A DISTRIBUTED DESIGN SCENARIO FOR AEROSPACE

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Abstract

The Aerospace industry is seeking continuous improvements with respect to cost reduction and reduced time to market. Global competitive pressures are driving organisations to adopt concurrent product development processes. Whilst these processes have led to reductions in re-work and with overcoming congestion in the design process, they do have limitations in a distributed environment. This paper describes a new scenario for overcoming some of the limitations of current processes, using a Core Team - Task Team structure. The software to support this new scenario is also described. Special attention is given to the interaction between the organisation and technology, the human factors and the product development process. Some of these issues are discussed together with their possible solutions and their impact during the implementation of this process.

1 Introduction

The last decade has seen several trends appearing in the way that aerospace companies operate including consolidation, globalisation and outsourcing to a greater extent. This has often been in response to increasingly competitive environments, reduced budgets and rapidly changing market demands. The most significant reasons for these trends has included competitive survival by finding cheaper labour pools in other countries with low-cost work forces [1]; benchmarking against others, and increased opportunities for risk sharing with collaborators.

In addition, recent years have seen these competitive pressures force manufacturing organisations to move from sequential, to concurrent development processes. The currently favoured approach to developing a complex product, such as an aircraft is to employ an Integrated Product Development (IPD) process described below.

This paper outlines the principles of the IPD process and some of the limitations associated with its use. The paper then goes on to describe a new scenario that is proposed for carrying out product development in a distributed environment. This new scenario, known as the Macro Concept, consists of schemes for introducing and managing teams across the product development process. The principle elements of the Macro Concept are described, including the technology to support the concept. Some key issues in the Macro Concept are discussed, and finally conclusions are drawn and future considerations made about the work.

2 Integrated Product Development

2.1 Principles of Integrated Product Development

IPD describes the participation of manufacturing and those functions traditionally associated with being carried out at the end of the development cycle, into the earlier stages of product development. This strategy uses customer involvement, cross-functional teaming and technology integration for product development cycles that are shorter and

cheaper. The use of cross-functional teaming has created Integrated Product Teams (IPTs) bringing together people with different skills to accomplish a specific task. These teams facilitate early involvement and increase the extent to which tasks can be carried out concurrently. It is not unusual for IPT members to be from different sites within the same company, from different companies and occasionally from different countries.

2.2 Limitations

Whilst the IPD process purports the benefits of lower development times, fewer engineering changes and less time to get a product to market, it does not easily manage product development in a geographically distributed environment. One underlying principle of the IPD process is to co-locate members on engineering projects allowing them to work together.

The difficulty with applying the IPD process and IPTs is that the use of multi-company consortia for designing future civil and military aircraft frequently precludes the co-location of management and design teams. In many cases it is neither practically or economically justifiable. IPTs can consist of as many as 200 people or more, and more firms are moving to new product development teams that are dispersed throughout the world [2].

Raffi [3] argues that in today's global business environment, collocation is neither feasible nor sufficient. Firms making products for the global market often benefit from representatives who live in local cultures and provide valuable information about the specific needs of the area. In addition, permanently collocating team members with other team members can have detrimental effects on the individual's well-being or their family. With larger numbers of people involved with product development teams, the potential for co-location of activities such as team building and meetings becomes reduced and more difficult to organise, but the need for a solution to address this problem becomes more compelling.

Collocation is often not sufficient for increased communication and interaction to occur. Allen [4] found that if the distance between two individuals were increased to 10 meters there would be a 70% reduction in the informal contact between them. If team members cannot be collocated extremely close to one another they may as well be miles apart. Moreover too heavy a reliance of oral communication can lead to poor written documentation which may result in costly errors. In respect of this, the emphasis for the Macro concept is about developing a product development process whereby individual team members can remain at their original location without collocating with other members of their team. It is necessary to consider communications technologies as one approach for overcoming some of the limitations of processes like that of the IPD process.

