Integrated Design and PLM Applications in Aeronautics Product Development

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Abstract
Well known challenges in Aeronautic industry, namely reducing time to market, risks and development costs, could be reached thanks to innovative design methods supported by PLM technologies. Such methods are based on integrated design or collaborative engineering enabling close exchanges and cooperation between the project partners. The paper proposes a survey on integrated design methods and PLM technologies. It presents the development of a collaborative design platform, as part of SEINE project, which aims to improve partners' cooperation in the French aeronautics supply chain. The paper also discusses how to include multiple expertises and integrated design in this collaborative platform.

Keywords:
Collaborative Engineering, Integrated Design, Data Exchange, PLM, Aeronautics Industry

1 INTRODUCTION

The aeronautics industry is hugely concerned by the competition between developed and emerging countries. In such a context, western companies develop strategic outlines and objectives to remain competitive [1]. By way of example, from one side the ACARE (Advisory Council for Aeronautics Research in Europe) insist on the following points [2]:

- Answering the customer needs: In term of security (Ex: five-fold reduction in the average accident rate), quality and affordability (Ex: 99% of punctuality, no more than 15 or 30 min waiting at the airport), environment (Ex: lower 50% of CO² emission, lower 50% of fuel consumption) and air traffic management system (Ex: n handle 16 million flights a year)
- Securing global leadership (Ex: Halve time to market with help of advanced technologies, a new framework that permits and encourages companies to work together more effectively)
- Establishing supportive public policy and regulation (Ex: Facilitate greater integration of European, national and private research programmes)
- Identifying research agenda

Whereas at another side, the NASA research orientations are concentrated on [3]:

- Improve mobility through the air and improve aviation capabilities
- Improve aviation for national security and homeland defence.
- Keep aviation safe.
- Security of and within the aeronautics enterprise must be maintained.
- The US should continue to possess and develop its world class aeronautics workforce.
- Assuring energy availability and efficiency for the growth of the aeronautics enterprise.
- The environment must be protected while sustaining growth in air transportation.

Face to these issues, the extended enterprise concept [4] aims to bring direct and indirect answers to some points of the above guidelines. In fact, it proposes a networked enterprise framework asking the actors of different companies to work together and then allowing to find product best solutions (By management of tasks), reduce the development time (By improvement of the communication), gain confidence between partners, etc. At the same time, this concept considers globalization context constraints, of which geographic dispersion of the partners.

Extended enterprise is made possible through other methodologies. And this paper will consider that collaborative engineering and integrated design are two among the most important ones.

According to the current engineering way of work and to the new possibilities, engineering activities could still strongly progress, especially in a collaborative mode. Indeed there is still a lack in the way of managing product data between the different partners. Then bring improvement in this domain could bring important advances to reach the aeronautic policy objectives. Collaboration in engineering activities will always need a neutral (politically, maybe technically) mediator that will organize the team work around the project and that will manage the product data concerning this project. The SEINE (Standard pour l'Entreprise Innovante Numérique étendue) project platform proposes to specify such collaborative engineering mediator and to prepare the basis for a future deployment.

In parallel, it could be ignored that an aircraft is deeply multidisciplinary and there is still many problems in exchanges of heterogeneous data, along the whole lifecycle as well as just inside the engineering step. In this sense, the collaboration in product development has to take the integrated design into account. The IPPOP project (Intégration Produit – Processus - Organisation pour l'amélioration de la Performance en ingénierie) provided results for integrated design and led to the development of a platform based on a PPO kernel (Product Project Organization).

This paper will first make a short review of research works related to collaboration in engineering activities and especially in the case of aeronautic, then it will present the SEINE project and its collaborative engineering platform. Finally, it will complete the vision of this platform by possible interaction with integrated design systems.

2 LITERATURE REVIEW

2.1 Aeronautic survey

The aeronautical industry is still considered as a leading one concerning technologies implementation and new concepts development. Moreover, projects in this domain are structured so as it is relatively well adapted to the methodologies presented in introduction: Indeed an OEM main aircraft project is clearly decomposed in many subassemblies developed by first suppliers that decompose again the assembly under their responsibility in subassembly and so on [4] [5]. Then collaboration case could be well identified. In consequence, many individual actions as well as governmental programs have been already engaged to develop collaborative product design.

