Frank-Lothar Krause
Editor

The Future of Product Development

Proceedings of the 17th CIRP Design Conference

BERLINER KREIS
Wissenschaftliches Forum für Produktentwicklung e.V.

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With 298 Figures and 22 Tables

Springer

Editor

Professor Dr.-Ing. Frank-Lothar Krause

Fraunhofer IPK
Pascalstr. 8–9
10587 Berlin
Germany

frank-l.krause@ipk.fraunhofer.de

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Preface

Product development is changing since its early beginnings. Especially since the time of industrialization the speed of this change has constantly grown. The 1960 saw the introduction of computers into product development. The development of computers and software are amazing artefacts. Product development methods have been generated for the use in teaching as well as for the use in industrial processes. Most of the methods have been created without the usage of computers. That means that even today conventional methods are still dominating and large numbers of tools and systems are used for the support of product development processes. However, still missing are methods of computer integrated product development.

»The Future of Product Development« comprises 68 papers from more than 20 countries. It is a collection of current industrial views and of research results. Three major industrial companies outline their demand for better product development, followed by the major vendors in the field giving their reply. The remainder are papers on current RTD.

The conference can be seen as a mirror of international tendencies in product development in the year 2007. It shows the urgent need for change in product development and for new solutions. The presentations in this conference are therefore of direct help for the industry and stimuli for ongoing discussions on enhanced product development. In this sense the presentations and the connected discussions are in turn initiating new research.

Despite its complexity the program is very much focused. Without the activity of the international program committee the conference program never could have been assembled. The merits for content and quality of the papers belong to them only.

Without the sponsors the whole approach, including the industrial and scientific exhibition as well as the large number of talks would not have been possible. Our grateful thanks go to all of them.

CIRP, the International Academy of Production Engineering has a long tradition in conducting Design Conferences. It is a great pleasure and obligation that Berlin was chosen for the 17th CIRP Design Conference. For the first time the conference was jointly promoted by CIRP and the Berliner Kreis – Wissenschaftliches Forum für Produktentwicklung e.V. (scientific forum for product development, a group of german speaking professors working in the field of product development). This co-operation is a unique opportunity to exchange experiences and ideas between industry and academia.

The proceedings give a very precise overview about the state of the art and ongoing changes in product development. We hope that they are of help for the industry as well as for research and teaching.

For all their special encouragement and help I would like to thank my chief engineers Helmut Jansen, Christian Kind and Uwe Rothenburg and the members of my group.

I thank the publisher as well as the typesetting and image editing team for their creative support in preparing the proceedings for print.

Berlin, March 2007
Frank-Lothar Krause

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PDM/ EDM as Integration Layer for Continous Workflows Based on Relevant Product Data

K.H. Mühleck

CIO Volkswagen Group,
Volkswagen AG, Wolfsburg, Germany

PDM and PLM are presently being widely discussed in the automotive industry. The car manufacturers demonstrate quite different technological approaches and advances. Nevertheless, the practical implementation is often insufficient.

Following several successful pilot projects at the Volkswagen Group, last year a start was made with the complete conceptual planning of a Group-wide implementation of a PDM/EDM program. The growing demands in regard to product range, shortened development cycles and increased efficiency have led to changes in the organisation. Last year Volkswagen began with the successful restructuring of the organisation including the introduction of vehicle-based business management, "project houses" (Projekthäuser) and so on.

In order to holistically fulfil the set goals in the Group, work processes had to be further adapted from a vertical to a horizontal structure. This is possible only in conjunction with substantially greater digitalisation and virtualisation. In order to do justice to the future demands in all segments of the process, it was necessary to introduce integrated Product Data Management (PDM) throughout the entire Volkswagen Group. PDM ensures integrated work processes with the respectively relevant product data throughout the entire product life cycle from design to development, production, sales, after sales all the way to recycling.

The introduction of PDM resulted in three main points of implementation for Volkswagen:

1. Further development of the work processes
   Optimisation of work processes throughout the product life cycle for the brands and model families in the Group.
2. Integration of the required product data
   Adapted to the new process, the required data are made available to the respective target groups (designers, prototype builders and so on) via integrated workplaces.
3. Disentanglement and simplification of the IT system structures
   In the course of preparing data for specific target groups, the existing IT system structures will be examined. Systems which are no longer required will be retired and the important systems will be integrated as far as technically possible.

DMU@Airbus – Evolution of the Digital Mock-up (DMU) at Airbus to the Centre of Aircraft Development

R. Garbade[1], W. R. Dolezal[2]

[1] Senior Manager DMU Integration, Airbus Deutschland GmbH, Bremen, Germany
[2] DMU Integrator, Airbus Deutschland GmbH, Bremen, Germany

Abstract
The Digital Mock-up within Airbus has emerged from discrete applications to full 3D Aircraft design and development. Since the late 1990s programmes like A340-500/600, A380 and A400M have paved the way for integrated DMU operations across Airbus and its supply chain.
One cornerstone detailed herein is the Product Structure. It is vital for concurrent distributed collaboration with the Configured DMU and draws on dedicated views on the Aircraft to satisfy individual disciplines' requirements for ways of working. Another crucial element is DMU operations over the Extended Enterprise (=Airbus plus partners and suppliers). It ensures that everybody can work with latest, complete and configured Digital Mock-up data.

Keywords
Configured Digital Mock-up (CDMU), Product Structure, Data Exchange, Extended Enterprise

1 Introduction

This numbers denote that the amount of reduction in the variability of response obtained by using regressor variables is about 97 % and it is about 93 %, if it takes the number of regressor variables into account. Furthermore, the sensitivity analysis is carried out in order to assess which input variables are the important factors in affecting the variability of each response as well as the overall desirability function. Additionally, this information is also useful in understanding which inputs are the limiting factors in the response variability and which efforts should be carried out in reducing the variability. By carrying out the t-test which compares the estimate value of each factor with its associated standard deviation to result in the t-ratio, the significant factors can be determined. Those are the process lead time, the resource number and the interaction between both factors. They have significant high values of t-ratio. They also have significant less probability of getting greater t-ratio than 0.05 (probability of significant level) which means rejecting the hypothesis that the parameter is not significant in the model.

