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Research Definition and Implementation

Aircraft Cabin and Cabin System Refurbishing – Optimization of Technical Processes

CARISMA

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Abstract

CARISMA is a cooperative industrial/academic research project of three organizations: An engineering office called ELAN located in Germany and two universities one in Hamburg, Germany and the other in Bucharest, Romania. CARISMA stands for "Aircraft Cabin and Cabin System Refurbishing – Optimization of Technical Processes". The aim of the research project CARISMA is two-fold. On the one hand it is the foundation for work intended to lead towards a PhD of Dipl.-Ing. Mihaela Niță at Politechnical University Bucharest in cooperation with Hamburg University of Applied Sciences (Prof. Dr. Scholz). On the other hand, it helps to investigate the "vision" of ELAN GmbH to establish itself as a completion center. A completion center carries out the conversion of an aircraft starting from the customer request up to aircraft delivery. Aircraft or cabin conversion scenarios could be Pax-to-Freighter, Pax-to-VIP, Pax-to-Pax (with different cabin layout). Prof. Dr. Scholz gives his view on how to lead the PhD candidate to a successful dissertation. Scientific details are given on Knowledge Base Engineering and its application to cabin conversion in the frame of the PhD project.

Contents

Definitions

AI Artificial intelligence (AI) is the intelligence of machines and the branch of computer science which aims to create it. Major AI textbooks define the field as "the study and design of intelligent agents" where an intelligent agent is a system that perceives its environment and takes actions which maximize its chances of success. Subfields of AI

are organized around particular problems [and] the application of particular tools. (**Wikipedia AI 2009**)

KBE Knowledge-based engineering (KBE) is a discipline with roots in computer-aided design (CAD) and knowledge-based systems but has several definitions and roles ... An early role was support tool for a design engineer generally within the context of product design. (**Wikipedia KBE 2009**)

1 Introduction

This Technical Note continues the Research Definition and Implementation of the project "Aircraft Cabin and Cabin System Refurbishing – Optimization of Technical Processes" (CARISMA). CARISMA is a cooperative industrial/academic research project of 3 organizations: ELAN, HAW Hamburg, PUB (see below for definitions).

This Technical Note is based on the Research Proposal written on 2008-06-13 titled "Aircraft Cabin and Cabin System Refurbishing – Management of Technical Processes (CARISMA)" **Scholz 2008**, which was meant as a draft. It was written after first consultations with ELAN GmbH and served as a basis for a common understanding between ELAN and HAW Hamburg. It helped in the negotiations of a Research and Development Contract between ELAN and HAW Hamburg. Furthermore, it led to Appendix A of that Research and Development Contract; Appendix A is detailing the 5 Work Packages of CARISMA (as far as ELAN is concerned).

Simultaneously, **Scholz 2008** served also as a first common understanding between PUB and HAW Hamburg and was the basis for consultative meetings at PUB in the last week of August 2008. Since then the topic was slightly changed. CARISMA now stands for "Aircraft Cabin and Cabin System Refurbishing – Optimization of Technical Processes". This change reflects the scientific and engineering nature of the project.

Scholz 2008 remains a helpful and valid document in CARISMA. General explanations to cabin and cabin refurbishing will not be repeated here.

2 Cooperation in CARISMA

Organizations involved in CARISMA are:

- Politechnical University Bucharest. In Romanian: Universitatea Politehnica din Bucureşti (PUB). **PUB 2009**.

- Hamburg University of Applied Sciences. In German: Hochschule für Angewandte Wissenschaften Hamburg (HAW Hamburg). Aircraft Design and Systems Group (Aero). **HAW 2009**, **Aero 2009**
- ELAN GmbH. **ELAN 2009**

Focal points of contact for all technical questions in CARISMA:
- For PUB: Prof. Dr.-Ing. Mihai Neamțu (neamtu@incas.ro)
- For HAW Hamburg: Prof. Dr.-Ing. Dieter Scholz, MSME (info@ProfScholz.de)
- For ELAN: Dipl.-Ing. Oliver Mönkemeier (oliver.moenkemeier@elan-edag.com)
- PhD candidate: Dipl.-Ing. Mihaela Niță (mihaela.nita@haw-hamburg.de)

Formal cooperation and legal commitments in CARISMA:
- Mihaela Niță and PUB: Doctoral Studies Contract and Appendix of Contract
- Mihaela Niță and HAW Hamburg: Work Contract.
- PUB and HAW Hamburg: Doctoral Collaboration Contract.
- ELAN and HAW Hamburg: Research and Development Contract.

