Results of an international Survey of the Implementation of Concurrent Design Centers

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INTRODUCTION

During the recent years a change and an increasing intensification of industrial constraints in almost every area of industry occurred, particularly in the sector of Astronautics. Indeed the progress of technical development mainly in the field of telecommunication- and information- technology enables today's engineers to concept and design exceedingly complex systems but it also challenges companies with accretive pressure in costs and time of development while quality standards arise. With this background, in the mid 90s, the idea of "Integrated Product Development" was formed and first implemented by Nasa (1994) and Aerospace Corporation (1999) [1]. ESA has implemented this approach in the Concurrent Design Facility (CDF) [2] and is now spreading this approach into European Space companies.

The Institute of Astronautics involved at the Technische Universität München did a survey in the application of concurrent design centres in industry [3] and training of students [4] in this research area did a survey about the practical implementation of this innovative method of product development in commercial and educational sectors [5].

With the purpose to present an overview of the current situation in assignment and configuration of CDCs, different operators were identified and contacted. Afterwards the different identified companies and Universities were questioned about the fields design-team, processes, tools (hard- and software) and infrastructure based on an online survey.

Additionally, the companies and research organizations had the opportunity to provide information about their specific experiences with the installation and operation of these Concurrent Engineering platforms. At the end of the survey, the results were analyzed and evaluated.

This paper will present the analysis of the evaluated data provided by companies and institutions as well of the published data in literature.

Overall, representatives of all facilities evaluate the experienced results of the recent years as consistently positive. Centres, which are mainly targeted at commercial issues, point out a drastic reduction in costs as well as in the reduction of time of development and a better embedding and identification of their employees. Research and educational facilities at universities focus on teaching future engineers this new method of design and training them in teamwork capabilities and soft skills, as well as providing the students with specific technical knowledge and the ability to use up to date software tools..

SURVEY

The Institute of Astronautics did in 2003 a survey in Germany to investigate the usage of concurrent engineering and use of design centre by German industry [6]. Whilst this survey was focused on all branches but mainly in the automotive sector, the study presented in this paper was done in 2005 focused the worldwide usage of design centres in space companies and organizations [5]. The results of the 2005 survey will be partially discussed with the results of the 2003 survey [6].

The first challenge in this study was to identify possible candidates for the survey and get in contact with them. Therefore in a first step a literature survey was done to identify possible companies and organizations. With this survey a list of contacts was generated to get a more direct contact for the third phase of the study.

The second step was to generate a list of questions based on requirement to get a general overview of how design center (DC), team organization, infrastructure, and tools look like at different industry and organizations. A side aspect of the survey was to get an impression of the financial implications when building up and have a design center running.

A questionnaire of roughly 60 questions was generated and a website (designcenter.systemsengineering.de) was created for the survey. The question were grouped into six categories

- General Information,
- Team,
- Process,
- Tools,
- Infrastructure, and
- Experience.

The reasons for providing a website to fill out all questions was to provide participants of the survey a possibility to do this in several steps as well as to copy information, if the company has several design centers on different locations.

After the questions and website had been build up and tested with data of institutes own design centre, all persons identified in step 1 were contacted by email. That who did not replied were contacted a second time more directly. From the feedback we got, some companies did not have a design center or they had not enough time to fill out the questionnaire.

Table 1 shows the list of 31 identified companies and organizations. As the design center at University Stuttgart was identified after the survey it was not contacted for the study.