Functional verification of landing gears. The Digital Mock-up was then used only selectively in everyday design. Stringent aerospace requirements and insufficient IS/IT hardware and software performance ruled out – for the time being - 3D CAD to be applied on a larger scale.

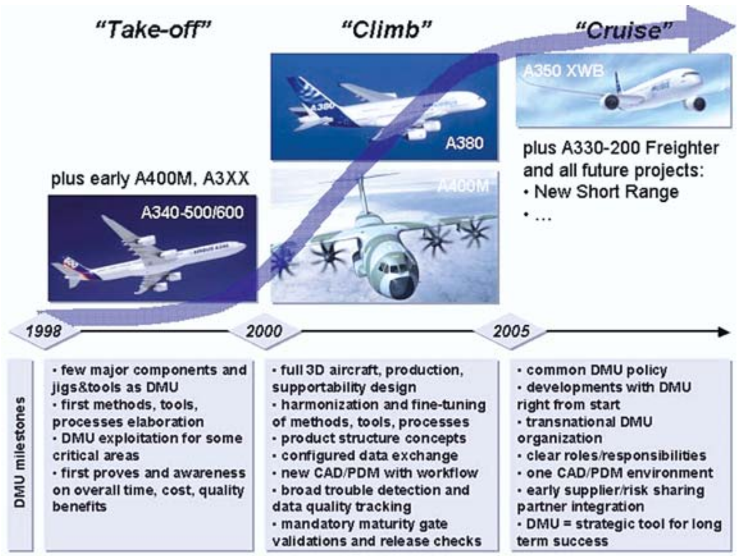

Fig. 1: Three phases of Digital Mock-up developments in Airbus

That changed in the second half of the 1990s. Feasibility studies and early concept design for A3XX (later named A380) and the military transport aircraft A400M already started in 3D. But it was the launch of the A340-500/600 Programme (long range derivatives of the basic A340 aircraft) that proved the advantages of a DMU for major components: it were both a business decision for keeping budget and schedule as well as higher IS/IT performance that were decisive in 1998 for going for a Digital Mock-up as complete substitute of Hardware Mock-ups. This wasn't done for the whole Aircraft though, but for assembly/integration critical areas.

Full-scale developments of A380 and A400M then broadened the knowledge base tremendously on how to create, exploit and manage the DMU. It was the time of "climbing" to new heights of developmental sophistication. It laid a solid foundation for latest Aircraft programme launches such as the A350.

The Configured Digital Mock-up (CDMU)

The definition of the DMU in Airbus is shown in figure 2:

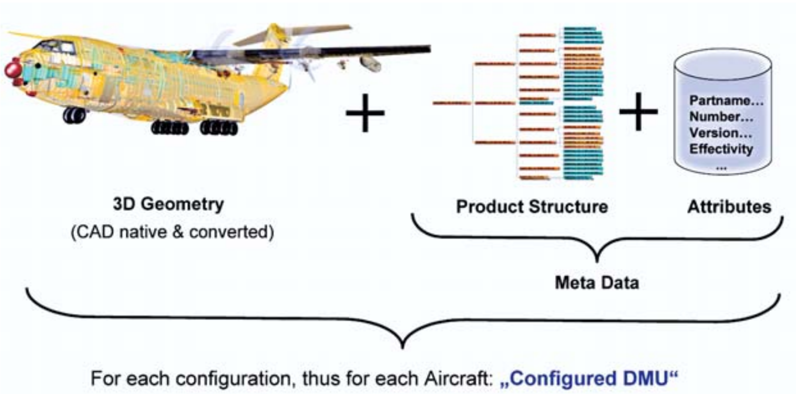

Fig. 2: Definition of the Configured Digital Mock-up at Airbus

The Configured DMU is more than a digital replica of a single Aircraft: each customer configuration, each study or investigational scenario is retrievable from the database. This is made possible by a sophisticated effectivity management based on relatively few configuration attributes. It is the basis for distributed concurrent engineering of both heavily customized products for the operators and parallel development of an aircraft family (e.g. passenger and freighter versions, stretched and shortened versions).

From an organizational point of view, DMU specific work commenced locally in Design-Build Teams, when a few designers started focusing more on issues like product structure handling, data exchange, trouble detection and visualization support during reviews. With new programmes that community grew fast. The job of the "DMU Integrator" began to emerge, with dedicated tasks, individual roles and new responsibilities. Realizing their key role for enabling concurrent creation and exploitation of the CDMU the DMU

Integrators from all four Airbus national companies are now being bundled in a single transnational organization. That enables harmonizing the ways of working with the DMU, leverages knowledge transfer across programmes and draws on synergies of core competencies beyond national borders.

Two crucial elements of DMU helping to meet the challenging objectives are explained on the following pages: the Product Structure and DMU operations across the Extended Enterprise.

This paper focuses on the product DMU itself, hence the Aircraft. There are, of course, other DMUs as well: e.g. 3D jigs and tools, production- and transportation facilities that usually fall under the "Digital Factory" realm, or DMU test benches and operative equipment that is developed and verified by the Supportability community.

2 Selective Cornerstones of DMU Development

2.1 The Product Structure

If the CDMU is the basis for 3D design activities, the product structure is its very heart. It is more than merely a "simple" breakdown of the Aircraft, and it is more than a drawing tree. In Airbus, the product structure is an *organized collection of business and technical information* related to the Aircraft. It not only takes into account the hundreds of thousands of parts that constitute the Aircraft itself. It is also the result of careful considerations concerning work-sharing, industrial flow, regulations of authorities, change process and configuration management as well as multiple requirements documents.

