COLLABORATIVE PROCESS MANAGEMENT IN THE EXTENDED ENTERPRISE

M. Callot
EADS Corporate Research Center, France

L. Saint-Marc
University Bordeaux I – LAPS, France

J. –Ch. Deschamps
University Bordeaux I, LAPS, France

M. Moly
AIRBUS France, Powerplant

Industrial Context

Aircrafts are complex systems to define and assemble. Their development requires association of several thousand engineers and technicians working together in a common process called concurrent engineering and that are often located in geographically distant companies (extended enterprise). The implementation of the design project in such integrated multi-disciplinary teams implies numerous exchanges of data (drawings, calculations, procedures, methods, means, etc.) between the designers to end in a compromise which is at the same moment acceptable for them and which answers the requirements of the customer. These numerous exchanges of data are not made in a sequential way but require numerous iterations contributing to the consolidation of the information supplied by disciplines (ex: Aerodynamics, Acoustics, Performance, Loads, …) inside collaborative teams.

Forced under the economic and technological pressure owed mainly to the internationalization of the market, the improvement of the performance in the design phase seemed indispensable. The concurrent engineering certainly brought a reduction of delays and a better dynamic of the design. But in order to reduce Engineering cycles, those demands of improvement are so increasing, that it affects engineering data availability and quality control.

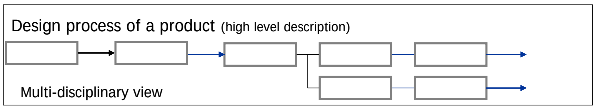
Research Objectives

The purpose of this paper is to give means to the discipline responsible for decision-making by proposing a method to enhance collaborative work concerning data engineering exchanges between all involved disciplines whatever their site or their firm. The main objective of this work is to enforce the collaboration between multi-disciplinary teams by:

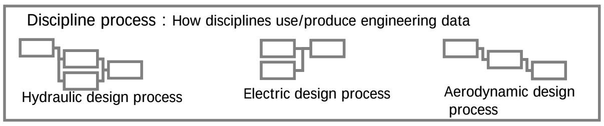
- Formalizing Collaborative Processes complexity,
- Enhancing collaboration work through the management of engineering data,
- Decreasing rework for designers avoiding obsolete information or over information.

What is a collaborative process?

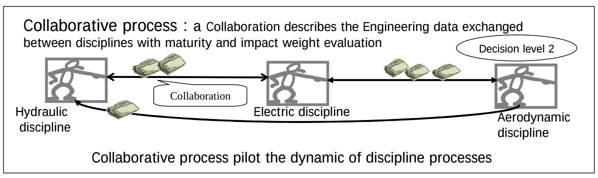
Design process focus on the description of multi-disciplinary activities and the information flows between these activities. A design process formalizes for example the design of the engine integration where different disciplines participate.



Discipline process focus on the description of activities and the information flows between these activities for a given discipline. This is specialized view of the design process, as Hydraulic design process, Electric design process and Aerodynamic design process.



Collaborative process focus on the description of engineering data exchanges between disciplines working together in order to reach a common objective. A collaborative process considers the discipline processes as black boxes and is a link between the design process and the different discipline processes.

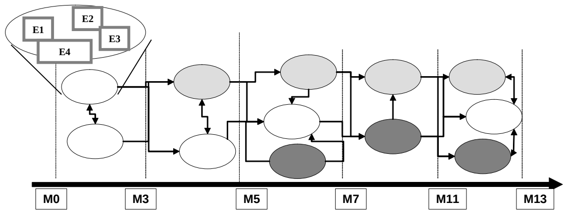


Formalizing a collaborative process

First step: identify collaborations

To face to the complexity and numerous engineering data exchange all along the product development life cycle, the first step of formalization is to examine the exchanges phase by phase or between two given milestones.

So, disciplines collaborating intensively during a given phase for reaching a common goal are grouped in a collaborative cluster. Collaborative clusters dynamically evolve along the product life cycle. We can consider that it is the same collaborative cluster if it concerns the same set of disciplines even it uses and provides different engineering data in different phases. Also, the engineering objectives can evolve for a same cluster all along the phases. The result is a "**Collaboration Layout**" showing the different collaborative clusters and the exchange flows between them.