Table 1. List of contacted companies and organizations

Operator	**Country**	**Information provided**
Arizona State University: Aerospace Research Center	USA	No
Astrium Ltd. – Satellite Design Office Stevenage	Great Britain	Yes
Austrian Aerospace GmbH	Austria	No
BAE Systems & Loughborough University: Systems Engineering Innovation Center	Great Britain	No existing DC
Boeing: The Center	USA	No
British National Space Center	Great Britain	No
Caltech: Laboratory for Spacecraft and Mission Design	USA	Yes
Cooperative Research Centre for Satellite Systems	Australia	No
Dartmouth College, Thayer School of Engineering: Engineering Design Centre	USA	No
EADS ASTRIUM GmbH: Satellite Design Office Friedrichshafen	Germany	Yes
European Space Agency: Concurrent Design Facility	Netherlands	Yes
Goddard Space Flight Center: Integrated Mission Design Center	USA	Yes
International Space University: Strasbourg Central Campus	France	No
Indian Space Research Organisation	India	No
Institute of Astronautics, Technische Universität München: Space System Concept Center	Germany	Yes
University of Stuttgart: Space Station Design Workshop	Germany	not contacted
Israel Aircraft Industries	Israel	No
Jet Propulsion Laboratory: PDC Team X	USA	Yes
Jet Propulsion Laboratory: PDC Team I	USA	No
Lockheed Martin: Advanced Technology Center	USA	No
MIT: Complex Systems Development and Operations Laboratory	USA	No
Newcastle, Engineering Design Centre	Great Britain	No registration yet
Northrop Grumman Integrated Systems	USA	No

Operator	Country	Information provided
Rutherford Appleton Laboratories	Great Britain	No
Saab Ericsson Space	Sweden	No existing DC
Spar Aerospace Limited	Canada	No
Stanford University: Space and Systems Development Laboratory	USA	No
Surrey Satellite Technology Ltd	Great Britain	No
The Aerospace Corporation, CDC	USA	No
The Italian Space Agency: Concurrent Engineering Facility	Italy	No
Wright-Patterson Air Force Base: Air Force Aeronautical Systems Center	USA	No

From the survey two different reports with the results were created. The first report contains all information including the answers of the participants. This version was sent out only to the participants. A second version with only the statistical results as presented here is available for everyone via the website.

RESULTS

The following viewgraphs show the answers of the participated companies and organizations. As most of the figures are self explaining only some interesting facts will be discussed and compared with the study from the year 2003.

Two interesting facts can be found in both studies the size of the teams and models used. In this study the team size at 88% of the participant is between 6 and 20 people. As each team member normally represents a subsystem this number can be compared with the number of subsystems in the German industry study where 68% have products up to 20 subsystems and 32% with more than 20 subsystems.

A second point regards supporting the design process by system models. In this study 56% of the participants use already models which over 50% uses dynamic models. In German industry 67% believe that a central parametric model is advantageous but only 40% have a parametric model implemented yet. This endorses the work done for creating modelling tools and models for designing space missions and systems.