Duration of contracts in CARISMA:
- Mihaela Niță and PUB: 3 years.
- Mihaela Niță and HAW Hamburg: 2 years, to be extended.
- PUB and HAW Hamburg: To the end of the PhD of Mrs. Niță (3 years).
- ELAN and HAW Hamburg: 2 years with the option to extend for another year.

Mutual benefits of the cooperation:
- For PUB: International cooperation and link to academia and industry at Luftfahrtstandort Hamburg (Hamburg the Place for Aviation) – the third largest place for civil aviation in the world.
- For HAW Hamburg: International cooperation, possibility for a cooperative PhD, link to industry with a knowledge gain in every day cabin design and constructions, financial support.
- For ELAN: Opportunity of an unbiased outside view and support in practical scientific approaches to problem solving in aeronautical engineering. Contact to the local university with a potential of attracting more students for project and thesis work as well as tapping into a pool of potential employees for ELAN, prestige of having supported a PhD in an international setting.
- For Mihaela Niță: Work towards a PhD in an industrially relevant setting, gain in international experience, possibility to improve on German and English language knowledge, insight into German academic engineering approaches, financial support from two sides (PUB and HAW Hamburg).

3 General Research Scope

This Section is largely based on Appendix A of the Research and Development Contract between ELAN and HAW Hamburg.

The **domain of cabin conversion** and refurbishing **is expected to grow** even in a time of general economic downturn. The reason for this is simple. A market change requires airlines to adapt and adapting to a new market situation means the need to convert the fleet. So even if money is limited in a downturn, the airlines can not avoid to at least investing in optimizing their fleet.

The **type of work** assigned to engineering offices also **changes**. In the past, classical assignments asked for design drawings. The future will see international big projects, covering the entire process chain of a complete cabin conversion to be assigned to companies outside of the aircraft manufacturer.

For **ELAN** the first priority will remain to carry out projects for its main client Airbus. However, a **vision for the future** is to enlarge the product portfolio, by offering conversion capabilities also for non-Airbus aircraft and to act as a **completion center**.

A **completion center** carries out the conversion of an aircraft starting from the customer request up to aircraft delivery (also called hand over). Some completion centers handle the conversion of smaller aircraft types in an autonomous way, from customer request up to delivery. A few big companies in the field also convert Airbus or Boeing passenger aircrafts. A completion center does not necessarily handle every activity which is part of the process chain itself. The decision "make or buy" has to be made and some activities are outsourced giving smaller players in the field or expert companies the possibility to participate.

Two **big completion centers in Europe** are e.g.:

- Lufthansa Technik (**LHT 2009**)
- Jet Aviation (**Jet Aviation 2009**)

Jet Aviation with its Basel based services gives its range of services on the WWW (**Jet Aviation 2009**).

> *Jet Aviation Basel has become one of the largest organizations in the VIP and business aircraft completions field in Europe, and has gained a worldwide reputation for outfitting and refurbishing. The company's highly skilled, professional craftspeople have the ability to fully complete and outfit green aircraft lacking any interior installation or refurbish already completed aircraft requiring anything from a minor touchup to a major refinishing. Capability and experience ranges from small through large-cabin business jets, including Learjets, Falcons, Challengers and Gulfstreams. In addition, Jet Aviation Basel is a designated, factory-approved completion center for the Boeing Business Jet (BBJ) and the Airbus 319 Corporate Jetliner (ACJ).*

Completion 2009 list 239 completion centers in the world many of them in the United States of America.

Task of the university is to support this real world problem of setting up a company to become a completion center. The university will take the scientific part in solving this problem. The tradition of German engineering research has always been to work on topics with reference to industry. In this way engineering departments at universities have always been among those, attracting the highest amount of third-party funds.