The product structure concepts were elaborated in the wake of A380 and A400M projects. The aim was to develop and implement standardized and transnationally harmonized rules how to best organize data and information, giving different disciplines their points of view on the product they prefer most for design and development. Thereby the visibility of the DMU in either view, customization and parallel working had to be ensured.

Data and information can be accessed in several *views*. These views arrange the data differently in very specific breakdowns, depending on priorities. Hence, the same item may belong to a contractual function, a design function, to an assembly or to a maintenance task. In everyday design the product structure is a working tool for thousands of engineers.

The two most dominant product structure breakdowns are the

- *Functional breakdown*; this is basically the point of view Engineering has on the aircraft. It decomposes the aircraft functionally top-down to major components, sections, zones, assemblies, sub-assemblies and to the single parts themselves.
- *Manufacturing breakdown*; it is the manifestation of how the Aircraft is assembled, in fact the bottom-up approach, from single parts to assemblies, sections and further up.

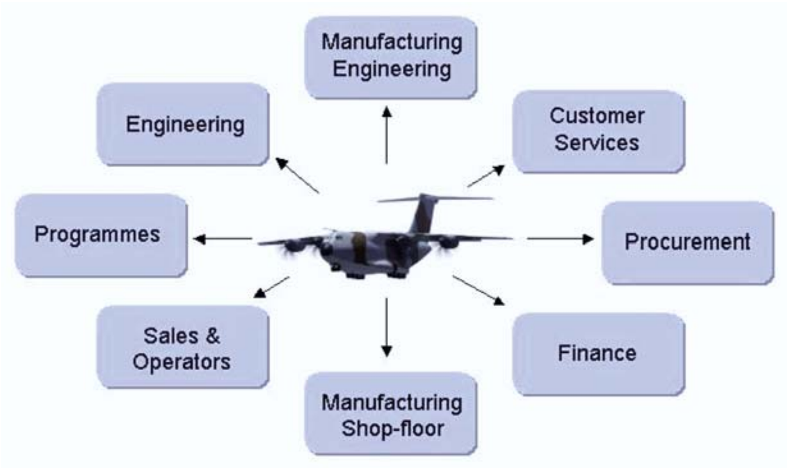

Fig. 3: Different disciplines extract their views from the Aircraft

For daily CDMU operations, three views have emerged as the most relevant ones; they are presented in figure 4 below:

The so-called *As-Defined* view is the major CDMU breakdown in the early phases of design. It organizes all different kinds of auxiliary models that are necessary for design trade offs: space allocation models of structures, systems and equipments, interface models, master geometry (loft and major reference planes and axis) and layout models. Till the end of Definition Phase these models are validated through maturity gates. Once sufficiently defined they remain in a “frozen” status. While design engineers converge to the best trade-off, manufacturing engineers can start elaborating the best built-concept based on As-Defined data. That takes place without interfering with the Engineering-preferred breakdown.

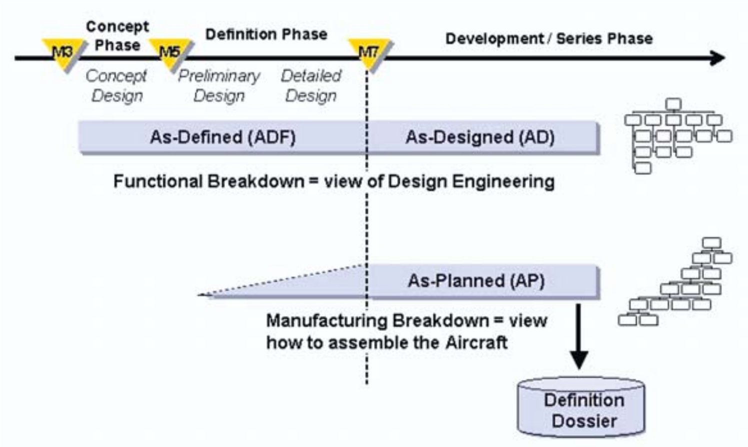

Fig. 4: Most relevant product structure views of the CDMU

The *As-Designed* view is the successor of the As-Defined in the Development and Series Phases, but made up exclusively of definition models which are then officially released via the PDM system.

Both functional views are organized in three areas:

- The *Upper Level*; it decomposes the aircraft top-down via six levels. It reflects aircraft family planning, typical Airbus work-sharing components, Airbus Aircraft sectioning and the international ATA classification (ATA=Airline Transport Association of America).
- The *Configuration Level*; this layer is made up of Configuration Items (CI), which reflect a specific function of the aircraft and the Link Object (LO) the holder of the configuration information.
- CIs are actually "management points" where it is decided which technical solution is taken for satisfying a given requirement.
- The *Design Level*; that's the area where design takes place and where the Aircraft is detailed down to the very single parts. The top assembly is called Design Solution (DS), which actually is the technical solution for a requirement. There can be several DS below one CI reflecting different ways satisfying the requirement: e.g. a metal Flap, a carbon fiber Flap and a hybrid Flap are evaluated during trade-off studies. One will finally be chosen as baseline solution for further detailed design.

The unique identification what finally will be built into an aircraft is the LO-DS pair: it defines what technical solution is taken (DS) for what types and/or ranges of Aircraft (e.g. what customer versions). Between As-Defined and As-Designed there is a so-called *transition* phase: it ensures that auxiliary models and final development data coexist during a certain period of time to ensure a consistent and complete CDMU while being able to track which data are migrated to the next phase.