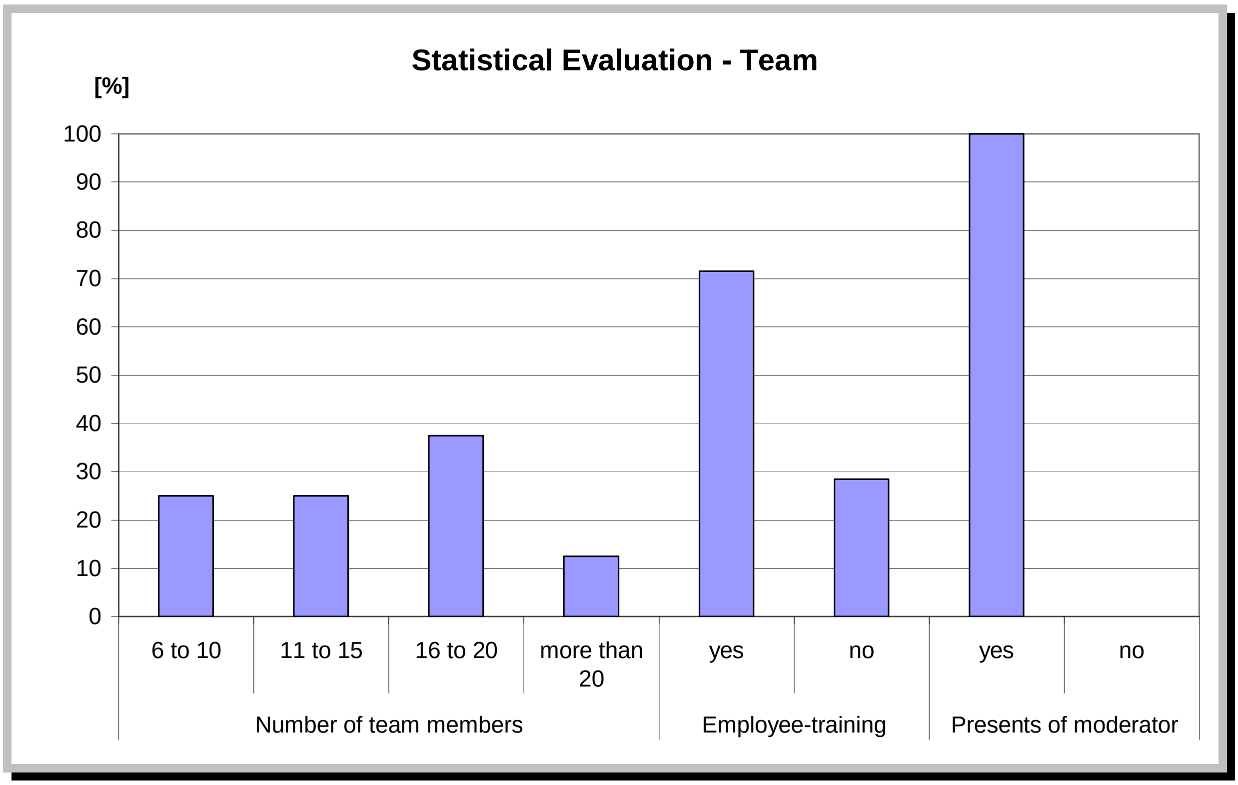

Fig. 1. Statistical Evaluation – Team

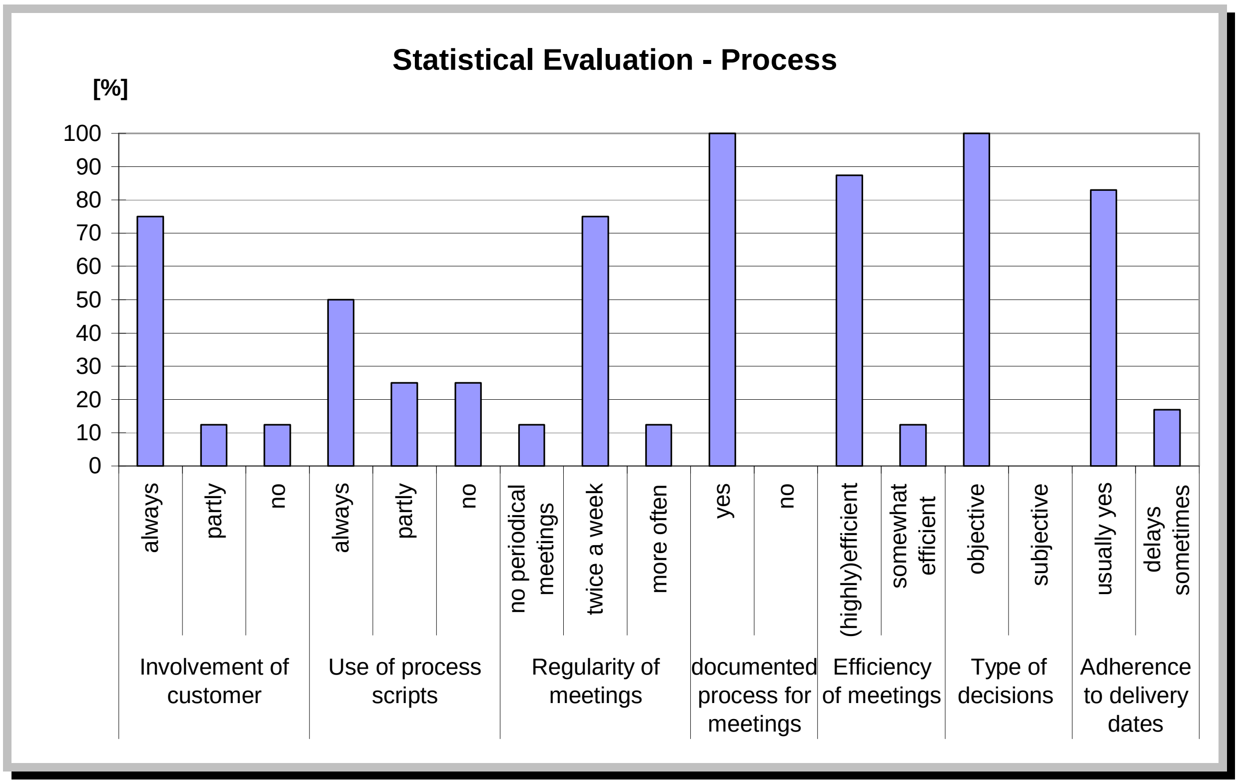

