VISIONARY INTEGRATION CONCEPTS FOR AIRCRAFT CABIN INTERIOR

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Abstract
A holistic approach on the development of new integration concepts for aircraft cabins is presented. Based on an extensive as-is analysis, first concepts were set up applying prevalent design for assembly guidelines and resulting in the definition of top-level-requirements for the design and integration processes of aircraft cabins. Further researches contained an analysis of the assembly processes of the cabin components and their product structures. A modularisation of the components was performed. Beside these evolutionary advancements for aircraft cabins, revolutionary concept ideas were generated, that imply unprecedented attachment principles, integration processes and component product structures. Amongst others, knowledge acquired in the course of benchmarking analyses with other industry branches was included in the development. The presented information consists of final and intermediate results of various joint research projects between Airbus Deutschland GmbH and the Institute of Product Development and Mechanical Engineering Design (PKT) of the Hamburg University of Technology.

1 INTRODUCTION
Rising cost pressure and the intended increase of produced units in the future lead to the necessity for aircraft manufacturers to achieve faster and more efficient aircraft production processes. In case of the aircraft interior, which is predominantly integrated in the final assembly line (FAL), whereas the brackets are mounted in earlier stages of the overall aircraft assembly, a large amount of requirements have to be considered. In general, high degrees of quality, design, functionality and not least the safety are expected from the aircraft cabin. Furthermore the interior is a highly customised product. The customers are free to choose from a large amount of different varieties or in various cases even to demand the furnishing of their own equipment. Over the time more and more functionalities and systems were installed in

AST 2009, March 26-27, Hamburg, Germany
the aircraft cabin. Due to the generally long life cycles of aircraft programs, massive adaptations and modifications of the product’s constructive designs were and still are necessary, leading to a vast elevation of the cabin complexity. The entity of continuously rising and partly competing requirements entails extensive efforts in the development.

Today the installation of the interior components is the final step in the overall aircraft production process. The cabin’s architecture is determined by the fact that the components have to be installed in the flight ready aircraft. The parts and modules are carried manually into the fuselage through the passenger door where they are attached to the aircraft structure. Due to differences in the aircraft structure assembly processes among the investigated aircraft program, occasionally particular components can already be introduced into the open fuselage prior to the mounting of the cockpit section. In general the passenger door represents the bottle neck concerning the component handling in the cabin integration process. Only door-suitable units can be used. These circumstances have serious negative impact on the assembly efficiency. In case of the tallest interior components, the lavatories and the galleys, partially even ready prepared and pretested units have to be disassembled to enable their transport through the passenger door.

Based on the present cabin architecture it will not be economically possible neither to handle the growing complexity nor to achieve even further optimisation in the assembly. In order to fulfil the future’s raising requirements, joint research projects between Airbus Germany and PKT were conducted in order to develop novel integration concepts for aircraft cabins.\(^1\)

The concepts to be developed address to different aspects of the aircraft interior. Also the included approaches and solutions have different scopes concerning a possible consideration in the aircraft cabin. On the one hand there are concepts that determine smaller adaptations to a few parts. On the other hand there are concepts that entail radical changes to the component design as well as the associated assembly processes and hence would require long term implementation.

2 STATE OF THE ART – DESIGN GUIDELINES (DFX)

In relevant literature many guidelines are released that give advice about the design of parts from an assembly point of view [1], [7]. First concepts for the optimisation of time efficiency are based on these so called design for assembly guidelines (DfA). The assembly relevant aspects of the cabin interior components must be designed to comply with these guidelines to reach a high level of assembly accuracy. An important role in the assembly is played by the constructive solutions for the cabin

\(^1\) CAAM – Cabin Assembly and Manufacturing, funded by Airbus
CoCaM – Concept for Cabin Modularisation, funded by Airbus
ModIS – Modular interior and system integration, funded by the Ministry of Economy and Labour Affairs of the Free and Hanseatic City of Hamburg (LuFo HH) in Cooperation with Airbus
Kabtec – cabin technology for comfortable passenger platforms, funded by the German Ministry of Economy (LuFo IV) in Cooperation with Airbus
components interfaces. In case of the aircraft interior there are relevant interfaces for the structural attachment and the connection of specific media like water, air, power or information. Next to the handling of the components joining in form of the connection of the interfaces is one of the two primary assembly tasks. An approach for the reduction of assembly time is the use of quick connecting elements for the interfaces, whose functionality is based on a combination of various DfA guidelines.

