Design Within Complex Environments: Collaborative Engineering in the Aerospace Industry

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Abstract The design and the industrialization of an aircraft, a major component, or an aerostructure is a complex process. An aircraft like the Airbus A400M is composed of about 700,000 parts (excluding standard parts). The parts are assembled into aerostructures and major components, which are designed and manufactured in several countries all over the world. The introduction of new Product Lifecycle Management (PLM) methodologies, procedures and tools, and the need to reduce time-to-market, led Airbus Military to pursue new working methods to deal with complexity. Collaborative Engineering promotes teamwork to develop product, processes and resources from the conceptual phase to the start of the serial production. This paper introduces the main concepts of Collaborative Engineering as a new methodology, procedures and tools to design and develop an aircraft, as Airbus Military is implementing. To make a Proof of Concept (PoC), a pilot project, CALIPSOneo, was launched to support the functional and industrial design process of a medium size aerostructure. The aim is to implement the industrial Digital Mock-Up (iDMU) concept and its exploitation to create shop floor documentation.

Keywords Collaborative engineering • iDMU (industrial Digital Mock-Up) • PLM (Product Lifecycle Management) systems

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16.1 Introduction

The design and the industrialization of aircrafts is a complex process. An aircraft like the Airbus A400M is composed of about 700,000 parts (excluding standard parts). Parts are assembled into aerostructures and major components, which are designed and manufactured in several countries all over the world [1]. Airbus design started in 1969 [2] with the launch of the Airbus A300B.

At that time drawings were created on paper. By the mid-eighties, the Airbus A320 and the CASA CN235 were designed using a Computer Aided Design (CAD) tool, for the 3D surfaces and drawings, and a Computer Aided Manufacturing (CAM) application, for numerical control programming.

In the mid-nineties, Product Data Management (PDM) systems and 3D solid modeling let Airbus to start building a product Digital Mock-Up (DMU), mainly to check functional design interferences. Then Concurrent Engineering was introduced and a huge project, named ACE (Airbus Concurrent Engineering) [3], started to develop and deploy methods, process and tools along all the functional design disciplines. A brief summary of the product Digital Mock Up (DMU) at Airbus is presented in [4].

The complexity of an aircraft as a product is not only at functional design level. The complexity is also related to the industrial design of the aircraft and the generation of the manufacturing documentation. The lifecycle of a typical aircraft could be more than 50 years. The number of versions, variants, customer customizations, modifications due to flight security, improvements, etc. and the need to develop and implement them is another important source of complexity.

During the last years different methodologies and techniques have been applied to deal with this complexity. The core idea of the Collaborative Engineering is to start with functional and industrial design from the beginning of the lifecycle building an iDMU. The iDMU lets influence Product, Processes and Resources each other and perform virtual manufacturing. PLM methodologies and tools are used intensively to help in the implementation and deployment.

The remainder of this paper is organized as follows: the next section explains the role of PLM in managing the process complexity in the aerospace industry. Follows two sections with an analysis of the ‘As Is—To Be’ situations and the functional model developed. Finally the paper ends with an introduction to CALIPSOneo Project as a proof of concept and some conclusions about the work.

16.2 The Role of PLM to Cope with This Complexity

PLM methods and tools are targeted to manage processes and engineering process in the first place. Therefore PLM is being introduced in the aeronautical industry to manage process complexity within functional and industrial aircraft design. The introduction of PLM methods and tools are part of the evolution of the engineering process already taking place in the aircraft industry. This evolution is due mainly to the technological evolution of software tools, the need to short time-to-market, to reduce cost and to increase quality and maturity of the development. PLM is also a main enabler of this evolution.

This evolution can be resumed in three engineering paradigms: traditional, concurrent and collaborative.

16.3 Traditional Engineering

The Traditional Engineering approach to design a product is the implementation of design tasks in sequence (Fig. 16.1). Main disadvantages of this approach are: only focused on product functionality, supported in drawings, different teams with lack of communication between them for which is often referred to as the "over-the-wall" approach [5], problems pushed down to the end of the lifecycle, and long time-to-market.