Fig. 2. Statistical Evaluation – Process

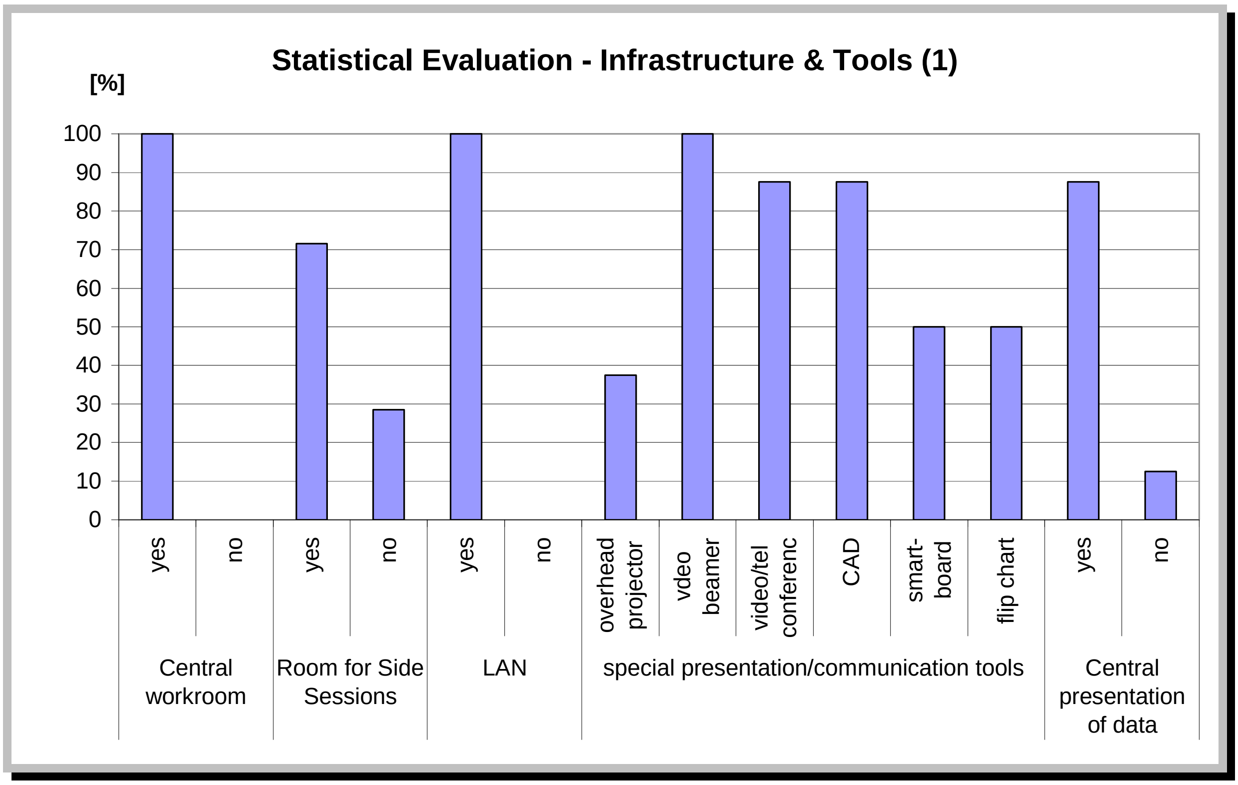

Fig. 3. Statistical Evaluation – Infrastructure & Tools (1)