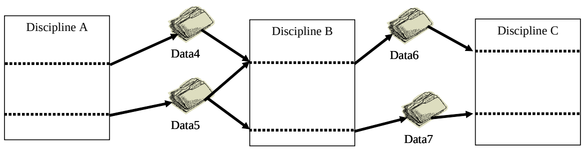


Second step: Identify engineering data produced/used by a Discipline

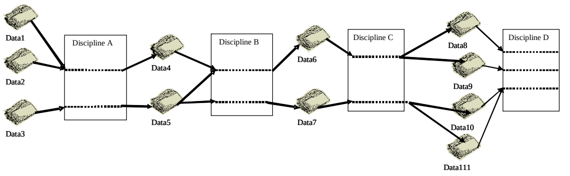
When a discipline produces a deliverable (an engineering data to be delivered to other Discipline) he needs other "deliverables" from its providers. An engineering data could be a CAD model, a specification, a requirement, a simulation model, a test request, …

We call collaborative environment the representation of engineering data used and produced by a discipline.

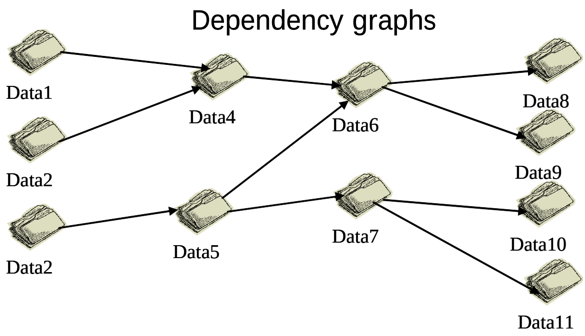
The following figure displays the collaborative environment for the discipline B.



Considering the fact that all disciplines have their own collaborative environment, dependency graphs can be built. Dependency graphs could be assimilated to a global network with data and disciplines.



This dependency graph can be simplified, focusing only on engineering data dependencies: sort of filter on the global network.



Step3: Identify Data Maturity states

At each exchange, the engineering data corresponds to a certain delivery state. This delivery state can be seen as the level of confidence the provider can affect to the data: we call it **maturity**. The engineering data will be used by different Disciplines and for them, knowing its maturity will allow them to decide if they can use the data for their work or if it is better to wait for an other release and then avoid rework risk. The maturity evaluation is subjective and each actor generally defines its own meaning in order to estimate his design work relative to his point of view: each designer has his own understanding of the maturity.

Example: Nacelle Geometry engineering data has 4 maturity states:

Nacelle Geometry without pylon geometry connection, without Fuel System space allocation

Nacelle Geometry with pylon geometry connection, without Fuel System space allocation

Nacelle Geometry With pylon geometry connection, with Fuel System space allocation along to a given accuracy

Nacelle Geometry with pylon geometry connection, With Fuel System space allocation with validated positioning

This maturity is local to a given Discipline and is fully understandable for internal actors but understanding can vary for the other disciplines. Moreover, the maturity is not always sharable nor Information Technology (IT) implementation compliant. So it is necessary to define an Information System (IS) point of view global to engineering through standard Product Life Cycle Management (PLM) implementation. It shall be common and shared for all the actors of Engineering. This IS point of view needs to make sense to be efficiently used by disciplines and must represent a consensus across the engineering data owner and other disciplines using that engineering data. It is necessary to define a maturity mapping between “oriented disciplines maturity definition” and “IS definition” proposed in order to determine standardized maturity levels. Those levels, representing a common scale for the data, shall be defined and fixed with flexibility for disciplines to use selected levels. Maturity is complementary to codification versioning for engineering data but could be a basis for versioning rules and configuration management.

Example: Nacelle Geometry engineering data has 4 standard maturity stats:

Maturity Rough: *Nacelle Geometry without pylon geometry connection, without Fuel System space allocation*

Maturity Preliminary: *Nacelle Geometry with pylon geometry connection, without Fuel System space allocation*

Maturity Reliable: *Nacelle Geometry With pylon geometry connection, with Fuel System space allocation along to a given accuracy*

Maturity Validated: *Nacelle Geometry with pylon geometry connection, With Fuel System space allocation with validated positioning*

Step 4: Identify impact weight

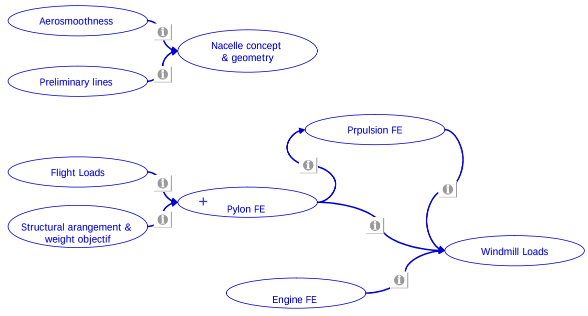
The dependency weight between 2 engineering data can be defined as the importance of the upstream data for the customer regarding the data he will provide. The importance (or impact weight) is characterized, for this data, by three levels: High, Medium and Low. The same engineering data can have many “impact weight values” depending of who uses this engineering data and for doing what.