16.4 Engineering

About 20 years ago, and with the introduction of the emergent PLM tools, a wide-company project, ACE (Airbus Concurrent Engineering) [3] was launched. Framed within the Airbus A340-500/600 development program, it aimed to develop and deploy concurrent engineering practices and the associated PLM tools.

Concurrent Engineering diminished the disadvantages of the traditional paradigm (Fig. 16.2). The wall described in Traditional Engineering still exits but it is not so high. The industrialization tasks are not as advanced as functional tasks in terms of PLM tools usage. The current deliverable is again the product DMU, interoperability and working practice issues cause that compact disks or memory sticks flies over

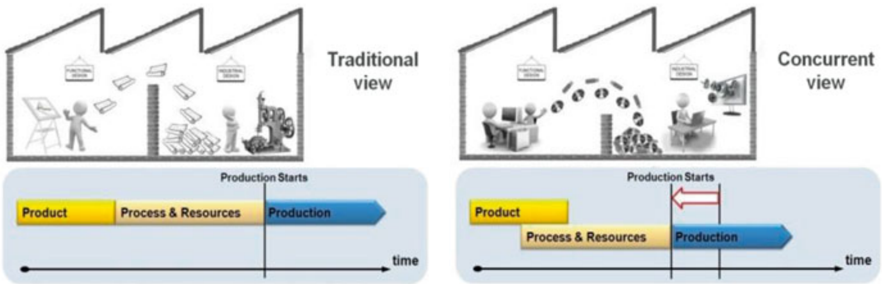

Fig. 16.1 Traditional view vs. concurrent view

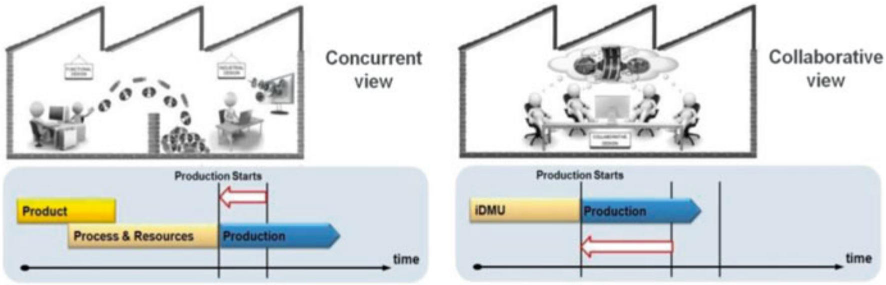

Fig. 16.2 Concurrent view vs. collaborative view

the wall instead of paper based drawings. Industrial design is not fully integrated with functional design, and it has little influence over the latter. They comprise two separate teams with dissimilar skills.

In fact, one of the most important reasons to have the wall is the certification process by the aeronautical authorities. Traditionally certification was made using the product definition, drawings, and marks the end of the aircraft design process. Concurrent Engineering still holds this idea and considers the aircraft design only as the functional design, enriched with manufacturing constrains and needs.

16.5 Collaborative Engineering

Nowadays the aim is a design process with a single team that creates a single deliverable including both the functional design and industrial design (Fig. 16.2). The main advantage is a further time-to-market reduction applying virtual validation by means of virtual manufacturing techniques. It is a new methodology that needs new working procedures and new PLM tools.

16.6 Analysis As-Is To-Be

Current or "As Is" situation (Fig. 16.3) shows an optimized functional design area with a clear deliverable: the product DMU. The concurrent process closes the gap between functional design and industrial design, and is intended to promote "Design for Manufacturing" and "Design for Assembly." The functional design deliverable, the "DMU as master," being a profitable item in the first stages of the life- cycle, becomes of decreasing use with time and meanwhile most of the industrial design tasks are still paper based.

