Integrated Product Development- a Key to Affordability

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Abstract

Integrated Product Development (IPD) has been a major approach to improve performance and cost effectiveness for the development processes within aerospace companies during the last years. It provides a structured approach on how to improve a development capability. At Saab the implementation of IPD has used an enabling approach with a starting point in maximising the individuals ability to contribute to and support a rapid convergence to feasible designs in a life cycle perspective. This paper presents the contribution and experiences from various components of the implementation at Saab.

1 Introduction

Almost all companies are subject to continuously increased pressure on cost, quality, flexibility and ability to respond to market demands with minimum lead time. In the case of Aerospace and Defence this challenge is characterised by a complicated market, long product life cycles and high technology level.

Key to achieve success is a strong product development capability with the ability to master cost, performance and lead time aspects of the complex products involved. Integrated Product Development (IPD) has been one initiative to meet these demands, with the focus set to provide enablers for the individual experts to best contribute in teams in order to favourably converge towards the design goals.

IPD strategy at Saab:

”A structured way to maximise the contribution from people, processes and tools to achieve product optimality”

Where product optimality reflects the balance between cost and performance that best meets customer demands. This definition could address all operational activities, while in this paper a focus is kept on airframe design and systems installation development. The major disciplines to integrate in this area are Airframe Design, Systems installation, Structural analysis, sizing, manufacturing engineering and customer support engineering, but of course other interfaces with strong interaction are also important, such as programme management and systems engineering even though those are not covered in this paper.

In the design of the development process at Saab some aspects have been central:

- Provide easy access to information and knowledge
- Use modelling and simulation extensively to provide knowledge support to engineers in early development stages in order to allow for mature decisions as early as possible.
- Minimise the lead-time from decision to delivery.

- Support and simplify vertical and horizontal communication internally and externally.
- Provide ability for the engineers and experts to utilise their expertise in an efficient manner

The process is designed to easily bring in new expertise and easily start interaction with the purpose to achieve a possibility to dynamically allocate expertise into projects, e.g. customers, suppliers and shop-floor people and let them contribute to the product at early stages. It follows from this and the focus on general abilities that the process is adaptable to the development of other products with similar characteristics as well as to support the inclusion of new design drivers.

The Design Build Team philosophy (DBT) has been applied to two major development projects at Saab in the early nineties, The Gripen 39 B two- seater fighter aircraft and the Saab 2000 commuter aircraft. Basically this facilitated :

- Team based organisation in order to promote cross functional interaction
- Early use of digital mock-ups (DMU) to support the understanding of the product concepts
- The use of business process re-engineering in order to improve efficiency and quality

Both these projects gained success in their application of DBT with substantial reduction in lead time and engineering change work. It was however obvious that many opportunities remained to be exploited after this step.

The following areas were identified as priorities for the next step

- Increase communication abilities
- Promote Decision ability
- Focus on the Integrated product rather than the parts
- Increase configuration management support
- Reduce workload on design engineers
- Reduce cost, change and increase quality

These served as the basis for the specification of IPD as being developed during -95 through -97.

2 Technologies and Methodologies

The technologies and methodologies described below constituted the implementation of the first generation of IPD as a follow-up to DBT and the way to meet the goals described above.

2.1 Development Rooms

The growing importance of IT to support communication and information generation in the teams was obvious. The obstacle of having the computer to support just individuals but not the team had to be overcome. The problem had two major contributors, firstly the individual often entered into difficulty in sharing his/ her information with the rest of the team. Secondly, there was limited interactivity since technology was immature and the engineer had to return to his/her computer to work with the model or database.

The development of technologies have opened the possibility to support interactivity to a much larger extent, not only can models be selected and viewed within less than a minute in complex products, but also could changes be introduced in a meeting and e.g. quick interference checks could be performed, linear analysis could be made given limited mesh change needs and so on.

Based on the above, a development room was designed , see figure 1, where two workstations and one PC provide computer power, two large screen projectors give the ability to view two of the three computers information simultaneously for the full team. The computers are normal installations on the network with ability to use any system and data available on the network given that the team have access authority.

Figure 1: Development room

This enables the team to work, in the room, viewing the design in its context from the CAD-system on one screen and discuss some type of issue or opportunity. On the other screen additional information available on the network can be viewed depending on the needs. Typical examples are bill of material (BOM) or other PDM information, analysis, simulation or scheduling information. Changes can be introduced and to some extent analysed interactively.