Example: The Nacelle Outboard Inboard FEM Object depends on the Fatigue Loads Object with a impact weight “Low”, but depends also on the Geometry Nacelle Object with a impact weight “High”. This means that Nacelle FEM Discipline has to pay attention to the maturity and delivery of Nacelle Geometry Object because there is a strong dependency between them. If the delivery of Nacelle Geometry is delayed or at a lower level of maturity than planned, the consequences could be important for the delivery in time of the Nacelle Outboard Inboard FEM Object.

Step 5: Enrich dependency graphs with indicator as maturity and impact weight

The dependency link between two engineering data can be enriched with the maturity and impact weight. The first indicator is evaluated by the provider of the engineering data and the second one is given by the users of this engineering data and can differ depending of their needs.

It is important to characterize the meaning of the impact weight and identify consequences for the users. If it seems not necessary to characterize the importance for the impact weight of Low or Medium, the impact weight of High should be explained by the user and he can indicate their needs concerning this engineering data. For example, the most important for the user could be to receive the engineering data at the planned date, even if the maturity is poorer than expected, or the most important for him is to receive the engineering data at the good maturity, even it is delayed, or it is critical for him to receive it with a good maturity and in time. The following figure illustrates a dependency graph for some engineering data with information to be displayed on the link as dependency weight.



Managing the collaborative process

Collaborative agreement

To ensure a commitment on an agreed delivery state for engineering data provided and engineering data produced, the method proposes to build inter-active Collaborative Agreement on these engineering data. It is up to the discipline to decide which engineering data they want to follow. Some criteria are defined as engineering data with a critical delay for delivery, or certified engineering data, or engineering data critical for the Aircraft delivery.

A Collaborative Agreement is built for each engineering data that is judged important or critical. The owner of the Collaborative Agreement will be the customer of engineering data needed for developing his own engineering data. Using this way the same discipline can have different roles in several Collaborative Agreements, sometimes he the role of provider sometimes, he das the role of customer.

In a Collaborative Agreement the different states of maturity of the engineering data needed must appear.

Analyze behavior of the collaborative process by Impact analysis

The interest to achieve an impact analysis is that every event on an engineering data concerning the delivery can have positive or negative effects on disciplines who use this engineering data. The purpose of impact analysis is to prevent negative effects by informing as soon as possible the disciplines concerned by a problem occurring on an engineering data and thus allowing them to take all preventive or corrective actions they consider appropriate.

Engineering dashboards

Engineering dashboards will display synthetic information helping the discipline responsible or the designer to take decisions. On these dashboards, there are three types of exploitation modes, exploitation mode for follow-up actions, exploitation mode for corrective actions and exploitation mode for anticipative actions. A simple question concerning follow-up actions could be: is the planned maturity states of an engineering data is effectively done?

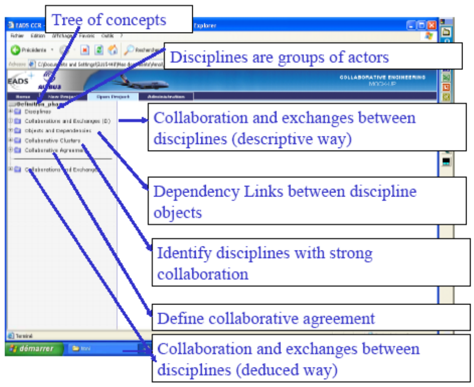
An anticipative action means that the user can launch analysis in order to anticipate possible problems. These analyses could be: for all existing Collaborative Agreements, make a comparison between engineering data planned delivery date and effective time needed to produce these disciplines objects. *(ex: "Engine Mesh" needs 5 weeks to be produced so it is impossible to be delivered for M7–2 months as requested in the Collaborative Agreement*) An other analysis could be to ask for the impact if an engineering data is delayed of "n" weeks and see the repercussion on others engineering data. In the same way, we can analyze the dependency weight values and calculate the critical path in order to identify potential bottleneck. This exploitation mode is similar to a risk analysis.

A corrective action means that the user wants to understand the reasons of a failure in engineering data delivery. These analyses could be: retro-propagation analysis through Collaborative agreements in order to understand issues in problem delivering. Another analysis could be to examine if it possible to slide some non-critical engineering data delivery in order to re-deploy resources (discipline designers) to more urgent task.

Collaborative platform

A Collaborative platform that will support the formalization and the management means of the collaboration is to be developed.

A mock-up has been developed as proof-of-concept. The main function of the mock-up at the end of year 2004 is to structure and formalize collaborations in order to give the means for the user to analyse exchanges and to be able to build collaborative agreements. No modelling tool on the market (like MEGA, Rational Rose, Enterprise Modeller, ARIS…) allows without customisation this kind of concepts.



