions. Additionally, the regulatory requirements, that the provider of engineering and design work should fulfill, were investigated.

The objectives of WP 1 were:

- To conduct an investigation towards the certification requirements with respect to cabin design and redesign work and the way these requirements can be fulfilled by a medium sized engineering office, like ELAN
- To identify the EASA requirements for receiving a DOA
- To adapt and transform these requirements into valid processes
- To present the current status of ELAN and the relation with Airbus, as well as the common activities
- To identify the general steps and processes required for ELAN to obtain a DOA
- To identify the phases and processes required to conduct a complete cabin conversion within a completion center
- To investigate process representation models and to identify the suitable one, which is to be used in WP 3 for generating optimized processes and relations between processes

2.2 Results

According to the objectives, results in the following areas were obtained:

- Certification principles and requirements for the specific case of cabin conversions
- Relation between ELAN and Airbus and current processes at ELAN
- Requirements for obtaining a Design Organization Approval
- Process Chain for cabin conversions within a completion center

2.2.1 Certification Principles for Aircraft and Aircraft Cabins

Certification authorities provide standards for the aviation safety and environmental protection. Certification authorities are also responsible for approving any design, manufacture or maintenance of airplanes or components, as well as for monitoring the implementation of the safety rules. Certification authorities are:

- International Civil Aviation Organization (ICAO)
- Civil Aviation Authorities
- Joint Aviation Authorities (JAA)
- European Aviation Safety Agency (EASA)
- Federal Aviation Administration (FAA)

Further on, the requirements coming from EASA will be discussed.

Certifications are possible under the following categories:

- Type Certificate - TC (Musterzulassung)
- Change of Type Certificate (Änderungen an Musterzulassung)
- Supplemental Type Certificate - STC (Ergänzende Musterzulassung)
- Repair approval (Rparaturzulassung)

Any organization that undertakes design work needs to apply for a Design Organization Approval.

Approval of Design Organizations

The approval of Design Organizations must be made according to Annex Part 21, Subpart J, to (EC) No. 1702/2003. This document sets the requirements that need to be fulfilled by any organization wanting to develop design work for aeronautical products. Requirements from Subpart J interfere with requirements from other sub-parts.

The Acceptable Means of Compliance and Guidance Material illustrate the means by which the requirements stated in the rule can be achieved. Once the compliance is demonstrated, the applicant receives a Type Certificate or, as it is the case, a Restricted or a Supplemental Type Certificate (**EASA 2009b**).

Certification of Aircraft Cabins under DOA

Every product is designed by a design organization having a *type certificate*, where all the specifications of the product are mentioned. In the case of cabin conversions, one is not talking about designing products, but designing *changes* to products. The design work needs to be classified in either *minor or major change* to the type design. Minor changes to a type design are to be classified and approved either by the Agency or by the design organization, if it has a DOA. The major changes can be classified by the DOA holder, but can only be approved by the certification authorities.

If the changes are conducted by other than the TC holder, then they need to be conducted under an STC. An applicant for a change to the type design of a product needs to submit an application which has to include the description of the change, including the identification of (article 21A.93 **EASA 2009b**):

- parts of the type design and manuals affected by the change
- certification requirements and environmental protection requirements
- necessary re-investigation in order to show compliance

The application for a DOA has to contain information about:

- The handbook – Design Organization Manual – furnished under 21A.243
- A statement of the qualifications and experience of the management staff and other persons responsible for making decisions affecting airworthiness and environmental protection (21A.243)

The Decision no 2005/05/c of the Executive Director of the Agency establishes certain application forms related to Agency"s Internal Certification Working Procedures. These forms can be found in the appendix of TN 1.

The EASA certification specifications – CS 25 and CS 23 – provide the requirements for certifying cabin related designs. Additional certification requirements in the field of cabin conversions come from operation – JAR Ops; a summary of these rules is presented in the appendix of Technical Note 1.

2.2.2 Relation between ELAN and Airbus and Current Processes at ELAN

The process of conversion can be defined as the sum of modifications taking place inside an aircraft, so to get from cabin type A to cabin type B. The product – the aircraft, is already designed by the TC holder and fulfils the rest of the airworthiness requirements. Therefore in the process of conversion, the DO which designed the aircraft has a major role. In order to conduct the design of a change, either minor or major, an organization not holding the TC for the respective product, can only show capability by applying for an STC under DOA. The difficulty encountered by a DO is to get the original information from the TC holder. As subcontractor for the TC holder Airbus Operations GmbH, ELAN GmbH developed its experience according to the Airbus system, i.e. according to Airbus requirements, Airbus style and Airbus input.

A project subcontracted from Airbus starts at ELAN with a Technical Proposal during the *Offer* phase, that Airbus needs to accept. Input in this case is a document called WPSS based on which the technical proposal is written.

The engineering work delivered by the subcontractors, becomes part of the internal „Airbus-way" of handling cabin conversions. The *Airbus procedure* with respect to design modifications related to cabin (undertaken by SEUC) is summarized by the following main documents (in this order):

- The customer makes a request which is formalized through what is called **RFC** (**Request for Change**).
- The RFC generates corresponding **MP**"s (**Modification Proposal**), which are documents containing all the technical changes implied by the customer request.
- The **MOD** (**Modification**) is the document containing the technical support for the change to be conducted, as well as the corresponding approvals; it may be composed out of several MP"s

The documents are tagged with a specific code number which shows for which type of aircraft is the modification valid. Based on these documents the SB"s are created, which represent, along with the kit of parts, the deliverable that goes to the customer. ELAN delivers the engineering work contained in the MP"s, MOD"s and SB"s for Airbus.

After confirming the offer, Airbus must deliver the necessary input information (mentioned already in the WPSS). Airbus asks for weekly reports from the subcontractor, showing that the milestones are being respected, and carries the responsibility for *certifying* the design. At the end of the project, Airbus includes the information provided by the subcontractor in the *SB* that is to be received from the client.

Further, the PL assigned at ELAN for the respective project makes an estimation of the working hours and costs and selects its team for delivering the results. Part of the *Organization* phase is now an internal Kick-off meeting and the assignment of tasks and input data to the employees. The next phase is the *Work* phase where the PL has the responsibility to deliver status reports to Airbus, to create LOOPs, CCSs and to provide support to the team members. The results are to be then delivered to Airbus, through the PL, within the *Delivery* phase. Possible defect reports are solved and a final evaluation is performed during the *After-work* phase. Figure 2.1 illustrates these processes.

Within the project the PL carries the responsibility for the project. His role is vital for the project, and the number of his work-hours is usually higher than the normal employee. PL tasks are summarized in Figure 2.2

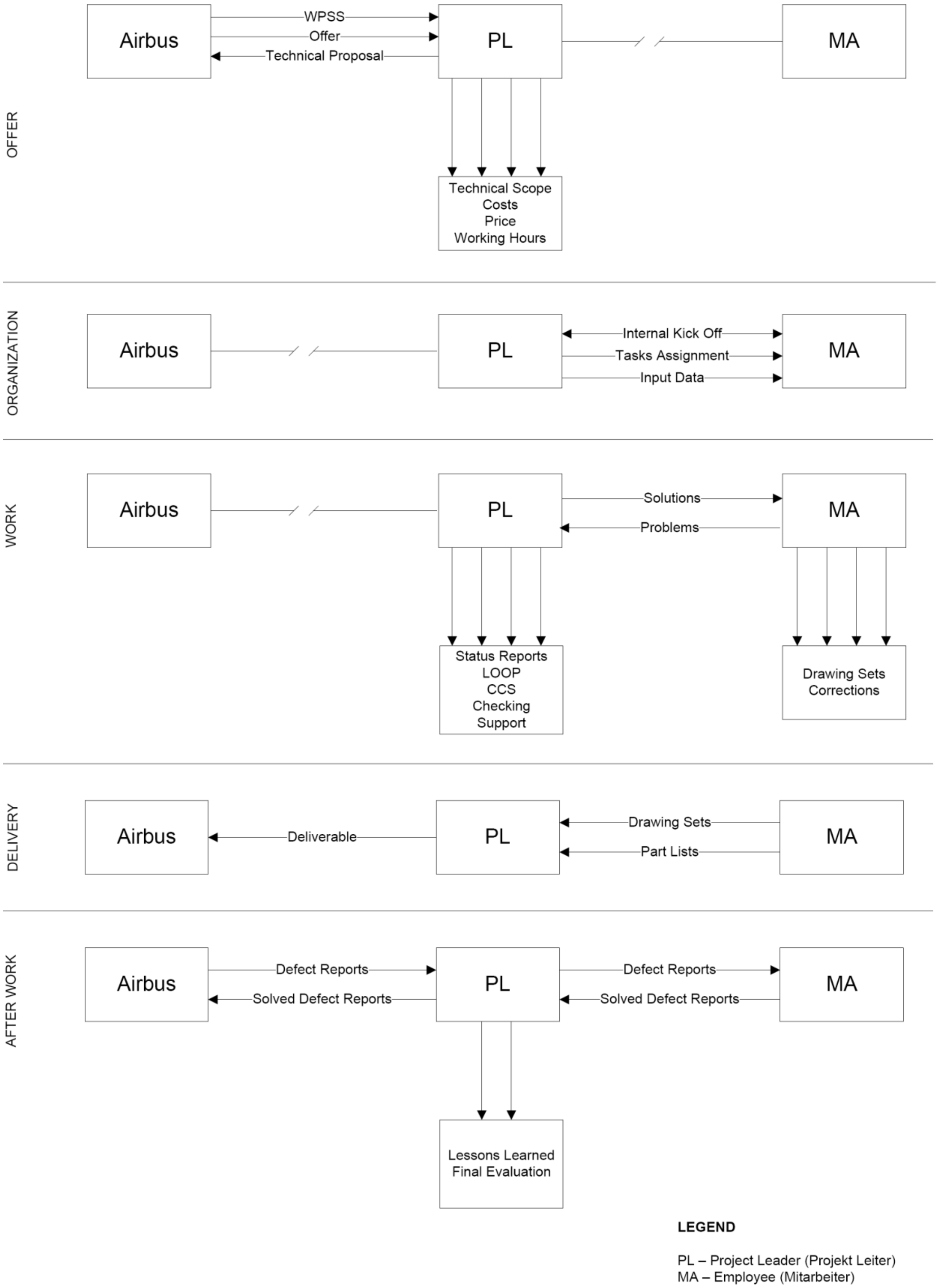


Fig. 2.1 Internal working procedure at ELAN with Airbus

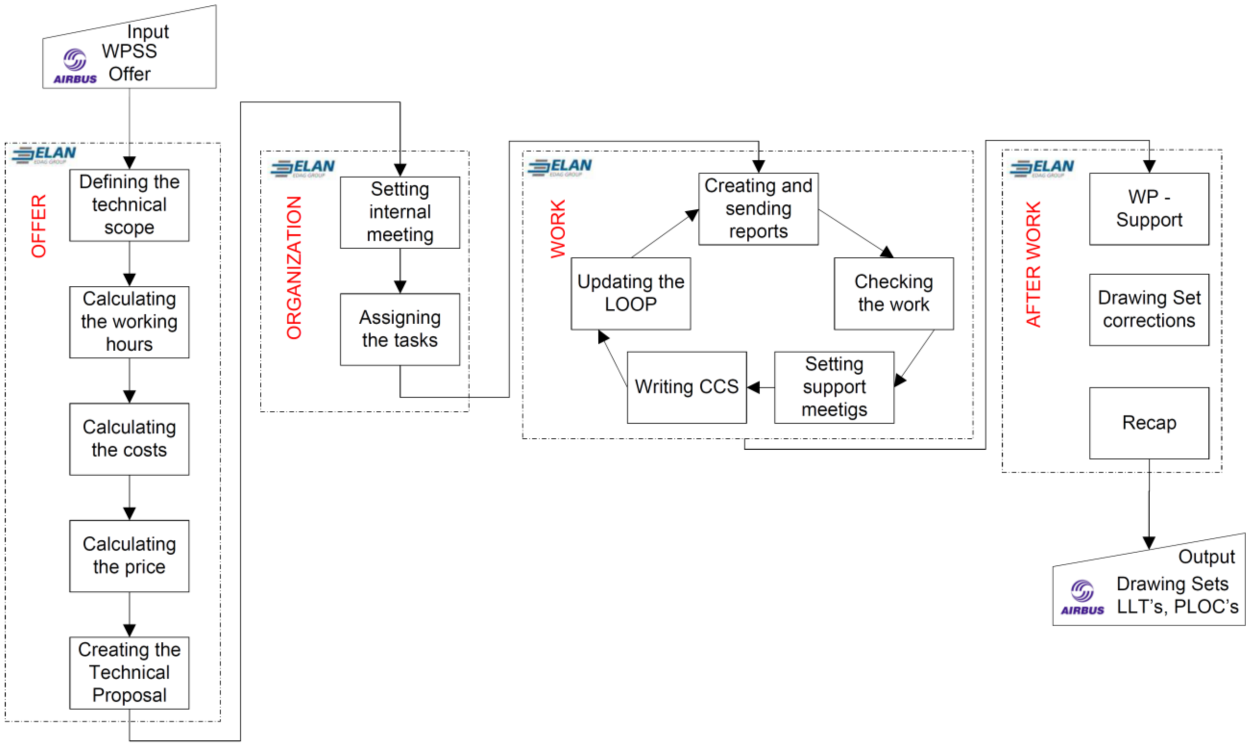


Fig. 2.2 PL responsibilities at ELAN

2.2.3 Requirements for Obtaining a Design Organization Approval

In order to carry Airbus independent conversions i.e. changes to type design, the design work needs to be performed under a STC that can only be issued by EASA to a design organization having a DOA. To set up a design organization in the form required by EASA to issue the approval, several requirements are to be fulfilled.

Scope of approval

The first requirement is to define a clear scope of approval, when the application is created. For the activities of a completion center, the Scope of Approval must contain the following:

- Product Type:
  - Small Aeroplanes (CS 23)
  - Large Aeroplanes (CS 25)
- Activities:
  - Supplemental type certificate (for each product)
  - Minor changes and repairs
  - Major changes and repairs
- Technical Fields
  - Installation of Avionics and Equipment
  - Environmental Systems
  - Electrical Systems

- Cabin Interior
- Galleys or other interior equipment

If the DOA is granted, the engineering office would have the following privileges (article 21A.263(c), **EASA 2009b**):

- Classify changes
- Approve minor changes and repairs
- Approve documentary changes to FM
- Approve design of major repairs to products for which it holds the STC

Personnel

The number of personnel for assuming the main responsibilities within DO is depending on the scope of work. The absolute minimum for a very limited scope could be defined for 5 persons; these functions can be further supplemented in the case for an engineering office of the size of ELAN:

- Head of the DO
- Head of the Office of Airworthiness
- Compliance Verification Engineer
- Design Engineer
- Quality Management Engineer

Figure 2.3 proposes a solution, according to the scope of approval and requirements from Part 21. Detailed responsibilities and functions of personnel can be found in TN1.

Monitoring System

The reason EASA is asking for an independent monitoring system is to make sure that undetectable errors and failures, which may not be observed by the Agency, are kept under control. Through the DOA itself the Agency is looking to develop among the design companies a safer and more complex self-control function. The purpose is to discharge the responsibility of certifying the product on the engineering and certification team of the DO, while EASA is supervising carefully the actions.

The *Independent Monitoring System* is an obligatory part of the *Design Assurance System* for any organization wanting to get the DOA. Here is what the Agency states in article 21A.239 (**EASA 2009b**):

> *(a) This design assurance system shall be such as to enable the organization:*
> *3. To independently monitor the compliance with, and adequacy of, the documented procedures of the system. This monitoring shall include a feed-back system to a person or a group of persons having the responsibility to ensure corrective actions.*
> *(b) The design assurance system shall include an independent checking function of the showings of compliance on the basis of which the organization submits compliance statements and associated documentation to the Agency*

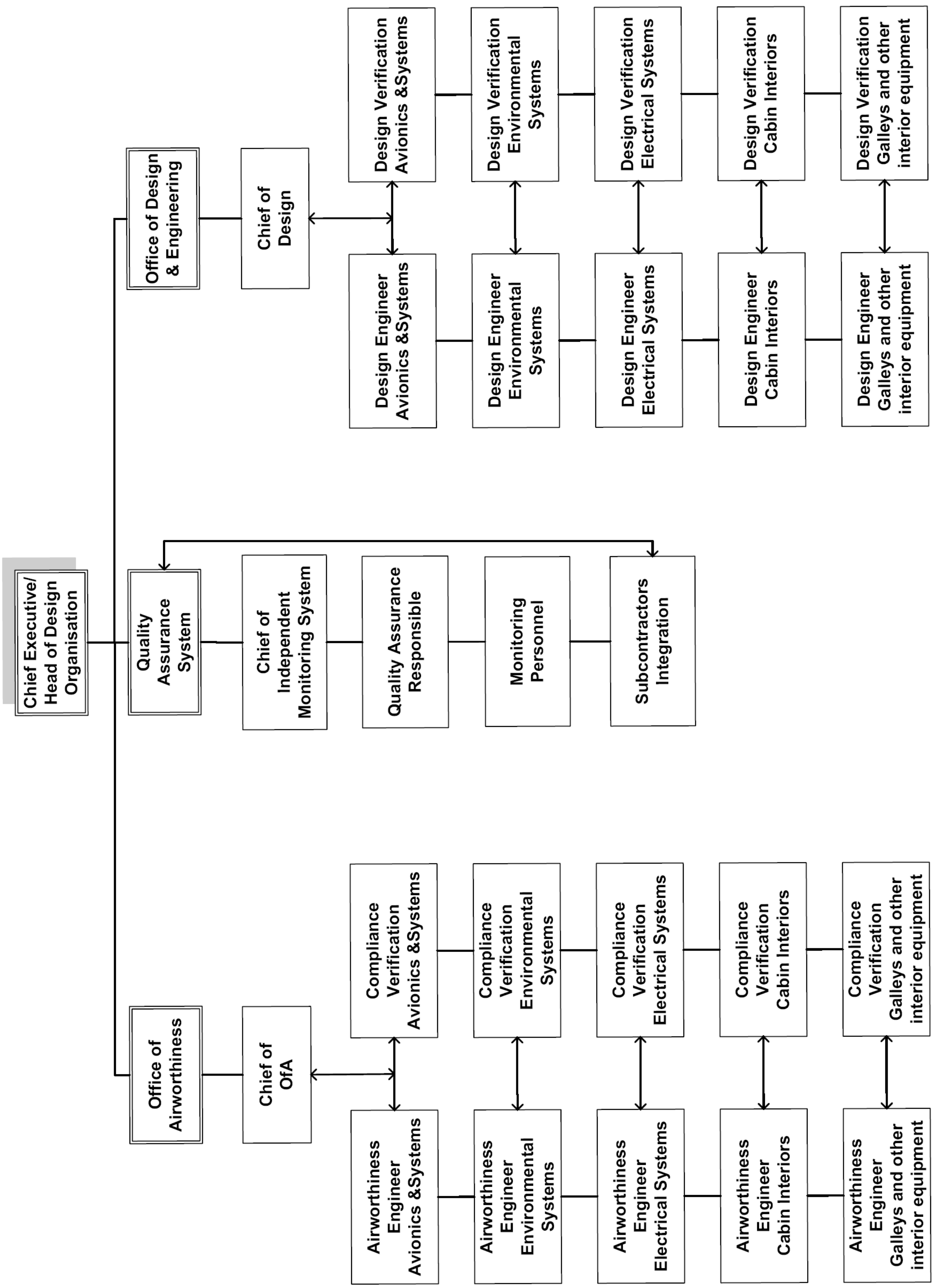


Fig. 2.3 Personnel within DO (according to EASA recommendation for ensuring approval)

The personnel involved in the monitoring function carries also the responsibility of the integration of the subcontractors, according to EASA. If part of the work is to be outsourced to organizations not having a DOA, the monitoring function of the contractor should be applied to the products coming from the subcontractors so as to ensure the airworthiness and quality expectations. In fact, all the eventual suppliers, whether they have a DOA or not, need to conform to the prescriptions of the contracting design organization.

