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PROCESS OPTIMIZATION AND INNOVATIVE WORK ENVIRONMENT FOR CONCURRENT ENGINEERING: CASE STUDIES IN THE AERO ENGINES INDUSTRY

Keywords: collaborative engineering, process optimization, web-conferencing, collaborative workroom

Abstract

User demands on their work environment during the development of complex products were analyzed in interdisciplinary concurrent engineering teams. The authors demonstrate that the current engineering process flow is characterized by alternating periods of high-intensity and standard-intensity cooperation needs. From this observation, a process optimization method is derived which groups periods of high-intensity cooperation requirements. For both of these periods, web-conferencing is the indispensable work environment. For periods with high-intensity communication the collaborative workroom concept offers valuable additional advantages.

1. INTRODUCTION:

Facing the challenges of internationalization involving international subsidiaries and joint ventures, MTU Aero Engines, a German engine company, simultaneously utilizes resources at various locations for engine design projects. Particularly highly complex components as used in aircraft engines make great demands on communication and cooperation among the design engineers. This is reflected in sophisticated specifications for collaborative work environments. The current analysis1 was aimed at assessing these demands. Moreover, methods to reduce the efforts for coordination of such design projects were investigated. This analysis which was performed in an industrial working environment is a cooperative project of MTU Aero Engines GmbH, the Chair of Ergonomics (Technical University of Munich) and 3D Systems Engineering GmbH (a product development consulting company).

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The communication and coordination analysis presented in this paper is based on the methods and results of the CONTACT project group [1]. They developed techniques to assign a basic hierarchy of 4 communication scenarios: 'information', 'coordination', 'decision making´ and ´problem definition and solution' – to increasingly complex collaborative applications [1]. In addition, the Media-Richness model was used as an investigational technique. It assigns the appropriate communication media to particular demands on communication and cooperation. Briefly, this model implies that the complexity of demands calls for an adequate richness of communication media including mail, email, fax, phone, PC conferences, video conferences, and finally face-to-face communication [2].

2. COMMUNICATION AND COORDINATION ANALYSIS

There are various methods for the systematic analysis of communication and coordination processes in concurrent engineering teams, such as the communication-process description language developed by the Technical University of Berlin [3], or the CONTACT communication plan [1]. Both methods differentiate between information flow and consultation/problem-solving. Information flow in these models basically means input for and output from the activities of successive processes, whereas consultation/problem-solving is aimed at coordinating simultaneous engineering processes [3]. Communication interfaces may be identified with the aid of the House of Communication methodology [4], Design Structure Matrix [5], or CONTACT communication plan [1]. The analysis described here is based on the CONTACT communication plan.

2.1 Communication and coordination in engineering teams

In a pilot study, communication and coordination during the design phase of an entire engine module (total process) was analyzed in a non-distributed engineering team. Media utilization by design engineers, broken down into information flow and consultation/problem-solving activities, was the main criterion for the assessment. For this intra-company survey, a standardized questionnaire was used.

The survey showed that approximately 2/3 of the communication activities were consultation/problem-solving and 1/3 information flow. As regards consultation/problem-solving in detail, oral communication dominated with 65%. Oral consultation/problem-solving in a non-distributed team was mainly managed face-to-face (see Fig. 1). A smaller fraction of verbal communication, i.e. about 25%, was reported for the information flow. The design engineers interviewed considered approximately 80% of the total information exchange to be necessary or at least useful for finding appropriate problem solutions.

The results of this study indicate that particularly consultation/problem solving, known to involve a high fraction of face-to-face communication, may pose problems for cooperation in distributed design environments, since it is particularly demanding to substitute face-to-face communication with collaborative applications.

