Design Center – A Collaborative Environment for the Integrated Development of Products and Services

Armin P. Schulz[1], Stephan Finkel[2], Michael Wieser[2]

[1]3D Systems Engineering GmbH
Ruppertstrasse 26, 80337 München
Germany
email: A.Schulz@3dse.de
http://www.3dse.de

[2]Institute of Astronautics
Technische Universität München
Boltzmannstr. 15, 85748 Garching
Germany
http://www.Lrt.mw.tum.de

Abstract

Companies experience increasing pressure to reduce time to market while providing responsiveness to market. This forces companies to rethink their processes and organization in particular in product development. But often companies experience that process reengineering, organizational restructuring or high-end tools do not provide the expected results.

This paper addresses why existing approaches have failed to release the full improvement potential. To create excellence within product development, the authors propose an integrated, collaborative environment as a common platform. This platform is called Engineering Design Center (EDC) and has been originated in space industry by NASA's JPL. In the beginning used for conceptual design of spacecrafts, EDCs are now transferred into other domains like aircraft or automotive industry, where they find different applications.

This paper describes the basic elements of an EDC and a generic implementation process. Implementation experiences from various industries are discussed and success factors are derived. As an outlook, an application perspective for the development of services is described.

1. Background

Caused by increasing globalization of markets in aerospace business, companies are facing a new challenge: While customer's requirements are more and more demanding, development times for high technology products have to be reduced to stay competitive within a global market.

Existing approaches to address this problem incorporate in particular concurrent engineering that is conduct currently subsequent processes concurrently to significantly reduce development time. This front loading of downstream activities necessitate increased synchronization among concurrent processes, which is typically done by integrated teams. These teams also address the aspect of barriers among different organizational units by their interdisciplinary composition. High-end tools like engineering data management systems, computer aided engineering systems the development process is speed up additionally, i.e. cost for verification by hardware prototypes is reduced by virtual prototypes.

However these approaches do not release the full improvement potential within the product development. This is mainly due to their focus on single aspects of the product development, like process, organization, tools. Design centers aim at an integration of these aspects within a collaborative development environment as a common working platform for the standing team using a clearly defined process and interlinked tools (Oxnevad, 2000).

The initial design center idea was introduced by Nasa's Jet Propulsion Laboratory (JPL). The JPL Project Design Center (PDC) was formed in June 1994 to respond the new NASA imperative of "Cheaper, Faster, Better." (Shishko, 2000; Cline and Colleton, 1998). In the meantime there have been several successful implementations of design centers in various areas. Some are listed in the following table:

Design Center	Organisation
Project Design Center	Jet Propulsion Laboratory, NASA
Satellite Design Office	Astrium Deutschland
Customer Demand Center	Fairchild Dornier
Concept Design Center	European Space Agency
Space System Concept Center	Technische Universität München

Table 1: selected implementations of design centers

2. Elements of a Design Center

In general a design center aims at reducing time and cost to market while increasing quality to market for any product under development. Implementation of a design center is based a clear organizational embedding, a personal empowerment of the team members and creating an awareness for change within the affected organization.

Figure 1 illustrates the three major elements of a design center (Schulz et al., 2001; Wilke, 2002):

- process
- team
- tools and infrastructure

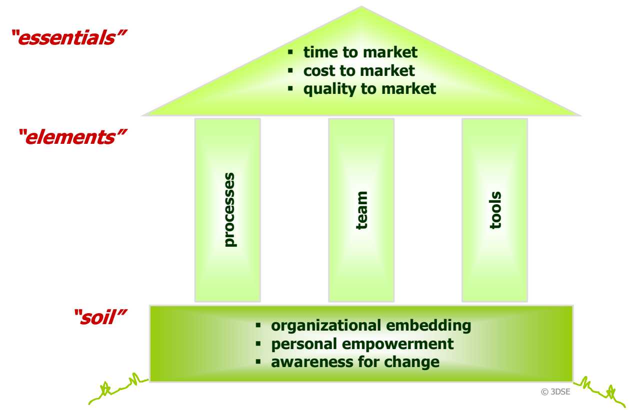

Figure 1: Elements of a Design Center

2.1 Team

The team is the most important element of a design center. It is providing the necessary knowledge and expertise to perform the assignment given to the design center. The team is further responsible for the entire process conducted within the design center that is the team is the process owner. In most companies teams are composed based on the mere availability of human resources, not on the availability of the right resources. Effective team composition is a major success factor of any collaboration in design. Therefore a structured method for "designing a design team" is necessary.