The description of the procedures within the Monitoring system is the task of the Monitoring Office. The same division is responsible for ensuring the quality expectations coming from the customer. The personnel involved in Quality Assurance will conduct the research towards the implementation of the proper Quality Management System. The decision will be taken whether to opt for the EN 9100 standard and/or for additional QM Tools.

Design Organization Manual

According to Subpart J, 21A.243(a) (**EASA 2009 b**), the DO has the obligation to describe the organization, the relevant procedures and the products or changes to products to be designed inside the Design Organization Manual, called *handbook* by the Agency. Another requirement from the Agency is the continuing amendment of the handbook, whenever a change in the DO occurs (21A.243(c)). The article 21A.265, about the obligations of the DOA holder, states at paragraph (a) that the handbook must be maintained in conformity with the design assurance system and at paragraph (b) that the Agency must be assured that the handbook is used as a basic working document within the organization.

To summarize, the Design Organization Manual (DOM) must specify all the instructions and procedures within the organization, required to perform the design. The information provided by the handbook must include the description of (AMC No. 1 to 21A.243(a), **EASA 2009d**):

- Tasks
- Organization
- Assigned responsibilities
- The way in which the DO performs all the design functions
- Human resources, facilities and equipment
- Recording system
- System for controlling and informing the Staff of the organization of current changes in engineering drawings, specifications and design assurance procedures
- Record keeping system to comply with 21A.105
- The means by which the organization monitors and responds to problems affecting the airworthiness, so as to comply with 21A.3
- The names of the design organization authorized signatories
- The clear definition of the tasks, competence and areas of responsibility of the Office of Airworthiness
- System monitoring of the design assurance system

Process Chain for DOA

The implementation of the EASA standards for creating a Design Organization can follow this sequence (Figure 2.4) (**CAMR 2009**):

- Preparation
- Implementation
- Evaluation
- Learning

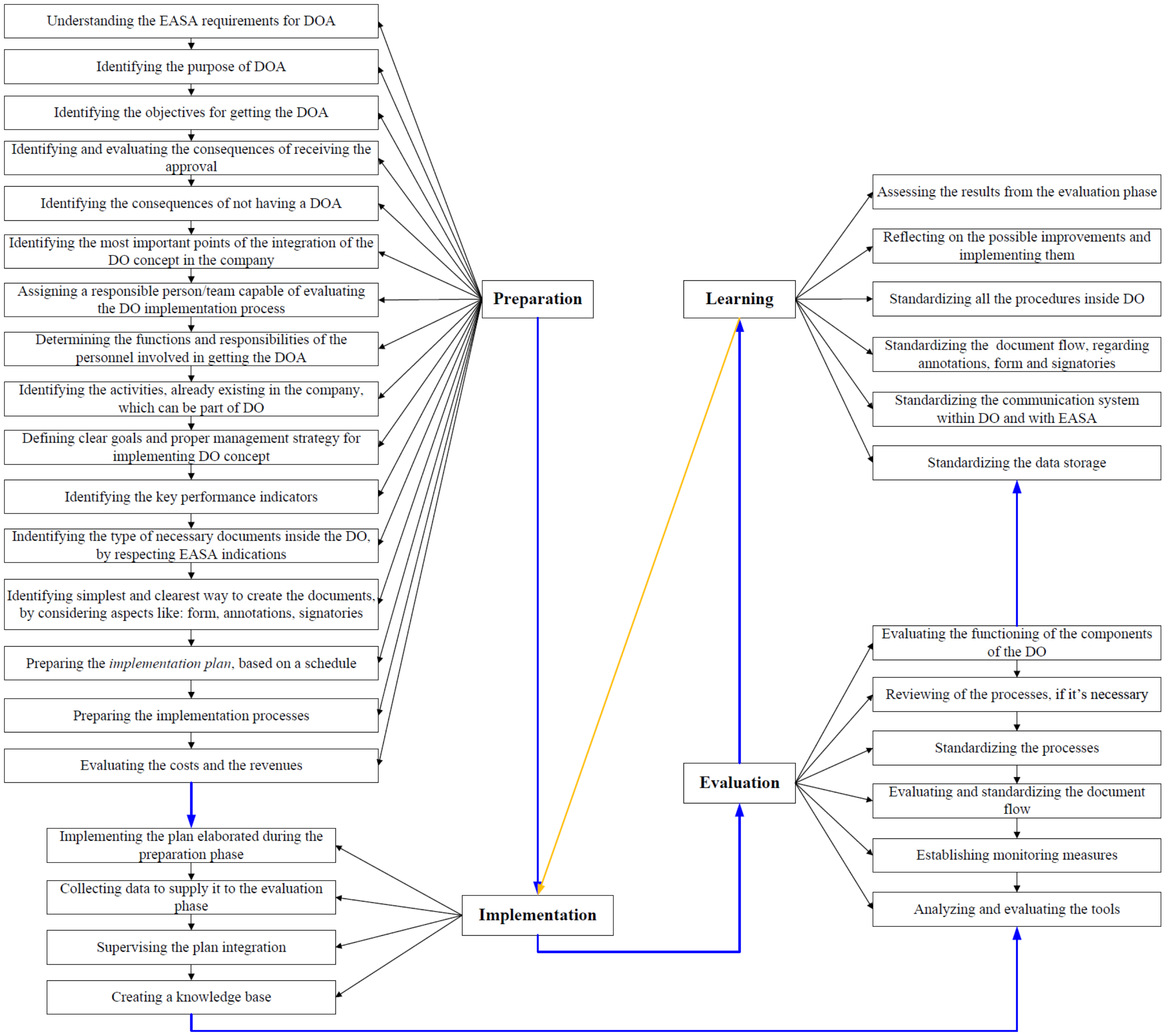


Fig. 2.4 Preparation for DOA implementation – Process Chain representation

2.2.4 The Process Chain for Cabin Conversion

There is not just one path towards achieving an optimized process chain. The flow of processes and documents for cabin conversion should be in such a way organized, that it minimizes parameters like: time, costs, effort and, especially, errors. The process chain description was divided into three parts (see Figure 2.5.):

- Part A, referring to the offer phase description,
- Part B, referring to the description of the processes for completing the conversion,
- Part C, describing the end processes and the deliverables going to the customer.

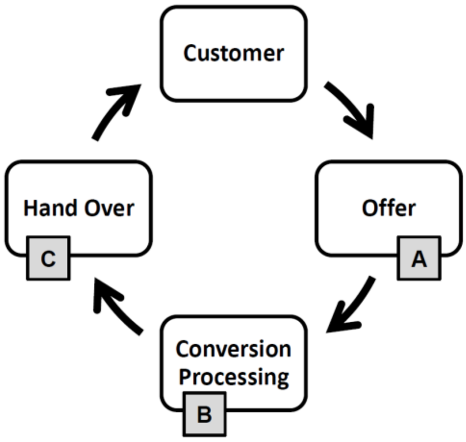


Fig. 2.5 Completion Center Concept for ELAN GmbH

The first attempt to define the customer requirements is made in the *Offer Phase*. If the offer is accepted by both sides, then the technical document, describing it and the technical implications, heads towards the *Conversion Processing*. The output of the processing, summarized all together in the *Hand Over Phase,* comes back to the customer, and a circle closes. The correct functioning of this system returns feedback from customer and allows the update of a virtual catalogue.

Description of phases and sub-phases

For the tasks representation in cabin conversion and refurbishing the following steps were followed:

- Engineers from engineering offices were inter-viewed
- Different sources of data were analyzed (industry cooperation with university, conference papers, etc)
- A list of tasks was created
- The relation between tasks was analyzed
- A DSM matrix was completed

Among all the sub-phases, illustrated in Figure 2.6, the *Certification* phase has major implications over the work activities. It starts already from the early phase of the design. The *Offer* phase represents the starting point of the process. The decision, whether to start or not, is the result of the negotiations between the customer and the completion center.

The *Offer Phase* starts with the Customer Request which is formalized through a preliminary document briefly describing the requirements of the customers and the implications within the

Completion Centre. In the same time, this document represents the first decision gate for both sides. If the two parts agree, then the Technical Offer document will describe in detail the actions which are to be followed in order to finalize the customer request.

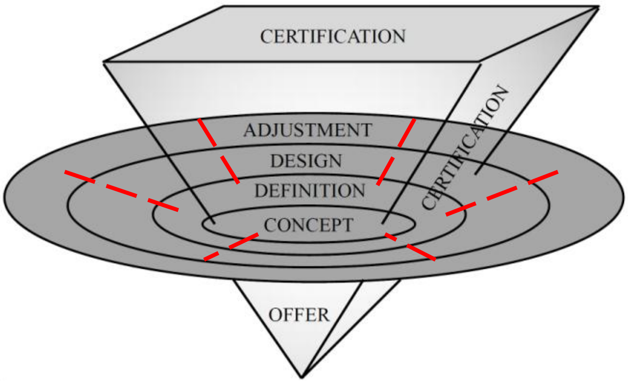


Fig. 2.6 Representation of the conversion processing cycle

Parallel to this activity, the engineering office should make a feasibility study, to see if it is a benefit for the company to accept the proposed task from the customer. For example, it would be quite difficult to comply with the requirements from customers having products not conforming to the type certification basis. If each decision gate ends with a “yes”, the outputs enter then the Process Chain B.

The *Conversion processing* cycle gathers all the phases related to the design and certification of the conversion work. These phases are:

1) Concept
2) Definition
3) Design
4) Adjustment

Each phase has its own number of sub-phases, which can also be further divided into smaller processes.

1) Concept Phase

The first stage in the development of a product is the conception. The actions required at the beginning of a project are mainly referring to:

- understanding and filtering the customer requirements,
- understanding and filtering the certification requirements,
- making an internal feasibility study,
- studying the design possibilities,
- organizing the work flow,
- developing the preliminary design,
- developing the testing and verification methods.

2) Definition Phase

The definition phase approaches the same issues more in depth, with the purpose of achieving the final version of the design. The main steps are:

- defining the certification basis,
- defining the Means of Compliance,
- defining the process steps,
- assigning and organizing a team,
- analyzing mechanical and electrical loads, tolerances,
- analyzing interference between components,
- testing the design,
- validating the design concept.

3) Design Phase

The design engineers perform the design work based on the prescriptions of a Chief of Design, assigned already in the conception phase, and those of the airworthiness engineers and Compliance Verification Engineers (CVE). Mainly, during this phase it is required to:

- perform the design according to the prescriptions elaborated during the earlier phases,
- verify the design (Design Verification Engineers),
- give feedback to the project leader.

4) Adjustment Phase

The adjustment phase sums up those activities aimed to improve the overall functioning of the company delivering the conversion. Some of the processes belonging to this phase are:

- getting feedback from every engineering department,
- detecting points of improvement,
- proposing optimized solutions.

5) Certification

According to CS 25.21 [8] the certification process of an aircraft means proving that the design complies with all the requirements stated in the specifications emitted by the Authority. For efficiency, the certification process should start from the early phase of the conception, in parallel to the design development activities. For reducing time and errors, certain aspects need to be already considered when the concept is developed. The certification process is under the responsibility of the Office of Airworthiness [9]. Mainly the steps are:

- establishing contact with the authorities,
- creating the means of compliance (tests and corresponding documentation),
- creating and approving the certification documentation, under DOA privileges,
- creating certification documentation for getting EASA approval (where the privileges do not apply),
- signing the declaration of compliance (responsibility of head of DO).

The *Hand Over* phase starts once the design is performed and verified. The form of the results is written documentation, describing the assembly process in detail. The size and complexity of the technical documentation depends on the size of the conversion project. Besides the technical documentation, assistance should be as well provided. The steps involved in this phase require:

- taking over the final version of the design documentation,
- creating the assembly instructions, based on the design documentation,
- verifying the documentation,
- providing assistance,
- delivering the results to the customer.

The output of the finalized conversion process becomes the input for the hand over phase, and receives the name "deliverable". Together with the deliverable, the engineering office needs to provide assistance to the customer, once the work package is finished. Under the hypothesis that the company performs only the design work, and not the manufacture and assembly, the deliverable is in fact a document, gathering all the data necessary for the design to be executed: technical documentation, procedures and instructions for assembly, part lists, instructions and cautions for continued airworthiness and maintenance.

The elements of the Process Chain

Below the all the identified elements of the process chain are listed.

1. OFFER		1.1	Receive request		
		1.2	Assign Offer Leader*		
		1.3	Analyze request		
		1.4	Contact customer and set first meeting		
		1.5	On the first meeting: initiate discussions and negotiations		
	+	1.6	Write CRTS (Customer Request Technical Sheet) in which:		
			1.6.1	Preliminary describe the technical implications	
			1.6.2	Make estimations (based on experience) regarding design effort, time, costs	
		1.7	Conceive preliminary solutions (for discussing it with the customer)		
		1.8	Create preliminary representation of the solutions found (with tools which fit the marketing function, i.e. Pacelab Cabin, Aircraft Scanner)		
	+	1.9	Make feasibility study		
			1.9.1	Analyse estimated results	
			1.9.2	Identify required resources	
			1.9.3	Estimate profit	
		1.10	Decide if go ahead; if yes, then:		
		1.11	Get signed agreement within a second meeting		
	+	1.12	Write DTS (Detailed Technical Sheet)		
			1.12.1	Estimate the size of the work package	
			1.12.2	Identify involved technical fields	
		+	1.12.3	Identify certification basis	
				1.12.3.1	Identify certification implications
				1.12.3.2	Set preliminary certification requirements
			1.12.4	Identify resources for performing the work	
			1.12.5	Make estimations regarding design effort, time, costs	
		1.13	Identify suitable project leader and personnel		
		1.14	Confront DTS with CR		
		1.15	Make adjustments		
		1.16	Send results further down (concept) in order for the work to be initiated		

Fig. 2.7 Process illustration: Offer Phase

2. CONCEPT		2.1	Analyze customer requirements			
		2.2	Perform aircraft inspection			
		2.3	Write document describing diagnosis			
		2.4	Identify the technical fields involved in the design process*			
	+	2.5	Initiate team organization for- and division of responsibilities between			
			2.5.1	Engineering		
			2.5.2	Design		
			2.5.3	Certification (OoA)		
		+	2.5.4	Quality Assurance		
			+	2.5.4.1	for each technical field	
					2.5.4.1.1	Avionics & Equipment
					2.5.4.1.2	Environmental Systems
					2.5.4.1.3	Electrical Systems
					2.5.4.1.4	Cabin Interior
					2.5.4.1.5	Monuments and other Equipment
					2.5.4.1.6	Emergency & Safety Equipment
	+	2.6	Plan the design & engineering process (by the Engineering and Design Office)			
			2.6.1	Assign teams for each technical field		
			2.6.2	Assign tools to work with		
			2.6.3	Choose QM strategy (! Before defining processes)		
			2.6.4	Concieve the process (what) chain of the work flow		
			2.6.5	Conceive the procedures (how) to be followed		
			2.6.6	Make optimization studies		
	+	2.7	Plan the certification process (by Office of Airworthiness)			
			2.7.1	Contact EASA and TC Holder		
			2.7.2	Identify certification basis		
			2.7.3	Analyze certification requirements		
			2.7.4	Transform Certification Requirements into technical rules		
			2.7.5	Identify means of testing and showing of compliance (MOC's)		
			2.7.6	Set classification procedures for minor and major chnages according to EASA (AMC&GM Part 21)		
			2.7.7	Send application for STC to EASA		
			2.7.8	Send application for major changes to EASA		
			2.7.9	Identify responsible persons for approving minor changes		
			2.7.10	Identify responsible persons for creating the documentation to be sent to EASA for approval (for major changes)		
			2.7.11	Verify the consistency of the certification basis		
		2.8	Identify required resources and tools			
		2.9	Decide if it's necessary to involve subcontractors			
		2.10	Conceive preliminary models			
		2.11	Consult/report to customer			
		2.12	Verify the fulfilling of customer requirements			
		2.12	Validate concept (regarding all aspects: work flow, work procedures, design...)			