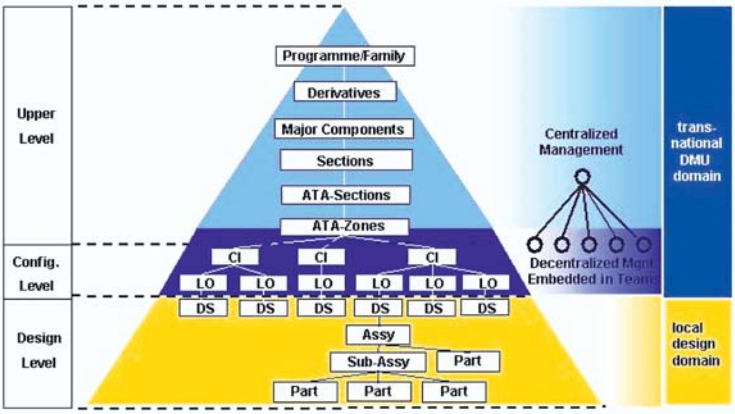

Fig. 5: Functional Product Structure breakdown

The very same CDMU in Development and Series Phases is shared by two views contemporarily: the As-Designed and the so-called *As-Planned* view. 3D geometry is the same, just the product structure breakdown - hence the view - is different. That is why data are also called "*ADAP-*" CI/LO/DS/ assemblies/parts, indicating their belonging to both views. The As-Planned view is the unique input from all product structure views to the official *Definition Dossier* (the collection of all relevant data that in the end define the Aircraft – 3D models, drawing sets, Engineering Change Notes, standards and processes specifications, bill-of-materials). The Definition Dossier itself is the input for the Manufacturing-, Inspection and Maintenance Dossiers – the documentation necessary to produce, service and operate the Aircraft.

The management of the product structure takes place centrally for the Upper Level. This ensures high quality and consistency of the breakdown for all distributed design teams. The Configuration Level is managed locally by DMU Integrators who work co-located in multidisciplinary teams. They ensure the breakdown to reflect design team requirements, the linking to the global CDMU and the visibility of the actual 3D design status. As both levels are managed organizationally under one transnational roof has several advantages: new rules and updates are implemented quickly and consistently company-wide and the CDMU is useable for all disciplines as it is based on agreed schemes.

2.2 DMU Operations over the Extended Enterprise

As it is with the aerospace business as a whole, large aircraft design and development too has become a very global endeavor itself.

Fig. 6: Airbus global distribution and diversity (as of November 2005)

From a DMU point of view that means that wherever and whenever designers may work, they will need to share relevant data and information on a near real time basis, as do their colleagues in Toulouse, Hamburg, Bremen, Filton or Getafe. The goal is being able to “design-in-geometrical-context” with complete, up-to-date, consistent and configured environment geometry and interface models. Therefore, data exchange and data sharing have become the “fuel in the pipes” of concurrent engineering.

The requirement calls for life cycle handling of high volumes of data, with considerable frequencies of exchanges and management of iterations. In Airbus Germany in 2005, in the A380 project alone, the average volume of DMU data exchanged internally with other Airbus sites ranged between 80 and 140 GByte per month, and exchanges with suppliers ranged from 50 to 90 GByte. Furthermore, closer and earlier integration of suppliers and risk sharing partners has put high emphasis on questions of interoperability of tools and systems. Once these new participants are on board design activities must see a fast ramp-up. Communicating a common DMU policy and flexibility on both sides solving everyday operational issues have turned out to be crucial elements for success.

In particular, the A380 programme is marked by a highly heterogeneous tool environment, adding further complexity to the most challenging Aircraft development project in the history of Airbus. 3 different 3D CAD systems, 2 assembly management tools and 4 different (mostly legacy) PDM systems within Airbus alone accounted for a great deal of operational DMU shortfalls. Design-in-geometrical-context was hampered by missing, outdated or flawed (e.g. through erroneous conversions) 3D models and meta data. That is why considerable efforts were laid in solving those issues and ensuring regular configured data exchanges internally as well as from and to suppliers.

At the end of Concept Phase the Airbus partners in the A400M programme switched to a new and common 3D CAD tool and a single new web-based PDM system. It eliminated many of the issues A380 had to face. This strategic step has not been followed though by all risk sharing partners. Also the architectural set up with four separate PDM instances resulted in synchronization problems among them. It forces to remedy a temporarily inconsistent CDMU while still having to handle a considerable number of data exchange transactions.

A350 actually benefits from experiences in both mentioned programmes. It uses the same CAD/PDM tool set as A400M as well as most of its methods and processes. But it bypasses potential shortfalls by working with a single-instance architecture and the strategic approach of ensuring smooth interoperability with risk sharing partners and suppliers.

Lessons Learned

Some of the lessons learned for DMU operations point right to be beginning of partnership: during the bidding process it is important to evaluate the best overall offer, not the cheapest. Suppliers and risk sharing partners must be able to cope with the fast pace of CDMU evolutions. They must know what to expect while Airbus taking a strong lead in ensuring their smooth synchronization with internal processes. This can best be done by going from classical data exchange to data sharing.

The transnational DMU organization has been established to be both the driver in enforcing, tracking and monitoring a high quality CDMU as well as its enabler for the multitude of departments over the entire Extended Enterprise. In the end, everybody is a little bit more interwoven with each other. But this is one important answer to ever-stronger market pressures. It does pay off, for both sides.

3 Steps into the Future

Near and mid term priorities are ensuring successful entry-into-service of the A380 and A400M. The DMU remains to be one of the crucial elements for dealing with development, customization and integration complexities in these two major programmes.

Recent troubles urged Airbus to launch the "Power 8" recovery programme. One of its key initiatives is to find ways to develop Aircraft faster. This is the focus of the "Development and Ramp-up Excellence – DARE" project. It aims for three things: (1) an integrated planning, (2) early involvement of the supply chain and (3) a common digital product model across the entire Extended Enterprise. This underlines the strategic importance of DMU for Aircraft development. The A350 XWB (XWB stands for "Extra Wide Body") is actually the first major new development programme that will benefit from that approach.

Another project is to prepare for pure digital 3D development. It aims at eliminating – as much as possible – 2D drawings from the design and manufacturing processes. This will further enhance reactivity and cut costs and time. It shall, in the end, close the remaining gaps between Engineering and Manufacturing and unite their distinctive 3D worlds to a common virtual development space.

