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Procedia Engineering 63 (2013) 336 – 345

Procedia Engineering

www.elsevier.com/locate/procedia

The Manufacturing Engineering Society International Conference, MESIC 2013

Collaborative Engineering: an Airbus case study

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Abstract

This document 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.
Airbus designs and industrializes aircrafts under Concurrent Engineering techniques since decades with success. The introduction of new PLM methodologies, procedures and tools, mainly in the industrialization areas, and the need to reduce time-to-market conducted Airbus Military to push the engineering teams to do things in a different way.
Traditional Engineering works sequentially, Concurrent Engineering basically overlaps tasks between teams using maturity states and taking assuming risks. Collaborative Engineering promotes a single team to develop product, processes and resources from the conceptual phase to the start of the serial production. The deliverable of the team is an iDMU (industrial DMU), a complete definition and verification of the virtual manufacturing of the product.

Keywords: Collaborative Engineering, iDMU, Concurrent Engineering, DMU

1. Introduction

The design and the industrialization of an aircraft, a major component, or an aerostructure is a complex process. Airbus has been involved on the design and the industrialization of aircrafts since the middle of the last century involving engineers from different nationalities located in different countries. To give an idea of the complexity, an aircraft like the Airbus A400M is composed of a set of about 700.000 parts (excluding standard components and

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doi:10.1016/j.proeng.2013.08.180

joints elements). All these parts are assembled into aerostructures and major components designed and manufactured in seven countries all over the world (Figure 1) (Aviation News Magazine 2013).

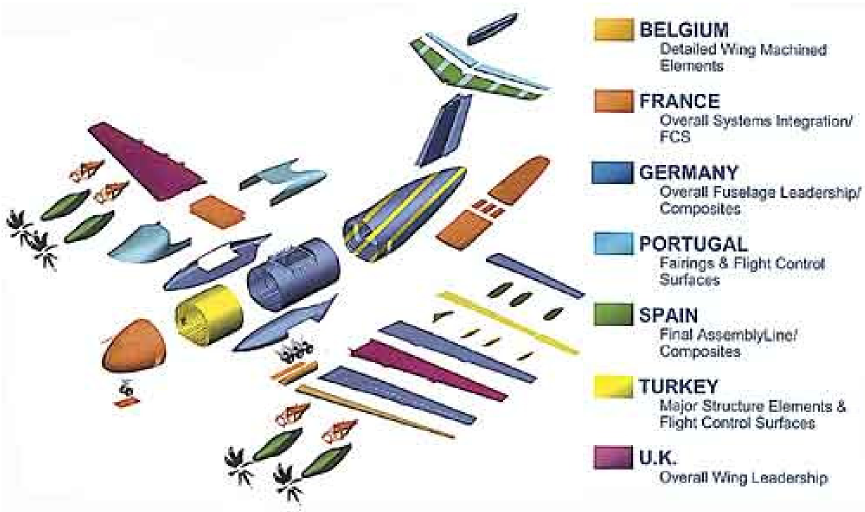

Fig. 1. Workshare split of the A400M

Airbus design started in 1969 (Airbus 2013) with the launch of the first aircraft, the Airbus A300, producing drawings in paper. CAD tools were introduced in the A320 to facilitate the 3D aerodynamic surfaces design and the drawings production process. Step by step, the functional design goes more and more automated and in the middle of the 80s, the Airbus A320 and CASA CN235 were designed using CAD for 3D surfaces, CAD for drawings and CAM for numerical control manufacturing.

In the middle of the 90s, PDM and 3D solids design let Airbus to start building an initial DMU, mainly to check functional design interferences. Then Concurrent Engineering was introduced into the Company and a huge project, ACE (Airbus Concurrent Engineering) (Pardessus 2004), started to develop and deploy methods, process and tools along all the functional design disciplines.

Since 1999 Airbus has successfully applied Concurrent Engineering to all the aircrafts design: A380, C295, A400M, and A350 with success. But the gain has been obtained mainly in the functional design area. Industrial design activities, also known as manufacturing engineering activities, work using CAx tools in isolated areas not fully integrated between them and without a real influence on the functional design.