Fig. 2.8 Process illustration: Concept Phase

3. DEFINITION		3.1	Define the QM strategy and follow it when detailing the processes
	+	3.2	Organize work flow (who & what does)/Create Work Breakdown Structure
		3.2.1	Identify and asssign personnel
		3.2.2	Identify tasks
		3.2.3	Define work procedures, corresponding to the type of work
	+	3.2.4	Identify types of documents and document flow
	+	3.2.4.1	to be produced by Design Engineers:
		3.2.4.1.1	Enginnering Orders
		3.2.4.1.2	Instructions for installation und assembly
		3.2.4.1.3	Appendices to CMM (Component Maintenance Manual) and AMM (Aircraft Maintenance Manual)
	+	3.2.4.2	to be produced by Airworthiness Engineers:
		3.2.4.2.1	Documents for showing compliance
		3.2.4.2.2	Approval documents
		3.3	Identify parallel processes and prescribe the parallel process performing
		3.4	Schedule work
	+	3.5	Define work procedures (how to do it) for
		3.5.1	Certification
		3.5.2	Monitoring
		3.5.3	Design
		3.5.4	Quality Assurance
		3.5.5	Relation with subcontractors
	+	3.6	Define the design concept
	+	3.6.1	Perform design studies for each technical field
		3.6.1.1	Identify interferences between technical fields
		3.6.1.2	Identify possible conflicts between technical fields
		3.6.2	Identify the feasible choice
		3.6.3	Validate design concept
	+	3.7	Prepare Certification
		3.7.1	Define Test and Verification Methods, according to the MOC's and specific for the type of design
		3.7.2	Create compliance check lists

Fig. 2.9 Process illustration: Definition Phase

4. DESIGN		4.1	Recieve and understand design assignments from responsible person (Chief of Design)
	+	4.2	Analyze and understand constraints specific to the design:
		4.2.1	Certification constraints
		4.2.2	Customer constraints
		4.2.3	Design limits
		4.3	Optimize tool selection (already indicated in concept phase, but also in concept phase)
	+	4.4	Perform design, including:
		4.4.1	Perfom simulations
		4.4.2	Perform 2D and 3D respresentations
	+	4.5	Perform design analysis and verification (Design Verification Engineer-DVE)
		4.5.1	Analyze the electrical and mechanical loads
		4.5.2	Analyze interference with structure
		4.5.3	Define tolerances
		4.5.4	Perfom assembly analysis
		4.5.5	Identify clashes
		4.5.6	In case of clashes, propose feaseble solutions
		4.5.7	Choose and apply final solution
	+	4.6	Perform design analysis and verification (Compliance Verification Engineer-CVE)
		4.6.1	Confrunt results of the DVE with the prescriptions from MOC's
		4.6.2	Report uncompliance back to the DVE
		4.7	Choose and apply final solution (after receiving feedback from CVE)
		4.8	Produce part lists
		4.8	Produce coresponding documentation (as described in the definition phase)
		4.10	Send documentation to get approval (to the OoA)

Fig. 2.10 Process illustration: Design Phase

5. CERTIFICATION	5.1	Receive documentation to be approved
+	5.2	Perform test and compliance verification procedures according to MOC
	5.2.1	for each component
	5.2.2	for the assembled components
	5.3	Create coresponding approval reports
	5.4	Send coresponding documentation (e.g. test results) to EASA (for major chnages)
	5.5	Approve minor changes under the DO priveleges
	5.6	Receive STC
	5.7	Recive approval for major chnages
	5.8	Prepare instructuons for Continued Airworthiness

Fig. 2.11 Process illustration: Certification Phase

6. HAND OVER	6.1	Collect technical documentation and approval documents
	6.2	Collect assembly instructions
	6.3	Prepare the documentation in the form required by the customer
	6.4	Deliver results
	6.5	Asign assistance team available upon customer request
	6.6	Register Lessons Learned
	6.7	Archive all data
	6.8	Perform final cost evaluation

Fig. 2.12 Process illustration: Hand-Over Phase

7. ADJUSTMENT	7.1	Get functioning feedback from every engineering department
	7.2	Analyze overall functioning of the DO
	7.3	Detect points of improvement
	7.4	Propose optimized solutions
	7.5	Create functioning reoprts
	7.6	Send reports to management
	7.7	Receive feedback from management
	7.8	Prepare updated procedures, as it is required, after reciveing instructions
		from management

Fig. 2.13 Process illustration: Adjustment Phase

2.3 Summary

The present economical context shows a growing market for cabin related activities. While OEM"s are increasing the pressure on subcontractors, by outsourcing larger work packages, the engineering offices, like ELAN GmbH, are seeking to further develop and increase their capabilities. In this context, the WP 1 of CARISMA research project, initiated the investigation of several important topics, such as certification requirements with respect to cabin design and conversion, background information for obtaining a Design Organization Approval from EASA, the process chain for cabin conversion. The process chain for a complete conversion was divided into three parts. A: Offer, B: Conversion Processing, C: Hand Over. The investigation shows a high complexity of the task of cabin conversion. This complexity can only be mastered in an organization that controls itself rather independently from the surveillance of the Certification Agency. The present regulations pay more attention to the aircraft manufacturers than to subcontractors. This, however, will change soon: according to the European Aviation Safety

Authority, the future will see the formation of specialized Centers of Excellence, formed by both manufacturers and engineering offices working on the certification of their products together.

3 WP 2: Market Research Completion Center

3.1 Objectives

The main objectives of WP 2 were:

- Presentation of the existing Completion Centers, their tasks, market share and location
- Investigation of aircraft data (manufacturer, aircraft family/class/model, age)
- Investigation of current market demands related to conversion and refurbishing of aircraft cabins
- Identification of conversion scenarios and factors driving these scenarios
- Determination of the duration and frequency of the modification scenarios for each case
- Determination of the aircraft fleet for the present and for the next 20 years
- Prediction of the market volume for the next 20 years

The information for achieving these goals is gathered from many examples found in real life.

3.2 Results

According to the objectives, results in the following areas were obtained:

- Existing completion centers
- Characteristics of the current cabin conversion and refurbishing market
- Driving factors in cabin conversion and refurbishing
- Aircraft world fleet – current and future trend
- Forecast of the market volume

3.2.1 Existing Completion Centers

A Completion Center can deliver a range of modifications from simple cabin upgrades to complete, highly specialized conversions, usually attributed to VIP aircraft. The range of cabin conversions throughout the commercial aircraft life can be as follows:

- *At age 0*: several initial standard cabin layouts are created by the aircraft manufacturer.
- *At age 5 to 20 years*: several cyclic cabin upgrades caused by worn out furnishing or due to change of aircraft ownership are undertaken inside a Completion Center; if the owner is a VIP, the design and engineering work normally demands a complex certification process, especially if the customer is asking for unusual furnishings.

- *After age of 20 years*: the only scenario possible is pax-to-freighter conversion, undertaken either by the aircraft manufacturer of within a Completion Center.

In common understanding, the notion Completion Center, refers to those organizations able to deliver aircraft cabin conversions independent of other companies. Lately, several other possible ways to define the term Completion Center have come into use. Accordingly, a design organization (DO) can call itself a Completion Center even without seeing the aircraft, by delivering only the design work. Another possibility for a company to call itself Completion Center is to conduct the work for the customers through intermediaries, as a developer. Figure 3.1 illustrates all these possibilities.

When looking at the companies dealing today with cabin conversions, some observations can be extracted:

- A frequent scenario is VIP Completion. VIP customers are usually high paying and high demanding. VIP completion on large aircraft can result in big contracts.
- Certification work is performed under the Aviation Authorities, which usually require a certificate showing the capability of performing the design (EASA and FAA call it DOA – Design Organization Approval). However, a company can function as a Completion Center without DOA, if certification work is subcontracted.

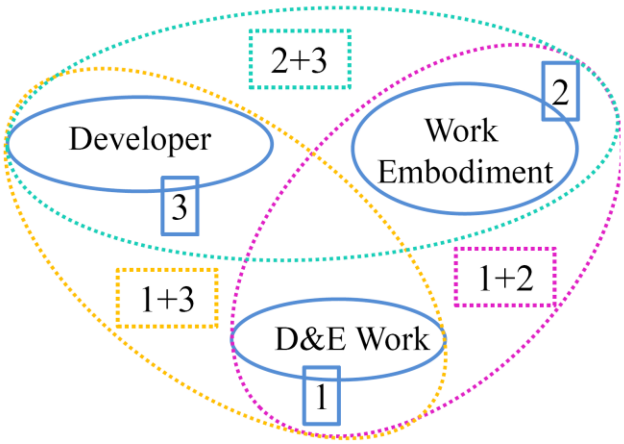


Fig. 3.1 Completion Center concepts

For the foreseeable future, it seems that the demand will be higher than the current Completion Centers can take. The results of an investigation towards the existing Completion Centers and their activities are included in the Excel document attached to this Technical Note, in the sheet called „Modification Centers" (Figures 3.2, 3.3 and 3.4).

The information gathered refers to the type of aircrafts on which the work is performed, the type of work scenario carried out and the location of the Completion Center.

On the first look (Figures 3.2, 3.3 and 3.4) one can notice the fact that Completion Centers are mainly focused in the North America (USA and Canada) and Western Europe. A strategy for a design organization (located in Europe) wanting to become a Completion Center would be to assimilate the market niche represented by the Asian market. The engineering work could be conducted in Europe, while the embodiment of the design can be transferred to the cheaper work force in the east (including Eastern Europe).

From a total of 97 Completion Centers included in the database, 61 deliver VIP conversions: the most expensive, therefore the most profitable market segment. Some conduct pax to freighter conversions and the rest is specialized in delivering cabin upgrades for aircrafts operated by airlines.

3.2.2 Characteristics of the Current Cabin Conversion and Refurbishing Market

The aircraft cabin undergoes several transformations along the useful life of the aircraft. Depending on the age of the aircraft, correlated with the operator requirements, the cabin may either be *upgraded* or *refurbished*, or it may completely change its destination through a *conversion* process.

Market Segments
Three market segments were approached. First, *airlines* need periodical cabin interior upgrades. Second, older passenger aircraft become the perfect candidate for *freighter* conversions. Third, private aircraft owners demand *VIP* conversions.

Airline Cabins are divided into several class types and class divisions:

- Domestic cabins – with economy, business and first class.
- International cabins – with economy, premium economy, business and first class.

Freighter Cabins are usually transformed from older passenger transport aircraft. Statistics (**Williams 2009**) show that almost 400 airliners in North America, about 100 in Europe and 110 in Asia and Africa fulfill the requirements to be transformed into freighters. Figure 3.5 shows the number and age of some aircraft models convertible from pax-to-freighter configuration.

VIP Cabins, owned either by private individuals or corporations, represent a challenging but fruitful market segment. The cabin interior plays an increasingly important role and the range of cabin options available to these operators is limited only by what can be certified.

Characteristics
Airline Cabins. The main class differences involve parameters like seat pitch, recline angle of the seat, seat type or IFE system. Airlines decide to upgrade the inner layout by changing these items. Some of the characteristics (**Scholz 1999**) of each class are summarized in Table 3.1.

Modification Center name	Type of work	In-house Interior Design	Aircraft types involved	Location
ADI Interiors	VIP cabin modification	yes		US
Aero Air, Inc.	Interior modification		Galaxy, Astra, Westwind and Twin Commander	US
Aero Industries / Richmond Jet	Interior modification	yes		US
Aerosmith Aviation, Inc.	VIP cabin modification	yes	Gulfstreams, Hawkers, Learjets, Challengers, Jet Stars, Diamonds, King Airs, Falcons, Citations and Westwinds	US
Airbus Corporate Jet Centre	VIP cabin modification		Airbus	
AirCraft Interiors Inc	VIP cabin modification	yes	Medium sized jet	Canada
Aircraft Interiors of Memphis, LLC	Interior modification	yes	piston and turbine aircraft	US
Air Hanson Engineering, Ltd	VIP cabin modification			England
AiROVATION Interior Restyling, Inc	Interior modification	yes		US
Akridge Aircraft Interiors, Inc.	VIP cabin modification	yes	Gulfstream	US
American Aircraft Interiors	VIP cabin modification		Citation, King Air, Conquest, Hawker, Lear, Falcon, Gulfstream, and Boeing.	US
Associated Air Center, Inc.	VIP cabin modification	yes	BBJ & ACJ	US
Austin Jet International	VIP cabin modification		Lears, Citations, King Airs, Hawkers, Gulfstream	US
AvCraft Support Services, Inc.	Airliner interior modification	yes	Dornier 328	US
AVMATS	Airliner interior modification	yes	Falcon, Hawker, and Sabreliner	US
Bizjet International Sales & Support	VIP cabin modification	yes	Citation, Learjet, Dassault Falcon Jet, Embraer, Gulfstream, BBJ	US
Bombardier Aerospace - Montreal	VIP cabin modification	yes	Bombardier Global Express, Bombardier Challenger	Canada
Bombardier Aerospace - Tucson	VIP cabin modification	yes	Challenger, Learjet and other aircraft	US
Bombardier Aerospace - West	Interior modification		commuter aircraft types	US
Bombardier Aerospace - Wichita	VIP cabin modification	yes	Learjet	US
Burnet Interiors sa	VIP cabin modification	yes		Switzerland
Cabin Crafters	upholstery and cabinetry	subcontract	up to Gulfstream V size aircraft	US
Capital Aviation, Inc.	VIP cabin modification	yes	up to Gulfstream IV size aircraft	US
Classic Interior Completions, Inc.	Interior modification	yes		US
Cypress Aviation, Inc.	Interior modification	no		US
Dassault Falcon Jet	VIP cabin modification	yes	Falcon Jet	US
Dassault Falcon Jet - ILG	VIP cabin modification	yes	Falcon, Challenger, Bae, Gulfstream. NDT and DAS	US
Dassault Falcon Service	VIP cabin modification	yes	Dassault Falcon Jet	France
Delta Interior srl	VIP cabin modification	yes		Italy
DO328 Support Services	Airliner interiors VIP cabin modification		Dornier	Germany
Duncan Aviation Inc. - BTL	VIP cabin modification	yes	Citations, Learjets, Hawkers, Falcons, Gulfstreams, Challengers and Astras	US
Duncan Aviation Inc. - LNK	VIP cabin modification	yes	Citations, Learjets, Hawkers, Falcons, Gulfstreams, Challengers, Astras	US

Fig. 3.2 Completion Centers and their characteristics, letters A to D

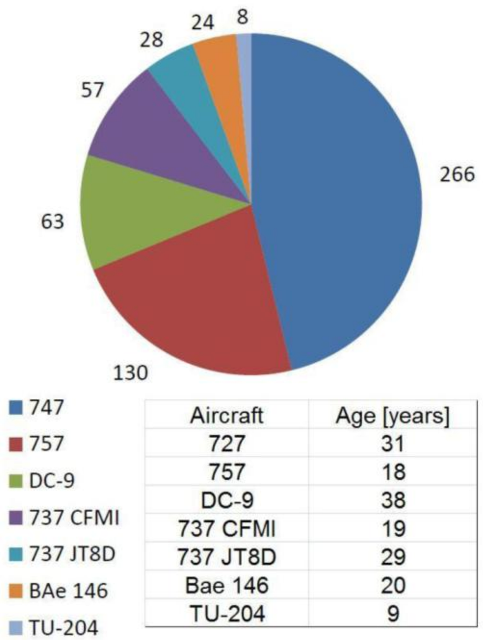
EADS EFW	Freigher Conversion		Airbus	Germany
EADS Sogerma Services	VIP cabin modification		Airbus	France
Eagle Aviation, Inc.	Interior modification	yes		US
Elliott Aviation	VIP cabin modification	yes		US
Executive Aircraft Corp. - Newton	Interior modification			US
Executive Aircraft Corporation - Wichita	Interior modification	yes		US
Field Aviation East Ltd.	VIP cabin modification	yes		Canada
Field Aviation East Ltd.	VIP cabin modification	yes		Canada
Florida Aircraft Interiors	Interior modification		single engine to small jets	US
Fokker Services	VIP cabin modification	yes		Netherlands
	Airliner interior modification		Fokker	
Flying Colours Corp.	VIP cabin modification	yes	Gulfstream, Cessna, Falcon, Lear Jet, Challenger, Sikorsky, Hawker, Beechjet. Extensive experience with Citation Series.	Canada
Garrett Aviation Services - SPI	Interior modification	yes	Falcon Service Center	US
Garrett Aviation Services - VNY	VIP cabin modification	subcontract	Gulfstream, Challenger and Global Express	US
Goderich Aircraft, Inc	VIP cabin modification	yes	Bombardier	Canada
Goodner-Crider Aircraft Painting	Interior modification	yes		US
Gore Design Completions, Ltd	VIP cabin modification	yes	BBJ, A340, 767, executive jets	US
Greenpoint Technologies, Inc.	VIP cabin modification	yes	Boeing	US
Gulfstream Aerospace Corp. - Dallas	VIP cabin modification	yes	Gulfstream	US
Gulfstream Aerospace Corp. - Long	VIP cabin modification	yes	Gulfstream	US
Gulfstream Aerospace Corp. - SAV	Interior modification	yes	Gulfstream jets	US
Hillaero Modification Center	VIP cabin modification	yes	King Air 200, Citation Bravo, Citation VII	US
Indianapolis Jet Center	VIP cabin modification	yes	Challenger & Learjet	US
Innotech - Execaire Aviation Group	VIP cabin modification	yes		Canada
International Jet Interiors	VIP cabin modification	yes	Gulfstreams, Challengers, Falcons, Hawkers, Jetstars, Citations and Learjets	US
Irkut	Freigher Conversion			Russia
Jet Aviation Basel	VIP cabin modification	yes	Gulfstream, Canadair for Challenger, Learjet, Dassault for the Falcon series	Switzerland
	Airliner interiors refurbishment		aircraft up to the size of a Boeing 747-400 and 767	
Jet Aviation West Palm Beach	VIP cabin modification	yes	Dassault Falcon Jets, Gulfstreams, Challengers and Hawkers	US
JetCorp	VIP cabin modification	yes	Falcon, Learjet, Gulfstream, Jetstar, Sabreliner, HS125, Citation and others	US
Jet Source, Inc.	VIP cabin modification			US
Jet Works Air Center	VIP cabin modification	yes	up to large cabin jets such as Gulfstreams and Challengers.	US
KD Aviation Inc. / Reese	Interior modification	yes		US
L-3 Communications Integrated Systems	VIP cabin modification	yes	narrow and wide-body aircraft.	US
Lufthansa Technik AG	VIP cabin modification	yes		Germany
	Airliner interior modification			