4 Conclusion

The last years have seen four major Airbus programmes being launched in relatively short sequence. Given the long development cycles of large transport aircraft this is a remarkable fact: it provided the unique opportunity to apply lessons learned of the new DMU discipline from one programme to the next almost without delay. The frontiers of DMU operations were pushed fast and relentlessly for reaping the full benefits of 3D development. But this came not for free, let alone guaranteed success, just by going 3D. It was the cumulated effort of a great many people that placed it in the centre of development. Only recently the Digital Mock-up Integration was acknowledged as one of Airbus' core competencies for successful Aircraft development. Having gained all that experience working with and managing the DMU we have reached our "cruise" altitude. The challenge now is to travel the long distances as effectively and as efficiently as possible, probably climbing to even higher levels along the way.

Knowledge-based Design – An Integrated Approach

A. Katzenbach[1] , W. Bergholz[2], A. Rolinger[3]

[1] DaimlerChrysler, Division of "Information Technology and IT Processes for Group Research and Mercedes Car Group /Development", Sindelfingen, Germany
[2] DaimlerChrysler, Division of Data and Process Management, Ulm, Germany
[3] protics GmbH, subsidiary of DaimlerChrysler, Division of Product Data Management, Stuttgart, Germany

Abstract
The dependency between products and processes in today's high-tech domains is very complex, and the resulting interrelations are difficult for the individual engineer to manage. This paper presents a methodological concept (templates) that standardizes the design process and its downstream processes. The results of an accompanying psychological user acceptance study are also presented and discussed.

Keywords
Design of Experiment, Product Development Process, Process Analysis, Process Optimization

1 Introduction

From a strategic viewpoint, the automotive market is a market in the endgame. This means that the market has over productivity of products and the differences are decreasing between the various automotive companies. Especially for the premium automotive manufacturers, it will be increasingly difficult to distinguish new innovation from the other automotive competitors. For this reason, the Mercedes Group formulated a strategy in the 1990s to rapidly expand its model range. In 1983, the C-Class had one car body, four engines, and one factory. In 1993, the range increased to four car bodies, seven engines, four design lines, and two factories, and by 2000, the C-class had five car bodies, seven engines, three design lines and four factories.

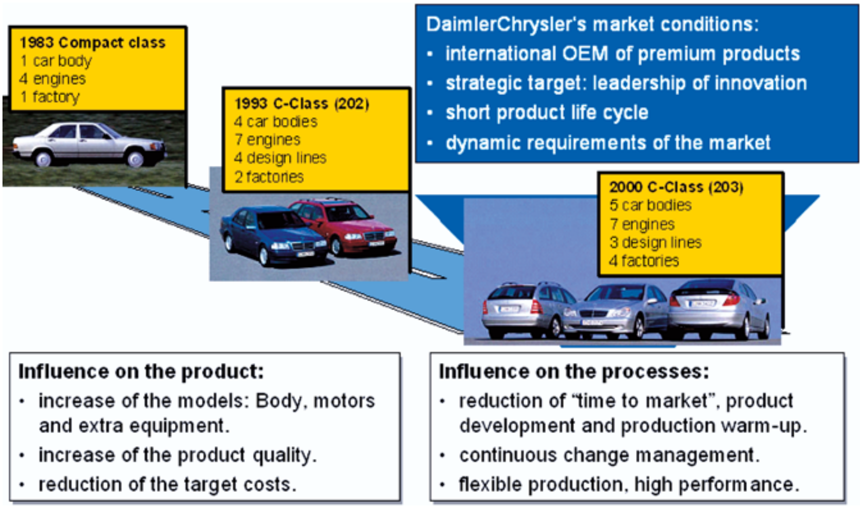

Fig. 1: Historical model of diversification of the Mercedes C-Class

The increase of model range required worldwide production in collaboration with other companies. The international merger is one way to generate an increase in production that is profitable. But this was not the only change. The features of the car changed dramatically, too. Electric, electronics, and software had a massive influx in the former mechanical-dominated automotive world. The result today is a higher degree of complexity in product, as well as in design and engineering processes. To handle the increasing complexity, the automotive companies implemented the digitalization of product development and the optimization of processes in the mid-1980s.

The investment in engineering increased proportionally with the extent of model range, whereas the amount of employees per model decreased. New IT systems and methods as well as changes in product development processes made this possible. One example of automation is the introduction of CAD systems, which were implemented to increase productivity and product quality, while reducing developmental effort. [1]

Despite these advances, the accelerated market trends resulted in increased quality problems at the beginning of this millennium. Entire industries moved into a period of consolidation that was characterized by high discipline of cost and process. Rapid innovations supported these bench-marks. Examples for this development are digital control of the highest degree and processes of immanent quality, digital prototypes, frontloading, digital factories, and integrated product data management.

To understand this trend, it is essential to realize that innovative products need innovative product development processes. These process innovations are often IT-driven. An important innovation is the topic of this paper, knowledge-based development with templates.

Templates as knowledge-based applications are a comprehensive approach for archiving and managing all essential information in a standardized product and process description.

The future of the automobile industry will bring new challenges that require such solutions. The results of a comprehensive study [2] predict for the automotive industry that three things will characterize the future:

1. A gap between high expectations and low prices.
2. Product consisting of "silicon and steel" and
3. Change of structure of creation of value. The first point means that we have a gap between the high expectations of customers regarding innovation and the reluctance to pay corresponding prices.