4 Industrial Work Packages

This Section is largely based on Appendix A of the Research and Development Contract between ELAN and HAW Hamburg. The work for the research project is divided into five Work Packages (WP).

WP 1: Identification of the Process Chain "Cabin Conversion"

In the frame of this work package all the elements of the process chain necessary for a successful cabin conversion should be identified and described. All the input parameters and all the relevant documents have to be considered.

The Cabin Conversion (CCO) branch of ELAN deals with cabin conversion for the customer Airbus. Today only a small part of the necessary processes is being conducted by ELAN, another part of the process chain remains in the hands of the ordering customer. An investigation has to be conducted about how the processes are divided between ELAN and Airbus. From there on, all the necessary process steps should be identified in order to carry out an independent and successful cabin conversion, while fulfilling all the EASA requirements.

WP 2: Market Research "Completion Center"

The department CCO of ELAN executes primarily cabin conversions for "long range" and "single aisle" Airbus aircrafts and therefore serves only a limited segment of the market. The demand for cabin conversion beyond this area should be appreciated through a market research. The following approach is being proposed:

- Investigation of aircraft data (manufacturer, aircraft family/class/model, age of the aircraft)

- Deduction of criteria which are relevant for cabin conversion (conversion cycles, conversion scenario like: Pax-to-Freighter, Pax-to-VIP, Pax-to-Pax, small/large aircrafts, extend of the conversion)
- Forecast of the market volume
- Investigation of companies offering cabin conversion and classification of these companies: position inside the process chain, aircraft types, type of conversion

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

Depending on the aircraft type as well as size and extend of the cabin conversion, identified process steps have to be investigated each in its unique depth and manner. For a selected cabin conversion example, the process chain should be described in sufficient detail. The elements of the process chain should be investigated based on the following criteria:

- Technology
- EASA Part 21 - DOA - Design Organization Approval / certification
- Costs
- Time
- Human resources
- Infrastructure
- Tools

The question should be answered, which resources are available at ELAN and which resources in the frame of a "make-or-buy"-decision have to be build up in-house or bought externally.

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

In the frame of the present activities of the CCO department, different tools are being used. Some of these tools are either specified by the ordering customer and have to be bought by ELAN. In other instances, tools of the customer can be used by ELAN through data links between ELAN and the customer. These tools are: CAD-Systems, databases and archives which can be used in the following domains:

- Design and layout
- Design and drawings (also for electric systems)
- Quality management
- Documentation

Tools that provide assistance in these – and even more general areas – are known as:

- Enterprise Resource Planning - ERP: Assistance in planning resources for the whole enterprise.

- Product Data Management - PDM: Storage of data and documents as a result of the product development.

For the determination of the required tools, necessary for the "completion center" scenario, the following approach is proposed:

- Analysis and evaluation of the tools used at ELAN (e.g. tools for the layout design, such as tools of the company Pace: Pacelab Cabin, Retrogen, PSUGen).
- Identification of other possible tools (e.g. tools for a 3D representation of the cabin), which could be useful for the process phases of a cabin conversion.
- Research and evaluation of the available tools on the market.
- Proposal of a range of tools for ELAN to adopt, having in mind past and future activities.

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

WP 5 investigates the project "completion center" as an investment for ELAN. The investigation comprises the examination of the business economics of planned activities and investments with the aim to support decision making by the management board.

- Amount of capital investment, costs, and expenditures (extend to which a DOA is applied for, hard- und software, business partner search, acquiring personnel, personnel training, acquisitions ...)
- Orders, benefits, revenues
- Costs-Benefits-Analysis, investment appraisal
- Chances, risks, sensitivity analysis

Table 1: Work industrial packages in CARISMA with duration and due date

WP	Deliverable	Description	Duration of work	Date
1	Report	Identification of the Process Chain "Cabin Conversion"	2 Months	31.03.2009
2	Report	Market Research "Completion Center"	3 Months	30.06.2009
3	Report	Analysis of the Process Chain "Cabin Conversion"	6 Months	31.12.2009
4	Report	Research, Analysis, Evaluation and Selection of Tools	4 Months	30.04.2010
5	Report	Planning of a "Business Case" for the "Completion Center"	5 Months	30.09.2010
6	Report	Final Report*	1 Month	31.10.2010

* The final report has the function to bring together the 5 WP's in a short general view and to comment on the remaining work, done during the last month of the project. The final report will comprise furthermore the lessons learnt and recommendations (description of open activities or worthwhile further research) with respect to a possible continuation of the research project (option for a third year).