Fig. 3.3 Completion Centers and their characteristics, letters D to M

Marshall Aerospace	VIP cabin modification Airliner interior modification	yes		England
MAV Aircraft Services	Interior modification	yes		US
McKinney Aerospace	VIP cabin modification	yes	Gulfstreams, Challengers,Falcons, Hawkers, Jetstars, Citations and Learjets	US
Mena Aircraft Interiors	Interior modification	yes	from Cessna 150 to Gulfstream II	US
Midcoast Aviation Inc.	VIP cabin modification	yes	Challenger, Embraer, Falcon, Global, Gulfstream, Hawker,	US
MJET	VIP cabin modification Airliner interior modification	yes	 Bombardier CRJ100/200	Canada
Mobarak Aircraft, LLC	Interior modification	yes	from a Cessna 150 to a Gulfstream GIII	US
Ozark Aircraft Systems	Interior modification	yes		US
Phazar Aerocorp Inc.	VIP cabin modification	yes		US
PrivateSky® Aviation Services, Inc.	VIP cabin modification	yes	Gulfstream GII, GIII, GIV, and GV	US
Ranger Aviation Enterprises, Inc.	VIP cabin modification	no	turboprops through midsize corporate aircraft.	US
Raytheon Aircraft Services - Little Rock	VIP cabin modification	yes	Raytheon aircrafts	US
Raytheon Aircraft Services - San Antonio	Interior modification		Raytheon	US
Raytheon Aircraft Services - Tampa	VIP cabin modification	yes	Raytheon aircrafts	US
Raytheon Aircraft Services - Wichita	VIP cabin modification		Raytheon	US
Savannah Air Center	VIP cabin modification	yes	Bombardier Challenger and Global Express aircraft, Gulfstream II's through Vs, Raytheon Hawker series, and Falcon 50 aircraft.	US
Sierra Industries Inc.	VIP cabin modification		Cessna Citation	US
Sky Harbour Aircraft	VIP cabin modification Airliner interior modification	yes		Canada
Stevens Aviation Inc. - Dayton	Interior modification	yes		US
Stevens Aviation Inc. - Greenville	Interior modification	yes		US
The Aircraft Completion Centre	VIP cabin modification			Australia
Trace Aircraft Completions	VIP cabin modification	yes		UK
	Airliner interior modification			
UAC	Freigher Conversion			
West Star Aviation, Inc.	VIP cabin modification	yes	Challenger, Citation, Conquest, Lear, Falcon and Hawker.	US
Western Aircraft, Inc.	Interior modification	yes	Beechcraft King	US

Fig. 3.4 Completion Centers and their characteristics, letters M to W

Freighter Cabins. The main differences between the airliners and freighters are the strengthened cabin floors and the broad top-hinged door on the port fuselage in addition to the absence of passenger cabin windows, which are "plugged". Other characteristics which differentiate the cargo aircraft are: the loading system and the flight deck systems. Table 3.2 incorporates these characteristics along with the usually affected aircraft.



Aircraft	Age [years]
727	31
757	18
DC-9	38
737 CFMI	19
737 JT8D	29
Bae 146	20
TU-204	9

Fig. 3.5 Number and age of selected aircraft models, convertible from passenger to freighter configuration (**Williams 2009**)

VIP Cabins. The operators of this market segment have challenging requirements ranging from waterbeds to stationary bikes, from custom artwork to special materials, like granite or marble. The interior of the modern business aircraft has evolved in line with the current technology, incorporating cabin management systems, wireless Internet and PDA (Personal Digital Assistant) connections. The engineers must develop the design under the certification constraints, while respecting the timelines. Completion scenarios based on such boundaries require increased effort in the preliminary design phase, in order to extract and define the wishes of the customer in technical terms. The VIP cabin characteristics are listed together with each possible modification scenario in Section C, Table 3.5.

Table 3.1 The different comfort standards on passenger aircraft

Class	Seat pitch (inch)	Seat width (inch)	Degree of recline	Electric seat controls	Leg-rest and lumbar support	Overhead / personal TV	Laptop power ports	Mini-cabin
Domestic Economy	30-32 (average)	17-18 (average)	+	No	No	0	No	No
Domestic First or Business	35-39 (legroom)	19-20	+	No	No	0	No	No
International Economy	30-36	17-18	+	No	No	+	No	No
Premium Economy	35-43 (legroom)	19-20	++	No	Yes	++	Yes	No
International Business	62-64 (legroom)	20-21	+++	Yes	Yes	+++	Yes	No
International First	73-93 (legroom)	21-23	++++	Yes	Yes	++++	Yes	Yes

Table 3.2 Usual specifications for freighter conversions

Type of modification	Description	Aircraft type affected	Airline affected
Freighter conversion	Incorporating a large wide cargo door in the fuselage Installing a new reinforced main deck floor Integrating cargo loading systems	B737-300/400 B757-200 A300-600 B767-200 B747-400	All airlines which provide freighter service and passenger service

Modification Scenarios

The renewal activities of airline cabins may affect:

- the cabin systems – IFE (In-Flight Entertainment), CIDS (Cabin Intercommunication Data System), in-seat power system, passenger oxygen, general illumination of the cabin, emergency lighting;
- the cabin layout – seating configuration (for passengers and flight attendants), position of monuments (galleys, lavatories), crew rest compartments, stowage room;
- or other cabin interior items – linings and furnishings like PSU (Passenger Service Units), curtains, partitions, ancillary equipment; placards and markings like cabin emergency equipment, floor covering.

Table 3.3 and 3.4 gather some exemplary specifications of the scenarios conducted by known *airlines* in the past years (**ChinaS 2004**, **Air Canada 2005**, **Cathay Pacific 2009a**, **Cathay Pacific 2009b**, **Air France 2009**, **Dragonair 2003**, **Japan Airlines 2007**, **Philippineair 2009**, **Swiss Air 2008**, **Swiss Air 2009**, **Woollard 2007)**. The characteristics, and therefore the refurbishing scenarios, depend on the destination of the aircraft. Usually wide body aircraft are furnished for international flights and single aisle aircraft for domestic flights.

Freighter cabins are completely converted by changing the destination of old passenger aircraft. Popular candidates for the pax-to-freighter conversion are, according to ACMG (Air Cargo Management Group) (**ACMG 2009**), for the narrow-body models, the Boeing 737-300s/-400s and 757-200s. For the medium wide-body category, the A300-600s and 767-200s are the major candidates. In the large capacity segment the preferred aircraft are 747-400s and MD-11s. Only the A300-600F, 747-400F, 747-8 Freighter, 777F, A320P2F and A321P2F are available as new-built production freighters, which means the majority of the additional freighters will be passenger-to-freighter conversions (**Dahl 2009**). It is interesting to note that no civil freighter exists that was designed specifically for this purpose. All civil freighters have been derived from passenger aircraft. Military freighters play only a minor role for civil freight transport.

VIP cabins. Several scenarios are possible in the case of VIP cabins:

- VIP High-End Completion – the completion center takes responsibility over the design and certification of the interior furnishing of the „green" (i.e. new) aircraft.
- VIP Cabin refurbishing – refers to aircraft which receive a new outfit while removing an old one; this scenario is valid especially for business jets. Such scenarios involve stripping and replacing of cabinetry veneers, soft coverings of the seats, carpets or the lighting.
- Pax-to-VIP conversion – some VIPs buy a former jetliner to use it as an executive aircraft.

Some of the difficulties encountered by these scenarios are:

- Exotic materials that have never been installed in the aircraft environment have to pass flammability and certification tests.
- Getting into bigger changes in the cabin, such as reconfiguring seating or repositioning lavatories and galleys, involves meeting recertification requirements.

Table 3.3 Exemplary specifications for airline cabin upgrading for international cabins

Airlines	**Aircraft type affected**	**Entire fleet type redesign**	**Premium economy introduction**	**Layout reconfigu-ration**	**New seat facility**		
					FC	**BC**	**YC**
Malaysia Airlines	B777-200	Yes	No	Yes	removed	Yes	Only IFE
	B747-400	Yes	No	Yes	Yes	Yes	Only IFE
Japan Airlines	B777	Yes	Yes	Yes	Yes	Yes	Yes
United Airlines	Entire long-haul fleet	Yes	No	No	No	Yes	No
Swiss Airlines	A330-300 A340	Yes	No	No	Yes	Yes	No
China Southern Airlines	B777	Yes	No	Yes	Yes	No	No
Air France	B777 A330 A340	Yes	Yes	Yes	Yes	Yes	Only IFE
Philippine Airlines	B747-400	Yes	No	Yes	removed	Yes	Yes
Dragonair	Entire long-haul fleet	Yes	No	Yes	Yes	Yes	Only recovered
Cathay Pacific	Entire long-haul fleet	Yes	No	Yes	Yes	Yes	Yes

Table 3.4 Exemplary specifications for airline cabin upgrading for domestic cabins

Airlines	**Aircraft type affected**	**Entire fleet type redesign**	**Cabin surfaces upgrade**	**Seats reconfigu-ration**	**New seat facility**	
					BC	**YC**
Swiss Airlines	Entire short-haul fleet	Yes	Yes	No	Yes	Yes
Finnair	A320	Yes	-	Yes	Yes	Yes
KLM	Entire short-haul fleet				removed	
SAS	Entire short-haul fleet				removed	
Olympic Airways	Entire short-haul fleet	Yes	Yes	Yes	Yes	Only recovered
Cronus Airlines	Entire short-haul fleet	Yes	Yes	Yes	Yes	Only recovered
Air Canada	Entire short-haul fleet	Yes	Yes	-	Yes	Yes
Delta Airlines	MD 90, MD 88	Yes	Yes	-	Yes	Yes

Table 3.5 VIP Cabin characteristics for each modification scenario

Type of modification	**Description**	**Aircraft type affected**	**Type of owner**
VIP High-End Completion VIP Cabin Refurbishing Pax-to-VIP conversion	Stripping and replacing: Cabinetry veneers Seats soft coverings Carpets and lighting Installation of specific equipment	All Executive aircraft: Business jets Business turboprops Corporate versions of airliners	VIP owner State government Business airlines

3.2.3 Driving Factors in Cabin Conversion and Refurbishing

Airline Cabin Upgrades

In order to remain competitive, an airline needs to periodically refurbish its fleet. Cabin equipment together with service and speed are the decisive factors in forming passenger perception of the airline's efficiency. Industry experts (**Flouris 2008**) explain that carriers now pay more attention to their cabin layout, design and IFE rather than the level of their aircraft performance. The aviation sector was affected by the current global economy crisis. Important observations are:

- Passenger and cargo traffics have dropped by 10.1 % and 23.2 % respectively compared to the level before the crisis (according to the International Air Transport Association‟s statistics17 released in March 2009).
- Airlines preserve cash. This is forcing them to postpone major expenditures such as jet orders and deliveries.
- Middle East carriers apparently received support from their state governments and have more cash than other airlines.

Driving factors are summarized in Table 3.6. The frequency and duration of the scenarios are summarized in Table 3.7. Table 3.8 summarizes the durations calculated based on the examples extracted in Table 3.7.

Freighter Cabin Conversions

The conversion of passenger aircraft into freighters offers an economic alternative to the purchase of new freighter aircraft. The pax-to-freighter conversions combine the advantages of a low empty weight with the resulting possibility to increase the useful load. The economical efficiency of such conversions is obtained through the use of wide-body aircraft (having a large fuselage cross-section). Such aircraft provide sufficient space for standard containers and pallets in the main and under-floor cargo compartments. The strategy used by freighter operators is to combine the increased freight volume with quick cargo handling. Table 3.9 summarizes the driving factors of the demand for freighter conversions.

The conversion of a passenger aircraft into freighter may occur only one time in the aircraft life. After the age of fifteen to twenty years, aircraft would not receive any more upgrades for passenger service due to their marketability. These aircraft become perfect candidates for freighter conversion. The simple conclusion to be drawn is that the pax-to-freighter conversions occur when the aircraft is no longer suitable for passenger use. These conversions take approximately four months (**EADS 2009**).

Table 3.6 Driving factors for international, domestic cabins and aircraft on operating lease

	Type of demand	Factors
International Cabins	Upgrade of International Cabins	Tool for differentiating between airlines Aircraft orders and deliveries are postponed
	Premium Economy introduction	To enhance airline reputation among travelers in Standard Economy To retain a base of loyal customers
	First Class redesign	Demand from successful people even in economical downturn Demand from passengers upgraded to First Class
	First Class removal	More and more luxury in Business Class for a lower fare Rise of all-business-class airlines
Domestic Cabins	New business seats facility	Short-haul flights drive the reputation of the airline among long-haul business travelers
	New seats facility	Reduction of fuel burn Extra seating capacity
All	Aircraft lease	Lower cash outlays Protects against aircraft obsolescence Fleet flexibility (change of capacity, new routes introduction, changing laws)

VIP Cabin Designs/Redesigns

A number of factors persuade business jet owners or operators to refresh the interior of their aircraft. The market for refreshing these interiors to keep up with the required standards should be busy over the next years (**Moody2008**). The demand for high-end completions has grown at a rate of 25 % to 30 % in the last 10 years.22 The unprecedented growth is due to:

- the high demand for large business and VIP aircraft,
- new airplanes and technologies,
- the arrival of new types of VIP aircraft.

This demand has been driven to a large extent by the demand from emerging markets such as Middle East countries, India, China and many of the former Soviet republics. These results are gathered in Table 3.10.

For determining the frequency and duration of a VIP completion, several examples were analyzed. The frequency, at which the interiors are refreshed during the aircraft useful life, could not be determined precisely. It is estimated that the time between two VIP modifications amounts approximately 100 months. Usually, the refurbishing of the aircraft interiors occurs when the aircraft is purchased by a new owner (**Moody 2008**). The average duration used for generating the forecast was 10 months. The age limit considered is 10 years.

Table 3.7 Frequency and duration for international, domestic cabins

	Airline	Aircraft type affected	Number of aircraft	Begin of retrofit program	End of retrofit program	Retrofit duration (months)	Equivalent duration for one aircraft retrofit (days)	Date of last retrofit program begin	Retrofit frequency (months)
International Cabins	United Airlines	Entire Fleet	-	-	2009	17-29	-	-	-
	British Airways	B777	32	2006-11	2010-01	39	37	2004-04 (end of program)	65
		B747	56	2006-11	2009-04	30	16	2004-04 (end of program)	60
		B767	-	None in 2007	-	-	-	2000	-
	Air Canada	-	20	2004-10	2007-02	29	44	1994	(120)
	Cathay Pacific	A340, A330, B777-300/400	42	2006-09	2009-04	32	23	2001	57-69
	Singapore Airlines	-	-	-	-	-	-	2002	46-58
		B777-300ER	18	2006-10	2009	27	43	(new delivery)	-
	Japan Air Lines	B777-200	15	2007-04	-	-	-	-	-
	Air New Zealand	B777-200ER	8	-	2009-06	-	-	2005-10	45
	Delta Airlines	B777	-	-	2010	38-50	-	-	-
		B767	63	2006-10	2010	38-50	21	-	-
	Swiss Airlines	A330, A340	34	Early 2009	2011-07	31	27	-	-
	Malaysia Airlines	B777-200	17	2004-12	2006-09-30	22	40	-	-
		B747-200	19	2004-10	2006-07-31	20	32	-	-
	Finnair	-	-	2009-04	-	-	-	2000	108
Domestic Cabins	Olympic Airways	B737-400	13	2000-09	2001-03	7	16	-	-
	Cronus Airlines	B737-300/400	6	2000-09	2001-03	7	36		
	Swiss Airlines	Entire short-haul fleet	52	2006-10-15	2008-04-10	18	10	-	-
	Air Canada	Entire short-haul fleet	142	2006-04	2008-06-01	22	5	-	-
	Delta Airlines	MD88, MD90	94 (2/3 of the fleet)	2004	2006-09	21-33	9	-	-

Table 3.8 Frequency, duration and average age of aircraft for each type of cabin

Type of modification	Frequency of cabin redesign program	Duration of one aircraft refurbishing	Equivalent duration of one aircraft refurbishing	Lower age limit	Upper age limit
Upgrade of International Cabins	65 months	3 months	31 days		
Upgrade of Domestic Cabins	84 months	15 days	15 days	0	20
Upgrade of aircraft on operating lease	84 months	–	15 (narrow bodies) or 31 days (wide bodies)		

Table 3.9 Driving factors for freighter conversions

Type of demand	Factors
Freighter conversion	Economic alternative to the purchase of new freighter aircraft Possibility to keep an aircraft no longer suitable for passenger use Modifications possible for virtually every modern aircraft type
Wide-body conversion	High degree of economic efficiency

Table 3.10 Driving factors for VIP Conversions

Type of demand	Factors
VIP Hi-end Completion	High demand for large business aircraft New airplanes and technologies New emerging markets : China, India, Russia
VIP cabin refurbishment	The need to keep interiors looking up to date Fractional owners make the cabin more worn out

3.2.4 Aircraft World Fleet – Current and Future Trend

Passenger Aircraft

Each scenario identified so far is suitable for a specific type of aircraft. For performing the forecast a great number of airplanes were included into a database. The data was filtered by criteria like airline, or type of aircraft. Table 3.11 presents the type of aircraft considered for the study.

Table 3.11 Aircraft classification by size

Aircraft body size	Type of flight	Aircraft model
Wide-body	long-haul routes	B747, B767, B777, B787; A300, A310, A330, A340, A350, A380; MD-11, DC-10;
Narrow-body	Short-haul routes Medium-haul routes	B717, B727, B737, B757; A319, A320, A321; ARJ-21; BAe-146; CRJ-700, CRJ-900; Embraer models; Dornier models; Fokker 100, Fokker 70; MD-80, MD-90; SSJ-100.

The tendency for the future estimated by market statistics (**Boeing 2009**) show that until 2027 aircraft will become more productive, being able to transport a larger amount of passengers. Each aircraft will be able to carry about 40 % more passengers than the average airplane today. Fewer airplanes will be needed to accommodate the same number of travelers. The consequence is that the fleet needs to grow by only 3.2 % each year, although RPK (Revenue Passenger Kilometers) will grow at 5.0 %, as shown in the Fig. 3.6.