In [6] authors present some European programs, notably the DIECoM project (Distributed and Integrated Environment for Configuration Management) that aim to improve cross-organisational integrated process and product configuration management in collaboration. Authors mention also the ENHANCE project (Enhanced Aeronautical Concurrent Engineering), which objectives are to define common way of working for the companies in collaboration and also to set operational tools for this collaboration [7]. ENHANCE results have led to a wider project called VIVACE (Value Improvement through a Virtual Aeronautical Collaborative Enterprise).

VIVACE project was co-funded by the European Commission to address Aeronautics' Vision 2020 objectives reducing development cost and lead time and is decomposed in three sub-projects: Aircraft studies, Engine studies and advanced capabilities [8]. This last one was especially focused on the collaboration (between organisation and development disciplines) and worked about an Engineering Data Framework management to improve it. Confirming the platform centric collaboration approach, a work package had also in charge to develop a hub to implement the different concept based on the standard step AP239. Along the different projects, it could be observe that standards was more and more taken into account as well as interoperability problems. In fact, interoperability could by considered as a support for the collaboration.

The interoperability needs are confirmed in projects like ATHENA project (Advanced Technologies for Interoperability of Heterogeneous Enterprise Networks and their Applications) in which standards have been also studies (Process standards: ISO15288, CMII; as well as product standards: STEPAP214, 233, 209, 239). Although this project is supported by EADS, it doesn't address only the aeronautic domain but also aeronautics, automotive, telecommunications, etc. Wished advances are knowledge support and semantic mediation solution, enterprise modelling in the context of collaborative enterprise, cross-organisational business processes, interoperability framework and services for networked enterprise and planned and customisable SOA (Service-Oriented Architectures) [9].

Another important point often underlined in the aeronautical research programs cited above is the progress of the SME in term of information technology. That was a central topic for the CASH project (Collaborative working within the aeronautical supply chain), that want to bring aeronautical SME into client digital processes. The working team evaluated the moment leading research to masteries it and then to adapt, package and disseminate methods and best practice

The above part lists a certain number of governmental programs, which has not the pretention to be exhaustive at all. It only shows the main aeronautic priorities and the motivation in removing barriers to allow the distributed and concurrent product development in the whole supply chain.

2.2 Collaborative engineering definition

The precedent parts have demonstrated that there is much interest in the methodologies for the engineering improvement. The following part will then review how they are understood in literature.

Collaborative engineering is a still relatively recent methodology; however it is already named under many names. And a first report is that some people don't consider collaborative engineering as a science. In [10], authors explain this ambiguity by its fuzzy position (between many disciplines) and situate it as the "practical application of collaboration sciences to the engineering domain". Visions like [11] are especially focused on geographical aspects: "Using collaborative engineering, the collocated team is replaced with an interactive team structure where the team members are geographically distributed and the best engineering talent can be applied to the design effort regardless of physical location". Other works are more focused on the interdisciplinary aspect and at the same time the temporal aspect like. In [5], it is underlined that some authors include integrated design and the lifecycle disciplines in the collaboration and others see collaborative engineering as an extension of concurrent engineering. Another aspect that plays an important role in many literatures is technologies aspect; however, this aspect is not the only and main one like remark [12] for who collaborative engineering is: ''an Internet based computational architecture that supports the sharing and transferring of knowledge and information of the product life cycle amongst geographically distributed companies to aid taking right decisions in a collaborative environment''

The former paragraph highlighted different definition points, but many authors have a more holistic approach. The research works of [10] introduce the following definition: "Collaborative engineering is a new socio-technical engineering discipline, which facilitates the communal establishment of technical agreements among a team of interdisciplinary stakeholders, who work jointly toward a common goal with limited resources or conflicting interests." Moreover, authors attribute a large scope to the collaboration actions, which could be "across various cultural, disciplinary, geographic, and temporal boundaries". They enlarged again this scope in an application case with the Airbus Company, adding the organisational range (Collaboration between or inside the organization). In [13] the definition is quite close to the previous one: "Collaborative Engineering supposes the Integration of the Product Development Process through Teamwork with all the areas involved in its Life Cycle. With this aim, product Design Methodologies and Tools are used to allow the regular exchange of the product-related information that is generated and to allow internal and external collaboration to take place. They are also employed to ensure that decision making is carried out in a synchronized way with general agreement, which thus allows firms to achieve the improvement of terms, quality and innovation required by the Client".