In Figure 1 two examples for the connection of water pipes are shown. On the left hand side a solution is presented, in which both hose ends have to be connected manually and locked using special tools plus extra elements. From an assembly point of view a favourable solution is displayed on the right hand side of Figure 1. In this case an easy to handle quick fastening device is used, that solely requires moving the levers around the duct.

Another potential for optimisation refers to the design of the assembly processes determined by the product structure. On overview of the present final assembly process is shown in the upper part of Figure 2. All cabin interior components are delivered in different states of pre-assembly to the final assembly line. The components are available in the form of single parts, sub-assemblies or functional units. In the final assembly line the parts are prepared and pre-assembled while other ready prepared components have to be disassembled right before their actual installation in the fuselage. The assembly is completed by obligatory reconditioning tasks. Due to the high amount of secondary assembly activities this procedure leads to high lead times and a high capital lockup in the FAL. Furthermore the product elements have a high variance dependency leading to additional difficulties for the product structuring.

The DfA guidelines recommend the relocation of preparative assembly steps into earlier phases of the overall assembly process. As shown in the lower part of Figure 2 the preassembly takes place at the supplier or separate facilities apart of the final assembly line. In this way assembly steps can be parallelised. In the final assembly line only ready prepared units need to be handled.

*Figure 1: Interface connection solutions*
3 CABIN MODULARISATION CONCEPTS

In order to implement an assembly process as shown in the lower part of Figure 2, certain characteristics of the cabin component’s product structures are required. The design of the product structure does not only follow the demands of the assembly but in first instance it has to comply with the requirements and intended functionality in the actual operation. A procedure for developing product structures in consideration of various influencing boundary conditions is part of the modularisation methods.

An approach for the modularisation was developed at PKT [2], [3]. The method’s goal is the generation of product structures designed for variety. The actual procedure bases on the improvement of conventional methods [5], which are adapted to the development of aircraft cabins. Several modularised concepts were developed regarding the cabin interior systems such as galleys, lavatories, storage compartments, seats and linings. Figure 3 shows a comparison between the actual and a modularised product structure of an aircraft galley.

An essential element of the modularisation procedure is the Module Interface Graph (MIG) developed at PKT and displayed in the centre of Figure 3 [2], [3]. The MIG represents an illustration of the product structure in an abstract form. Herein the elements are mapped approximately to their geometrical position on the graph. In the second step the interfaces are represented by lines between the elements clearly differentiated depending on their type such as structural, energy or material. In the presented case of an aircraft galley, the modularisation of the initial product structure leads to the aggregation of elements and so to the formation of two taller sub
modules. In connection with few different inserts and additional functional units the galleys function is realised.

Figure 3: Current vs. modularised product structure – MIG and assembly chart

Subsequent to the development, the modularised concepts have to be evaluated by pointing out the achieved benefits. From an assembly point of view the resulting assembly sequence is relevant since it is decisive for the required expenditures regarding lead time, costs or resources. For the presentation of the assembly sequence the assembly priority chart is used as shown in the lower part of Figure 3. This chart is about a network plan in which necessary assembly tasks are represented by boxes and their interdependencies by connection lines. The boxes are plotted at the earliest point of time where the execution is possible. The connection lines end at the latest point of execution. The length of the box illustrates the specific duration of the assembly task. Due to the reduction of internal interfaces, a saving of lead time in the assembly can be achieved for the presented modularised galley concept.

In connection with the conducted projects CoCaM and ModIS the entire integration process of the cabin of an Airbus A320 family aircraft was analysed. With the thereby obtained information an extensive basis for further developments and comparative assessments of future cabin concepts was created. The related assembly priority chart of the overall cabin integration process is shown in Figure 4.
The development of modularised cabin components shows an evolutionary character. On the basis of the current product structures, assembly optimised concepts are generated. This procedure is summed up in Figure 5.