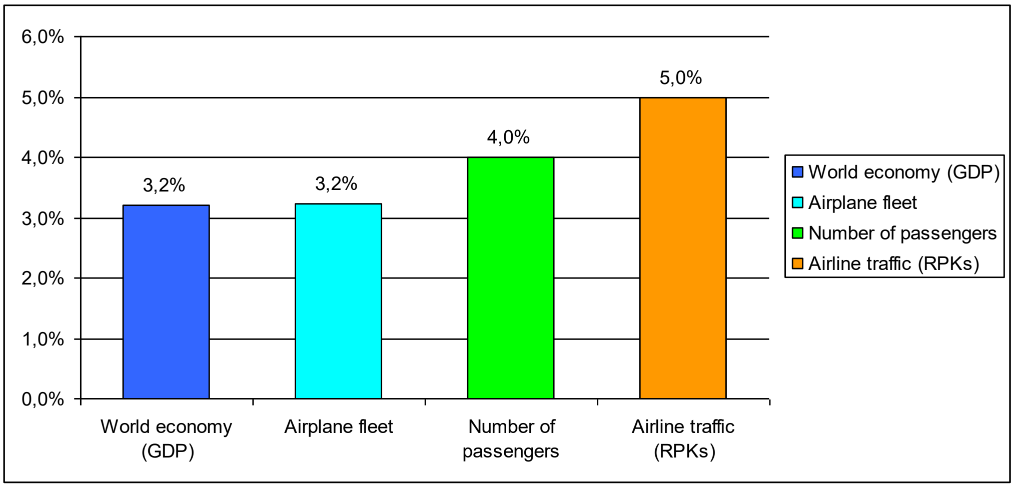


Fig. 3.6 Passenger key growth rates (based on **Boeing 2009**)

66 % of the fleet development will be due to new deliveries. 3 % of the current fleet will be converted, generating demand for freighter conversions. As market liberalization stimulates opening of new international routes and aircraft capabilities improve, twin-aisle airplanes will be the fastest growing market segment. Single-aisle airplanes primarily serve markets within regions. The sheer size of these markets means that the single-aisle category accounts for the largest share of future deliveries (from 63 % to 70 % of the global market in 2027) (**Boeing 2009**).

Regional jets currently account for 18 % of the worldwide fleet, but this will reduce to 8 % by 2027. That there is a significant growth in the Asian market as European and North American market growth rates will decline. Over 40 % of twin aisles will be delivered to airlines in Asia-Pacific. Strong domestic growth in China, India, and other emerging Asian nations is contributing to high demand for single-aisle airplanes in Asia-Pacific. Approximately 60 % of new airplanes needed in Asia will be in the single-aisle category. The conclusion to be drawn is that the market is growing especially in Asia-Pacific for single-aisle and for twin-aisle category (**Boeing 2009**).

Freighter Aircraft

In the next two decades, the average annual growth of the world airfreight fleet is forecasted to a number of 6 % (**EADS 2009**). The world freighter fleet is predicted to double, while the air freight will triple. More than 3000 additional freighters will be needed to accommodate the traffic growth and to allow the fleet renewal - three quarters of this demand will be satisfied by the conversion of mid-life passenger aircraft. Taking the forecast of 1414 retirements into account, 3358 airplanes will be added to the freighter fleet by 2027. Nearly three-quarters of freighter fleet additions will come from modified passenger and combi airplanes, with 863 new production freighters entering the fleet during the forecasted period. The disparity between tripling traffic growth and doubling fleet growth owes to the shift toward wide-body freighters, which will result in a fleet-wide increase in average freighter airplane payload. More than 60 % of all additions to the fleet will be in the wide-body category, that is, medium wide-body plus large freighters. This aggregate category will increase in share to 65 % of the fleet in 2027. Freighters will maintain about a 10 % share of the total airplane fleet during the forecast period (**Boeing 2009**).

Executive Jets

In 2008, the global business aircraft fleet was considered to comprise of 27000 turbine airplanes (jets and turboprops), of which 68 % belong to U.S. operators (**Watson 2009**). The latest market forecast of the Teal Group predicts deliveries of 12768 business aircrafts worth 195.7 ·109 US $ over the next 10 years (**Starfield 2009**). If the same annual growth rate and the same market share between the different segments are kept, then the forecast for the period 2009-2029 can be obtained (Fig. 3.7).

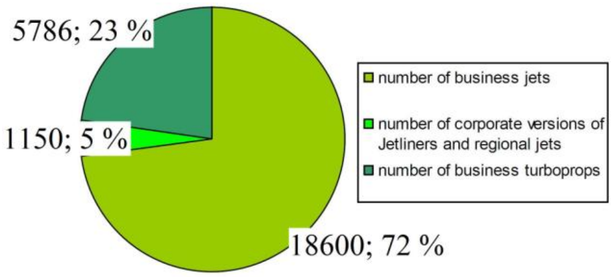


Fig. 3.7 Business Aircraft Deliveries 2009-2029 (based on **Starfield 2009**)

The business aircraft market has been hit harder by the economic crisis than any other aircraft market. Financing business jets is also more difficult than financing jetliners. Teal's forecast assumes a three-year downturn. The key demand drivers ─ economic growth and corporate profits ─ will only recover in late 2010 to early 2011 (**Starfield 2009**)

The results of this world fleet evolution analysis, along with the criteria identified for each scenario, the forecast for the cabin conversion demand was made.

3.2.5 Forecast of the Market Volume

The forecast of the market volume for the cabin upgrades and conversions for the next 20 years was performed on an enclosed Excel database which groups the entire current and future world fleet of freighters and executive jets. It also includes 63 types of the biggest airplanes on commercial use (23311 aircraft).

The Excel database can be updated with new information and can generate up to date forecasts according to the new input data. The VBA (Visual Basic for Applications) tool was used to program and compute the results.

The program also identifies the suitable scenario for each type of aircraft or if an airline is low cost or not. Each aircraft included in the database encloses data with respect to the world region, airline, first delivery date or lease termination. Finally the code writes, for each aircraft, the number of upgrades/conversions which are going to be undertaken in the next 20 years.

Forecast Method

The method used for the computation was to scan each sheet and each row of the database while looking for specific characteristics. For each aircraft:

- the table sheets were scanned,
- the characteristics of the aircraft were filtered,
- the scenario parameters were scanned and the scenario was identified and written in the database,
- the number of modifications was computed and written in the database.

Forecast Results

The results of the forecast applied on the several databases are presented in Fig. 3.8. Over the next twenty years, 10154 programs for the retrofit of international cabins and 23226 for domestic cabins will be undertaken. The demand for the cabin conversion of leased aircraft will create 4244 additional cabin modifications on airliners. 2625 conversions from jetliners to freighters will be planned. Last but not least, the most important demand will come from 25536 modifications of executive aircraft cabins at VIP standards.

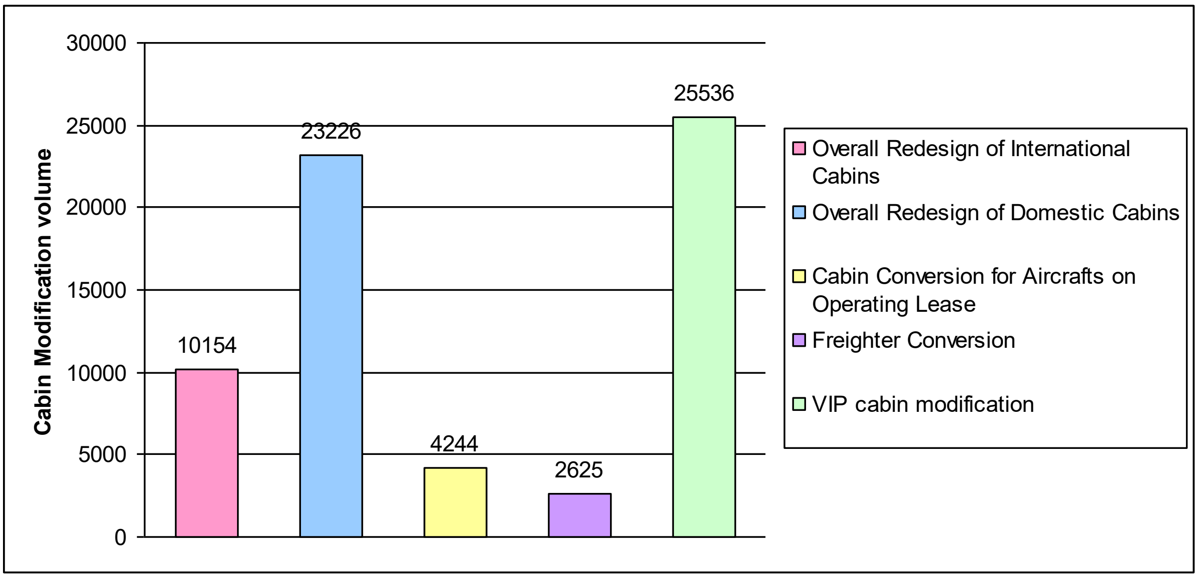


Fig. 3.8 Cabin modification world volume 2009-2029

Demand for Upgrades of International Cabins. A large part of the 10100 forecasted wide-body cabin redesigns come from Asia-Pacific area (29 %). Together with China and Middle East, more than 55 % (6000 cabin retrofits) of the demand will be concentrated in a single world continent. Therefore, the Asia-Pacific market will have an important influence on this segment (see Fig. 3.9).

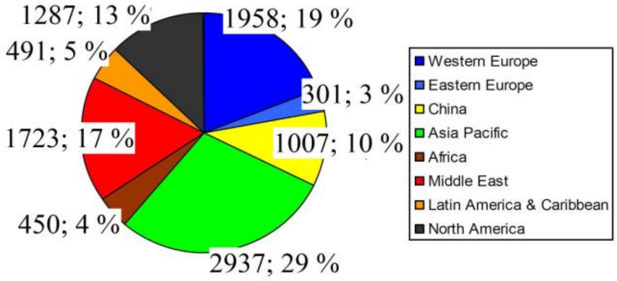


Fig. 3.9 International Cabins: Cabin Retrofit World Distribution 2009-2029

In following positions come Western Europe and North America with respectively 19 % and 13 % of the market share. These results were expected due to the relative small part of the wide-body deliveries in these two regions. Moreover, as it has already been shown, the redesign of wide-body cabins is a tool for differentiation between airlines.

That means, even if aircraft deliveries and orders could be postponed due to possible economical downturns, such as today, airlines will continue to redesign their cabins in order to attract customers at minimal expenses (compared to the purchase of a brand new aircraft). Therefore, the demand for the redesign of international cabins will continue to grow.

Demand for Upgrades of Domestic Cabins. The North American market will drive the global demand of 23200 domestic cabin retrofits along with the Western European market (respectively 28 % and 23 % of the market share). This is due to the high number of existing narrow-bodies in these regions. However, Asian markets (China, Middle East, Asia-Pacific) are still strong and approximately 60 % of new narrow-bodies will be delivered in these regions (Fig. 3.10).

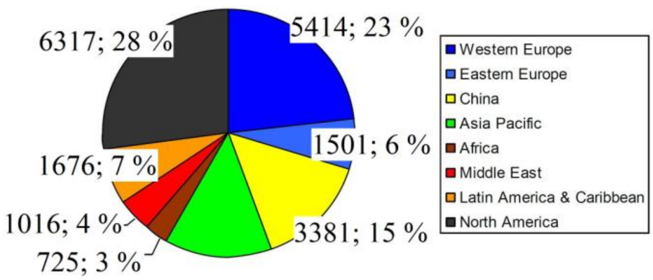


Fig. 3.10 Domestic Cabins: Cabin Retrofit World Distribution 2009-2029

The world demand for cabin redesign of narrow-bodies appears to be a lot stronger than the demand for international cabin redesign. It has to be reminded that the price of such a retrofit is a lot higher than the domestic cabin retrofit price, and this is due to the expenses required by the innovation in premium cabins.

Although comfort and amenities on short-haul flights also drive the airlines reputation, most of them do not currently put the emphasis on it and focus on wide-bodies.

Demand for Cabin Upgrades of Aircraft on Operating Lease. The chart below (Fig. 3.11) shows that most of the 4200 cabin conversions of leased aircraft will be undertaken in Europe and in North America with respectively 41 % and 17 % of the market share. This world distribution of the demand is certainly due to the great proportion of Low Cost Carriers (LCC) in Europe and in North America, which operate a great percentage of the leased aircraft. However, the Asian market follows the trend of the market share (China, 13 %, Asia Pacific, 10 % and Middle East, 6 %).

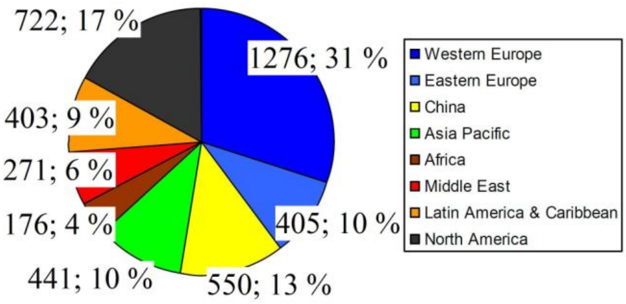


Fig. 3.11 Aircraft on Operating Lease: Cabin Retrofit World Distribution 2009-2029

It is to be remembered that the leasing of aircraft allows carriers to be more flexible towards the market expectations: they can preserve their cash in time of economical downturn; they can meet the market change by quickly remodeling their fleet and they can always offer the passengers new aircraft. For these reasons, the market of aircraft leasing is expected to grow as more and more full service carriers (along with LCC) decide on aircraft leasing, due to the above mentioned advantages.

Demand for Freighter Conversions. A strong demand for freighter conversions comes from North America with 55 % of the market share. The second position is shared by Western Europe and Asia-Pacific. This is probably due to the high number of freighters operated in North America (Fig. 3.12).

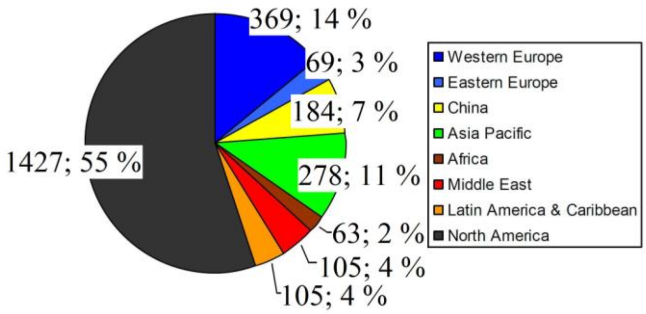


Fig. 3.12 Pax-to-Freighters Conversion: World Distribution 2009-2029

Demand for VIP Completion. Among the 25500 VIP modifications that are forecasted for the next twenty years, specialists currently see strong interest from India, Russia, the Middle East as well as China. Traditionally, most of the VIP conversion business has been generated by the Middle East. Specialists think there is enough potential for further growth of the market in this area. It seems that individuals from Russia can afford to ask for bathrooms, dining areas, bedrooms, libraries, children rooms. Russia could dominate the sector within five years, exceeding even the Middle East in its demand. However, the recent crisis has put many of the demands on hold. Growth is also coming from the South American market, especially in Brazil, and mainly in the business jet segment. India‟s fast-growing economy is increasing demand, where a lot of interest in the ACJ and BBJ for both VIP and corporate transport is foreseen (**Parker 2008**).

The very high price of a VIP conversion transforms this market segment into the most profitable, therefore most important scenario of the market. The AeroStrategy estimates that more than 3.3·109 US$ were spent in 2007 on completing green VIP aircraft and upgrading in-service large executive airplanes. AeroStrategy forecasts that those expenditures could grow to more than 3.8·109 US$ annually by 2015. Typically, VIP aircraft buyers spend up to 100·106 US $ for a top-of-the-range completion (**Searles 2008**).

3.3 Summary

WP 2 investigated the emerging and growing market of cabin conversions, and forecasted its evolution for the next 20 years. It is known that companies in cabin conversion and refurbishing are currently overbooked. Together with WP 5, the results of WP 2 serve in management decision making towards the vision completion center. The technical note identified several meaningful cases and predicted the market volume and the world distribution for each of them: 1.) international cabins, 2.) domestic cabins, 3.) aircrafts on operating lease, 4.) freighter conversions and 5.) VIP cabin modifications. This implied the determination of cabin modification/conversion scenarios, as well as their duration and frequency. Factors driving the cabin conversion and refurbishing were identified. Several aircraft databases, containing the current world feet as well as the forecasted fleet for the next years, were analyzed. The results were obtained by creating a program able to read and analyze the gathered data. It was shown that about 38000 cabin redesigns will be undertaken within the next 20 years. About 2500 conversions from jetliners into freighters and 25000 cabin modifications at VIP standards will emerge on the market. The North American and European markets will keep providing good business opportunities in this area. The Asian market, however, is growing fast and its very strong influence on demand puts it in the front rank for the next 20 years.

4 WP 3: Analysis of the Process Chain "Cabin Conversion"

4.1 Objectives

The objectives of WP 3 were:

- Analysis and optimization of the process chain identified in WP 1
- Identification of the required input information for conducting independent cabin conversions
- Presentation of case studies on both Airbus and Boeing aircraft

4.2 Results

According to the objectives, results in the following areas were obtained:

- Optimization of the Process Chain for cabin conversions
- Engineering input information for cabin conversions
- Engineering output information for cabin conversions (form of deliverables)

4.2.1 Optimization of the Process Chain for Cabin Conversion

Chosen for the optimization of the process chain were optimization methods based on what is called Design Structure Matrix (DSM). DSM is a quadratic matrix with identical row and column headings, called Design Structure Matrix (DSM), containing relations and interactions in their nodes (see Figure 4.1).

		1	2	3	4	5	6	7
Offer	1	1						
Concept	2	1	2	1				
Definition	3	1	1	3	1			
Design	4	1	1	1	4		1	
Adjustment	5	1	1	1	1	5	1	1
Certification	6	1	1	1	1		6	
Handover	7	1	1	1	1		1	7

Fig. 4.1 Example of DSM showing the relations between the main phases of the process chain for cabin conversion

Based on the DSM of the process chain for cabin conversion identified in WP1 and summarizing about 143 processes, several analyses were performed:

- *Partitioning* – this delivered the optimal sequence of the processes and tasks
- *Eigenstructure analysis* – this delivered the most important processes (with the highest eigenvalues)
- *Cross Impact analysis* – this delivered groups of processes belonging to five spheres: reactive, dynamic, impulsive, low impact and neutral.