Collaborative Engineering promotes to integrate design teams, both functional and industrial, to assume a unique deliverable, iDMU (industrial DMU) rather than delivering a product DMU. Also promotes to make intensive use of PLM tools to perform virtual manufacturing and therefore to guarantee a ‘free errors’ result in the shop floor (Lu 2007). The last step, feed work instructions to the shop floor, is done exploiting the iDMU (Menendez 2012) where is the full definition of the manufacturing activities.

Airbus Military has launched a pilot project to develop and deploy Collaborative Engineering methods, process and tools over a new development, the A320neo Fan Cowls. The low complexity of the aerostructure selected, the manufacturing technologies involved and the Airbus Military expertise on the design of fairings makes it an excellent sample to launch a pilot project.

2. Review of the traditional, concurrent and collaborative process

The evolution inside Airbus from Traditional Engineering to Collaborative Engineering through Concurrent Engineering is a logical way. The technological evolution of the tools, the need to short the time-to-market, to reduce cost and to increase quality and the mature of the development teams are the trigger of the process.

2.1. Traditional Engineering

The Traditional Engineering, also known as sequential engineering, approach in the industry for design a product is the implementation of sequential design, often referred to as the 'over-the-wall' approach (Boothroyd 2007). Disadvantages of this process are obvious: focus on product functionality and drawings, lack of industrial design, problems growing at the end of the lifecycle, different teams with lack of communication between them and long time-to-market. A complex product, like a modern aircraft, cannot be designed in this way.

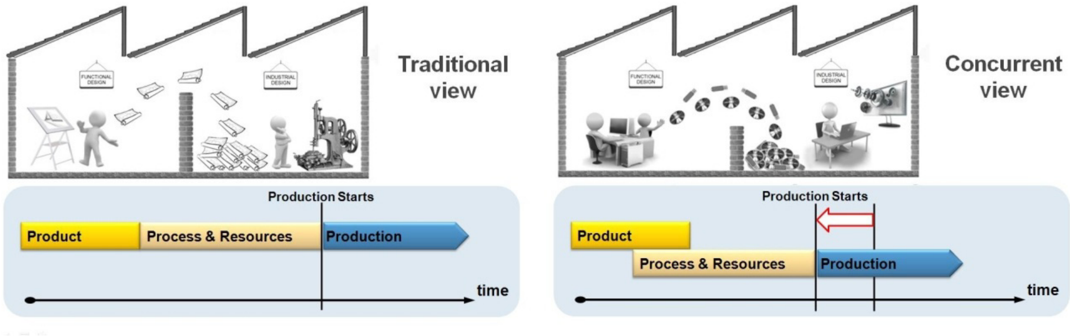

Fig. 2. Traditional view vs. Concurrent view

2.2. Concurrent Engineering

During the last decades, methodology and technology advances have taken a decisive influence on engineering activities. In recent years, Concurrent Engineering has become a widely accepted concept and is regarded as an excellent alternative approach to the Traditional Engineering process. Inside Airbus almost twenty years ago and with the introduction of the emergent PLM tools, a wide-company project, ACE (Airbus Concurrent Engineering) was launched during the development of the Airbus A340-500/600 to develop and deploy concurrent engineering methodologies, process and the associated PLM tools.

A set of milestones was developed to help to define a controllable Concurrent Engineering design process, to understand the interrelations between technical processes, to describe input/output of activities between milestones, to reduce risk by improving transparency of the design process and to implement and conduct design and program reviews (Figure 3).

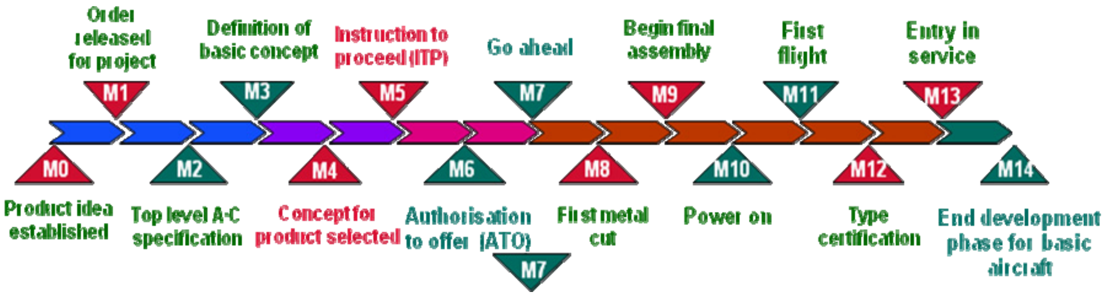

Figure 3. AIRBUS Product lifecycle and development milestones

In Airbus, Concurrent Engineering aims at enabling a times and costs reduction, by putting together in a multidisciplinary way of working all the relevant skills that contribute to product engineering, and by setting and managing the operational conditions of work in parallel (Pardessus 2004).