Every work package (WP) will end with a report. This report represents the fundamental deliverable of the work package and its evidences of the fulfillment of the contractual duties of the contractor HAW Hamburg for ELAN GmbH (see Table 1).

If applicable, the reports will be complemented by software, drawings, publications, presentations and student papers.

5 Proposal for an Extension to CARISMA towards a PhD at PUB

A PhD topic should have a certain width but also a certain depth in one (possibly two) of its main topics. Looking at the Work Packages, several topics could be considered to be developed in more depth. WP 4: "Research, Analysis, Evaluation and Selection of Tools" seems to be a good starting point for a more in depth investigation. For the sake of completeness at this point, some basics from **Scholz 2008** are repeated here and placed into Section 5.1.

5.1 Tools in Cabin Refurbishing

Basic **drafting tools** for cabin layout, design and refurbishment are CCD (Catia Cadam Drafting), CATIA V4 and CATIA V5.

At Airbus (Germany) aircraft data is stored in a large **data base** (running on a host computer). The data base consists of many subordinate databases and tools that were developed in-house decades ago, tailored to the specific needs. Three main parts of data can be differentiated: *Basic Data* (management of modifications, management of deadlines, standards data base, ...), *Definition Data* (equipment data base, electrical system data base, ...) and *Production Data* (drawings, part lists, ...). For each aircraft part, a dataset (Bauunterlage) is required, consisting of: drawings, part list, engineering change note, and control sheet (Bauteilsteuerungsblatt). The engineer has access to the data with special **tools** like TAKSY (management of drawings, part lists, ...) or ZAMIZ (read-only access to drawings).

Planning the refurbishment has to be achieved without the aircraft being present, because it is still in operation during that time. So the datasets are the only means for the engineer to prepare the refurbishment. If a part of the refurbishment process is done by engineering offices outside Airbus (subcontractors), they have access to the Airbus data base in order to consult, extract and modify data. For every work process a detailed **documentation** is prepared. Every result produced has to be checked and signed, proving that the regulatory requirements are fulfilled.

Computer **tools** were designed **that support the generation of cabin layouts**. These tools are applied during early aircraft design (for generation of the standard layout) or during negotiations with customers (for generation of an individual cabin layout).

Already in the 80th research has been done using **expert systems** in aeronautical engineering. **Alsina 1987** applied expert systems to wing design. XKL was an early expert system for the configuration of the layout of passenger cabins (**Kopisch 1993**) and was based on PLAKON (**Cunis 1991**) a special expert system called configuration system.

Pacelab Cabin of Pace Aerospace Engineering and Information Technology GmbH (**PACE 2009**) is a standard aircraft cabin configuration tool. It significantly streamlines the modeling and positioning of cabin interior items as well as the utilization of results by applying a consistent **Knowledge Based Engineering** (KBE) approach. Pacelab Cabin is applied at Embraer (**PresseBox 2008**) and at Sukhoi Civil Aircraft Company (SCAC) for the Sukhoi Superjet 100 (**BDLI 2008**). Airbus has sponsored a tailored development of Pacelab Cabin to suit Airbus' needs. This much extended version is however not available in public. Pacelab Cabin in its standard and public version was reviewed by **Seeckt 2004** at HAW Hamburg.

5.2 Knowledge Based Engineering in Aircraft and Cabin Design

Knowledge Based Engineering (KBE) represents the technological implementation of the Knowledge Management vision and strategy for the engineering business. KBE offers designers a technology to capture and reuse product and process multidisciplinary knowledge in an integrated way, in order both to reduce time and cost for engineering applications, automating repetitive design tasks, and support conceptual design activities. KBE provides designers with tools to virtually access their ideas, model the multidisciplinary aspects of products, manipulate geometry and annexed knowledge and support the investigation of multiple what-if on their design (**TU Delft 2009a**). Figure 1 symbolizes this approach.