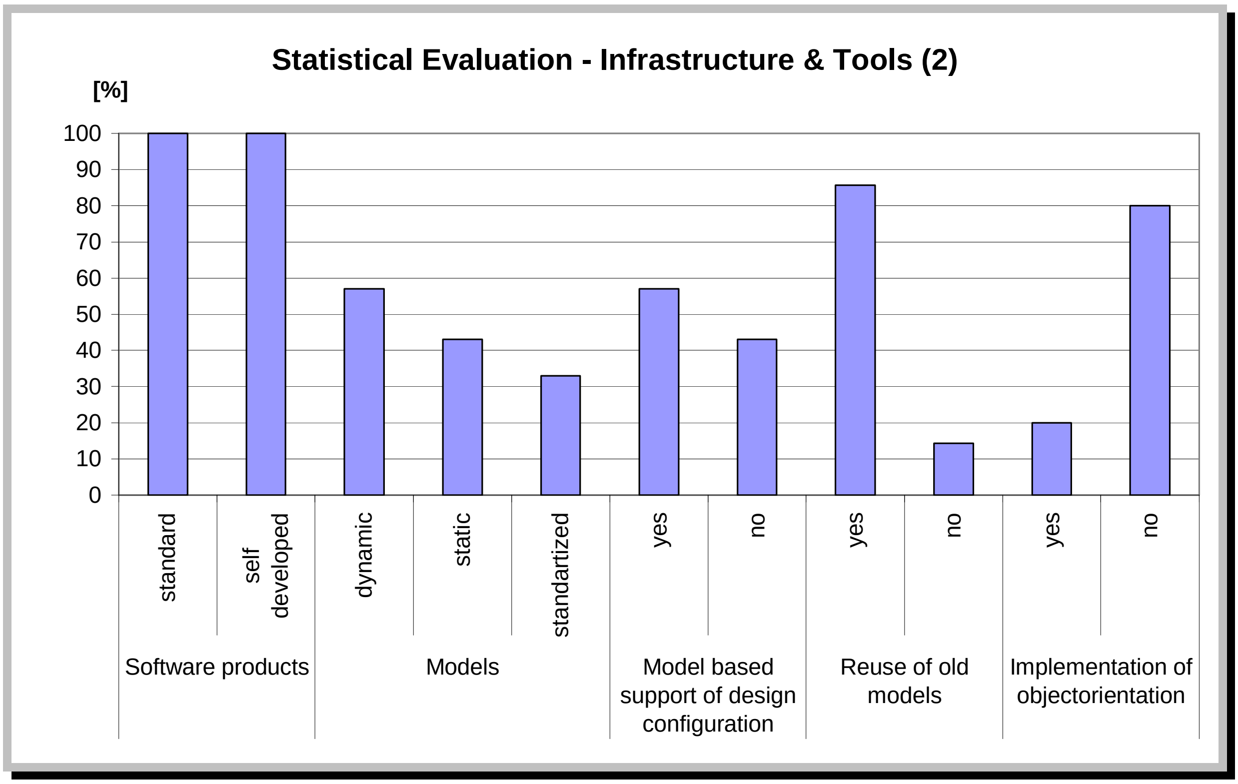

Fig. 4. Statistical Evaluation – Infrastructure & Tools (2)