There are still disadvantages, although the wall described in Traditional Engineering is not so high, but it still exists. The industrialization tasks are not as advanced as functional tasks in terms of using PLM tools. The current deliverable is the product DMU and compact disk or memory sticks flies over the wall instead of drawings. Industrial design works after functional design with little influence over it. There are two separate teams with dissimilar skills.

2.3. Collaborative Engineering

To break the wall between functional design and industrial design and to perform the design process with a unique team with a unique deliverable, the iDMU is the objective of the Collaborative Engineering. It is a new methodology that needs new procedures and new PLM tools. Main advantages are the further reduction of the time-to-market, the virtual validation through virtual manufacturing techniques and the benefits derived from the existence of a unique team with a unique deliverable.

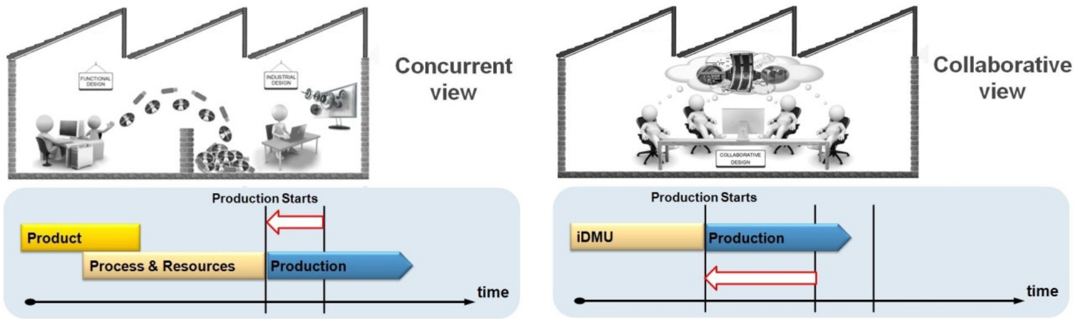

Figure 4. Concurrent view vs. Collaborative view

As a summary, a table comparing the main characteristics of the three different ways to engineer: traditional or sequential, concurrent and collaborative, is presented (Table 1). Five representative characteristics are showed underlying the main differences: timeframe, teams, deliverable, focus and objective.

Table 1. Engineering: Traditional vs. Concurrent vs. Collaborative

Characteristic	Traditional	Concurrent	Collaborative
Timeframe	Sequential	Overlapped	Shared
Teams	No	A few	Unique
Deliverable	Drawings	DMU	iDMU
Focus	Product design	Reduce time	Customer
Objective	Design for Functionality	Design for Assembly	Virtual Manufacturing

3. Methodology

The concepts of Collaborative Engineering were shared inside the Company by the functional and industrial design areas as an answer to the current challenges and issues in the aeronautical field described before. An ‘As Is - To Be’ analysis was made to have a clear idea of the current situation and the future desired situation (Figure 5).

Current or ‘As Is’ situation shows an optimized functional design area with a clear deliverable, a product DMU. The concurrent process close the gap between functional design and industrial design and feeds functional design with manufacturing information to facilitate ‘Design for Manufacturing’ and ‘Design for Assembly’. The functional design deliverable, the ‘DMU as master’, is a valuable item in the first stages of the lifecycle but the value for the process goes down with the time and most of the industrial design is made using paper and not integrated tools.

Future or ‘To Be’ situation shows an optimized functional and industrial design area with a clear deliverable, an iDMU. The previous gap does not exist because of the collaborative way to build the iDMU and the virtual validation on it. The design (functional and industrial) deliverable, the ‘iDMU for all’ is a valuable item along the overall lifecycle. Sustaining can now exploit the information contents into the iDMU to produce shopfloor documentation in a wide variety of formats.