Prof. van Tooren (well known at PUB) has promoted KBE in aircraft design quite a bit. He stresses the importance of KBE to aircraft design in his inaugural speech at TU Delft (**van Tooren 2003**).

KBE has been applied in many ways in aircraft design. **TU Delft 2009c** contains a package of 16 papers to the topic. KBE has been related to empennage and control surface design, aircraft structures, Blended Wing Body (BWB) design and morel general to Multidisciplinary Design Optimization (MDO). It becomes apparent that not all research in the field is based on AI programming principles. Often just the KBE approach implemented in a procedural programming language is called KBE.

When considering this wider sense of KBE in aircraft design with procedural programming languages, it can be stated that also Aero (**Aero 2009**) at HAW Hamburg has gained experience with KBE. The software package PrADO from TU Braunschweig applied in the project "Green Freighter" (**Scholz 2009**) could be classified as KBE.

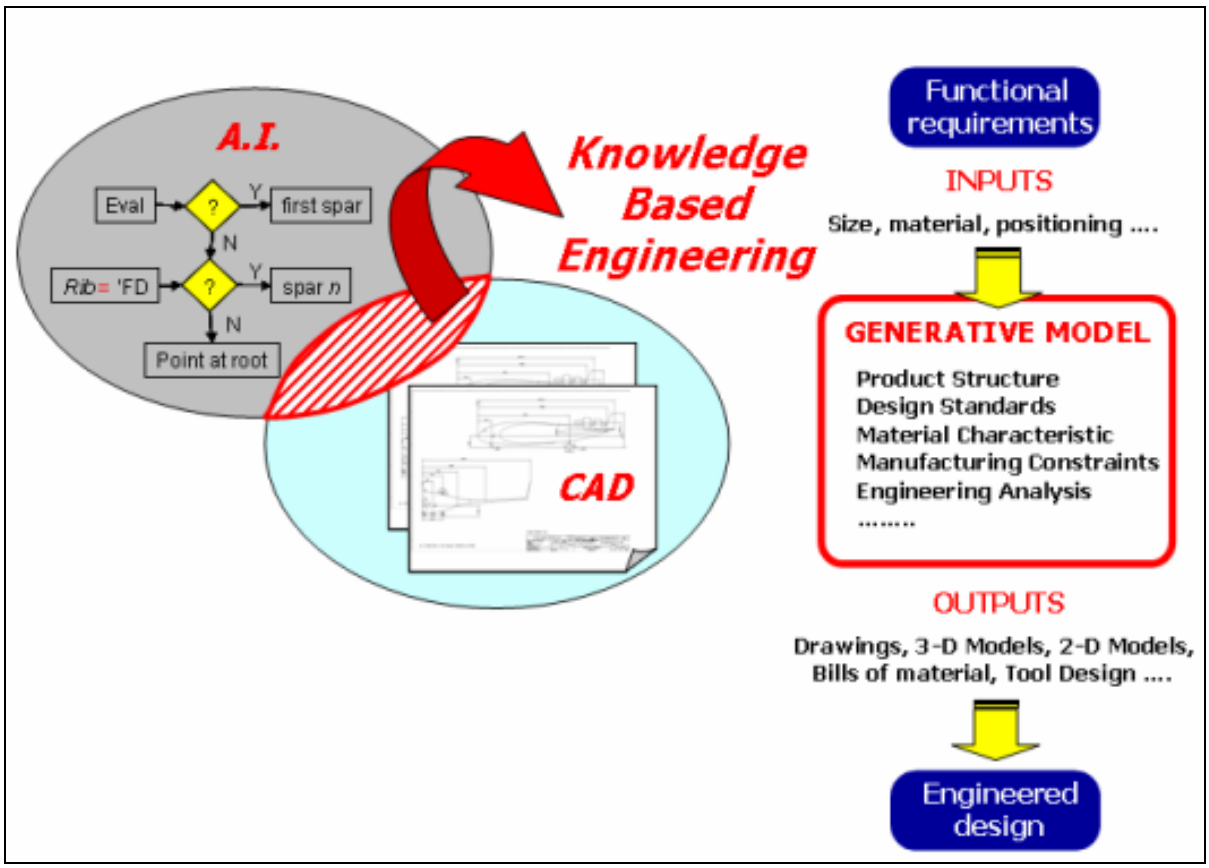

Figure 1: Knowledge Based Engineering (KBE) in aircraft design (**TU Delft 2009b**)