2.3 Communications Technology

Traditional communication methods across geographical distance have been the telephone, fax machine and the postal service. Recent years have also seen increased use of technologies such as email, video conferencing and electronic communication via the Internet. These technologies have radically changed the possibilities for future teamworking, by reducing the necessity to collocate team members as frequently as has previously been the case. The use of current communication-enabling technologies is discussed in greater detail, within the context of the Macro Concept outlined below.

3 The Macro Concept

3.1 Outline

In response to the IPD limitations, a future scenario is presented using a Core team - Task team structure, known as the Macro Concept. The scenario allows distributed teams and team members to operate as a single entity when co-location is not necessary or possible. Fundamental to improving the communication and the operation of both the Core team and the

Task teams is website based software[1] and a supporting workbook. The software is described in more detail in section 4. The following sections define the Core team and Task teams and their roles within the product development process under the Macro Concept. The outline presented describes the top two levels of the Core team and Task team structure. Issues surrounding subsequent levels in the supply chain are discussed in section 5.

3.2 Core Team

The Core team is the central group in this new scenario and has the responsibility of managing the whole Design, Manufacture and Entry-into-Service (DME) process. The Core team is responsible for realising the project. It owns the product and the DME process and establishes sets of Task teams to perform the actual tasks required to achieve a customer requirement. Following the launch of the Task teams, the Core team monitors the progress of the Task teams within the context of the entire project. The Core team consists of multi-disciplinary senior level experienced specialists lead by a Core team leader. A senior level Management team involved in initiating the project will probably select Core team members. The skills required of Core team members include systems integration and key technology skills along with management and communication skills. The Core team will be looking at the overview of the project, and be responsible for creating the overall project context and managing the delivery of the product. They will not carry out any of the tasks themselves, but will monitor Task team progress. In essence, the Core team members are 'managers', 'advisors' and 'thinkers'. Members of the Core team might be members of several other Core teams for different products.

Due to complexity of the Core team's role in the overall product development process, it is assumed that its' primary manner of operation will be face-to face meetings. To support this method of operation, a paper-based workbook is being developed. The software will also support the Core team.

3.3 Task Teams

In contrast to the Core team, Task teams are responsible for delivering specific, specialist aspects of the DME. Task teams are similar to IPTs. They work on specific tasks following the agreement from the Core team. They are temporary in nature and can "plug" into the Core team in response to a need. They take information from the Core team; perform a specific task and then supply resulting information back to the Core team.

Task teams within the Macro concept, are likely to be made up of individuals from different functions, different sites and probably different companies that may be geographically distributed. The Core team is given the freedom to request the inclusion of specialist team members into the Task teams if they feel it is required. The team members are integrated into a single team to achieve a common purpose, and following the achievement of this purpose they will disperse. One of the benefits of using the Macro concept is that team composition or performance is not compromised by the geographical location of its members. In many cases, it will be optimised by the introduction of technical specialists who will become team members via virtual membership.

One key aspect of this concept is that the objective given to the Task team from the Core team is not pre-defined. Design freedom is offered to the Task teams, and control by the Core team is carried out through constraint-definition (for example, budget, weight limit, size limitations) and risk management. This is anticipated to result in increased innovation and technical superiority. In contrast to the Core team, Task teams contain the *'specialists'* and *'doers'* in the process.

4 The Software

The concept for the software that supports the Macro Concept was originally developed by a company called Team Performance Limited.

[1] Website address: www.teamperformance.net

This technology provides an intermediary between expensive active facilitation required for the traditional approaches to team building, and cheaper passive technology such as 'chat rooms' allowing team members to discuss issues and communication without the need for collocation. In general, Core teams are more likely to receive the active facilitation and training, and have budgets that support frequent face-to-face meetings. In contrast, Task team members tend to be left to accomplish the tasks, often with access to communication technology, but with lower budgets for active facilitation and collocation.

The technology provides a single access point where a distributed team can be guided through the normal team building process. It provides the opportunity for basic communication to occur, about who is responsible for what, when, where and how. The consequence of using the technology is that face-to-face meetings are reserved for essential reasons rather than simply to feedback progress or to request help. In this situation, meetings can be used more effectively for problem solving and idea generation.