Bringing the use of these development rooms into the team environment provided support for more dynamics in the meeting. The use of the tools, combined with the goal to improve the ability to reach joint decisions in the team, lead to the design of a methodology to take ”action like” minutes from the meetings. A particular structure was formed, and tools were developed to support this. Initially the methodology was supported by standard ”Office” software which was found to not being sufficiently efficient in a networked environment. To improve efficiency an early web-application was created.

The minutes application uses ”screen grab” technology and allows users to pick any information from the computers and add it to the minutes with views, annotations, identification of responsible and terms during the meeting. An integrated archiving functionality is provided with the ability to follow design rationale from specification to released and verified product definitions. Several generations of the application have been developed and there is a continuous demand for more information to be handled within the application, e.g. scheduling.

A current challenge is to identify support for easy search in the archive in order to promote reuse of earlier engineering solutions in new applications.

2.2 DMU and CAD

In the early DBT level, the DMU was run on a Mainframe computer with limited performance. Furthermore, so called mock-up solids were used, while wireframe models still were the master CAD-models. The models were grouped on an assembly level. These factors provided a limited technology basis where retrieval and analysis were difficult or impossible. Interference checks took a night and so on. Despite all those limitations compared to current technology, the project leader for Saab 2000 had to rely on the DMU instead of a physical mock-up in order to meet the tight schedule for the project. The response time for a physical mock-up would have been unacceptable. The use of this early digital mock-up was a clear success despite the above deficiencies.

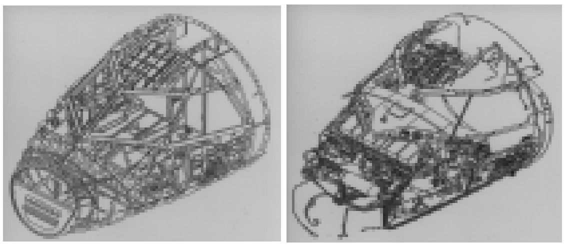

Figure 2: The Saab 2000 cockpit DMU

Current technology implemented on the IPD-level includes exact solids CAD on workstations, high performance visualisation, simulation, analysis and retrieval tools and a model structure with one part instance in each model which allows a flexible and rapid build up of different context scenarios.

The PDM support in early stages of development available when IPD was designed was limited. The weak area in the current solution is the somewhat cumbersome establishment of models for different product configurations. The requirements on the PDM-system to make progress in this area includes e.g. being able to master many concepts subject to intense change and provide good retrieval and analysis capabilities to compare the pro’s and con’s of the different concepts.

The use of exact solids and a well mastered DMU is the key to use the data for a number of application areas. In addition to visualisation and analysis it is used for simulation of manufacturing and customer support activities. Future applications include e.g. expanded use as shop-floor documentation and technical publications.

In the early days of the DMU we often experienced a difficulty with the release of the DMU-information. There was a wide range of opinions on when the information was mature enough to share with others. Often, the designer unintentionally assumed a similarity between DMU release and manufacturing release, where cost was committed. But for the DMU it is obviously important to share information early in order to detect conflicts and eliminate mistakes as early as possible. The normal pattern was that there was some reluctance to share information which contained designs with unresolved problems, but after a while in the pilot projects when the team had experienced the power of the DMU, it was again much easier to do early releases.

When the use of the DMU was expanded to multi team co-ordination, we again experienced some reluctance, probably due to the human reaction that it is unpleasant to share with a large audience something one knows has deficiencies. We experimented with things like the wording (e.g. changing the word from release to publishing), and after some time users realised the benefits from early communication by all projects involved in the development.

2.3 Analysis and Simulation

Analysis and simulation in a wide sense covers areas from stressing and aerodynamics to assembly and shop floor simulation. Many areas of analysis have improved during the last decades where different performance aspects have become much more predictable.

The improved predictability has probably influenced the design decisions in the early stages of development such that it has been easier to justify a solution from a performance or functional point of view, rather than from a cost or manufacturability view.

Only in the last decade have areas such as assembly simulation and other manufacturing related simulations been able to contribute with sufficiently short response time to match performance simulations at early stages. This is a very fortunate development that has to be taken further, in order to meet the demand from the continuous movement towards more cost focused design criteria.

If the information provided fails to balance the level of consideration in the design criteria, which normally is the case, this need to be met through other efforts. One method utilised is the use of the different roles in the team, and try to strengthen the ability to influence decisions for people from disciplines having lower level of quality information available .

An example is that in early stages the manufacturing engineer could have difficulties in catching up with the consequences of design decisions. By making him/ her the one who runs the web based application for taking minutes from the meetings, he/ she can to some extent control the flow and have all possibility to influence the design from the very beginning.