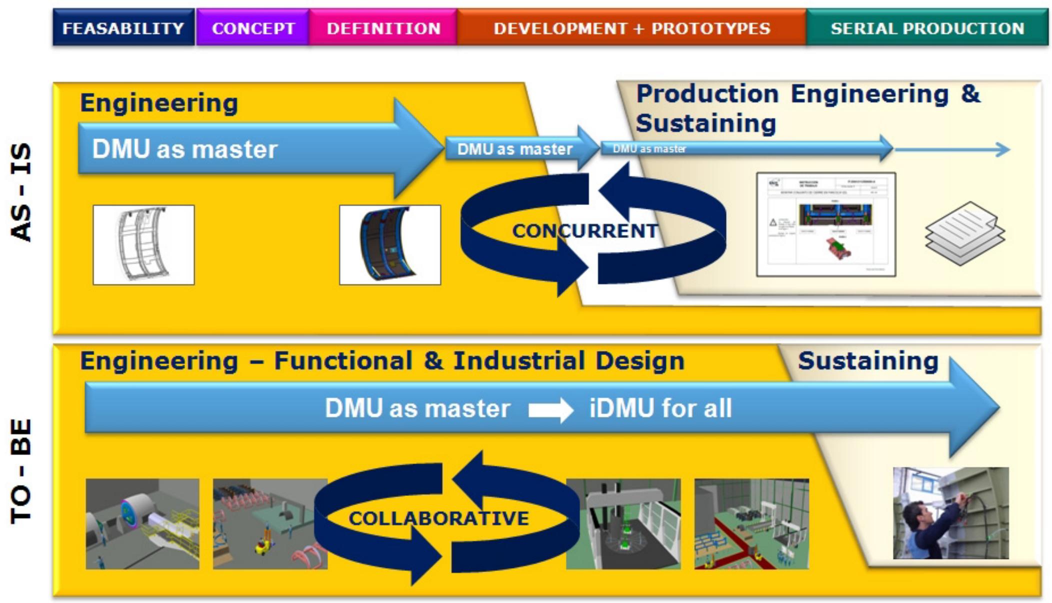

Fig. 5. Analysis ‘As Is - To Be’

After the definition of 'As Is – To Be' situation, a functional model was launch (Figure 6) to define the overall functions and relationships. Despite an organizational model, the functional model shows the main functions and information flow involved in the development and production of an aircraft.

Management activities are represented by the box 'Manage', in charge of 'program management, cost & planning' and influencing 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 (Menendez 2012). All the deviations coming from the shopfloor in terms of 'Deviations (non conformances, concessions...' are inputs to 'Engineer', included in the 'iDMU' and send to 'Operation'. The final output is an 'As built' iDMU that fits with the real product launch by 'Operation'.