4.1 Structure of the Software

The key to building the Core and Task Teams without meeting is to create self-managing teams where individuals take responsibility for their own tasks as well as the collective goal of the team. The team leader becomes a facilitator making sure that everyone in the team has agreed the collective mission and each other's tasks. This higher level of commitment within the team increases collaboration between the team members and allows the experts to define their own tasks. Creating these self-managing teams requires a high level of discussion and agreement, all without meeting. In order to enable this to happen the software has been designed by taking the principles of the team building process and placing them inside private notice board areas. Within the software each team has access to three major notice board areas. These three areas correspond to the three stages of "*Plan it*", "*Do it*" and "*Share it*".

4.2 The Core Team

It is very important for teams to have a good understanding of what the people on the team are trying to achieve and how the different tasks conform to achieve the overall objective. It is also important that everyone has the opportunity to understand the ultimate aim of the project, and to know his or her individual role towards achieving this objective. The first stage in using the tool, "*Plan it*", allows the Core team leader to prepare a team plan consisting of an initial purpose, some possible milestones and the creation of Task Teams for carrying out the work. When the Team Leader has done this, the rest of the Core Team members are invited to discuss and agree these issues. Once the Core Team has agreed the Task Teams required, they monitor their performance in the second stage of the tool, "*Do it*", by accessing a public area of the Task Team workspace, called the Notice Board. Based on the feedback received from the Task Teams, the Core Team can create progress reports on the performance of the complete project. Finally, within the third stage of the tool, "*Share it*", the Core Team is able to publish progress reports of the complete project as well as the purpose and milestones where Management and sponsoring companies can see them.

4.3 The Task Teams

The Task Teams also have to work through the same three stages of the tool, but with some small differences to the nature of the information required at each stage. The Task Team leader is given access to review the Core Team's mission, deliverables and Task teams in order to provide the context to see where their work fits into the overall project.

The first stage of the Task Team area, "*Plan it*" allows the Task Team leader to construct a team plan for the Task Team. This team plan consists of the mission, the deliverables and the tasks that will be carried out in order to achieve the Task team purpose. In understanding how to improve team performance one of the problems that teams have is that they often don't know what they are

trying to achieve. This results in many inefficient meetings as individuals try to do the work. In order to overcome this, individuals need to know what the main objective of the team is. This then becomes the mission, the achievement of which will determine whether or not the team is successful. Team members also need to know the deliverables required in order to achieve the mission. Finally, the team members need to know the tasks required to be carried out in order to attain the deliverable. When the mission, deliverables and tasks have been entered by the team leader, the rest of the team is invited to discuss the team plan. It is this process of agreeing or disagreeing the issues within the team plan that the Task Team becomes a self-managing team, rather than being dictated their mission, deliverables and tasks by the Core Team.

The second stage of the Task Team area, "*Do it*", provides a space where each team member can keep informed on progress by regularly adding individual progress reports. The team leader uses this information to produce team progress reports. Finally, the Task Team is able to "*Share it*", by publishing their mission, deliverables and tasks on their Notice board in order to allow the Core Team, sponsors, and other interfacing Task teams to access this information. Whilst this facility provides the opportunity to assess the progress of the Task teams and any complications experienced, it does not create the "Big Brother" feeling often perceived with many open access tools. This is because the Task team has full control over the information that is placed in the notice board area.

4.4 Supporting Tools

All of the teams using the software may need extra support of one kind or another throughout the duration of a project. For example, two Task teams may be working on the development of different aircraft components that need to be integrated on the final product. The lack of a common Computer Aided Design (CAD) tool may make this difficult to do. Alternatively, a Task team may be having a disagreement about a particular task and may require either specialist technical help, or help from a team-building expert to assist them in resolving the conflict. The software will attempt to provide access to tools and services that may be required.