2.3 Integrated design definition

By making more and more complex items, the Man began to decompose the product development. We have changed from a global approach to a Cartesian one. In [14], it is underlined that the cutting of problems brought a new problem: the integration. In addition, authors add that integration has to be done at company model and process level, at data level and at tools level.

This last level is main subject of [15], which takes the notion of integration effort in account: "new tools can be added to make the system more capable in solving design problems. This also implies that the system can be easily configured, e.g. without the need to change existing source codes". Considering all the different levels, [16] propose an application case using the PDES/STEP standard to integrate many disciplines.

In [17], authors agreed that integrated design is a methodology based on concurrent engineering environment. They remind that a designer make part of a team, a team is composed of many different competencies (Technologists for technological solutions choices, analyst for stresses analysis with mechanical analysis tools, manufacturers, maintenance partners …) and in an integrated design approach, "each of those actors must participate in the joint effort and indicate the own constraints as soon as possible during the design process". They finally propose to federate all the experts around one reference product database. A second possibility is to make interface between expert bases.

For [18], integrated design "extends the scope of the design phase, such that the subsequent process requirements are considered alongside the product design" and "Due to the incorporation of the later stages of the development cycle in the design stage, integrated design increases the information available to the designer and, hence, increases the design certainty in the early design process".

As a short conclusion after this review, we can notice that the three notions that are "collaborative engineering", "integrated design" and "concurrent engineering" are strongly linked. In order to have a simple and concise view, the paper will remain that temporal aspect of the collaboration is mainly addressed by concurrent engineering, multidisciplinary aspect by integrated design and geographic aspect by collaborative engineering.

3 AERONAUTIC PLATFORM FOR MEDIATED COLLABORATION

3.1 The SEINE project

SEINE means "Standard pour l'Entreprise Innovante Numérique Etendue" that we could try to translate by "Standard for Innovative Digital Extended Entreprise". It was proposed by the GIFAS ("Groupement des Industries Françaises de l'Aéronautique et Spatiale" : meaning "Aeronautic and Spatial French Industry Group) and was in line of the French project call named "TIC&PME 2010" ("Les Technologies de l'Information et la Communication & les Petites et Moyennes Entreprises" meaning "ICT&SME, Information and Communication Technologies & Small and Medium Enterprises). The main goals was to improve and standardize, using the innovating digital methods, the data exchanges (Data as well as process) between OEM and suppliers in the Aeronautics and Defence sector (and then these of other sections having quite the same skills and suppliers) [19]. Those improvements will be done through two axes: An SCM (Supply Chain Management) axis and a PLM (Product Lifecycle Management) axis, which is the only part of the project this paper has interest in.

Like some projects presented in section 1.1, the main points treated are the collaborative engineering in aeronautical supply chain, the product data standards, the SME integration in the digital processes and the building of a platform. This platform approach could be explained by the essential necessities for aeronautical companies to use a "neutral" place for exchange and reconciliation like we said before, but also by the project methodology itself. Indeed, the research done here could be considered like "action research" as detailed in [20] because it addresses a complex problem so it asks systemic approach and amelioration cycle, it contribute to direct problems related to the topic, there is a need to realize studies at the same time as implementation and it need to employ change strategies. In this case, a platform gave a base to the project for applying this way of working.

Below is written some of the objectives to reach the goals:

- Assess and choose standard data model.
- Specify standard collaboration processes for the specific case of aeronautic.
- Define platform services and functionalities needed to support the collaboration.
- Implement concepts through a working platform
- Write global specification for the deployment of an "in production" platform

The innovating contribution compared to other projects, which have a relatively holistic view, is that data management processes are centred on the gap between the companies (i.e. exchanges processes) and not on the global companies processes, even if, the specification begin from companies effective business scenarios (Reconciliation between company processes and business processes was also described). Because purpose is not to redefine complete collaboration (processes through the whole extended enterprise) but to improve exchanges and communication, according to the fact that people and companies are more productive working in their own environment [17].

Although the positioning is different from other projects, there is also a dynamic vision (processes) and static vision (data model).