Partitioning

This type of optimization algorithm aims to reorder the sequence of the elements in order to obtain a lower triangular matrix (according to the convention from Figure 4.1, otherwise the algorithm would deliver an upper triangular matrix). This is achieved by manipulating the rows and columns of the matrix such that the coefficients move closer to the main diagonal and reduce the negative feedback between the elements. Minimizing feedback eliminates the process iteration and spares time.

Figure 4.2 illustrates the results of the partitioning algorithm on the coarse matrix shown in Figure 4.1. Figure 4.3 illustrates the results of the algorithm ran on the fine matrix (of all 143 processes).

		Offer	Concept	Definition	Design	Certification	Handover	Adjustment
		1	2	3	4	6	7	5
Offer	1	1						
Concept	2	1	2	1				
Definition	3	1	1	3	1			
Design	4	1	1	1	4	1		
Certification	6	1	1	1	1	6		
Handover	7	1	1	1	1	1	7	
Adjustment	5	1	1	1	1	1	1	5

Fig. 4.2 The partitioned matrix obtained from the original matrix shown in Figure 4.1

This analysis required a long preparation time and the main difficulties consisted of:

- understanding the dependencies between each process,
- inserting them into the matrix,
- having a clear view over the whole complex structure.

After overcoming these difficulties and running the algorithm, the following conclusions were extracted:

- Definition, Design and Certification phases are coupled (light blue); they create an information cycle which needs iteration, and therefore further optimization.

- Other small couplings exist between the teams for engineering, certification and quality assurance.
- A detailed analysis of the matrix and of each of the illustrated dependency allows a better understanding of the results.

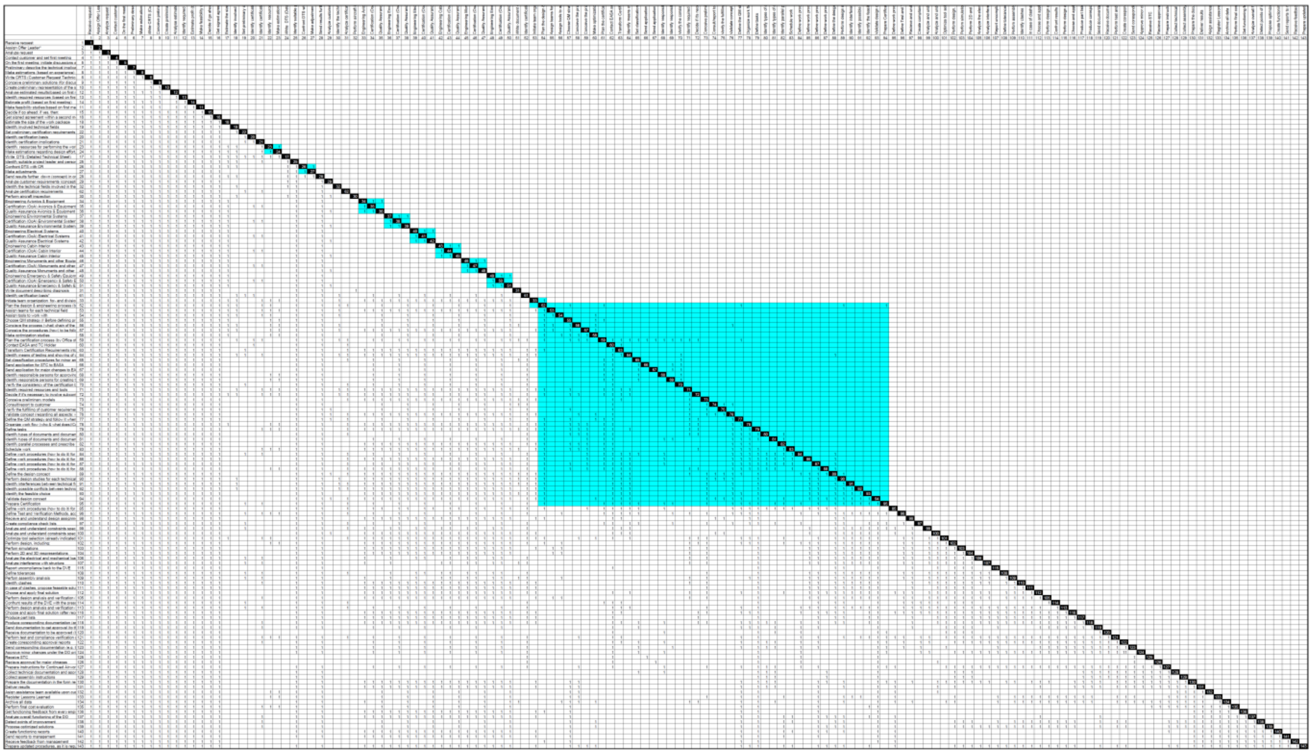


Fig. 4.3 The partitioned DSM resulted after running the partitioning algorithm on the original DSM matrix

Eigenstructure analysis

The eigenstructure analysis for DSMs was developed by Smith and Eppinger in **Smith 1997**. In our case it helps underlining those processes which have a major influence on the system. The interesting similarity was found between the dynamical behavior of a physical system and the behavior of the tasks/processes of an engineering system. In both cases large magnitude positive eigenvalues give information about the convergence of the system.

Each iteration causes rework; in order to perform the eigenstructure analysis, the amount of rework was quantified through a Work Transformation Matrix (WTM). The off diagonal elements of WTM represent the strength of dependence between tasks – for our analysis, the rework necessary for each task. The diagonal elements represent the time that it takes to complete each task during the first iteration (see Figure 4.4).

The eigenstructure analysis of the process chain was performed on the WTM under the consideration that the amount of rework is 100%. In this way the problem became simpler to handle (by inserting 1 instead of proportions of 1) and the results were covered by the largest safety margin possible. The steps for conducting the analysis were:

1.) Building the WTM.

2.) Calculating the eigenstructure i.e. eigenvalues and eigenvectors of the matrix.
3.) Interpreting the magnitude of the eigenvalues.

The results are summarized by Table 4.1.

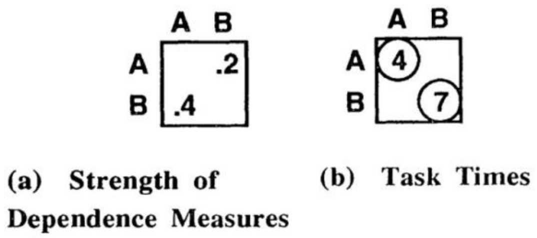


Fig. 4.4 Work Transformation Matrix (**Smith 1997**)

Table 4.1 The processes with the largest eigenvalues

Process ID	Process Title	Eigenvalue
50	Organizing team for certification	6.43
51	Organizing team for quality assurance	2.21
52	Planning the Design & Engineering process	2.21
53	Assigning Teams for each technical field	2.31
106	Analyzing electrical and mechanical loads	1.62
113	Performing design analysis and verification	1.62
121	Perform test and compliance verification	1.00

Within a Completion Center, it seems that certification, along with quality assurance play a key role along with the planning the design and engineering process and the team selection. A second major importance is represented by the tasks grouped under the design analysis and verification. The results are plausible, especially when considering the way EASA developed the DOA requirements. For EASA the self control capability of each design organization presents a major importance.

Cross Impact Analysis

The aim of the Cross-Impact Analysis was to identify several meaningful influence zones (as indicated in the Cross Impact Diagram from Figure 4.5) and the processes belonging to them. The values representing the strength of the relations are summarized per row and per column. There are five meaningful zones which can be identified:

1.) *Zone I: Reactive Processes* – Changes of elements in this area have a strong influence on the system; they give a lot of information to the rest of the components.

2.) *Zone II: Dynamic Processes* – Changes of elements in this area have an important influence on the system; the information exchange is strong on both sides.

3.) *Zone III: Impulsive Processes* – Elements in this area have a small influence on the system but are strongly influenced by other system changes.
4.) *Zone IV: Low Impact Processes* – Elements in this area have a small influence on the system and are poorly influenced by other system changes.
5.) *Zone V: Neutral Processes* – Elements in this area find themselves at the intersection with other domains; neutral means safe from unexpected effects.

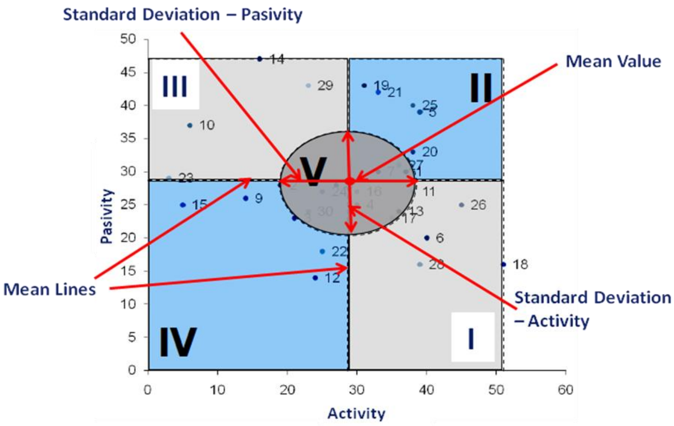


Fig. 4.5 Cross Impact Diagram (based on **Phleps 2009**)

Due to the large number of processes the resulted diagram was not easy to interpret. However „clouds" of processes could be identified. The diagram is shown in Figure 4.6 and an overview of the results in Table 4.2.

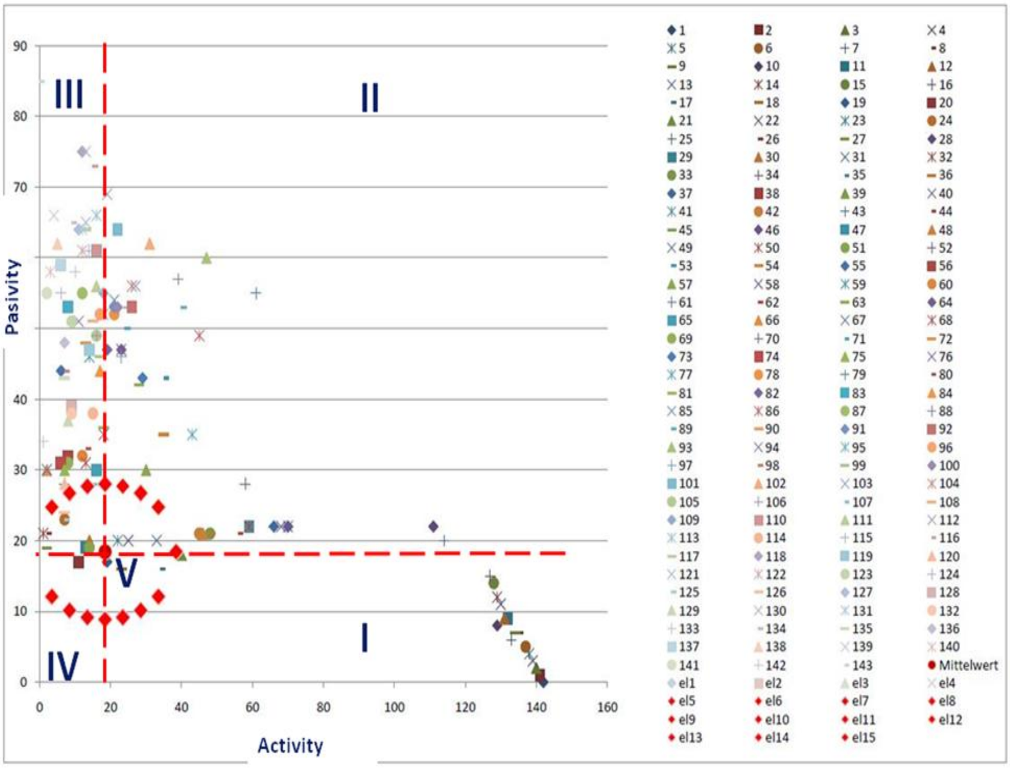


Fig. 4.6 The Cross-Impact Diagram based on the DSM

Table 4.2 Selected processes for each zone of influence

Zone I	(2) Assign Offer Leader (126) Receive approval for major changes (9) Conceive preliminary solutions for discussing it with the customer (based on the first meeting) (10) Create preliminary representation of the solutions found (12) Identify required resources (based on the first meeting) (14) Make feasibility studies (16) Get signed agreement
Zone II	(94) Validate design concept (87) Define work procedures for quality assurance (79) Define tasks (definition phase) (93) Identify feasible choice (when it comes to interferences) (design phase) (73) Conceive preliminary models(concept phase) (61) Identify certification basis (concept phase) (54) Plan the design and engineering process
Zone III	(137) Analyze overall functioning of the DO (133) Register Lessons Learned (75) Verify the fulfillment of the customer request (139) Propose optimized solutions (for the functioning of DO) (143) Prepare updated procedures for the functioning of the DO (138) Detect points of improvement (of the DO) (119) Send documentation to EASA (to get approval)
Zone IV	(27) Make adjustments of the DTS after confronting it with CR
Zone V	(17) Write DTS (18) Estimate the size of the work package (24) Make estimations regarding design effort (30) Perform aircraft inspection (31) Write document describing diagnosis (32) Identify the technical fields involved in the design process (concept phase) (62) Analyze certification requirements (concept phase)

Processes in zone I, like feasibility studies or getting the signed agreement, strongly influence the rest of the processes: unless the contract is signed and the technical proposal accepted, the rest of the processes are not run anymore.

Processes in zone II, like validating the design concept or identifying the certification basis, are very important for the functioning of the system and require a lot of information from the rest of the processes.

Processes in zone III, like proposing solutions for an optimized functioning are processes which require a lot of feedback information from the rest of the processes, while their influence may be important in the future, and not for the respective project / iteration.

Processes in zone IV, like adjusting a document, once new information is available, have a low impact on the system.

Processes in zone V, like estimating the size of the work package and design effort, are in the neutral zone. They are important for the system, but the results are rather expected.

4.2.2 Engineering Input Information for Cabin Conversions

Aircraft Documentation

The necessity of creating international standards for aviation technical documentation was covered by the Air Transport Association of America. Their publications are known as ATA-Specs. Some of the most important publications are (**ATA 2009a**):

- *ATA Common Support Data Dictionary (CSDD)* – is a catalog of all data elements, terms, and tags that are used throughout ATA specifications.
- *ATA iSpec 2200 Information Standards for Aviation Maintenance* – is a global aviation industry standard for the content, structure, and electronic exchange of aircraft engineering, maintenance, and flight operations information.
- *ATA iSpec 2200 Extract: ATA Standard Numbering System* – is an extract from ATA iSpec 2200, which provides the industry-wide standard for numbering aircraft systems, often referred to as system or chapter numbers
- *ATA Spec 100: Manufacturers' Technical Data* – it contains format and content guidelines for technical manuals written by aviation manufacturers and suppliers and is used by airlines and other segments of the industry in the maintenance of their respective products

The aircraft manuals, written after the ATA specifications, are listed in Table 3.5. These manuals are created by the aircraft manufacturers (or suppliers) and are required for operating and maintaining the airplanes.

More than 25 manuals, used in one of the fields:

- aircraft maintenance,
- aircraft configuration and definition,
- training of maintenance personnel,
- flight operations,

are written after the ATA specifications.

Table 4.3 Manuals of which configuration is described in the ATA iSpec 2200 (**Scholz 2002**)

Manual	Abbreviation
Maintenance Procedures	
Aircraft Maintenance Manual	AMM
Aircraft Recovery Manual	ARM
Component Maintenance Manual	CMM
Consumable Products Manual	CPM
Engine Cleaning Inspection and Repair Manual	CIR
Engine (Shop) Manual	EM
Fault Reporting and Fault Isolation Manual	FRM/FIM
Non Destructive Testing Manual	NDT
Power Plant Buildup Manual	PPBM
Service Bulletin	SB
Structural Repair Manual	SRM
System Schematic Manual	SSM

Weight & Balance Manual	WBM
Configuration Control of Product Definition	
Aircraft Illustrated Parts Catalog	AIPC
Component Maintenance Manual Parts List	CMMPL
Engine Illustrated Parts Catalog	EIPC
Engine Parts Configuration Management Section	EPCM
Power Plant Buildup Manual Illustrated Parts List	PPBMIPL
Tool and Equipment Manual	TEM
Wiring Diagram Manual	WDM
Training	
Systems Description Section	SDS
Flight Operations	
Flight Crew Operations Manual	FCOM
Master Minimum Equipment List	MMEL
Universal Applications	
Component Manual Index	CMI
Publications Index	PI
Service Bulletin Index	SBI
Service Letter	SL

When an airline wishes to modify or update the configuration of the aircraft cabin, the information contained in these manuals becomes important also for the engineering work behind the redesign activity. However, the information contained in the manuals is not accurate enough in order to conduct the conversion of the cabin without additional engineering input. In most cases, the original drawings are required. Table 4.4 summarizes conclusions with respect to the utility of these technical documents.

Table 4.4 List of useful technical documents and their characteristics

Technical Document	Form	Engineering Input Information	Usefulness
AMM	Digital image data	Dimensionless 2D Drawings	Informative
AIPC	Digital image data	Dimensionless 2D Drawings	Informative
SRM	Digital image data	2D Drawings with dimensions (not all)	More than Informative
SSM	Digital image data	Dimensionless 2D Drawings	More than informative
WDM	Digital image data	Dimensionless 2D Drawings	More than informative
ITEM	Digital image data	Dimensionless 2D Drawings	Informative

Access to aircraft

Usually the airplane cabins are being upgraded or converted during a maintenance check. In this case the airline can facilitate the direct access to the airplane. Another possibility to have direct access to the aircraft is to seek the agreement with companies providing services in the area of aircraft disposal and recycling (see **AFRA 2009**). Agreements can also be set between ELAN and other Completion Centers, either with the purpose to use their documentation or in order to have direct access to aircraft. In this case a win-win situation must be identified.

Having access to aircraft provides the engineers with:

- an overall understanding of the pre-mod cabin layout,
- the possibility to measure and inspect different parts involved in the conversion,
- the possibility to take scaled pictures.