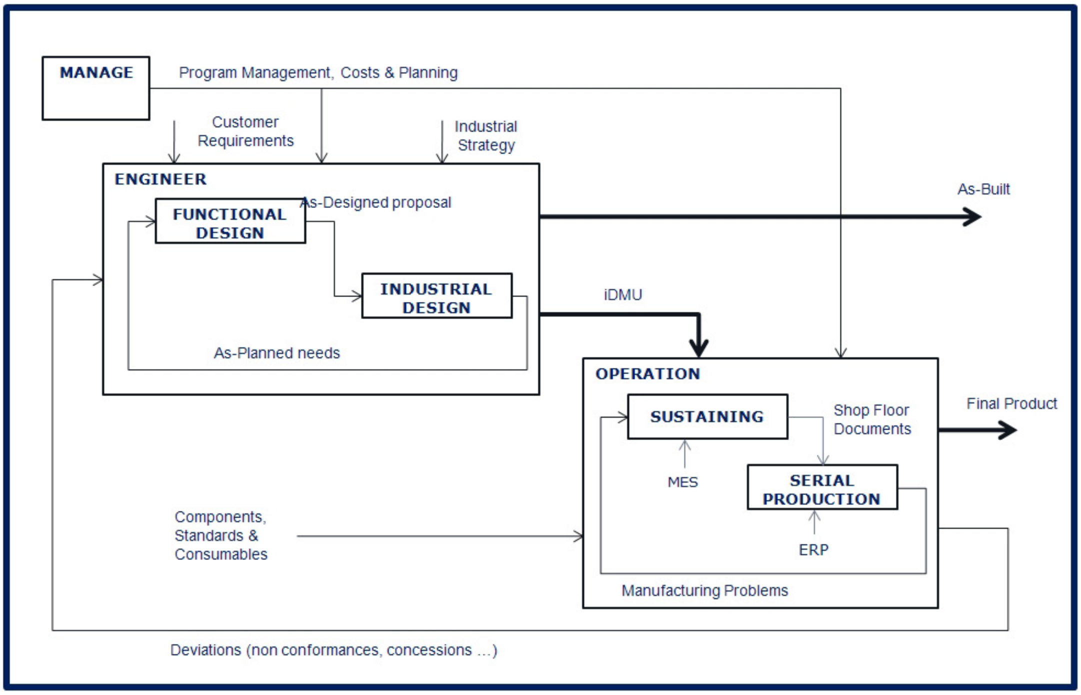

Fig. 6. Collaborative function model

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', in charge of exploit the iDMU, with the help of MES (Manufacturing Execution Systems), to launch 'Shopfloor Documents' to 'Serial production'. All the 'Manufacturing Problems' which can be managed without modifying the iDMU are managed by 'Sustaining'. All other items affecting the iDMU are derived to 'Engineer' as deviations. The output from 'Operation' is the final physical products who fits 100% with the 'As built'.

4. Digital MockUp (DMU) and industrial Digital MockUp (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. One of the main concepts to change is the engineer deliverable: from the ‘DMU as master’ to the ‘iDMU for all’.

‘DMU as master’ is a standard inside Airbus (Garbade 2007). All the information related to the functional aspects of the product is included in the DMU, as in the past was included in drawings. Aspects like ‘design in context’, clashes-free product and so are fully deployed. DMU is the reference for the product functional definition, and it is built in concurrent engineering taken into account manufacturing constraints.

A set of PLM tools like CAD for authoring and PDM to hold the configuration are involved in the functional design process. A view of the DMU as is produced today in Airbus Military is presented in Figure 7.

‘iDMU for all’ is a new concept. It is the main enabler of the Collaborative Engineering and provides a common virtual environment for all the aircraft development stakeholders. Functional design and industrial design are part of a single design process. Both designs progress together in a way that both of them influence each other.

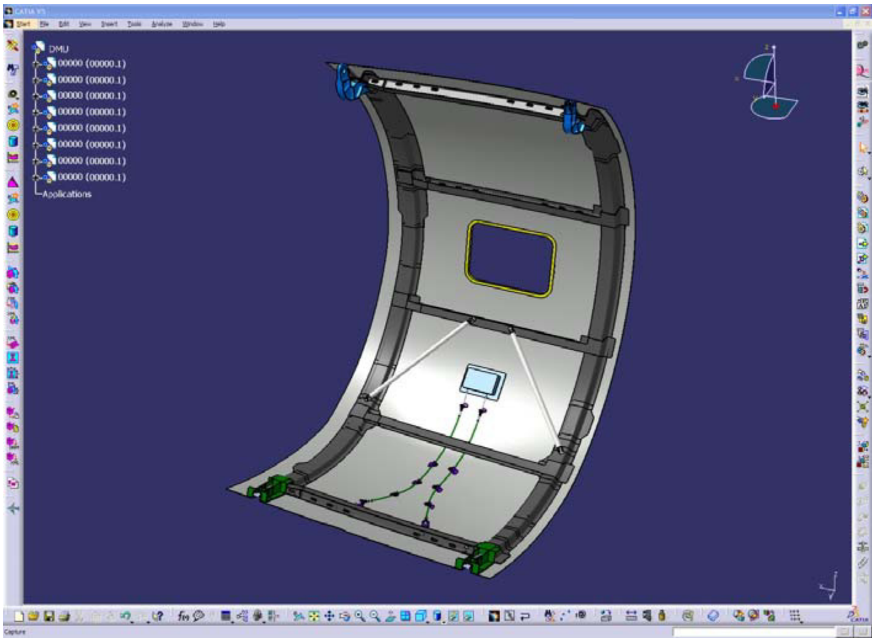

Figure 7. A320neo Fan Cowl Digital MockUp (DMU). (Not a real DMU due to confidentiality)

iDMU collect 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. 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 8 shows a view of the A320neo Fan Cowl iDMU.