TITLE	DESCRIPTION
ASP PDM	Minimum PDM services provided in ASP mode (Application service provider) for companies without such systems which must integrate the customer digital chain.
SME Shared Workspace	Creation of secure workspaces to provide an exchange place and manipulation in such environments.
Data protection	To ensure that data dropped off on the platform are walled (needed because the platform is shared between many organizations), protected for hackers and also that access are controlled.
Context delivery	Delivery of context data from the customer PDM system to the supplier in order to allow the "design in context"
Engineering data package	Product data exchange (Particularly product structure) between partners through the platform.
Collaborative review environment	3D Real time product revue between many actors on data on the platform including all classic revue functionalities (Cuts, annotations, measures, communications).

Table 1: Main cases treated in SEINE

3.2 Exchange processes specification

An example of business scenarios considered for the specification work was a customer and his supplier that design together a rough part and machining instruction each other at the same time to produce innovative alternative and iterate about it. Another example and more classical case was a customer gives the responsibility to a supplier to develop a sub-assembly, he delivers the specification, and then the supplier makes his work, provide the customer with the completed work, who has to integrate the sub-assembly in the full product.

Such scenarios led to many "Use Cases", which are seen here as main process bricks needed to complete a scenario. After a selection, seven of them were retained to demonstrate the ideas. Table 1 illustrates these different main uses cases treated in the SEINE project.

It has been remarked that all this different "Use cases" can be decomposed in many different services. As an example: Engineering data package consists in requesting the elements to send to the platform, packaging it, delivering the package to a partner through the platform and acknowledging the partner reception. Context delivery consists in selecting the context element, sending it to the platform, distribute element context depending on the partners and notify the partners. The both Use Cases has common services like "Send product data package", "Receive product data package" or again "Archive envelop".

3.3 Reference data model

The previous section proposed to unify the exchange "protocol". However, during the execution of the exchanges, this protocol has to be support by a neutral reference model in order to allow semantic correspondences in communication between the heterogeneous environments. We have seen earlier that heterogeneity could be solved by two kinds of solutions: systems using the same database or translations between the systems that have their own database. And yet, aeronautical industry needs to own the element they work on at home (For questions of property right, psychology, etc.). So as project (meaning a node of the OEM final product) is the intersection of each case of collaboration, SEINE proposes a walled standard reference product structure that will archive and conciliate the partners work.

Many neutral data models exist so there is a choice to do like did in [21]. Among the standard possibilities, the two mains retained were STEP AP239 (PLCS) and STEP AP214. An evaluation has been done depending on the maturity, the application target, the standard nature, etc. The first choice was finally the last one because more matured and meet better the first need (meaning for the demonstration step). However the two propositions are not incompatible and the second one fit better to the final needs. That is why, it is planned to migrate at long term to the PLCS standard.

3.4 Use of PLM concept

It could be imagined to specify a new collaborative information system from nothing, but PLM systems proposes interesting concepts, especially important in aerospace industry what is attested in [22]. Moreover, PLM systems are already in production in aeronautical companies and the collaboration system mustn't ask changes to private systems, what is named as "non-invasive" system in [8]. In fact, it has been decided to consider current PLM capabilities to define the platform specifications.

Among the different PLM concepts, many of them have been used, not to support the product development as usual, but to enable performing data management exchange in engineering collaboration. The following lines give examples and suggestions.

- Use of lifecycle to follow processes: the first idea people think when we talk about processes is "workflows". However today, cross organizational workflows are difficultly realized, processes steps are not effectively traced, etc. Thus, the lifecycle could be seen as a "workflow tracer". In this case, lifecycle expressing the workflow has to be affected to a specific object because maturity of the different objects (parts, documents, ECM: Engineering Change Management, etc.) could not be sacrificed for this use of lifecycle. Then objects carrying the exchange lifecycle are linked to the product data objects that have their on maturity and receive different signatures, process states, and other process information during the running the process
- Use of the product structure: This paper agrees with the idea that people and companies are more effective if they work with their own language in their own

environment. Then, the work team will be more productive if common model is able to receive the data specific to the different companies. But these specificities must be seen only by the people concerned. Moreover, due to the aeronautical project structure (see above) the collaboration could be centred on the product structure. In fact, neutral product structure has been extended with company specificities (Attributes, etc.) and access to the customized parts depended on people organization, people role and node level in the product structure

- Notification for data pull: During the exchanges, data could be pushed or pulled by the collaborative system to owned systems. Data push allows a better synchronization, but is submitted to many constraints (Security, etc.); while data pull let too much liberty. Then subscriptions mechanisms were used to find a compromise and simulate a flexible data push.