**Figure 4: Assembly chart of the overall cabin integration process, additional details**

**Figure 5: Evolutionary Development by Modularisation**
4 VISIONARY INTEGRATION CONCEPTS

With regard to the long-term time horizons of the aircraft developments and the long operation times of the aircraft programs, innovative concepts should be considered to achieve more extensive lead time benefits. According to the evolutionary procedure shown in Figure 5, different approaches to develop concepts were deployed. As presented in Figure 6, brainstorming sessions were performed and comparable branches were investigated in the course of a functional benchmarking analysis.

![Figure 6: Visionary approach for innovative concepts](image)

In the following chapter various concepts that were generated are presented. The concepts still are in the status of a first idea. The expected benefits as well as the technical feasibility have to be analysed.

A differentiating cabin integration concept was introduced by Airbus. The concept’s focus is the assembly of large modules consisting of the cabin lining and the overhead storages. As shown in Figure 7 the elements are pre assembled in way that an arch-like structure is achieved. Due to the self-supporting characteristics, the modules can be integrated in one step into the aircraft fuselage.

![Figure 7: One step cabin integration](image)
Another concept idea developed by PKT contains an independent pre-assembly of the hatracks and the wall panels into a complete module designed for variety. Thereby amongst others, the process design guideline shown in Figure 2 can be implemented. In this way the overall amount of interfaces to be connected can be reduced and the execution of final assembly line tasks parallel to prior production steps is made possible. Based on this basic principle the resulting effects as well as necessary design changes and adaptations will be analysed.

Due to the geometrical dimensions of the modules a major reorganisation of the aircraft production process would be obligatory. Since the modules cannot be transported through the passenger door, a wider entry to the fuselage has to be provided. A possible solution could be the mounting of the cockpit section at a later point of the aircraft production process, which is executed after the cabin integration. Thereby the whole fuselage cross section would be available for the handling of the cabin components. In order to enable and support the module handling the use of a device is intended to which the modules are attached.

In Figure 8 a possible assembly situation is shown. The attachment of the modules is intended to combine the main assembly tasks handling and joining which can be achieved by the use of a rail based fastening system. The modules are attached to the device outside of the aircraft to enable and support the transportation and the mounting to the fuselage.

![Figure 8: Overview of the track based cabin modules integration concept](image)

The expected benefit of the concept is a reduction of the lead time. Assembly tasks can be performed parallelised and at earlier phases in the overall aircraft production process. Thereby it might be possible to optimise the processes by for example outsourcing pre-assembly tasks to a supplier. Furthermore possibilities to use the device not only for handling and mounting but also for logistic purposes have to be investigated.

Next to the analyses of the benefits, solutions have to be developed to achieve the desired functionality, avoiding additional weight of the cabin. A possible specific weight optimising design solution for the fastening system of the modules is
presented in Figure 9. It contains the integration of the intended track as a structural part of the hatrack. The feasibility of a comparable type of hybrid design was approved in connection with a research project\(^2\) for aircraft galleys conducted by PKT [6].

![Figure 9: Hybrid design - structural integration of the track element into the hatrack](image)

The compliance with other requirements has to be investigated. Further exemplary critical aspects are the following

- The general feasibility of the open fuselage cabin integration and its effects
- Overall financial balance concerning reduction of costs due to shorter lead times versus necessary investments for the devices
- Close tolerances of the clearances between the modules
- Maintainability of the cabin, disassembly, safety, etc.

5 CONCLUSION

The extensive analyses of the product structures and assembly processes of the aircraft cabin provide a solid basis for the development and evaluation of integration concepts. The presentation of the results in form of the assembly priority chart and the Module Interface Graph enables an easy and effective usage of the gained knowledge. In this way, critical aspects of the assembly, for example the components influence on the lead time, or optimisation potentials can be identified. By means of the adapted method a procedure was proposed which supports the systematic development of modularised concepts. First approaches were already detailed including an investigation of their specific characteristics and potentials using the example of the track based integration.

Future activities concentrate on the enhancement of the different ideas. In this context the benefits and resulting effects have to be investigated. Further methods have to be adapted or proposed to support the development and enable a holistic approach to new concepts.

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\(^2\) EFTEC – Efficient Technologies on Basis of Novel Sandwich Structures for Interior Equipment, funded by the Ministry of Economy and labour Affairs of the Free and Hanseatic City of Hamburg in Cooperation with Mühlenberg Interiors GmbH & Co. KG Hamburg.
6 REFERENCES