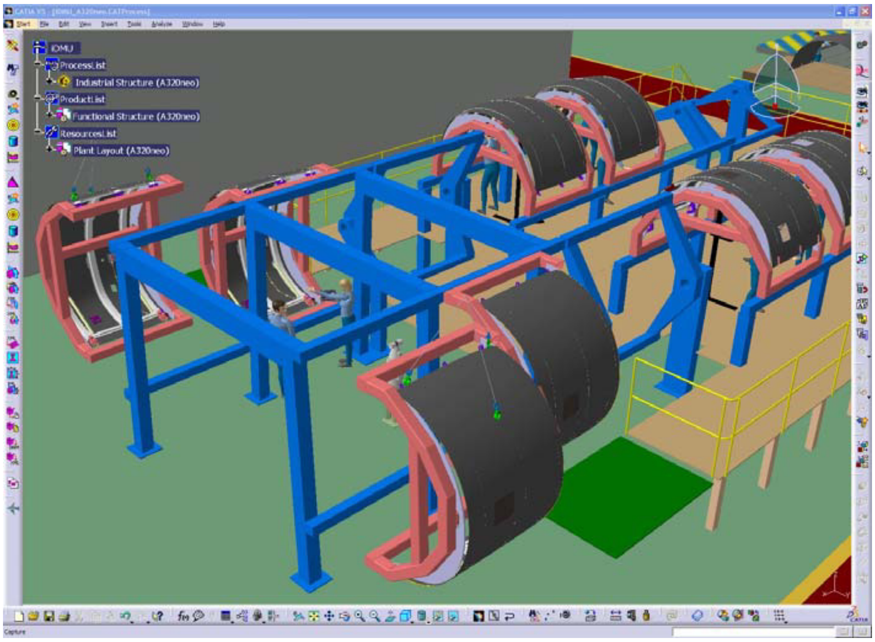

Fig. 8. A320neo Fan Cowl industrial Digital MockUp (iDMU). (Not a real iDMU due to confidentiality)

5. Collaborative engineering pilot project inside Airbus

A new development has been selected as pilot project. The A320neo, a new version based on the A320, the Airbus single aisle aircraft family will be provided with a totally new, fuel-efficient and eco-friendly engine. Included on the new engine, Airbus Military will develop a new carbon fiber fan cowl made by fiber placement technology.

Due to the lack of time needed for A320neo fan cowls deployment, the moderated size of the aero structure and the previous experience on carbon fiber fan cowls in the A340 and A380 aircrafts, Airbus Military decides to launch a multidisciplinary team composed of all Functional design, Industrial design and Services disciplines to deliver an iDMU.

In parallel an R+D project, CALIPSOneo, was launched to support the development, customize and deploy PLM process and tools needed from the pilot project. CALIPSOneo involves Engineering Companies, IT companies, Vendors and Research Centers and Universities (Menendez 2013).

CALIPSOneo makes use of the newest PLM tools. Also implements the new methods and process needed to support a new style of design. Basic developments derived from previous projects, related to digital manufacturing techniques implementation (Menendez 2012), (Mas Morate 2012) and aircraft conceptual design modeling (Mas Morate 2012), are taken as an input. Collaborative working procedures definition, modeling and implementation into collaborative software tools will be the main results of CALIPSOneo (Butterfield 2005).

The A320neo fan cowl pilot project and the R+D CALIPSOneo aims to demonstrate:

- Collaborative Engineering concepts applied to aircraft design and manufacture.
- Capability to generate an iDMU. 3D product, process and resources.
- Virtual validation using iDMU. Virtual first, real after.
- Configuration based on individual iDMU per specimen.
- Availability of PLM tools, develop, customization and deployment of new capabilities.
- Use of new PLM tools at design engineering level.
- Capability to exploit iDMU to produce shopfloor documentation.

6. Results and conclusions

Collaborative Engineering is a broader approach derived from the previous Concurrent Engineering experiences. The availability of new technologies and the maturity of the teams are the key success in the pilot project. Several barriers were identified and had to be overcome to implement Collaborative Engineering:

The first issue is in relation with the software tools: the integration of different software applications is an industrial and research issue well documented in literature. PLM tools used to industrial design implementing resources and processes need to be well interfaced with functional design tools (Rouchon 2012). An overall configuration management tool will integrate also the three different configurations: product, process and resources altogether. The solution adopted was to promote the harmonization of a common set of PLM and CAD tools but still there is a large amount of interfaces with other commercial and legacy systems.