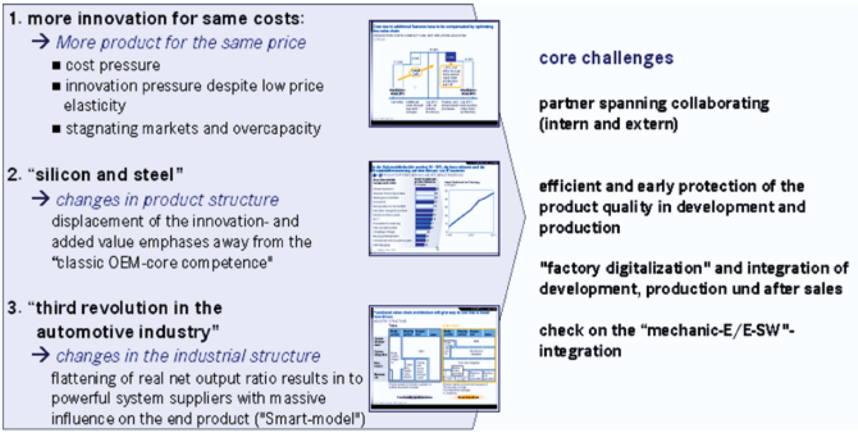

Fig. 2: Future trends in the automobile industry

This combination of trends increases cost and process pressures and intensifies competition. The proportion of electric, electronic, and software components in the automobile will continue to increase. The classic competence that OEMs enjoyed during the previous century will decrease, and consequently the OEMs' portion of the creation of value will decrease. OEMs will have to integrate many suppliers. The structure of the industry will change and perhaps will make history as “the third revolution of the automotive industry”.

Several solutions have emerged to meet these challenges. The automobile companies are working on integrating the development processes for mechanical, electric, electronic, and software, as well as on the down stream of process chain, inclusive companies of partner integration, global collaboration, and multi-discipline optimization. In particular, knowledge-based development is an important approach for handling the challenges.

But the technical side of templates is not the only important factor for successful introduction. Human beings, as a significant economic resource, as well as issues about their cultural differences, are frequently forgotten. This oversight makes the introduction of new technical systems more difficult. However, when human thinking and behaviour, as well as cultural aspects, are taken into account, the implementation of such processes not only increases motivation but also helps to anticipate and reduce potential barriers.

2 Engineering Templates

2.1 Template Classification

Templates as knowledge-based applications are a comprehensive approach for archiving and managing all essential information in a standardized product and process description.

Each car line, each assembly, each component contains various and numerous characteristics that require dedicated development steps. From conceptual design, through all design stages to data archiving, sophisticated development methods and IT solutions must be employed. Seamless and just-in-time information for all downstream processes and an unambiguous and easily performable process definition are assumed. Using template technologies is the key to handling most of these aspects in a modern CAD system. The schema in Figure 3 shows the correspondence between external factors and the specific template-based design stages. Increasing content within the four template extensions can be distinguished. The level of detail increases as it moves from the outer shell to the centre. **Function templates** contain only rough geometrical information and are mainly used for providing the main dimensions and specification values. Application of **concept templates** includes the main characteristics of vehicle models like sedan, convertible, station wagon, or SUV. They are the foundation for best practice design concepts. The digital validation of functional principles is the task of **study templates**. The detailing of such a validated concept leading to a full geometrical description of parts, including relevant information for manufacturing and final assembly, can be done in **part templates**. Within all layers, the design engineer can use specific templates for the different modules of a vehicle.

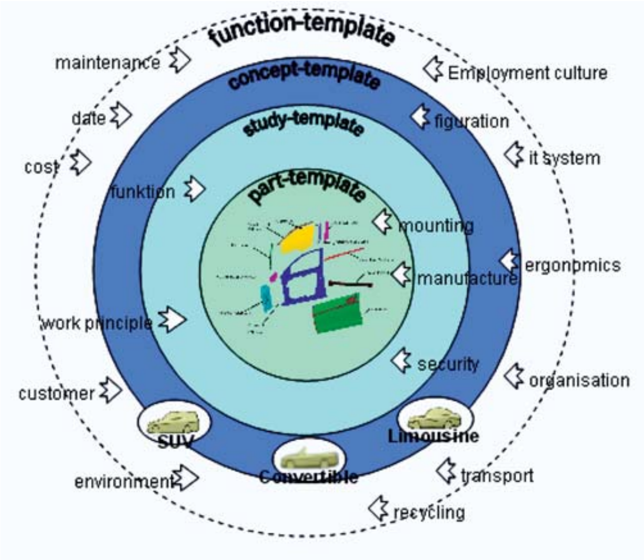

Fig. 3: Requirements for a template-based product description

A tight collaboration between DaimlerChrysler Group Research and Mercedes Car Group Development facilitated the development of the methodical foundations first implemented in the body in white, powertrain and chassis design domains. The outcome of this study was published at the 2005 DaimlerChrysler EDM Forum in Stuttgart [3].

2.2 Link Management

To provide the opportunity to include all geometrical and non-geometrical information independent from the process step, a specific PDM archiving concept was developed. It enables data retrieval with different points of view. A generic information structure, independent of the level of detail, is the basis for the archiving of all templates.

This structure is a summary of different information aspects of a comprehensive product description. Depending on the concrete development task, the necessary information is activated and shown in the expected context. The structure distinguishes between parts with product part number and so-called arrangement (support elements). The generic information set creates the structure for all input data for the templates and links all underlying datasets existing in the PDM database to the part description.