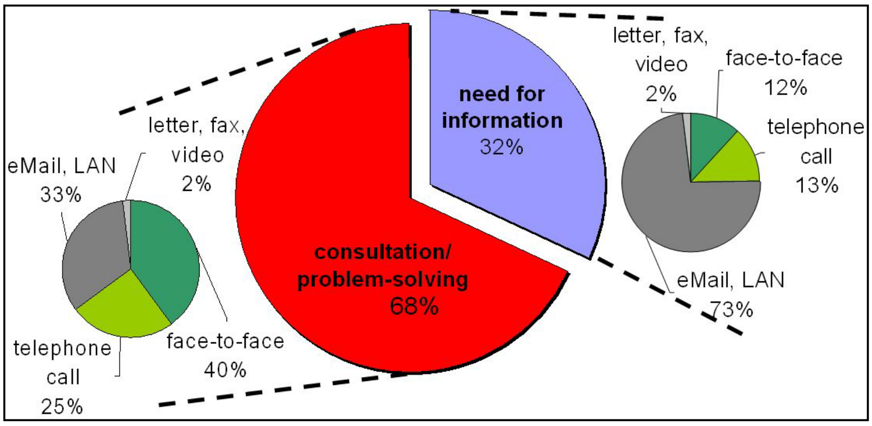

Fig. 1: Distribution of communication a non-distributed team

2.2 Temporal pattern, scenarios and intensity of consultation

In an additional study, the communication between a remote team (Rocky Hill, Connecticut) and the core teams (Munich, Bavaria) was analyzed. The Rocky Hill team (team A) designed an engine component. This process is referred to as a sub-process of the overall engine design process. We were particularly interested in consultation/problem-solving with the Munich teams (teams B1, B2, C, D) and recorded the communication scenarios and communication intensities occurring during particular project phases. Based on the communication plan developed by the CONTACT group [1], the Rocky Hill team, the Munich teams, and additional divisions such as production or product configuration were included in the communication plan shown in Fig. 2. The Rocky Hill sub-process was arranged along the time axis as a flow process chart. Consultation/problem-solving was symbolized by vertical lines, which started at a particular activity of the Rocky Hill process and pointed towards the associated activity of the communication partner. The line colors symbolize the respective scenarios. We choose scenarios slightly different from the original communication plan, i.e. information (blue), queries (violet), and solution/decision-making (red). Line thicknesses represented communication intensities, broken down into low, intermediate and intensive. During a workshop, the estimated scenarios and intensities were directly drawn in the communication plan by members of the teams involved. This procedure proved to be a fast and effective method to document the temporal pattern of these complex communication activities.

In the communication plan obtained (Fig. 2), periods of intensive and standard intensive communication are easily identified by the density of the vertical lines. Periods of intensive communication are supposed to occur in the second and fourth of the five process phases illustrated. In the second phase, the Rocky Hill team intensively communicates with the Munich teams and additional divisions. Prevailing scenarios include queries and solution/decision-making. The interaction intensities are particularly high with teams B1, B2 and C. High consultation/problem-solving demands also characterize the fourth phase. Here, the information and queries scenarios predominate showing a high intensity towards team C.