Team members are trained in using the necessary tools and comply with the process. The composition of the team is based on the necessary functional disciplines (e.g. subsystem specialists for the system to be designed) but also on the skills required for team integration. In order to achieve the agreed improvement, roles and responsibilities of each team member have to be clearly defined. This is especially necessary to prevent redundant work results. Basic prerequisite for each team member besides extraordinary skills within its discipline is its willingness and ability to view its own assignments in the context of the entire system under design. This includes not only the ability to evaluate alternative system design concepts in terms of their impact on subsystem design, but also changes within a subsystem in terms of their impact on system design. Design decisions continuously have to include these considerations.

Given a certain team assignment, the ideal composition of a team can be based on a structured process for selection of ideal team members. Besides technical skills within the necessary disciplines team members also have to provide for certain soft skills. Wilde based on the work by Myer and Briggs has investigated various roles needed for a complete team. He has come up with an approach to evaluate a team and its members concerning their judgment and perception domain. He found that an ideal team consists of certain roles, if a role is missing or represented by several team members the team performance deteriorates (Wilde, 1999). Besides this structured process team building activities are as necessary to set up a "team spirit" enabling a real team delivering high performance results.

2.2 Process

Two aspects drive the process within a design center: first, the overall assignment of the design center at hand, second, the interdependencies within the product to be designed. Thus the process is usually defined in two layers. A macro-layer incorporating the overall process structure divided into phases assigned to design sessions and a micro-layer structuring each session. The overall process should be as simple as possible, with clear checkpoints and gateways. Besides there has to be a definite assignment of responsibilities of team members to each process step.

The clear and documented structure of the overall process separates the responsibility of the team from other processes and defines its inputs as well as outputs. Complying to macro-process and the micro-process within each session has to be enforced by using "scripts", which may even be based on workflow management systems or the team leader, moderating each session.

While designing and implementing the macro- and micro-processes within a design center, participation of the team is critical for acceptance of the process, that is the team must own the process.

2.3 Tools (and models)

For a model-based support of the early product design stage the software ThinkSystem® has been designed. Using the software the product to be designed is modeled incorporating all subsystems in a generic language. Each subsystem is modeled concurrently by a team member based on its major properties and their functional interrelations. Thus the "design knowledge" of each subsystem specialist is captured in a common model, which also indicates interdependencies among subsystem properties and functions. Impact of changes can be easily detected. Alternative product concepts can be evaluated and compared. Inconsistencies among subsystem are prevented. Models can be reused in future projects. However ThinkSystem® cannot and shall not automate the design process. It is the design process based on reusable models, which increases transparency about design decisions and their impact for all team members and thus enhances the design process.

2.4 Infrastructure

The infrastructure of the design center is the real common platform for the design team, the design process and the tools. It aims at enabling the best possible collaboration of team members within their process using their tools. The dedicated room equipped with state-of-the-art multimedia technology ensures direct and interactive communication and information exchange among team members. Work results are displayed visible for each team member. Design decisions and their impact can be visualized and discussed in real-time. Application sharing and video-conferencing tools additionally enable an integration of development partners, suppliers or even customers into the design process. Figure 2 exhibits a possible layout of a EDC type infrastructure.

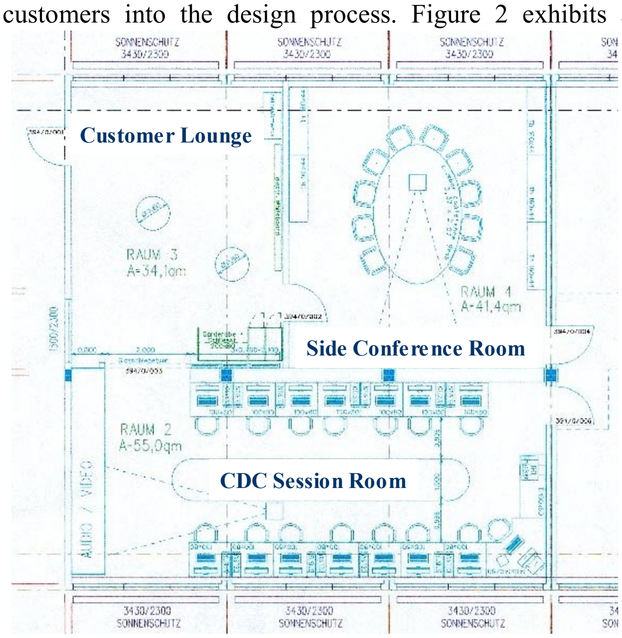

Figure 1: The Customer Demand Center at FDC [Finkel et al. 2002]