Measuring inside the aircraft
Once the access to the aircraft is ensured, the next challenge is to obtain correct measures for each of the items involved in the conversion. An optimal way to solve this problem is a correlated approach between:

- the use of the predefined measuring points (German: Datum Masse) as reference points; these coordinates are specified in the *Frame Specs* (**Müller 2010**),
- the use of LASER based measuring equipment.

Combining the use of the LASER devices with scaled photos and simple scaled sketches represents a reliable source of data. The inspection engineers could apply the following work breakdown:

- previous familiarization with the affected cabin area, including available reference points,
- previous creation of the cabin area schematics,
- previous preparation of a reference scale,
- utilization of a high precision measuring device (LASER) for determining the distances,
- utilization of digital photos taken together with the visible reference scale,

Input information from airlines
Besides the aircraft manuals, the airlines also possess the history of the respective aircraft changes in the form of SB‟s, which provide important information. The airlines also receive valuable information from the equipment or components manufacturers (different than the aircraft manufacturer), e.g. the hatrack bins and doors (which are currently produced by Fisher for Airbus SA), or the monitors from the IFE system.

A very important source of information that an airline can provide is the aircraft itself, available for inspection and measurements. However, in most of the cases the original drawings from the aircraft manufacturer are required. These are usually obtained by the airline itself from the aircraft manufacturer, based on an agreement. If the airline does not provide the completion center with this information, than the completion center itself must look for an agreement with the TC holder of the respective aircraft. The data is in this case obtained in exchange of money, while the conversion project must still remain profitable overall (**Manitz 2010**).

Data from the components manufacturers
When it comes to installing different new devices or items (e.g. monitors as part of IFE, literature pockets, or even seats), part of the information comes from the manufacturer of the respective items. He possesses drawings and installation instructions, but he needs as well additional information from the aircraft manufacturer (connection possibilities for the monitor, monuments layout for installing literature pockets, or seat rails layout for the seat installation).

ELAN may obtain form the components manufacturers not only item related information, but also aircraft related information.

New designs under DOA

If ELAN possesses a DOA, it can perform – under the DOA privileges – changes to the type design (see Section 2). Depending on the complexity of the conversion and on the wishes of the customer airline, where input information is no longer available and the original dimensions of the Airbus components cannot be measured, ELAN can offer a new design to the customer. An example of such a situation is the sidewall lining. It would be more difficult to reproduce the design, than to design a new lining, according to the wishes of the customer. ELAN has the experience to perform the task, but currently lacks the Design Organization Approval and the experience in certifying the design.

Other sources

Inverse engineering

Inverse engineering is a method used by the Future Projects engineers at Airbus, in order to redesign the concurrent airplanes (from Boeing). Based only on the available public information sources, they need to understand how the original design was made and recalculate the flight performances. However, this method is not accurate enough when it comes to the aircraft interior parameters. Another disadvantage is that a lot of time input is required in order to achieve feasible results. The same method is used by the so called Advanced Scanner and 3D Photocopier: the characteristics of a product that already exists (or part of them) are being transformed through the computer into a virtual product.

Old documentation

Original old aircraft documentation can only be bought from aircraft manufacturers which declared bankruptcy. A well known example is the Fairchild Dornier. This would however be useful only for the Dornier aircraft which would currently require a refreshment program.

Pacelab Cabin

The program is already known to ELAN. The advantage of this program is that it contains a database of aircraft contours which can be exported to CATIA. In this way the time necessary to redraw the contours, especially when exact information about dimensions is lacking, is spared. The program is also useful to create preliminary cabin layouts in the preliminary phase of negotiation with the customer. If ELAN becomes Airbus independent, the Offer phase grows in importance, especially due to the tight relationship required with the airline.

Engineering Output Information

The SB"s (Service Bulletins) represent the form in which the engineering work is further transmitted to the aircraft operator, which has the responsibility to implement the instructions comprised within. The content of a deliverable must cover, in essence, the same topics as an SB.

The STC‟s are issued by EASA only under DOA (or AP to DOA). The issued STC represents the certification approval of the respective change. Based on the form of an STC, a deliverable should specify:

- the title of the document and the aircraft involved,
- the design change specifications comprising of installation instructions and drawings,
- the requirements and the limitations,
- the operational characteristics,
- the necessary materials,
- the parts lists and kit lists,
- warnings and cautions for the workers.

The exact form of deliverable is to be discussed with the customer airline during the Offer phase.

Internal working procedure

The possible future procedure for fulfilling the task under the „Airbus independency‟ conditions is summarized in Figure 4.7. This procedure is based on the following steps:

- Determine missing information.
- Check the available possibilities of obtaining the missing information:
    - if ELAN can obtain the data on its own
    - if the aircraft or component manufacturer can supply the data or related data
- Once the information is available, continue the standard (current) internal procedure.

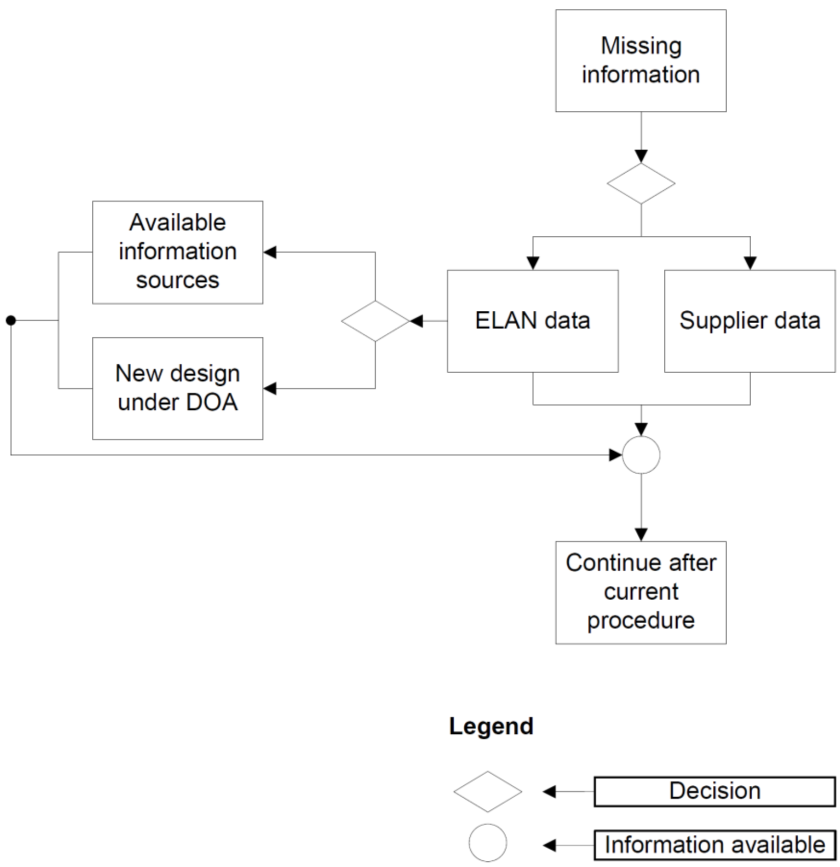


Fig. 4.7 Internal working procedure at ELAN without Airbus

4.2.3 Case Studies

Two study cases were analyzed, in order to find out which are the implications of an independent conversion in a typical case. First, the Condor case, for Airbus aircraft, and second a virtual conversion for a Boeing aircraft. For each task the input data, the difficulties, the alternatives to overcome the difficulties, as well as the „do-ability" of the respective task were identified.

It was concluded that simple conversions can be currently performed without major problems, by the currently employed ELAN engineers.

Some of the difficulties encountered are:
For mechanical tasks:

- A feasible alternative is always inspecting the aircraft, measuring and making photographs. Observations / difficulties with this concern:
    - The first condition in this case is to have the aircraft available enough time for the inspection.
    - If the airlines are not willing to set an aircraft inspection date, another possibility is to seek the agreement either with completion centers like Lufthansa Technik, or with aircraft disposal companies.
    - When measurements in front and in the rear of the fuselage are required, a systematic method (like in FEM) must be applied and enough measuring points must be selected, in order to get to the required measuring tolerance.
    - A problem in measuring is defining the „point zero", which must be constant along the entire project; the flexibility exist to choose a different point for each case/aircraft.
- The cabin layout – position and dimensions of seats, monuments and hatracks along with the fuselage contour is almost for all refurbishing scenarios required. When measuring all the dimensions and rebuilding this layout, the question arises: how exact are the measurements, how big the tolerances should be. The answer may come only from practice, and experience will play a major role.
- Depending on the type of the refurbishing/upgrade/modification, specific information is required. Usually several small tasks within the same project are related and require the same type of information: e.g. when a hatrack bin requires a modification, this must be done according to the seats and monuments layout; once these layouts are known, they may be used for instance also for the carpet installation. Therefore, the same information (seats, monuments layout) may be used several times – the effort for gathering it must be efficiently managed, in accordance with (as far as possible) its plural utility.
- The long term advantage of this approach – rebuilding the designs based on aircraft inspection – is that an own ELAN database will be formed and used as a knowledge base.
- Several items are either very difficult or impossible to measure – e.g. lateral covering (lining). The alternative is to measure only basic dimensions and to redesign the hole lining again, in accordance with the airline wishes. A small lining modification would not be

possible, but to redesign it and to produce a new concept is possible. ELAN engineers have enough experience to handle the design, however, this is achievable only under DOA.

- DOA gives enough flexibility to ELAN to cover, theoretically, the missing parts of measuring and inspecting, by creating new designs. This involves certification activities (granted in any case by a DO approval). Another issue is the production of these new designs. ELAN may consider getting a POA (Production Organization Approval) as well.

For electrical tasks:

- A long inspection time would be required for understanding the system, the connection possibilities, as well as the implications of each change.
- Most of the equipments are produced by Airbus or Airbus partners and Airbus information is required
- If a new equipment is installed (especially for CIDS, e.g. a new smoke detector), it must be verified that the respective equipment can function inside the system, as part of a whole.
- The complexity of an „Airbus independent" task (with electrical implications) is rather unpredictable, as unexpected problems may occur during the conversion processing, which otherwise might have been easily solved with Airbus input. A prediction of the duration for the CIB case (or any other) under these circumstances is difficult to make. This would be unacceptable in practice, however ELAN would grow in experience and the duration would decrease in time.

Current alternatives for increasing the know-how of ELAN are:

- Seeking collaborative partners among airlines, suppliers or design and production organizations.
- Getting access to aircraft destined to be removed from service, recycled or deposited, by contacting aircraft disposal companies.
- Hiring experts or former employees of design organizations/engineering offices that dealt with conversions of (also) other aircraft types than Airbus.

4.3 Summary

Three types of analyses (partitioning, eigenstructure analysis and cross impact analysis) performed for optimizing the process chain for cabin conversion:

- highlighted the most important processes,
- provided the optimized sequencing of the processes,
- underlined the coupling between design and certification phases.

In order to perform independent cabin conversions (based on this process chain) proper input data is required. For complex conversion scenarios, the agreement with the TC holder (either through the airline or ELAN) is a must. If the required information is obtained, the internal working procedure may remain unchanged.

After analyzing two different study cases, two main conclusions were extracted:

- Simple upgrade scenarios can be achieved without Airbus input, with the available information from airlines.
- Complete and complex conversions are achievable if ELAN develops new designs itself – the only way to do that is by applying for STC‟s through DOA.

5 WP 4: Research, Analysis, Evaluation and Selection of Tools

5.1 Objectives

The aim was to investigate suitable tools required when setting up a Completion Center. The selected range of tools is to reduce rework and therefore optimize the processes inside the company.

5.2 Results

5.2.1 Categories of Tools and Corresponding Requirements

There are several categories of tools indispensable for such a completion center:
1.) *Design and Engineering* (i.e. Computer Aided Design Tools – CAD) – for creating 2D and 3D layouts,
2.) *Analysis and Simulation* (i.e. Computer Aided Engineering – CAE) – for stress calculation and mechanical simulation,
3.) *Data Management* (i.e. Product Data Management – PDM) – for data archiving and administration,
4.) *Resources Management* (i.e. Enterprise Resources Planning – ERP) – for resources management and process optimization.

Some of the selection criteria for each category from the point of view of a Completion Center are summarized in Table 5.1.

Table 5.1 Categories of tools and selection criteria

Category	Criteria
CAD and CAE	*Compatibility* with other types of software (CAD, CAE, PDM) or with old and future versions of the same software, *Operability* - such as duration of a medium sized task, *Functionalities,* *Visualization* capabilities – for CAD only, Already implemented in the CC or not.
PDM	*Operability* of the database , *Access management* for multi work and suppliers, SDM[1], PLM *capabilities,* *Integration* implications (e.g. set-up duration and complexity), Supplier *access.*
ERP	*Functionalities* *Operability* *Integration* implications

[1] SDM – Simulation Data Management

Regarding category 1.), it must be underlined that usually the work of a Completion Center is required late in the aircraft life. This is the reason why, due to the long aircraft lifetime, data can be very old and not compatible with the standards at the time of the cabin conversion. Additionally the CAD software of a Completion Center must be compatible with other necessary software (e.g. CAE for stress calculation) and with the data format from the manufacturer. Currently CATIA is already established in aeronautical industry as the most common and reliable CAD software. Thus the only aspect that would be interesting to analyze in comparison to other similar tools is its rendering capability. Rendering has a special significance in cabin refurbishing activities. A close cooperation with the customer is required in order to understand the requirements. Tools allowing rendering and 3D visualization play a key role during the negotiation phases, allowing time reduction in defining the preliminary design solutions.

With respect to category 2.) it must be noted that there is a huge variety of packages available from each editor, that may include or not certain functionalities, such as: nonlinear analysis, post/pre processing, dynamics and motion, etc. Both CAD and CAE tools have been developed according to the needs of aerospace industry. This is the reason why the experience already accumulated in using them is a decisive criteria.

If the first two categories are quite well established in the industry, tools for categories 3.) and 4.) – Data Management and Resources Management are more difficult to evaluate and to implement. The main reason is the high customization required to match the needs of each company. The reference company used in this survey is a medium sized Completion Center, able to conduct small to complete cabin conversions.

A common criterion is the price of the licenses as well as involved expenses for each tool (e.g. investments for achieving necessary computer requirements). However, the technical capabilities should be of prime importance.

5.2.2 Evaluation of Relevant Commercial Tools

The following evaluation system was used:
0: tool function is not present or really disappointing.
1: tool function is basically performed.
2: tool function meets all requirements.
3: tool function ensures best performances.

Design and Engineering Tools with good rendering and visualization capabilities selected for the evaluation were: **(1)** CATIA V5, created by Dassault Systèmes (DS), **(2)** Rhinoceros V4, created by McNeel and **(3)** Showcase 2011, created by Autocad. Results are indicated in Table 5.2.

Table 5.2 Evaluation of selected CAD tools with respect to visualization capabilities

Criteria	Tool (1)	(2)	(3)
Compatibility with CATIA -current and future versions	2	2	2
Operability	2	2	2
Duration of a medium difficult task	1	2	3
Necessary computer power	1	2	2
Ongoing modification possibility	0	0	2
Real time rendering	0	0	2
Total	**6**	**6**	**11**

It seems that the best rated tool is Showcase 2011. Still, it must be noted that CATIA V6 has progressed in rendering tasks and that Rhinoceros V5 will be soon commercialized with real-time rendering capabilities.

Data Management Tools selected for the evaluation were: **(1)** Innovator, created as an open source by ARAS, **(2)** Windchill, created by PTC, **(3)** Teamcenter created by Siemens, **(4)** Enovia, created by DS, **(5)** EMK, created by ANSYS, **(6)** SimManager created by MSC Software and **(7)** Simulia by (DS). Results are indicated in Table 5.3.

Table 5.3 Evaluation of selected CAE tools

Criteria	Tools (1)	(2)	(3)	(4)	(5)	(6)	(7)
Compatibility with CATIA	2	2	2	0	0	0	1
Database operability	2	2	1	2	2	2	2
Access management for multi work	2	2	1	1	2	2	2
Access management for suppliers	2	2	1	1	0	0	1
SDM capabilities	0	0	3	0	3	3	3
PLM capabilities	2	1	2	2	0	0	0
CMII certification	3	0	2	0	0	0	0
Others	3[i]	0	0	0	1[ii]	1[iii]	1[iv]
Total	**16**	**9**	**12**	**6**	**8**	**8**	**10**

[i] Open source
[ii] Supports data handling from other ANSYS products
[iii] Integrated access to SimManager from MSC applications, compatibility with other CAE application through web-browser interface
[iv] Configurable connectors with other CAD and CAE tools

For this category it appears that the two best tools are Teamcenter and Innovator. Innovator has weaknesses in SDM capabilities. These can be, however, easily overcome by adjoining dedicated software like SimManager or by adding this functionality to the program, as Innovator presents the open source advantage.

Resources Management Tools selected for the evaluation were: **(1)** Sage ERP X3 Premium Edition, **(2)** SAP Business Suite, **(3)** Oracle E-Business Suite and **(4)** Microsoft Dynamics. The most important capabilities of the selected tools are summarized in Table 10. Usually the functionalities of this sort of tools are personalized for each company.

The tools analyzed in Table 5.4 provide almost the same functions. An ERP tool needs to match the needs of each user. An optimum selection should be performed based on a close cooperation with the tool editor. Certain functionalities can be appreciated only by testing them. The price, the availability and efficiency of the support service are other criteria which need to be matched. Based on Table 5.4, it seems that the two best candidates for a Completion Center are Sage ERP X3 Premium Edition and Microsoft Dynamics.