There are expected to be three main categories of tools within the software. The first group within the three categories is planning tools. These tools will include a timesheet facility and a standard project planner. With the technology it is possible to integrate the existing tools used by the organisation into the software, for example, SAP or Microsoft Project. The second category of tools is those concerned with team building. These tools will include an alignment tool to check that all members of the team have a common and agreed understanding of their mission and tasks. This group of tools is also likely to include personality assessment tools and a series of tools to assist in cultural problems, similar to those described in section 5.2. The final category of tools is task tools. These are the actual tools required to carry out the tasks, for example, CAD tools. Again, it is possible to link into the tools that already exist within the organisation.

4.5 Inter- and Intra- Communications

Control of the communication between individual Task Teams and between the Core Team and the Task Teams is a critical issue, which is now being addressed in the management of the software.

It is tempting to suggest that a high level of communication should be permitted between individual Task teams, as is the case when teams are co-located. The argument is that such one-to-one discussions between team members have to be advantageous as this allows for the rapid solution of technical problems. This type of horizontal communication can be viewed as intra-communication between Task Teams, which avoids the involvement of the Core Team. Configuration control would still be maintained by the Core Team through the use of classical configuration control mechanisms. It would seem that this type of communication would be

useful for the efficient working of Task teams and not hinder the control required to ensure that the product model, owned by the Core team, is not prejudiced. However, as the number of Task teams increases and as the design progresses along the time line and the number of Task team levels increases it is clear that information chaos will result with this type of uncontrolled communication. At the present time the Macro project is only giving limited consideration to intra-communication protocols and mechanism but it is recognised that a different communications paradigm is required from that employed with large co-located design teams. However, no experimental work has been undertaken to provide data upon which to create a communications model.

It could also be argued that free exchange of information between Core and Task teams would be advantageous allowing the Core to watch and control Task teams without having to wait for regular meetings at which problems may have emerged too late for effective treatment. This type of inter-communication between different levels in the team structure should be less prone to the creation of a chaotic environment as it involves a one-to-many interaction rather than many-to-many interaction in the intra-communication case. However, a different set of problems arises if this one-to-many type of communication is freely permitted which have been seen in trials undertaken within the Macro project. First, is the confusion with respect to who owns the design activity being undertaken by the Task team. If the Core can intervene at will, the Task teams leaders and members become confused as who is responsible for what. Secondly there is the tendency for a Task team to make sure that the Core team viewing the process from on high cannot clearly see what is actually being done! If the software is to be used the Task team will ensure that the information provided would prove acceptable to the Core. Thus, information will only be placed into the software when it is seen to be acceptable or when a major crisis occurs and emergency help is required. To overcome this problem inter-communication is strictly controlled in the software so that the Core Team ***cannot*** gain access Task Team information unless it is posted to the Notice board.

The software has helped to highlight a number of problems associated with distributed teams not normally seen in co-located teams or, at least, to the same extent. Many of these problems are related to the fact that a distributed design organisation working on a major project is an example of a complex system and is exhibiting behaviour patterns recognised in organic and other large scale self-organising systems.

5 Issues for Consideration

5.1 Human Factors

In order to develop a new approach to improve the development of a new product, it is necessary to understand the 'human' interfaces within a process like the Macro concept. Complex systems derive value from the relationships among their parts. These interactions make a system much greater than its parts. Rechtin notes that "the greatest leverage in a system is at the interfaces" [5]. Browning [6] points out that the key to managing teams effectively lies in ensuring proper interfaces between teams followed by facilitating the smooth transfer of information across these interfaces. One major issue concerning the management of Task teams is that different levels of task complexity between interdependent teams can lead to interface difficulties. For example, one team might have a "big picture" perspective of a project while another team can only see the detail.

The Task teams within this process must be responsive and highly effective, even in a distributed environment. The Task teams will be subject to performance measures to ensure their own performance is up to standard, but are empowered to perform the task, as they know best. The performance measures allow the Core team to monitor the activities and outputs of Task teams, and be alerted to difficulties or delays that could jeopardise the

project schedule. It is anticipated that the Task teams will be empowered to carry out the tasks. Increased empowerment leads to greater motivation and ownership of the task and hence greater accountability to deliver to the requirements. Teams that are empowered to a greater extent are more likely to develop strategies to ensure that their task is achieved.