5.3 Extension to Current Tools in Cabin Refurbishing Based on KBE

The most important drawing in cabin conversion and refurbishing is the **cabin layout**. It is basically a plan view of the cabin. The cabin layout has to take many **design limitations** into account: certification rules, aircraft boundary conditions (from structures and aircraft systems) and customer requests. For this reason, it is almost incomprehensible for a human mind to optimize the cabin layout without compromising these design limitations.

The company PACE offers the **most advanced** environment for today's **tools in cabin conversion and refurbishing**. PACE tools are based on Knowledge Based Engineering (KBE) and hence Artificial Intelligence (AI). The company describes its capabilities on the WWW (**PACE 2009).**

> *PACE has developed **specialized solutions for cabin conversion** and upgrading which largely automate the generation of retrofit drawings and delta part lists. By flexibly linking and*

comparing pre- and post-statuses of cabin interiors (also extending to cabin systems like passenger service channels, floor-mounted systems, etc.), our software allows to assess different conversion strategies based on comprehensive data. The latter includes detailed lists of new, recycled, unchanged, and surplus parts, retrofit drawings of pre-status and post-status including grid references, and delta part lists. These may be exported conveniently to bills-of-material or PDM systems.

In a personal conversation, PACE revealed that the claims made in the quote above are not really put into practice yet. The customized version built for Airbus includes only some of the features mentioned.

Accordingly there is **new ground for research** that can be covered. Based on up to date scientific knowledge relevant to practical and industrial engineering it could be the aim to work on a tool that supports cabin conversion. The tool will support – much like Pacelab Cabin – the design of a cabin layout. The Cabin Conversion tool however will be able to generate a "delta" list between two layouts, generating detailed lists of new, recycled, unchanged, and surplus parts. All this will take design limitations (see above) into account. The amount of work necessary would be too much for a PhD project (in addition to the other important Work Packages to work on). The aim for the PhD candidate should be (in addition to the more general research as described in Section 4)

1. to investigate the theory of artificial intelligence (AI) and knowledge based engineering (KBE) and its possibilities to an application in the field of cabin conversion and refurbishing,
2. to investigate the application of KBE in the field of aeronautical engineering / aircraft design / cabin design and to relate this knowledge to the field of cabin conversion and refurbishing,
3. to show with example programming how AI/KBE techniques can be applied to cabin conversion and refurbishing.

The intension of the company PACE is to build a public version of its Cabin Conversion tool and offer it to the major completion centers in the world (compare with Section 3). PACE is highly interested to work together with a university in this field. This common work will most probably be outside of a formal contract. PACE may support university activities in exchange for some input of the PhD student. Based on this **synergy with PACE** and results from step 3, it would be possible

4. to show how such a KBE-based Cabin Conversion tool could be put into practice.

The initial step forward in this matter will be done with the **master thesis** of Bianca Szasz from PUB. HAW Hamburg will purchase a development license of Pacelab Cabin. The thesis will apply Pacelab Cabin to a small cabin design problem. The main focus will be to implement rules and understand the KBE approach of the tool.

ELAN is willing to support this depth added to the PhD topic, because of the company's interest to see the PhD candidate succeed in her endeavor – understanding at the same time that the results of this in depth investigation may have only limited value to the company's

goals. The KBE extension of the PhD topic is incorporated into Work Package 4, where it forms an addition to the investigation of Pace tools.

6 Summary

This Technical Note describes the cooperation in CARISMA between the PhD candidate, PUB, HAW Hamburg and ELAN. The general research scope is laid out, which comprises the academic part of establishing a small/medium company as a completion center. For this purpose five Work Packages have been defined together with ELAN. They should also form the basis for the PhD project at PUB. In addition to a suitable width, a PhD topic should have a certain depth in one (possibly two) of its main topics. An extension to current tools in cabin refurbishing based on Knowledge Based Engineering (KBE) is identified to provide a valuable additional in depth task to the PhD topic.

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