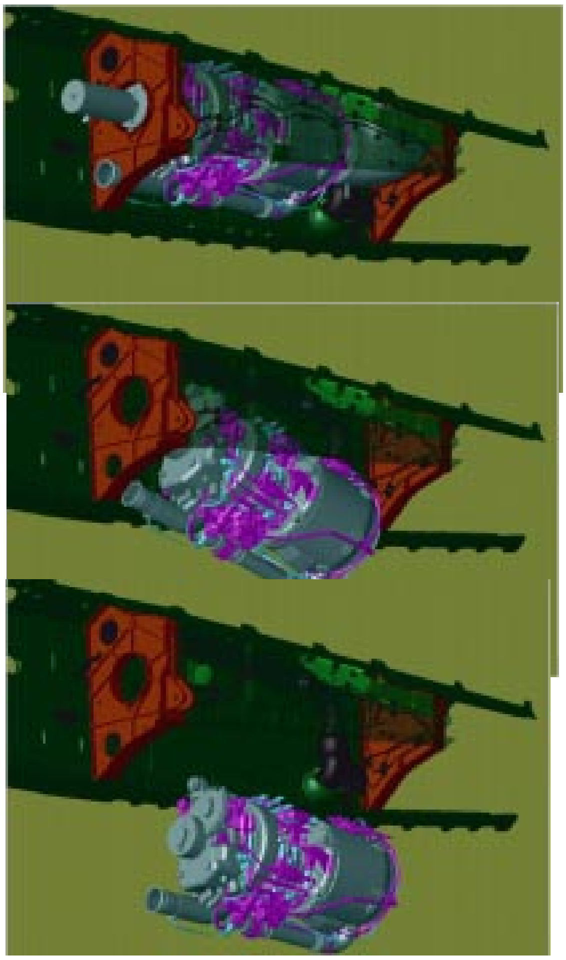

Figure 3: Assembly simulation example

Another issue in the same category is that different disciplines are progressing based on different information, which sometimes makes it difficult to maximise the profits from the concurrent development, e.g. the stressman is approaching the product in a different break-down approach than the systems installation engineers or the manufacturing engineer. Co-ordination is therefore needed during the evolution of the product in order to avoid decisions focusing on a limited set of design drivers due to the lack of certain types of information.

In general, models for analysis and simulation are considered as a part of a model concept where the models are established in early stages of design and maintained throughout the life cycle in order to remain as the main information carrier for the product aspect concerned. Early models are often mathematical simulations to be refined and correlated with experimental data or experience from application later on (e.g. ground vibration test for eigenfrequencies, manufacturing cost for costing or operational properties). The model concept serves as a strategy to make the best use of available information.

2.4 PDM

An effect of the application of IPD is that information is communicated more frequently to a larger group of people. The extended use of information technologies causes an information explosion. These two factors generates a strong demand for improved support of information distribution and management. Non experts can then get good support to ensure that they work towards the most current information with e.g. the proper planned effectivity.

Further, the continuous demand for increased product differentiation strengthen Configuration Management as an important factor to master differentiation while maintaining cost effectivity and quality.

All the above are driving the development of PDM-systems that supports the management of information throughout the product life. To achieve a PDM system where previous information can be related to forth- coming information and where existing procedures are migrated to new ones is a delicate task. New productive and precise procedures that exploit the abilities available in commercial PDM systems need to take into account to a certain level earlier routines, maybe designed towards other priorities, in order to make the migration feasible.

The experience at Saab, where we migrate existing product definitions into the new PDM-system, is that it is a huge task to achieve this in terms of system adaptation as well as in procedural development and migration work. The resulting PDM system improved the ability to master the growing complexity as well as smoothening the information handling for IPD.

Migration work has contributed to improve information quality thanks to increased validation possibilities in the PDM-system. This is partly due to technology improvements, but mainly due to the information model consistency and integration for a larger information set.

The handling of product information is one of the areas where much progress is expected in the coming years. The product definition has changed from being drawing and BOM driven, to more rely on CAD-models and PDM handled configuration definitions. This opens up huge potential for increasing the retrievability of information, handling the full life cycle, and mastering a broader product differentiation as well as presenting information in an ”easier to understand” way. All this is contributing to increased efficiency, quality and customer satisfaction.

Working with partners often create challenges for PDM on a detailed level, e.g. through different part numbering systems, different release procedures and change management. A shared database is often needed if efficient interaction is to be achieved with a clear risk of driving IT cost for a co-operation.