There are two ways for examining collaborations:

1. The first one uses a top-down approach: the collaborations are described even if the user doesn't know exactly what engineering data are exchanged. Collaborations are strengthened as the data are collected. This is called a **declarative way.**

2. The second one is a bottom-up approach: the user knows exactly all the exchanges of engineering data between different disciplines and collaborations are calculated automatically. This is called a **deduced way**.

Consistency checks allow using these two ways (declarative and deduced) for merging.

The collaborations are structured by phases. A collaboration is defined by choosing a discipline customer and refers to a context, i.e. an Aircraft reference and a phase (Feasibility, Concept, Definition, Development, Certification). The user can see the engineering data exchanged in this collaboration. When the exchange has been defined, the engineering data appears just below the discipline.

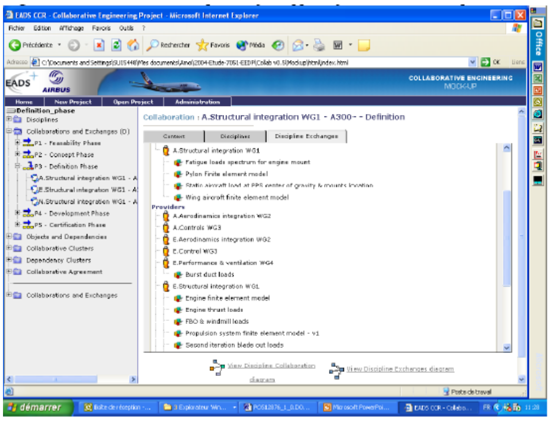
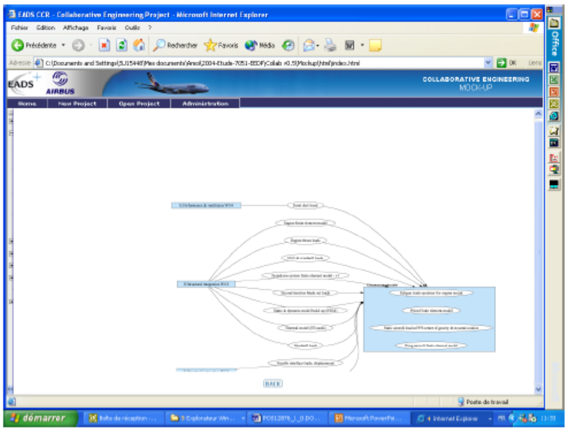
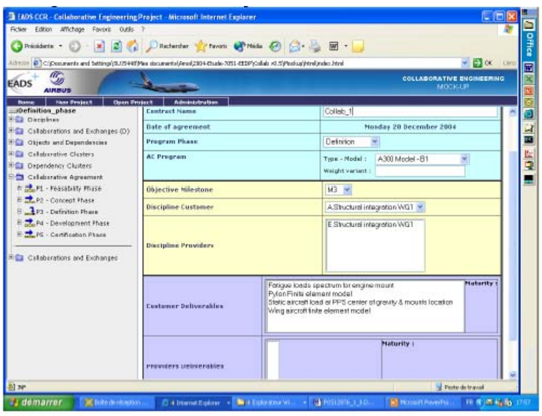


Diagram of exchanges can be displayed when selecting "View discipline exchanges diagram" in the bottom of the window.



Collaborative agreements are defined for a phase.



Conclusion

Collaborative work is not only sharing information, even if this dimension is important. Disciplines working in a collaborative way have to know exactly the viewpoints or needs of each of them. Introducing tools which analyse collaborations will help disciplines to identify and analyse the exchanges and more of that to pilot the dynamic of their discipline processes through the dynamic behaviour of the collaborative process. These new ways of working represents a human and organizational challenge for facing to increasing performance in the enterprises

References

[1] Dunyach, J.C., "*CE in Aeronautics*" Proceedings of the 6th International Conference on Concurrent Enterprising - ICE 2000, Toulouse, June 28-30, 2000.

[2] Terwiesch, C., Loch, CH., De Meyer, A (2002) *"Exchanging Preliminary Information in Concurrent Engineering: Alternative coordination strategies*" Organisation Science Vol.13, No.4, pp.402-419, 2002.

[3] Saint-Marc L., Callot M., Reyterou C., Moly M., Girard P., Deschamps J.-C.(2004), *«Toward a data maturity evaluation in collaborative design processes »*, Design 2004, Dubrovnik (Croatie).

[4] Kvan T. (2000), *« Collaborative design : what is it?»*, Automation in Construction, Vol. 9, pp 409-415.

[5] Callot M., Saint-Marc L., Moly M, Trebucq B.; *"Collaborative processes enabler «* INCOSE 2004 Toulouse