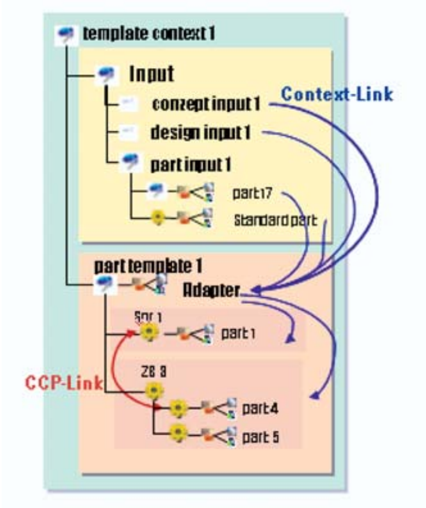

Fig. 4: Concept template technology at DaimlerChrysler

Only a suitable PDM solution can ensure such a dynamic information flow. The sophistication of CAD functions requires a higher level of PDM capability. A real, valuable benefit can be achieved only through the integration of CAD and PDM. In addition to the known PDM requirements, such as configuration management, versioning, and release and change management, the capability to administer constraints and so-called “multi-model links“ is essential. This means especially the constraints between geometrical elements and parameters within parts as well as constraints between parts and subassemblies. More than 2,500 links are needed to define an entire body-in-white structure within a concept template [3]. This link management generates the capability of dividing complex structures into template-based and usable part structures. Without this capability, it would be impossible to share the complete information and knowledge of a multi-part assembly among numerous design engineers.

The mandatory use of template-based design processes leads to a continuous improvement of the design maturity, from the early phase down to detail design, and prevents endless iteration. The reuse of these approaches depends on the degree of flexibility and adaptability of the predefined templates. The predefinition, by using knowledge-based form and function features, facilitates this reusability. These feature applications are not only part of detail design; they can also define and mutate conceptual structures through an internal protection structure.

Using knowledge-based templates is an appropriate approach for integrating proven concepts or systems into a new product design. They contain all the information necessary to define the technical behavior in a general context. The disadvantage of this approach is obviously the intensive effort needed to define and maintain a universal template concept that considers all potential variants of future design instances.

To succeed in the development and deployment of such a sophisticated concept, technical and conceptual aspects must be considered. The most important part of the game is the human being – the engineers and designers who have to perform this new process and methods.

3 Psychological Aspects of Template based Engineering

The common definition of working systems has already been described in the human-technique-organization approach. The working system consists of social and technical substructures. Humans, technology, and organization are interdependent and interacting components. The task is the center of the working system [4]. The interaction between the substructures has also been described [5]. All components for solving the working requirements are known.

The previous discussion of the templates focused mainly on technical design with the purpose of process optimization. However, human, organizational, and cultural factors should also be considered. In the following, human factors are considered to ensure a successful introduction of templates and, therefore, a standardization of the process. The cultural aspects and the organizational aspects, which also have a strong impact on working systems, are only mentioned in this context.

Early integration of the user is the best way to consider human requirements in time. Disadvantages of the previous process and aims of the new process have to be presented. When developing templates the integration of the user supports the acceptance of the new technology and prevents un-necessary concerns because the designer's thinking and behavior are considered [6].

A failure to consider the designer's thinking and behavior when solving a design task results in a mental workload which decreases the acceptance of templates. Constructional defects and motivation loss may lead to financial penalties. Therefore, a cognitive ergonomic design of templates is also important when considering financial aspects.

At DaimlerChrysler AG, a study was conducted to analyze critical incidents when using templates. Based on the results of this study, improvements for the design of templates were conducted. In the study, two different construction elements were compared. One construction element was composed without features and then was composed with features. In total, six designers participated in the study and were subjected to the experimental conditions. For reasons of comparability, participants were constrained by means of pre-assigned variables to the experimental conditions. In the first part of the study, the participants had to redesign a construction element (adaptation construction) whereas in the second part of the study a further adaptation construction had to be made. The participants who solved the first task with the feature solved the second task without the feature. Participants who solved the first task without the feature at the beginning of the experiment solved the second task with the feature accordingly. Therefore, each participant worked with both terms of the experiment. Initial results indicate that the construction element with features was estimated differently depending on CATIA V5 Engineering expertise. Persons with low CATIA V5 Engineering expertise considered the implementation of a construction element with features as less effective. The shorter design time and the faster creation of geometries were seen as an advantage whereas the loss of the overview and the complexity of the design element because of the strong structure were seen as a disadvantage. The design time was different depending on the type of template and the design task. The persons who had used the construction element with features solved the more complex design task faster in terms of the design time, whereas in the construction of the less complex design task, the group without features was faster. The visual analysis of the videotaped design process will provide further information about critical incidents and their solutions. Additionally, in the second part of the study, the handling of information about multi-model links was analyzed – the engineer should identify all multi-model links. All participants took advantage of the possibility of quickly changing with the multi-model links. However, they also criticized the loss of the overview of the existing coherences. Considering that the body shell model has more than 2,500 multi-model links which are not directly visible in the CAD system, some thought must be given to alternative solutions. The degree of complexity increases because of the non-transparent presentation of the multi-model links and the interdependency within and between the construction elements. Previous studies show that human beings have difficulties with solving complex problems that come with mistakes and that eventually [7, 8, 9]. Therefore, information about the interdependency of the construction elements caused by the multi-model links has to be given. The highest priority should be given to the development of a user friendly information system which represents multi-model links.

4 Summary

The dynamics of today's business requires comprehensive, optimized processes that can be reliably performed only through the use of standards. The template methodology described in this paper is an example for process standardization extending the usage of CAD systems. Template technology provides all relevant process information directly from the CAD system. Each design stage can be performed by a template extension. The challenge for a suitable template concept is achieving balance between standardization and flexibility, as well as incorporating the ability to store and retrieve all information in a PDM system. Another significant factor is the acceptances of the user who has to realize the concept's succeed. Only a comprehensive approach to the development process, template methodology, and human behavior can implement this new technology successfully.

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Cross Disciplinary Methods for Accelerated Product Delivery

C. Grindstaff

UGS Corp., Executive Vice President Products, Plano, Texas, USA

Abstract
Consumer requirements for product convenience, functionality and quality have lead to an explosion of diversity and complexity of market offerings. Successful enterprises must use sophisticated and highly optimized engineering and manufacturing techniques to stay competitive. These same market demands drive products to market with decreased time available between introductions of new product models. These rapid innovation cycles must be executed with lean processes that are continuously improved and optimized yielding reduced costs.