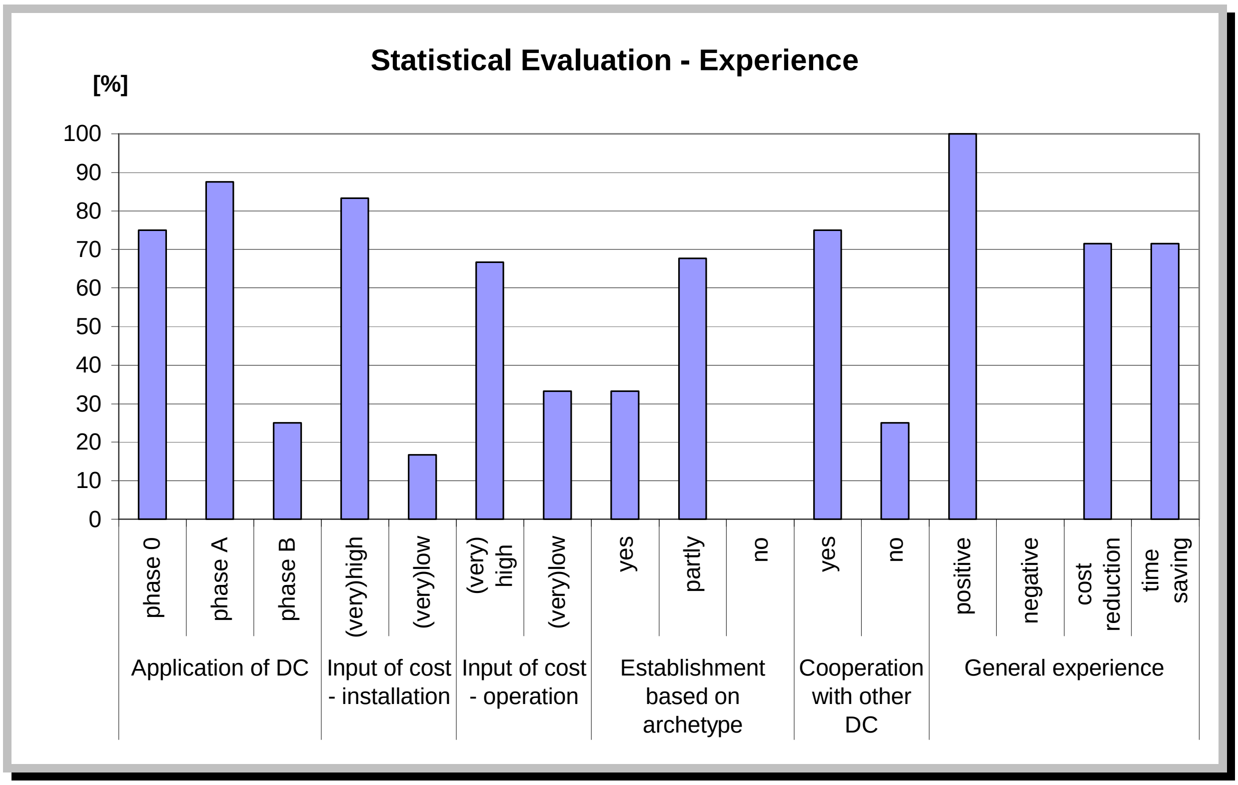

Fig. 5. Statistical Evaluation –Experience

RESULTS OF STUDY

Overall, the survey documents that all included operators of design centres evaluate the application of design centres as an excellent idea to face new challenges of complex systems and product development. Hence a diversification regarding the respective field of operation of the different facilities has to be considered.

Universities use this concurrent engineering platform mainly to familiarise the future generation of engineers with the methodology of systems engineering as well as to qualify students with specific software tools and applications. Additionally the students are able to enhance their theoretical knowledge in various fields of space systems and learn to collaborate in teams.

Facilities that are operated commercially focus on reduction of costs and time of development, whereas the quality of studies has already achieved a high level of standard. The involvement of the customer during the complete design process from the beginning of conceptual design to detailed definition of the system is an important step to ensure the achievement of objectives. Since the customer defines constraints and main goals together with design team representatives, the risk of failures is minimised. Compared to former conventional studies it was possible to reduce the time of completion for phase 0/A studies from months to few weeks, and it is not unusual to achieve a cost reduction of up to 75% [3]. Besides economic advantages there are also social advantages for the participating individuals. In a comfortable working atmosphere, which is absolutely essential for best results, team members are encouraged to expand their expertise by closely working together with other subsystem specialists. Hence they have the opportunity to get a wider overview of the system coherences and are able to see how their specific field of activity is embedded into the global design process.

Considering the statistical evaluation of the survey, some similarities and also differences attract attention:
The team size varies from small teams (6 to 10 members) to teams with over 30 participants depending to the actual task. A redundant allocation of subsystem experts is characteristic for Team X teams (JPL PDC), so that every discipline is represented by more than one engineer. This enables JPL to conduct several design studies concurrently and to interchange subsystem experts of different teams if necessary.

Every design team of the surveyed operators is supported by a moderator who leads and coordinates the Design Sessions. Often, the moderator has several other duties as well (e. g. primary interface for the customer).

All design teams follow documented processes during meetings. The level of detail of proceedings varies from complete structured processes to flexible adoption to the specific task.