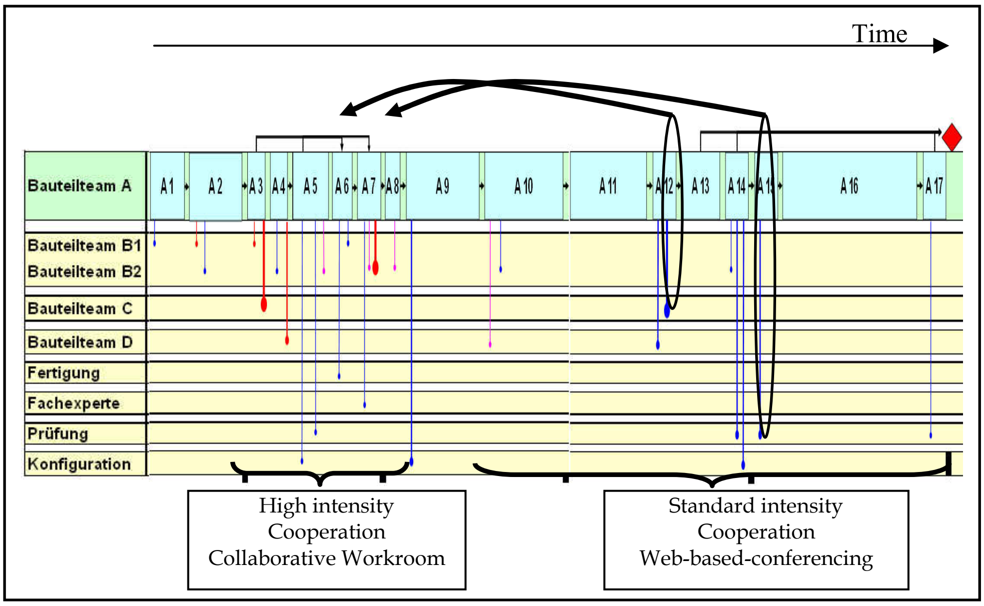

Fig. 2: Communication plan team A

3. INNOVATIVE WORKING ENVIRONMENTS AND COOPERATION PROFILES

This analysis demonstrates that communication intensities are not uniform, but may be subject to considerable temporal variability. Basically by their different consultation/problem-solving demands, two cooperation profiles could be identified:

- Standard-intensity cooperation is characterized by standard communication density, predominantly of the 'information' and 'query' type.
- High-intensity cooperation shows dense communication demands, mainly of the 'solution/decision-making' type.

These two profiles differ substantially in their demands on innovative working environments. In an additional step, we began to assess the suitability of different working environments to meet the requirements of standard- and high-intensity cooperation.

3.1 Web-based conferencing for standard-intensity cooperation

According to the Media Richness model, a conventional collaborative application such as web-conferencing appropriately meets the requirements of standard-intensity cooperation. Recently, Rupp [6] investigated the relevance of functional components of web-conferencing tools at MTU Aero Engines. In agreement with the results of others [7], whiteboard with graphic and sharing capabilities were considered the most relevant functions (Fig. 3).

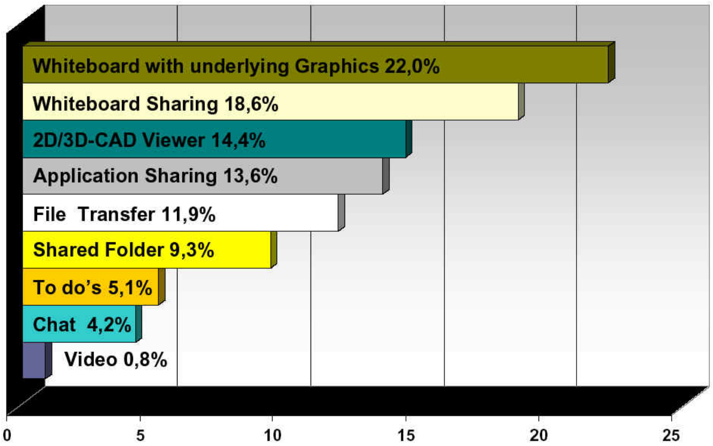

Fig. 3: Functional requirements for conventional collaboration tools (percent considered absolutely necessary) [6]

In an additional in-plant survey, product designers judged interchangeable graphic file formats sufficient for 3D-viewing during standard-intensity cooperation periods. However, at least one user should be able to rotate, move, measure, and zoom graphic models. A small video picture of the dialog partner may be useful at the start of each session, or if the partner is not personally known. Crucial for interdisciplinary collaboration are cross-platform capabilities (UNIX and Windows systems) and, mainly for out-of-plant contacts, high data security. High-end solutions such as application sharing were not considered useful during standard-intensity cooperation periods, particularly not in interdisciplinary communication. "Four tools could be recommended for implementation at MTU Aero Engines: E-vis, OneSpace, Sametime and Webex". The choice is also influenced by the tools external engineering partners use, "Therefore, it was decided to implement Webex and Sametime [6]".

3.2 Collaborative Workroom for high-intensity cooperation

In phases that require intensive communication among a variety of disciplines and that are dedicated to problem-solving/decision-making, effective means are required to support the corresponding team effort. A solution, called "design centers", has been successfully implemented in various fields of the aerospace industry [8, 9]).

Concurrent engineering teams use design centers (the term 'collaborative workroom' was used within the present project) to investigate alternative system designs and the related costs in a more integrated fashion than it was previously done. These teams focus on both technical and economic aspects of the system under definition. The efficiency of conceptual studies and proposals increases since the teams use integrated tools, perform their work in real-time concurrent engineering sessions, and benefit from their learning curve. The key elements of a Design Center are 1) the team working in the design center, 2) the process the team follows within its design sessions, and 3) the infrastructure that support the team in its work. These three elements will be presented in greater detail now.