2. 5 Supplier/partner Integration

Since a high degree of the aircraft content is developed and supplied by other sources than the system integrator, it is important to achieve interaction mechanisms which supports co-ordination where needed. Obviously this integration is dependent on how decomposable the work is. The first operational step is always to minimise the interaction needed between the parties. The next step is to identify which information is important to co-ordinate/ exchange and at what frequency it needs to be co-ordinated. At Saab we have basically worked with three levels of technology for integration

1: e-mail and file transfer
2: replication of data sets at a certain frequency
3: remote clients with shared databases

Sorting on these levels appear to be sufficient from an IT point of view. The difficulty is almost always to resolve security issues. The level of technology becomes a prerequisite for the type of methodology and tools that are needed to achieve a cooperational support. Often, a low technology level is driving increased complexity in the methodology in order to ensure e.g. configuration management. A practical level is normally level 2 where the selected DMU and analysis data are replicated at the supplier site with maximum delay of some hours. The same applies for the project web as described above as well as for planning information and so on. Information produced at the supplier site is released to the data storage at Saab.

The many supplier and partner relations that follows from the involvement in several aircraft projects with several partners drive the complexity of the company operations. In order to minimise this complexity and maintain the ability to optimise the performance of operations a strategy is used where clear interfaces are applied with limited impact on internal processes.

2.6 The Development Process

The process is the basic mechanism to manage and monitor a development. It does contain macroscopic and microscopic methods and measures to achieve a situation promoting continuous improvement and performance. The overall process contains methods to ensure global properties of the product, and ensuring that the product is maturing properly, through e.g. review schemes. It further identifies critical interactions with other processes.

On a more detailed level different activities are defined to a required level, e.g. change management or review content. Many of those procedures have a strong relation to the software support provided in systems like PDM.

One essential property of the process is the improved ability to manage the level of concurrency that is used as well as the way to understand how concurrency could be further optimised.

2.7 Teams

The basic idea with the team is to form a group where the involved people cover the needed skills and they together start to interact and co-operate to meet their targets in the best way. Again, for a complex product many teams are needed and interaction and co-ordination of the teams is very important. This drives the need for good communication abilities and ease to understand a product concept.

Furthermore, the manning of a team often consist of a core of people from the major disciplines, while they need to expand the team for particular tasks where additional expertise is needed, such as bringing in suppliers or customers. It is therefore important to provide good support, not only for the team to understand the product, but also to give them the ability to easily involve other people. The development rooms, the DMU and the visualisation tools are playing a significant role for this ability.

The participants in the team need to have sufficient design domain knowledge to be able to act strongly in the team. They need to understand the importance of the integration to other domains and the implication of their decisions to other disciplines. We have normally experienced a positive reaction to work in teams, but in some situations where people are new to their jobs, or when we have peaks in workload we have seen tendencies to go back to a functional organisation and as well getting away from co-location with the team.

This probably reflects the difficulty to master the domain consequences. It needs to be met by training and support mechanisms like experienced mentors and networks, otherwise there is a risk that domain knowledge does not develop as it should.

3 Discussion

Integrated Product Development offers a structured approach to continuously improve performance of an organisation as well as adapt to new business situations. The evolution of IPD is supported by information technology progress with the obvious risk of being a victim of technology focus. We have provided technology as a, probably necessary, enabler to make progress. The approach has demonstrated good results. Further, it has hopefully established a way of acting that promotes continuous improvement. The possibilities for individuals to contribute and to interact with their teams and tools has increased.

Still, it has by no means been trouble free. Reaching consensus and overcome initial reluctance have sometimes been hard. To minimise these problems we have been careful in the selection of pilot projects, ensuring that involved people are reasonable positive to change, and above all that the task will gain substantially from the new methodology or tool.

This was clear when IPD was introduced, compared to DBT, since the team culture was in place and there was a common attitude that team interaction was obvious. Experiences from early DMUs in the DBT level contributed to quickly make use of and appreciate the IPD level of methodology and technology. From this it is further obvious that IPD need to be a continuous step-wise evolution utilising the increasing maturity in the organisation.

The development of IPD in -95 to -97 followed up with implementation in -97 to -98 have been a most interesting experience. The pilot projects were well received, and the implementation was accelerated compared to our planning in order to create benefits as widely as possible throughout Saab development as soon as possible. This generated some pain due to too rapid growth, but when that was overcome we found it very satisfying to have a full implementation of IPD to the achieved level. No development work takes place based on other methodology.

The continued development of IPD consists of refinement of the current level as well as design of a next generation IPD aiming at improving e.g. the management of many design alternatives, life cycle PDM, co-operational ability in multi partner environments and cost prediction.