Future or "To Be" situation shows an optimized functional and industrial design area with a clear deliverable: the iDMU [6]. The previous gap is eliminated by the

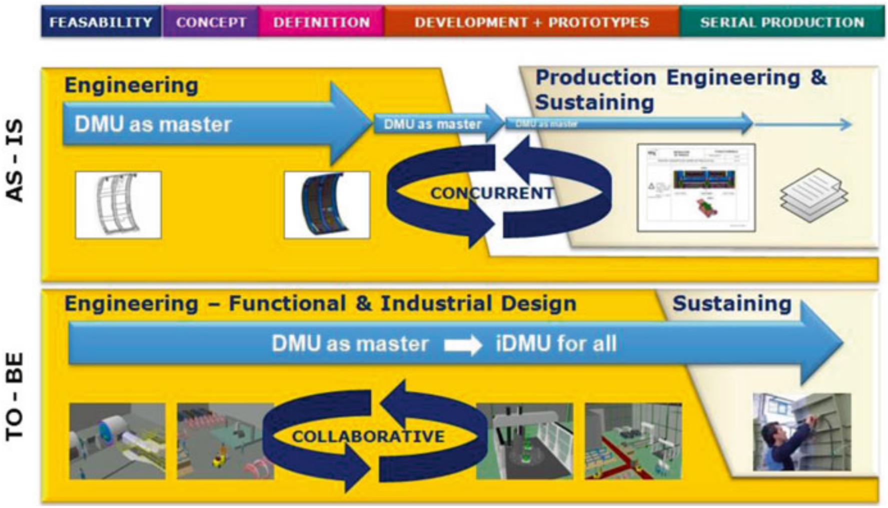

Fig. 16.3 Analysis "As Is - To Be"

collaborative way of building the iDMU and the virtual validation of it. The design (functional and industrial) deliverable, the "iDMU for all," is a valuable item along the whole lifecycle. The information contained in the iDMU can now be exploited by Sustaining, to produce shopfloor documentation in a wide variety of formats.

This new collaborative design methodology requires also new procedures. In this work we can only discuss the core of the procedures change, and this can be done within this analysis As-Is To-Be.

Current As-Is Concurrent Design procedures are based in a well defined DMU lifecycle made of exhaustively defined maturity states. DMU maturity states are controls for the industrial design tasks. The different Industrial design tasks cannot be started until the DMU reaches the corresponding maturity state. There are also procedures controlling the evolution from a maturity state to the following based on approval of all the stakeholders. This way, the industrial design only can progress on the tracks of the functional design, and processes and resources life- cycles are less exhaustively defined.

In the To-Be Collaborative Procedures, the maturity of product, processes and resources must evolve at the same time. The product DMU is not delivered at defined states to the industrial design. Instead, product, processes and resources are available at any time to all the development stakeholders working in a common environment. Maturity states are superseded by control points or maturity gates which are common to product, processes and resources and are passed by agreement between the stakeholders.

This new collaborative design methodology requires also a rearrangement of functions as proposed below.

16.7 Functional Model

A functional model (Fig. 16.4) shows the main functions and information flow involved in the development and production of an aircraft.

Management activities are represented by the box "*Manage*," comprise "*program management*, *cost & planning*" and influence all the downstream functions.

Development activities are represented by the box "Engineer," controlled by the output from "*Manage*," "*Customer requirements*" and "*Industrial strategy*". Development activities include "*Functional Design*" and "*Industrial Design*," working together as a single team to develop product, processes and resources from the conceptual phase to the start of the serial production. The deliverable is an "*iDMU*," a complete definition and verification of the virtual manufacturing of the product [6]. All the deviations coming from the shopfloor, in terms of "*Deviations* (*non conformances*, *concessions*), are inputs to "*Engineer*," included in the "*iDMU*" and sent to "*Operation*." The final output is an "*As built*" iDMU that fits with the real product launch by "*Operation*".