The **infrastructure** is the element to support the team and the design process. The infrastructure comprises computers and software (according to the requirements of the interdisciplinary team members), central information repositories and a dedicated facility/room that is equipped with modern visualization hardware (Fig. 4) and a video conferencing system.

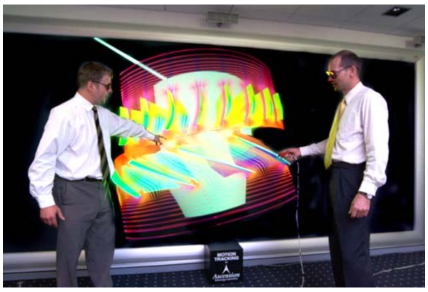

Figure 4: Example for visualization in collaborative workroom [10]

The second core element for a collaborative workroom is the **process** the design team follows. A clearly defined, structured and officially implemented macro-process is required. The macro-process determines the structures of the overall design tasks by being as simple as possible, tailorable and with clear check points and milestones. A definite assignment of responsibilities to the individual process steps is necessary, as well as a clear assignment of what the collaborative workroom team or what the departments are responsible for. The macro-process contains a number of design sessions in which the team meets to develop/improve the product.

Last but not least the **team** is the third core element of the Collaborative Workroom-approach. It is the most critical element: Working in a collaborative environment changes the way engineering development is usually carried out: It is important that team members fully incorporate the new philosophy of working together in an integrated team in real working sessions (not mere meetings). The team is usually structured into a core team consisting of technical and financial experts and, depending on the topic of a design session, the core team is supported by further specialists. These additional experts are invited to the sessions as required.

If the core elements described above (team, process, infrastructure) of a collaborative workroom are defined and implemented effectively, significant improvements can be achieved in product development processes. Especially in early design phases, in which the level of detail that needs to be modelled within the specialists' domains is not too deep, time savings of more than 50% have been achieved (e.g. the proposal process for entire aircrafts [11]). These time savings can be used to investigate an increased number of product variants/alternatives, which improve the quality of the product which in return reduces a product's life-cycle cost.

3.3 Process optimization for concurrent engineering

Collaborative applications proposed for high-intensity cooperation periods are cost-intensive and frequently used by different design teams in several projects. As a rule, they are not available on demand. Moreover, effective usage of these facilities implies a structured cooperation concept and intensive planning. It thus makes sense to combine temporally distributed high-intensity processes into few blocks. This allows the use of these facilities with optimum efficiency. With the aid of the Communication Plan, processes with high consultation / problem-solving demands are easily recognized and their time sequence can be optimized. In this project, it was possible to transpose single processes with high consultation / problem-solving demands from periods with otherwise standard communication intensity into blocks with high communication intensity. For instance, some design steps of the Rocky Hill team requiring frequent queries could be shifted from processes 12 and 15 to earlier project phases (Fig. 2) with known high cooperation intensity. Thus, the additional use of cost-intensive facilities could be avoided. Beyond its original intention, the communication plan can be used as a highly effective instrument for process modeling.

4. CONCLUSIONS

For the design of complex components, consultation / problem-solving is an essential mode of communication. In a non-distributed team, consultation/problem-solving is effected mainly face-to-face. To replace this communication mode in a tele-cooperative environment for spatially distributed engineering teams is particularly complex. Moreover, it was found that within the course of a design project, periods with high cooperation demands may alternate with periods of comparatively standard cooperation demands. For both of these periods, web-conferencing is the indispensable work environment. However, for periods with high-intensity cooperation, the collaborative workroom concept offers valuable additional advantages, such as high-end communication and visualization tools, process support, and data consistency for various applications. Efficient utilization of cost-intensive high-end communication tools is facilitated by temporal process optimization, i.e. by forming blocks of processes with high cooperation demands. In extension of the CONTACT group's communication plan, a valuable instrument for temporal process optimization was developed.

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