5.2 Culture

One issue for teams like IPTs and Task teams is that they comprise of members from different functions, sites, companies or countries. Current research within the project has identified that this causes problems due to cultural differences between the different elements of a team. Culture does not only occur at a single level, say organisational level, it also occurs at subcultures throughout the teams. The structuring of work influences patterns of interactions found within organisations [7]. The division of organisations into functions and specialist areas has promoted a greater creation of subcultures. Each subculture develops it's own language, norms and perspectives on its missions and objectives increasing the complexity of the interactions between the subcultures. For example, cultural differences occur between team members from different functional divisions, or from different sites of the same organisation. One individual claimed a difference of up to 50% between the way one site works to another, and in many cases it was often felt to be like working with another company. Cultural differences also occur between different organisations.

Whilst a considerable amount of work has been carried out in this field, there is very little work that considers the composition and structure of these types of teams. Current research is leading to the development of a technique that can be used to identify attributes of culture that cause discord and misunderstandings within teams, between the different elements. This technique is anticipated to lead to more efficient team management and improved communication between team members. Greater understanding of this area of work is vital in an industrial environment that is becoming increasingly consortium based and globalised to a larger extent.

5.3 Supply Chain Issues

Initial considerations for developing the Macro Concept have been at the top level of the supply chain, i.e. whole product and major sub-system level. It is necessary to consider issues for the Macro Concept throughout the supply chain. For example, as the product decomposition cascades through the supply chain, it is probable that major sub-systems of the whole product, i.e. engines, wings, cockpit etc. will have their own sub-Core Team to manage sub-system development. As the decomposition cascades through the major sub-system these components might also have sub-Core teams to co-ordinate the management of several Task teams at a lower level. The Core-Task team arrangement becomes self-reproducing throughout the supply chain. One of the major consequences of this is that a Task Team member at one level of the supply chain might become a Core Team member to a task team at a lower level in the supply chain.

6 Conclusions

This new scenario is seen as a future product development framework to support aerospace companies in managing the difficulties of a distributed environment yet maintaining product innovation and flexibility.

The research team is itself, multidisciplinary in nature and distributed across different locations. The members have been using the software to test its value. In addition, another research project being carried out in the aerospace industry is being used as a testing platform for the software. This project consists of 15 different teams across several different countries. As new applications, ideas and tools are developed for integration into the software they will be installed for use by this team for evaluation purposes. There are many questions still to be answered during the remainder of the research work. For example, the decision processes involved in the

decomposition of a product for its development. One of the multi-national consortiums investigated during this research carried out high-level product decomposition based on the major functional components corresponding to each prime contractor involved. In another organisation, decomposition was based on geographical position within a single country. Whilst it is not uncommon in practise to find that product decomposition is based partly on political, historical or geographical reasons, the introduction of a distributed product development scenario increases opportunities for decomposing a product without having to consider geographical location as a deterrent to effective product development.

Other issues to be addressed during development of the Macro Concept concern the use of different product development processes. Using individuals from different organisations on the same team introduces issues surrounding the different product development processes applied by the respective individuals. It is anticipated that the Core Team will manage the complete product development process using a generic product development process. In order that team members within Task teams are able to work alongside team members using different processes, there will be guidance within the software and the workbook, on the alignment of different processes.

There is also the issue of information transfer. There is evidence that collaborating companies are often reluctant to share "knowledge" and information for fear of perhaps giving away their commercial advantage. One intention of the Macro Concept is that organisations will be able to work alongside other organisations without giving away information that may be of commercial advantage to another organisation. The collocation of team members together within a single organisation often gives individuals more access to information merely by being present within that organisation, than is intended. The Macro concept allows organisations to work together yet geographically apart reducing opportunities for information that may be of commercial advantage to one organisation to be discovered by others.

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