3. EDC Application for Hardware Products

3.1 Satellite Design Office (SDO)

Unlike JPL`s PDC the Satellite Design Office at Astrium is focused on satellite system design instead of overall mission design. Within the SDO concept studies and fixed-price proposals were established faster and at higher quality than before. Better means, increased overall consistency, number of alternatives, traceability and reproducibility of the process were major benefits of the SDO approach (Mager and Hartmann, 2000).

The idea underlying the SDO was to use the methodology of concurrent engineering as well as state-of-the-art information technology. Concept studies or proposals shouldn't be done sequentially and paper based, but integrated, concurrently and model based.

The models used within the SDO also capture the design knowledge of the early satellite design (i.e. cost models; Hartmann and Quirmbach, 2000; Quirmbach, 2001). This results in a transparent and readily available experience from former projects, that is easy to retrieve and ready to use. Standard templates were provided, to fully document the process within the working sessions, that by the end of the SDO process the satellite design documentation is automatically already finished.

Already in its first year of operations the SDO indicated a significant reduction of cost and time. By using a standardized working philosophy, a high performance team in an adequate multimedia environment, with appropriate engineering specialty tools, it was possible to deliver proposals at a higher level of quality, while reducing cost and time (Wilke et al., 2000a).

3.2 Space System Concept Center (S2C2)

To provide aerospace engineering students with the latest knowledge about team based and concurrent design of spacecraft, the Institute of Astronautics decided to offer a design center workshop called "Space System Concept Center" (Vollerthun et al., 2000; Wilke et al., 2002b). To achieve this goal, the S2C2 - workshop was designed in such a way, that students get their first hands-on experience in:

- Spacecraft design
- Systems engineering and modeling
- Teamwork and concurrent engineering

To cover all domains in the workshop, the students had to develop not only their subsystem models, but also design their subsystem as part of an overall satellite design. The results of the overall system design had to be summarized in a final report and presented to the employees of the institute (Schiffner 2002).

To provide a state-of-the-art infrastructure one of the institute's laboratories was reconstructed. Similar to the SDO the focus within the S2C2 is within the early phases of satellite design. To enable a conceptual satellite system design within one week the software MuSSat (a predecessor of ThinkSystem®) is used, which has been developed by the Institute of Astronautics in close collaboration with Astrium. Within MuSSat a model of the satellite is used for parametric design of the spacecraft concept and its critical properties (Wilke et al., 1998; Wilke et al., 1999].

Besides that the S2C2 is used as a research and test facility. New methods, processes, and tools concerning the design center approach are developed and verified within the S2C2. Results are used to adopt the methods, processes, and tools under development and then transferred into various industrial domains.

With the realization the S2C2 environment a new way engineering education is provided. The tendency towards a specialized engineering education is in strong contrast to the demand of companies. The S2C2 concept may educate engineering students in terms of interdisciplinary team and an concurrent design approaches.

3.3 Customer Demand Center (CDC)

The CDC is a design center used for the preparation and management of customer related aircraft modifications (options). All design centers implemented so far aim at developing concepts for space missions or satellites, i.e. they are used to- define a system rather than to develop concepts for the modification of existing systems. The application of the design center approach at Fairchild Dornier (FD) differs from the other design centers, as it is tackling a different product (aircraft) already in service (Do 328 family). As demand for their products increases, Fairchild Dornier is committed to meeting their customers' requirements using the most advanced equipment and processes in the industry. Within this effort, the preparation of proposals for customers interested in the procurement of 328-aircraft was supported by the design center approach. The goals for Fairchild Dornier's Customer Demand Center were similar to its predecessors in space business in terms of reducing time and cost, as well as to enhance process transparency.