Production activities are represented by the box "Operation," controlled by the output from "*Manage*" and by the output from "*Engineer*" "*iDMU*." Operation activities include "Sustaining," which is in charge of exploit the iDMU, with the help of MES (Manufacturing Execution Systems), to launch "*Shopfloor Documents*" to "*Serial production*." The "*Manufacturing Problems*" that can be managed without

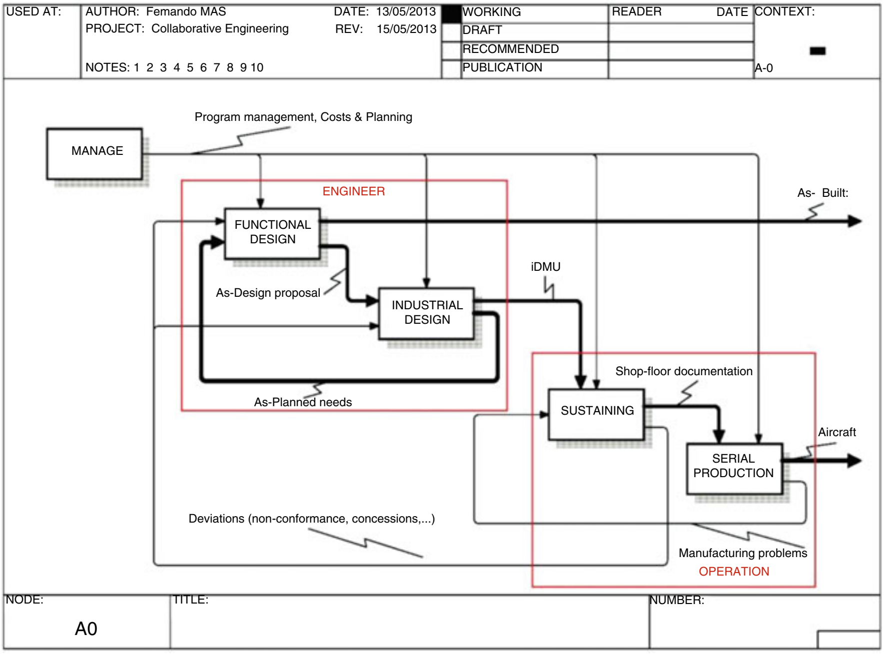

Fig. 16.4 Collaborative functional model

modifying the iDMU, are managed by "*Sustaining*." Any other item affecting the iDMU is derived to "*Engineer*" as deviation. The output from "*Operation*" is the final physical product that fits 100% with the "*As built*."

16.8 Digital Mock Up (DMU) and Industrial Digital Mock Up (iDMU)

Collaborative Engineering involves a lot of changes: organizational, teams, relationships, skills, methods, procedures, standards, processes, tools and interfaces. It is really a business transformation process [7]. One of the key changes is the engineering deliverable: from the "DMU as master" to the "iDMU for all" (Fig. 16.3).

"DMU as master" is a standard inside Airbus [4]. All the information related to the functional aspects of the product is included in the product DMU, e.g. aspects like "design in context" and clashes-free product are fully deployed. The DMU is the reference for the product functional definition, and it is built in concurrent engineering taken into account manufacturing constraints.

The "iDMU for all" is a new concept. It is the main enabler of the Collaborative Engineering approach and provides a common virtual environment for all the aircraft development stakeholders. Functional design and industrial design are part of a single design process where they progress together and influence each other.

The iDMU collects the information related to functional design plus all the information related to industrial design: manufacturing and assembly process, associated resources, industrial means and human resources [6]. All is defined in an integrated environment, where complete and partial simulations are done continuously, and at the end of the design phase, they guarantee a validated solution. Figure 16.5 shows an example of a 3D view of an iDMU.

16.9 Proof of Concept Project: CALIPSOneo

To make a proof of concept (POC) of implementing the Collaborative Engineering paradigm using PLM tools, an R + D + i project called CALIPSOneo was launched. CALIPSOneo is a joined effort that involves Engineering Companies, IT companies, PLM Vendors, Research Centers and Universities.