4 INTEGRATED DESIGN CHALLENGES

In such aeronautical mediated collaboration, high level exchanges between industries were addressed. Under the “high level” term is understood “product structure level” (Figure 1). However, authors think that collaboration should be also possible at a lower level, namely data (ie parameters) level of the different product model. In fact, loud product structures managed by PDM are necessary to develop a product in a collaborative mode, but aren’t adapted to integrated design because not flexible enough in term of data heterogeneity (They are only linked to the 3D models). Indeed, manage directly data content instead of files itself and product structure allow avoiding format constraints, simplifying heterogeneity but also collaborating around the precise specific information needed without move related information.

In order to support the collaboration about “low level” data and then collaboration between the different competencies, another neutral data model has been considered in addition to the first neutral model used in SEINE, namely the PPO model. This paper has interest the PPO neutral model because it is generic enough to map the low level and heterogeneous data. Moreover, a platform based on a kernel implementing those concepts has already been developed in the IPPOP project.

As the two models have to define the same product, a synchronization link has to be made between the both. That is why an interoperability module has been then developed between PPO kernel and PLM collaborative platform to synchronize the product structures with the files and the PPO model, based on XML exchanges through XSLT translation [23] . The correspondence between the two models was mainly organized around the “part” concept in term of product structure because parts reflect the design intention: For example expert first reflexions, will be organized around components that will led to parts. Those parts have then to be managed (Maturity, lifecycle, etc.) what is done in PLM system.

5 SUMMARY

The paper showed the SEINE contributions in the Aerospatiale context: It defined a reference space to receipt the product data in the gap between companies. It described collaboration “protocols” focused on the exchanges between the organizations and the PLM concepts supporting the exchanges processes. It also mentions the step abilities to do this. Finally, it extended the product structure collaboration to data content in order to add integrated design dimension to this collaboration.

The different limits the works presented in the paper and that could be invested in further works are:

The link and the synchronization between data content and files themselves (Because the parameters manipulated in the PPO kernel and the files using these parameters are still manually updated), the connection with limited effort to couple of any new digital tool to the two collaboration platforms (Because mapping and connection between the considered elements was still quite loud and manual) and also rely those works with other systems DMS (Data Management Systems).

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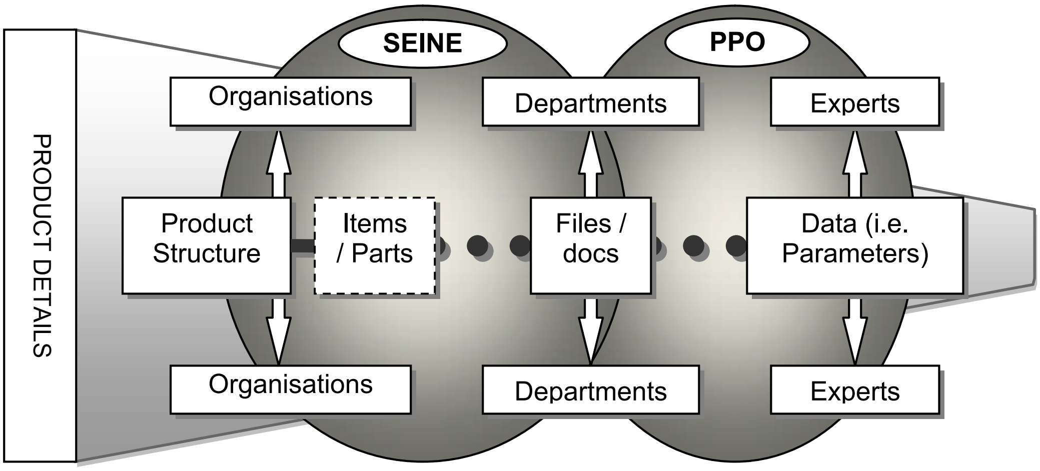

Figure 1: SEINE and PPO systems interoperability.

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