Table 5.4 Evaluation of selected ERP tools

Tool	Description
Sage ERP X3 Premium Edition	Access with simple browser Multiuser capability (up to 1500) Complete integration with MS Office Customer Relationship Management module PDA applications Automatic reading of documents Good customization capabilities
SAP Business Suite	Several modules for total quality management: Supplier and Customer Relationship Management, PLM, Supply Chain Management, Human Capital Management, Travel Management Good customization capabilities
Oracle E-Business Suite	Structures all supplier communication through a secure internet-based portal (called iSupplier Portal) Several modules: Customer Relationship Management , Supply Chain Management, Email Center (able to classify incoming e-mails and route them to qualified agents), Travel & Expense Management, Human Capital Management (with applications like iRecruitment, iLearning), Project Collaboration (providing real-time access to information related to each project) Good customization capabilities
Microsoft Dynamics	Able to connect to another ERP solution (Headquarters) Complete integration with MS Office Only compatible with Microsoft SQL Server or Windows Server Several modules: Customer Relationship Management , Supply Chain Management Good customization capabilities (in C++ or C#)

5.3 Summary

WP 4 covered the selection process of tools in order to meet the needs of a Completion Center. The areas of this study concerned design and engineering, data management, quality management and resource management. Tools which provide assistance in these domains are known as Computer-Aided Design (CAD), Product Lifecycle Management (PLM) and Enterprise Resource Planning (ERP). The tool selection was based on different criteria which fit to each category of tools. The results showed that a range of different tools needs to be adapted to the entire set of requirements throughout the process chain. Tools must be able to communicate and sometimes be linked to each other. All the management tools (for data or resources) have to be configured and customized according to the company needs and the CAD solution used. WP 4 also investigated possible solutions for additional issues, such as writing technical documentation, using 3D scanners for reverse engineering or using tools certified under

Configuration Management II. The best established CAD tool in aeronautical design and engineering is CATIA. For cabin conversion activities a CAD tool needs to have also good rendering and visualization capabilities. Based on our limited evaluation of the most well known tools, it seems that Showcase 2011 edited by Autodesk, can fulfill the required functionalities. For data management, it seems that the open source Innovator, created by Aras is the best candidate. Innovator also has a 4 stars CMII certification.

6 WP 5: Planning of a "Business Case" for the "Completion Center"

6.1 Objectives

The main objectives of WP 5 were:

- to provide background information about the most important economical terms involved by a business case, such as: investment, cash flow, risks, turnover,
- to create a tool to serve management decision making for the business planning
- to use the tool in order to evaluate the vision completion center

When designing the tool, the purpose was to create as much automatism as possible in order to have quick results when changing values of the input parameters, such as costs per hour, number of personnel, number or type of projects, etc.

6.2 Results

6.2.1 Investment Planning

Key terms in investment planning are: risk, return on investment, break-even point, cash flow, investments, cost breakdown structure.

Risks can be evaluated through several methods, either qualitative or quantitative: fault tree analysis, SWOT analysis, Ishikawa fishbone, failure mode and effect analysis, risk classification matrix, risk breakdown structure, failure mode and effect critically analysis, quantitative risk assessment codes.

Return on Investment (ROI) or **Rate of Return (ROR)** is the *effective interest rate* of the investment (**Scholz 1999**). Others define ROI as the sum of interest plus repayment of principal per annum (**Fink 1999**).

Break-Even-Point (BEP) represents the moment in time when the invested capital is repaid.

Cash Flow is the movement of cash in and out of a company /project. The total cash flow will represent the change in cash balance – positive or negative – over the calculated period. The condition of a realistic cash flow schedule – what the EXCEL Tool also tries to attempt – is a detailed cost estimate and a practicable project plan (**Flouris 2008**).

Estimating investments highly depends on the accuracy of expenditures estimation. For the case of ELAN two expenditure groups can be identified in connection with the required investment:

- expenses required to deliver the project results to the customer
- expenses required to ensure the capability to achieve 1.)

Cost Breakdown Structure (CBS). Two types of costs were included in the breakdown: *direct* and *indirect* costs. *Direct costs* include personnel, training, sales and miscellaneous costs. *Indirect costs* refer to the office space and workspace costs. Additional costs were represented by the *Project Zero*. Project Zero is seen as an initial investment required to start implementing the vision Completion Center.

6.2.2 EXCEL Tool

The tool for evaluating the business case was build such as:

- The user has the possibility to define up to 20 conversion projects for the period 2011-2015. Defining a project means setting its complexity, its value, the total men quarters required, as well as the training intensity (in the *Global Project Timeframe* Sheet).
- Default values are set (in the *Definition* Sheet) for parameters such as: costs per hour per type of employee, percentage of costs per phases per type of project, number of people foreseen for DOA, quarters in which a specific phase is active etc. These values can be overwritten by the user.

Calculated (in the *Summary* Sheet) are: total costs, total personnel required as well as cash flow, profit-turnover ratio (German: Umsatzrendite), minimum investment (at the beginning of quarter 1) and return on investment. Any change in the *Definition* or *Global Project Timeframe* Sheet reflects automatically in the *Summary* Sheet.

6.2.3 Assumed Ramp Up for Completion Center

In order to test the efficiency of the tool and make a preliminary analysis of the vision Completion Center, three scenarios were run:
Scenario 1: small investments, small number of projects
Scenario 2: medium investments, small number of projects
Scenario 3: large investments, large number of projects

As a middle solution Scenario 2 resulted not to be the best solution. It seems that only two ways are beneficial: either conducting small and safe projects one after the other with a smaller team and a smaller outcome, or adopting the strategy of a „booming economy", i.e. investing strongly and have higher profit in the end.

From the definition of *profit* (turnover minus expenses) results that a higher profit is obtained if *turnover is increased* and *expenses are reduced*. The turnover (i.e. the project value) depends first of all on the amount of work estimated during offer. This sets the price that is to be paid by the customer. A certain price flexibility should be allowed in order to face competition.

Expenses can be improved if several factors are modified. Parameters that can be varied are:

- staff costs (internal, external, experts)
- training costs
- indirect costs
- risk allowance
- sales costs
- miscellaneous costs
- „k"factors
- Number of people for DOA
- Number of men quarters

Table 6.1 illustrates the impact on *profit*, *minimum investment* and *ROI* of part of the above-mentioned parameters. To note that the variation of the „k"factors was from 0.6 to 0.7 (i.e. + 17 %) for „k" factors for internal staff, from 0.3 to 0.2 for „k" factors for external staff (i.e. -33 %), while the same experts requirement was considered (i.e. 0 % deviation for „k" factors).

Table 6.1 Variation of parameters and their impact on gain, investment and return on investment

Parameter	Symbol	Deviations			
			Gain after 5 years	Minimum investment	ROI
Staff internal	SI	- 20 %	+ 4 %	- 11 %	+ 10 %
Staff external	SE	- 20 %	+ 2 %	- 7 %	+ 7 %
Staff experts	SX	- 20 %	+ 3 %	- 3 %	+ 3 %
Training costs	T	- 20 %	+ 0.3 %	- 1 %	+ 1 %
K staff factors	K	+ 17 %, - 33 %, 0 %	+ 0.8 %	- 3 %	+ 2 %
Combination of parameters	SI+SE+SX		+ 7 %	- 21 %	+ 20 %
	SI+SE+SX+T		+ 7 %	- 22 %	+21 %
	T+K		+ 1 %	- 3 %	+ 3 %
	SI+SE+SX+T+K		+ 8 %	- 24 %	+ 24 %

Among the parameters that influence the costs, the most important are the staff costs. Most significant part of the staff costs is the salary. The reduction in costs for internal staff has of course the greatest impact, due to the higher number of internal employees. External staff follows shortly, due to the fact the higher costs. If both costs and amount of external employees are reduced, then the advantage is considerable and the internal staff costs could be kept constant (i.e. no salary reduction would be required).

The analysis presented may not be realistic enough due to its roughly approximated inputs, out of which the most sensible one is the *project value*. The project value can be „tuned" so as to always get a positive balance from every project. It would be then in the responsibility of the sales directors to make these project values realistic and find customers willing to pay the price.

6.3 Summary

WP 5 aimed to aid the evaluation of the business case Completion Center. It first delivered background information about business economics, summarizing basic elements about chances and risks, revenue and profit, investment and cash flow. It then applied it for a management tool conception.

The management tool was build to analyze the different possibilities to proceed towards this vision. Most important roles of the tool are:

- to estimate the amount of money required to obtain positive cash flows over the five years period[1],
- to help selecting a vision strategy by using the tool to analyze different scenarios.

The user of the tool has the advantage of fast input changeability and intermediate visualization of the results. It allows the adaptation of the inputted data to match a required output. The user has the flexibility to practically build its own cash flow curve by changing parameters like project value, number of staff, training intensity, etc.

The examples discussed indicate that results are very sensitive to parameters like project value. Only ELAN engineers can appreciate realistic project values. However, based on this limited evaluation, it seems that two alternatives bring ELAN forward towards the vision „completion center": one with higher profit (Scenario 3) and one with less profit (Scenario 1). A middle alternative seems to be too costly for the predicted gain.

Staff costs have the highest share in total costs. These costs can be reduced by adopting several alternatives:

- limited use of external staff and experts,
- involvement of a smaller number of DOA members,
- optimization of training costs.

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1 i.e. minimum investment at the beginning of quarter 1

Some of the trainings (for instance for the utilization of a new PDM platform, or for structural design) could be in-house performed, by ELAN engineers or engineers from the mother company EDAG.

7 Conclusions

Following the results of CARISMA, the economical context and its trends, the conclusions can be summarized as follows:

- An independent design work needs to be certified by certification authorities (EASA for Europe). Cabin conversions, defined as a sum of modifications to an initial type design, can only be performed under a STC. A STC can be received if ELAN has a DOA. Therefore, the way to independent cabin conversion starts with the application for DOA. An alternative is the cooperation with DOA partners, but this leads to certain disadvantages and to a only quasi independency.
- In order to receive the approval, the company needs to „grow" a design assurance system, in order to prove – to EASA, to the customer, to themselves – that they can perform a safe design.
- A design assurance system can be backed up by optimized processes, efficient work and coordination of funds, efficient tools and efficient people.
- The market of cabin conversions is rather un-sensitive to economical fluctuations and forecasts (own or public) show a constant growth.
- The long time experience in cabin conversions of ELAN engineers represents a perfect background for growing capability. ELAN engineers can already perform small conversion scenarios in an independent way.
- Tools play a major role in designing, archiving and managing data and contribute to an efficient work environment.
- ELAN lacks experience in sales, production and logistics.
- Since the vision completion center seems to be vital, selecting the proper strategy towards it is also vital.
- When analyzing the business plan, several factors are of importance, as they contribute to the variation of the cash flows. Such factors are: initial training intensity, number of employees that are going to be part of DO, percentage of required external employees and experts, number of projects and their duration, etc.
- A tool was developed to help evaluating the best strategy. It seems it"s better to assume a higher initial investment as this leads to higher profits.

List of References

ACMG 2009 URL: http://www.cargofacts.com/. – Air Cargo Management Group (2009-05-28)

AFRA 2009 URL: http://www.afraassociation.org/index.cfm (2009-12-02)

ATA 2009a URL: http://www.airlines.org/public/publications/ (2009-12-02)

Boeing 2009 URL: http://www.boeing.com/commercial/cmo/ (2009-04-10). – Article title: Current Market Outlook 2009-2028

CAMR 2009 NAGALINGAM, Sev: *A Guide to Introducing Concurrent Engineering in your Organisation.* – Based on research conducted at the Centre for Advanced Manufacturing Research (CAMR), of the University of South Australia. URL:http://www.smartlink.net.au/library/concurrent.pdf (2009-06-22)

Dahl 2009 DAHL, V. Robert: Holding Pattern for Freighters. In: *Air Cargo World*, 1 November 2003. – URL: http://www.aircargoworld.com/features/11 03 _1.htm (2009-06-01)

EADS 2009 URL: http://www.eads.com/1024/en/businet/aeronaut/efw/fields/freigh ter.html (2009-03-09). – Article Title: "EADS EFW - The Airbus Freighter Conversion Experts", 19 June 2009.

EASA 2009b EUROPEAN AVIATION SAFETY AGENCY: *Commission Regulation (EC) No 1702/2003, Annex Part 21,* September 2003. – URL: http://eur-lex.europa.eu/LexUriServ/site/en/oj/2003/l_243/l_24320030927en00060 079.pdf (2009-02-17)

EASA 2009c EUROPEAN AVIATION SAFETY AGENCY: AMC and GM to Part 21 : Acceptable Means of Compliance and Guidance Material for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organizations, October 2003. – URL: http://www.easa.eu.int/ws_prod/g/doc/Agency_Mesures/Certification_Sp ec/decision_ED_2003_01_RM.pdf#page=145 (2009-02-17)

Fluoris 2008 FLOURIS, Triant; LOCK, Dennis: *Aviation Project Management*, Hampshire, Ashgate, 2008

Manitz 2010 MANITZ, Sascha: Engineering input information at Heath Tecna : Interview. Hamburg, 2010-05-19. – Mr. Manitz is Regional Sales Director at Heath Tecna

Parker 2008 PARKER, D. Andrew: Incredible Interiors: Modern VIP Cabins. In: *Aviation Today Daily Brief,* (1 November 2008). – URL: http://www.aviationtoday.com/am/categories/bga/Incredible-Interiors-Modern-VIP Cabins_27215.html (2009-06-15)

Scholz 1999 SCHOLZ, Dieter: *Flugzeugentwurf – Lecture Notes.* Hamburg University of Applied Sciences, Department of Automotive and Aeronautical Engineering, 1999

Williams 2009 WILLIAMS, Tom: The Management of Programmes at Airbus : Presentation. Hamburg, 2009-06-04. – Organization: RAeS Hamburg Branch

ChinaS 2004 URL: http://findarticles.com/p/articles/mi_m0EIN/is_2004_Nov_ 1/ai_n6278264/ (2009-05-19). – Article title: "China Southern Continues Modernizing Fleet With Major Retrofit", 1 November 2004

Air Canada 2005 URL: http://www.asiatraveltips.com/news05/1011-AirCanada.shtml (2009-06-1). – Article title: "Air Canada unveils all new seating featuring industry-leading lie flat suites", 10 November 2005

Cathay Pacific 2009a URL: http://www.cathaypacific.com/cpa/en_INTL/whatonboard/ourfleet/ b_747_400 (2009-05-27)

Cathay Pacific 2009b URL: http://www.aviationtoday.com/pressreleases/16374.html (2009-05-27). – Article title: "Cathay Pacific Airways Brings Luxurious New Seats and Cabin 'Look and Feel' to Major Cities", 08 October 2007

Air France 2009 URL: http://corporate.airfran ce.com/index.php?id=communiques_detai l&tx_ttnews[tt_news]=4395 (2009-05-27). – Article title: "La nouvelle cabine Premium Voyageur sur les vols long-courriers d"Air France, 20 March 2009

Dragonair 2003 URL:http://www.dragonair.com/da/en_INTL/aboutus/pressroomdetail s?refID=2d457b7f88410110VgnVCM10000021d21c39 (2009-05-27). – Article title: "Dragonair unveils HDK195-Million Redesign of Aircraft Cabins, Service En-hancements", 20 January 2003

Japan Airlines 2007 URL: http://press.jal.co.jp/en/release/200701/000661.html (2009-05-19). – Article Title: "Japan Airlines to Introduce Domestic First Class for the First Time & Introduce New International JAL Premium Economy in FY2007", 17 January 2007

Moody 2008 MOODY, Elyse: Cabin Fever. In: *Overhaul & Maintenance*, October 2008. – URL:http://www.aviationweek.com/aw/generic/story_generic (2009-05-19)

Müller 2010 MÜLLER, Klaus: Work Package 3 : Analysis of the Process Chain Cabin Conversion : Meeting. ELAN GmbH, 2010-04-01

Philippineair 2009 URL: http://www.philippineairlines.com/news/may_14_ pal_refurbishes_b747_with_world_class_amenities.jsp (2009-05-26). – Article Title: "Philippine Airlines refurbishes B747 with world-class amenities", 14 Mai 2009

Phleps 2009 PHLEPS, Peter: Szenariostudie im Rahmen des Spitzencluster Leuchtturmprojektes „Effizienter Flughafen" : Workshop presentation, 14-15 October 2009

Scholz 2002 SCHOLZ, Dieter: Standards als Mittel zur unternehmensübergreifenden Zusammenarbeit in der Luftfahrt-Industrie : Dokumentation nach ATA iSpec 2200. In: SCHOLZ, Dieter (Editor): *Fit für die ATA iSpec 2200 (Forum: Fit für die ATA iSpec 2200 – Technische Dokumentation in de Luftfahrt-Industrie, TANNER AG, Lindau, 30.04.2002).* Bonn : Deutsche Gesellschaft für Luft- und Raumfahrt, 2002. – DGLR-Report 2002-01, ISBN 3-932182-25-1

Searles 2008 SEARLES, A. Robert: *Demand For Executive/VIP Completions On The Rise*, 2008-04 -21. – URL:http://www.aviationweek.com/aw/generic/ story_generic.jsp?channel=om&id=news/om408vip.xml (2009-05-01)

Smith 1997 SMITH, P., Robert; EPPINGER, D., Steven: Identifying Controlling Features of Engineering Design Iteration. In: *Management Science*, Vol. 43 (March, 1997), No. 3, pp. 276-293.

Starfield 2009 STARFIELD, Kate: *EBACE: Business jet deliveries hit by economic meltdown,* 2009-05-12. – URL: http://www.flightglobal.com/ articles/2009/05/12/326321/ebace-business-jet-deliveries-hit-by-economic-meltdown.html (2009-06-10)

Steward 1991 STEWARD, D. V.: Planning and Managing the Design of Systems. In: KOCAOGLU, F. Dundar; NIWA, Kiyoshi: Technology Management : The new International Language (PICMET '91 - Proceedings of Portland International Conference on Management of Engineering and Technology Portland Oregon USA 1991). Portland, 1991, pp. 189-193. - ISBN: 0-7803-0161-7

Swiss Air 2008 URL:http://www.swiss.com/web/EN/about_swiss/media/press_releases/2008/Pages/pr_20080410.aspx?1243855120183&Country=US (2009-06-01). – Article title: "New seats now installed throughout SWISS"s European fleet", 10 April 2008

Swiss Air 2009 URL: http://www.psfk.com/2009/02/swiss-air-redesigns-their-first-class-suites.html (2009-05-19). – Article title: "Swiss Air Redesigns Their First Class Suites", 19 February 2009

Watson 2009 WATSON, Blair: *Navigation Errors a Key Business Jet Safety Concern,* 2008-05-29. – URL: http://www.aviation.com/safety/ 080529-business-aviation-safety-concerns.html (2009-06-10)

Woollard 2007 WOOLLARD, Deidre: *United Announces New Seats for International Business Class*, 23 July 2007. – URL: http://www.luxist.com /2007/07/23/ united-announces-new-seats-for-international-business-class/ (2009-05-27)