CALIPSOneo uses the newest PLM tools. It takes as input developments from previous projects, related to digital manufacturing techniques implementation [6, 8] and aircraft conceptual design modeling [9] and other initiatives reported in literature [10–12]. The project aims to demonstrate the capabilities of newest PLM methodologies and tools to:

- To implement the Collaborative Engineering concepts described above. To implement a common 3D work environment for all the stakeholders. To implement an iDMU and virtual validation by using it.

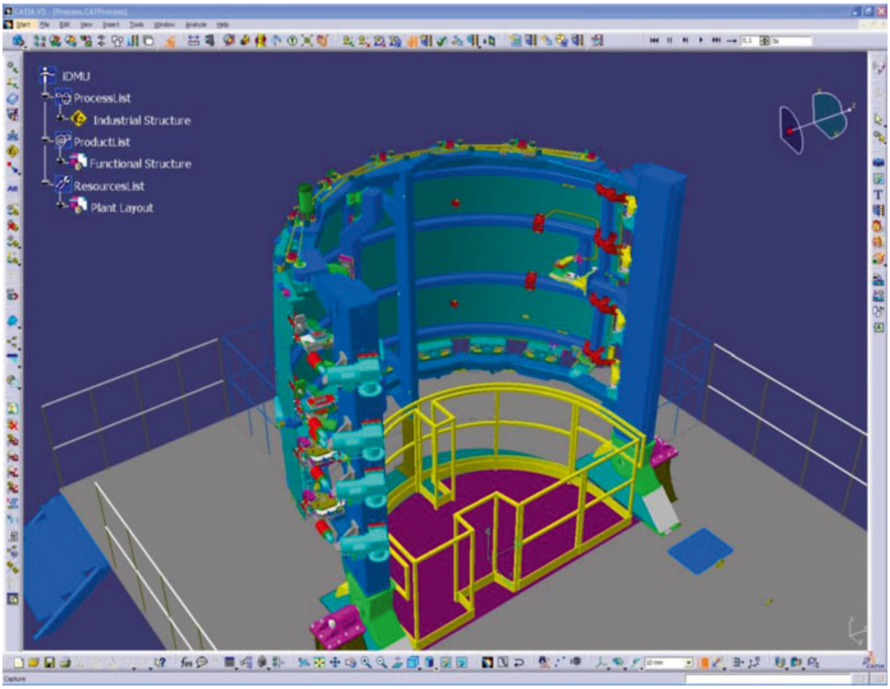

Fig. 16.5 Fan cowl industrial digital mockup (iDMU) (not a real iDMU due to confidentiality)

- To implement configuration based on individual specimen (single aircrafts).
- To assess the benefits of the iDMU concept when compared to the usual practices for the industrial design.
- To assess the availability of PLM tools to develop and deploy new capabilities. To assess the capability to exploit the iDMU to produce advanced shopfloor documentation.

To use of the latest PLM tools for a proof of concept of the new design collaborative paradigm needs a sound technical support, for this reason the PLM tools manufacturer Dassault Systèmes were incorporated as a partner.

Also a sound project development methodology was necessary; the NDT (Navigational Development Techniques) methodology was selected. NDT was developed by the IWT2 research group (University of Sevilla) [13].

16.10 Conclusions

Collaborative Engineering is a broader approach derived from the previous Concurrent Engineering experiences. The availability of new PLM systems and the maturity of the teams are the key elements in the success of its implementation. During the development of the CALIPSOneo project, which is still running, several issues were identified. One of them is them is the complexity of managing a real pilot case in parallel with the development and deployment of the associated PLM tools.

The PLM tools are the key enabler in creating and managing the industrial DMU (iDMU) and the iDMU is the key enabler of the collaborative approach. For this issue, the adopted solution was to set up a multidisciplinary working team model, where engineers, experts on the industrial design tasks, and PLM experts work altogether conducting industrial and CALIPSOneo R + D + i tasks.

Engineers were trained in understanding how PLM tools could help in the industrialization design process and PLM experts were focused on customizing and using the PLM tools to create the iDMU.

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