The second issue is the application of the Collaborative Engineering functional model: the harmonization of functional design area and industrial design area having different departments and different heads. Despite the organizational issue, the concept of a unique team doing all design functions has a large set of implications. Most of the result of the pilot project has been reached except those relating to this aspect.

The third issue is the skills of the engineers to use PLM tools in an effective way. After assessing alternatives, the solution adopted was to set up a multidisciplinary working team model where engineers focused on the industrial design tasks and PLM experts created the requested iDMU and simulations. Engineers were trained in understanding how PLM tools could help in the industrialization design process. PLM experts were focused on customizing and using the PLM tools to create the iDMU.

7. Next steps

The next step should be consolidating the collaborative process, methods and the associated engineering teams. Extend the collaborative culture inside Airbus Military as a standard.

In parallel, Airbus Military will start with the development of a large aerostructure or a major component to introduce more variables to the previous collaborative engineering. Intensive use of extended enterprise involved in the collaborative process will open new issues and challenges. The size of the iDMU associated will also discover new technical difficulties. Finally the management of a large iDMU configuration will show the need for new capabilities to be developed.

As a third step, the introduction of the collaborative process in a light or medium military transport aircraft will consolidate the collaborative engineering methods, processes and tools along the Company.

Finally, collaborative process will involve Services area to include maintenance and operations design in the iDMU a complete the lifecycle.

Acknowledgements

Authors wish to express their sincere gratitude to colleagues from Airbus Military, Universidad Politecnica de Madrid, Universidad de Sevilla and partners of CALIPSOneo project for their collaboration and contribution to the projects.

References

Airbus 2013. The timeline. Airbus, a leading aircraft manufacturer. Retrieved in January 2013. http://www.airbus.com/company/history/the-timeline/

Aviation News Magazine 2013. AIRBUS A400M. Retrieved in January 2013. http://www.aviation-news.co.uk/archive/a400m.html

Boothroyd G., Knight W.A., Dewhurst P., 2007. Product design for manufacture and assembly. New York : M. Dekker. 1994.

Butterfield J. et al., 2005. An Integrated Approach to the Conceptual Development of Aircraft Structures Focusing on Manufacturing Simulation and Cost, AIAA 5th Aviation, Technology, Integration, and Operations Conference (ATIO), 2005.

Garbade R., Dolezal W.R., 2007. DMU at Airbus – Evolution of the Digital Mock-up (DMU) at Airbus to the Centre of Aircraft Development User Keynote, the Future of Product Development. Proceedings of the 17th CIRP Design Conference, 3–12. 2007

Lu S.C-Y., Elmaraghy W., Schuh G., Wilhelm R. 2007. A scientific foundation of collaborative engineering, CIRP Annals - Manufacturing Technology, Volume 56, Issue 2, 2007, Pages 605-634, ISSN 0007-8506, 10.1016/j.cirp.2007.10.010.

Mas Morate F, Menendez J. L, Servan J., Gomez A., Rios J., 2012. Aerospace Industrial Digital MockUp exploitation to generate assembly shopfloor documentation. Proceedings of 29 International Manufacturing Congress. Belfast. 2012

Mas Morate F, Rios J., Menendez J. L., Gomez A., 2012. A process-oriented approach to modeling the conceptual design of aircraft assembly lines. International Journal of Advanced Manufacturing Technology. 2012 Vol. 62 ISSN: 0268-3768.

Menendez J. L., Mas Morate F., Servan J., Rios J., 2012. Virtual verification of an aircraft Final Assembly Line industrialization: an industrial case. Key Engineering Materials. Material Science and Engineering. February 2012, Vol. 502, pp. 139-144. ISSN 1662-9795

Menendez J. L., Mas Morate F., Servan J., Arista R., Rios J., 2013. Implementation of the iDMU for an aerostructure industrialization in AIRBUS. Submitted to the 5th Manufacturing Engineering Society International Conference. MESIC13. Zaragoza. June 2013

Pardessus T., 2004. Concurrent engineering development and practices for aircraft design at Airbus [Conference]. Proceedings of the 24th ICAS meeting. Yokohama.

Rouchon C., 2012. V6 deployment in new business Jet. Top 5 PLM breakthroughs. Proceedings of 3DEXPERIENCE FORUM Europe 2012. Brussels. 2012