To realize the project a phased approach was chosen. Before starting with the CDC-implementation, a study was performed to assess the potential benefits and the required organizational changes to implement a concept design center into the proposal process. One of the most important steps during the Prototype Stage of the project was the definition and formulation of the CDC's tasks and responsibilities. Based on the defined responsibilities, the relevant business processes had to be mapped to ensure the set up of optimal processes within the CDC. After the definition of the main elements of the CDC, the Customer Demand Center had to be established not only in hardware but also the organization's awareness (Finkel et al., 2002).

To prove and possibly adapt the concept, a pilot operations phase was initiated. The CDC concept included one standing core team, having life-cycle responsibility for the planning, as well as the initiation and management of the entire option proposal, and development process. Team members covered all organizational units, participating along the process. The team, working within an appropriate infrastructure (see figure 2), used a specifically tailored process, supported by engineering specialty tools and models (i.e. cost model).

Results of pilot operations already indicated significant savings in terms of time, although some areas of improvement remained. Measures for the identified fields of improvement were taken, so that a further reduction of time and cost can be reckoned.

4. DC Application for Service Products

4.1 Why service products?

In Germany right now only 30,7 % of the country's gross national product are obtained in the secondary sector (industry), but 68,0 % in tertiary sector (services). 2/3 of the employees work in the tertiary sector. In the USA the economy is even more service focused (industry 18% and services 80%). Having a closer look at the production sector some 40% of the employees are involved in "hidden" services. Therefore there is an even bigger application area for the design center idea beside the traditional hardware products domain – the service products domain.

Services are usually not seen as independent products of a company and aren't defined as products while i.e. goods or software are. Often there is no documentation about service contents, what the services are about, or about the processes or resources, that are necessary to deliver the services. Services often exist by chance. "Total customer care" is a main strategy to keep competitive in a global market. That means a company is required to meet all customers' needs - satisfied by products and services. In consequence, most of the companies indeed do not meet all customers' needs. Meanwhile more and more traditional companies are getting aware of this gap and thus offer tailored services in addition to their products. For example, in automotive business, navigation and on-route information services are provided in order to satisfy all different kind of customers needs.

As rather mature engineering methodologies for development and deployment of products already exist, there might also be a structured way to develop services, called "service engineering". Besides that, the EDC approach will be helpful in speeding up the service development process.

The system "service" can be seen as an hybrid product, namely as an integration of a technical and a social system, whose balance can differ in dependence of the service, that is offered. To develop such hybrid products, there are a lot of interdependencies between the material and immaterial parts of the product. For example, different designs of the physical product influence the services, that can be offered or can't be offered, and also vice versa. Therefore it is very important to integrate the service discipline in the entire product development process in order to adapt the product elements to the service elements.

4.2 Range of services

On one hand there are services with a high degree of automatism (e.g. telecommunication), on the other hand there are also services with a high grade of interaction, which is the social content between humans (e.g. consulting). If you look at services with a high degree of automatism, those services can be developed in a similar manner as technical products. Services with a high grade of social content are not as easy to develop in a straightforward way. The process and the result of those services can be often nonrecurring and cannot be developed in advance. That does not mean that concepts for those services cannot be developed within an EDC type environment. Nevertheless the system “service” exists of many more components und activities than just the interaction between the service provider and the customer. Think for example of a trip on an airplane from A to B: The social contents at the check-in and onboard the airplane are very visible and important for the customer, but the service consists of much more than that, e.g. get catering on board, get fuel in the airplane on time, get luggage into the right airplane, etc. All these processes behind the line of services visible to the customer have a high potential for optimization. Therefore these can be developed within an EDC type environment.

4.3 Differing process and team

Looking at the model of a common manufacturing process, then you see that there is usually an input from the customer at the beginning of the process (user requirements) and an output from the company at the end of the production process (product). The production process of a service is usually synchronous to the consumption process by the customer. In consequence, the process is visible for both the service provider and the customer. Some activities are iterative, last a longer time and include several interactions with the customer. Some activities may be invisible for the customer and the service provider.

Modeling the service process enables the service provider to get a better understanding of what activities are needed for a specific service. For example, the service provider can identify invisible activities. Resource requirements for these different types of activities may be quite different. While visible activities typically need highly qualified personnel, invisible activities may be automated or done by less qualified personnel.