To support the design process, most facilities are equipped with state of the art presentation and communication tools. Microsoft Excel (or Microsoft Excel based self developed applications) is the most common software to link the different involved departments together, so that changes in specific subsystem parameters influence the complete design status.

THE DESIGN CENTER PROTOTYPE

Another possibility to summarize the results of the survey can be expressed in a theoretical description of a design center prototype. For describing this prototype for each characteristic only those answers of the survey were used which represent an average value.

Everyone, who is willing to implement the idea of concurrent engineering, shall be aware, that for a successful implementation of a design center the team should be involved and included during the definition phase for the new design centre [3]. This includes the process definition phase as well as for defining the infrastructure and required tools and models used in the design center. Only when the team is involved in the definition phase, it will identify itself with the process and centre and provide best results.

The Team

Using the answers regarding team size and members (Fig. 1) from this survey the requirements for a design center team can be defined as following:

- The team in a design center consists out of 10 up to 20 team members and an additional moderator.

- The customer is also in the design sessions present.

The Process

After defining the team and it’s members, the next step will be defining the process which shall be used. The process varies from company to company. Therefore a general process can not be defined. Although certain characteristics can be identified from statistical results and summarized here (Fig. 2).

- The overall process which is supported by the design center approach shall be clearly defined and documented.
- The process steps during the design center sessions shall be defined by process scripts.
- The team should meet twice a week.

It should be mentioned that the process is not fixed after the first definition phase. Instead it should be revised from time to time by the team.

The Tools

As mentioned for process definition for tool selection a predefined set of tools can not mentioned here. Each company has internal constraints as well as the tools depend on type of system developed and the process supported by the tools, but some general aspects can be mentioned here (see Fig. 4).

- The tools provided for the team will be both standard software and own developments.
- The tools should allow a easy reuse of the models even they are not based on object oriented modeling methods.
- Dynamic models should be used during the design.

The Infrastructure

As the tools support the process the infrastructure will support the team with it’s process and tools. Even the tools and process are not clearly defined yet, some general aspects of the infrastructure can be derived from the answers in section “Infrastructure and Tools (1)” (see Fig. 3).

- The design center should be a dedicated room with the possibilities of side session. This can be achieved having smaller conference rooms or workrooms beside the design center.
- The design center shall provide enough space for all team members, customer and an additional moderator.
- As the team should do a model based development, each team member must be able to access the model and work with it. This workstation will also be the interface to the department represented by the respective team member.
- It shall be possible to create CAD models and present them to all team members.
- A video conference system should be integrated into the design center.
- Arrangement of the equipment shall allow having a central presentation board with minimum one beamer, a smart board, and flip chart.
- All computers are connected via LAN to enable to integrated work.

FUTURE PROSPECTS

A possibility for further enhancement is the efficiency of meetings as well as the overall quality of design studies and the development of integrated design models. Yet only some of the analysed facilities have already implemented or adopted a design model to support the precise design configuration. Another chance to improve the overall quality of design studies is a more extensive and specialised training, primarily for new employees. The advancement of cooperation between universities and companies could partly substitute such an expensive and time-consuming training so that new employees only have to be introduced to the specific software tools and particularities at the respective facility.

With further development of information technology applications as well as a further familiarisation of team members with these optimized or even new tools, it’ll be easier to conduct design studies in collaboration with Design Centres at different sites. As operators like NASA or EADS run several Concept Design Centres, partly distributed over several countries, this seems to be a great opportunity to utilise synergy effects of different teams.

But it must said, that due to the low number of feedbacks, the statistical conclusion should be censoriously questioned.

As the results of the study shall also provide the participants with information about how others have implemented the idea of design centres and which are the good lessons learned, it is suggested to repeat a survey in two yearly intervals with questions coming up from the participants. Possible topics for future surveys may be cover the topic of data exchange between design centres and simulation tools, detailed list of possible tools, or how to use the design centre in later phases of product development.

As not only companies are using design centres but also research organizations and universities, cooperation between industries specifying their needs and research organizations finding possible solutions can be easily achieved by extending the survey platform as a platform for exchange of knowledge and information.

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