The team designing a service product within an EDC type environment has to be supplemented by a representative of the service team, stating the requirements from a service point of view. The more visible the service, that is going to be offered is, the more members from the service team have to take part in the EDC sessions.

5. Benefits of introducing a Design Center

The implementation of a design center approach significantly changes the „organizational landscape“ of an enterprise. These changes usually evoke resistance and skepticism among employees. These barriers may be overcome by clearly communicating the strong benefits of a design center approach. Some major benefits, which have been identified and validated in various implementations are listed and elaborated below.

5.1 Reduction of cycle time

Using an overall model based system development process, enables all team members to focus on the creative part of design and not to bother about formalisms and routine tasks. Models can be reused since most products exhibit a similar structure for several product generations. Subsystem interdependencies captured within the models enable a straight and direct interaction, point out inconsistencies on system level and illustrate the impact of changes. Consistency within system level design is achieved much faster than without using any models.

Besides using models, in particular the close collaboration of all team members working as a standing team in an environment, which provides all necessary tools shortens the time spent on iterations. The almost complete concurrency of all activities of the design process within the EDC enables significant cycle time savings of up to 60%. The team is able to perform design decisions on system and subsystem level in real time and considering all relevant aspects.

All EDC type environments introduced so far have published metrics about realized savings in terms of cycle time. NASA’s PDC could cut cycle time by a factor of five. SDO and CDC have published similar figures.

5.2 Reduction of cost

Reduction of cycle time directly translates into cost. The more often the process now run in the EDC is repeated for various programs or projects, the more significant cost savings will be. For an average of 12 projects run within the EDC a break even of typical EDC investments will be reached within twelve months. Doing more projects using the EDC approach, break even will be even shorter.

Indirect cost are reduced by sound design decisions reached on a system level and by the entire team. The structured process including clear responsibilities reduces redundant activities. High quality of designs already in the early design stages reduced the probability of necessary changes in latter design stages causing high cost (“rule of ten”).

All EDC type environments introduced so far have published metrics about realized savings in terms of cost.

NASA's PDC could cut cost for delivering a proposal from US$ 250.000,- down to US$ 70.000,-.

5.3 Enhancement of quality

The increased consistency of system level design by using models and reaching design decisions within the entire team greatly enhances design quality. Each aspect of system and subsystem design is considered when deciding about alternative concepts, design baselines, and final design. Thus already during early design stages a rather mature system design is resulting satisfying all relevant requirements. Savings in terms of cycle time may partially be used to investigate additional design alternatives, which further increases the quality and maturity of the eventually selected design alternative.

Since all design decisions are well documented, it is possible to reconstruct the decision making process. Design decisions are linked to requirements. The impact of changing requirements on the concept under investigation can readily be evaluated to make the design robust towards such uncertainties.

5.4 Management of design knowledge

Modeling the product as well as the process captures the design knowledge of the enterprise and makes it readily available and usable for other teams. Design decisions become very transparent and reproducible. Design decisions my even be re-evaluated under new circumstances. Knowledge is no longer stored in paper based documents and filing cabinets but in executable models.

Based on models, it is also possible to break down the product into modules, which might be used for various applications. Identifying such modules enables a company to provide different variants of product with less effort. Knowing the critical properties of products is a key advantage to respond quickly to changing markets. New products can be developed in a shorter time and old products can be kept competitive by upgrading few key properties.

6. Conclusion

Design centers enable significant improvements within early product and service development in terms of:

- cycle time reduction (up to 60%)
- cost reduction
- quality enhancements

A design center typically consists of a core team, responsible for the entire process with clearly defined roles and responsibilities. The team is supported by a transparent and well-defined process, structured in sessions on a macro-level and in scripts or checklists on a micro-level. The design centers infrastructure equipped with engineering specialty and multimedia tools enables real design sessions of the team and an interactive communication of the team. Work results can be produced and discussed with the team in real-time and provide the basis for rapid iteration cycles.

The implementation of a design center approach significantly changes the „organizational landscape“ of an enterprise. These changes usually evoke resistance and skepticism among employees. Efforts to overcome these barriers like intense communication, integration, training and coaching of the team are often undervalued. But in particular the acceptance or rejection of the approach by the people within the organization decide about success or defeat of a design center.

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