Keywords
Knowledge Based Engineering, Product Development Process, Process Analysis, Process Optimisation

To help enterprises cope with these pressures, IT vendors are delivering software solutions that support more efficient engineering and manufacturing business processes. This has often been accomplished by developing tools that mimic physical processes, extending these software tools' functionality, improving their performance and expanding their scalability to meet rising enterprises' needs. However, the weight of global competitive pressures is forcing enterprises to make fundamental changes to underlying engineering processes. Today's design, engineering and manufacturing processes must be distributed, multidisciplinary and highly automated.

Supply chains continue to lengthen globally. Organizations must have ways to utilize insight from experts wherever they are in the world and whenever they are available to contribute. This global network of innovators must have reliable collaboration tools to supply them accurate information, to evaluate alternatives and to communicate their decisions.

The rapid innovation cycles demand reduced decision time. Practitioners from all disciplines must coordinate their decisions early and concurrently. Considerations from requirements, aesthetics, engineering as well as manufacturing must be balanced and reconciled as early and accurately as possible. Domain specific intelligence incorporated into the design digital product development environment is now routinely employed to augment engineering judgments. New tools are becoming available that can extend the automation to a distributed and scalable network of innovation.

IT systems, which are intended to support the digital product development, currently provide capabilities that let their users benefit from methods like parametric design, standard part re-use, digital mock-up and product structure editing.

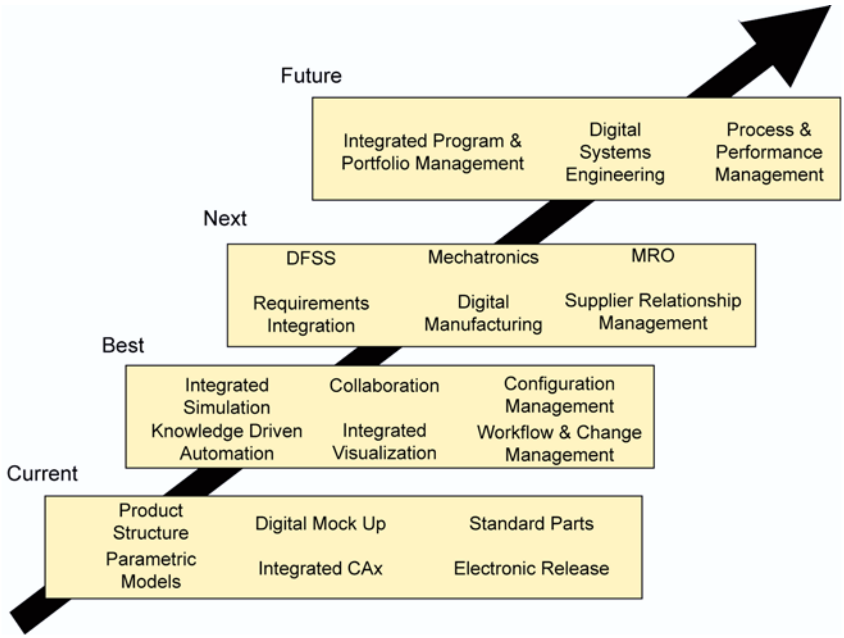

Fig. 1: Roadmap of Digital Product Development support

By leveraging knowledge-based automation techniques, push-button functionalities can be established in mechanical engineering tasks for generating variations of engineering solutions. Requirements can drive design parameters and initiate virtual validation procedures. Integrating business processes via common information backbones can eliminate wasted efforts in information allocation and re-use. Harmonizing the design intent with its consequences in the subsequent life cycle phases like manufacturing, assembly, maintenance and disassembly will eliminate complete loops of iterations resulting in lower engineering change costs. Methods like Design for Manufacturing, Design for Assembly and Design for Maintenance are being supported by today's state-of-the-art systems providing the incorporation of technology relevant information into the design environment.

Time spent iterating product engineering results until the released design is reached, can be shortened by corporate-wide integrated visualization techniques based on 3D representations of products. By "actively" combining packaging mock-up functionality with the design supply chain these 3D representations can be utilized to support engineering review processes during multiple phases of the product development process. However, the shape (form and fit) of a product represents only a portion of its many properties. A complete model of a product goes beyond its shape to include functional behavior, NVH and dynamic behavior under operating conditions. Performance and fidelity of the simulation tools for these models are critical.

A complete product model is far more complex than a traditional packaging mock-up. Today's increased dependence on mechatronic components drives electrical specifications, software functionality and their various configurations to the same level as shape and other physical properties. To cover this broad range of information, IT systems typically need to combine cross disciplinary functions to satisfy engineering decision making requirements.

The highest possible efficiency increase in the design and manufacturing phases of the production process, however, can be achieved by an end-to-end vertical integration between all the stages of the production ranging from virtual product development, down to the physical shop floor operations. Such degree of integration will introduce new possibilities of simultaneous product development, manufacturing planning and the design of the shop floor automation systems. Users of these combined technologies will achieve the highest quality, adaptability and fastest production processes.

Configuration management becomes important because of the diversity of product configurations resulting from different markets on the globe and various target user groups like consumer goods, automotive or defense. To support team work and to achieve combined usage of various applications in an engineering environment, collaboration strategies for IT systems need to be defined based on the target user scenarios. All functions and business relevant information of a globally distributed production enterprise need to be available at any location, at any time, concurrently. This is achieved by a Cross Disciplinary collaboration of IT systems in a network of customers and their suppliers.

Such networked engineering environments practice methods of co-design in multi-system environments. The simultaneous availability of manufacturing related rules and information during the design phases and the incorporation of these into the product and process models provide the necessary associativity between the product design and manufacturing processes as well as facilities. Since in conventional processes most of the critical make/buy decisions need to be made in the early stages of product development, the available cost data is usually imprecise. Practicing design for manufacturability with reusability considerations on processes and plants can minimize the duration of tasks prior to start of production and improve the precision of cost estimations for the production of developed goods.

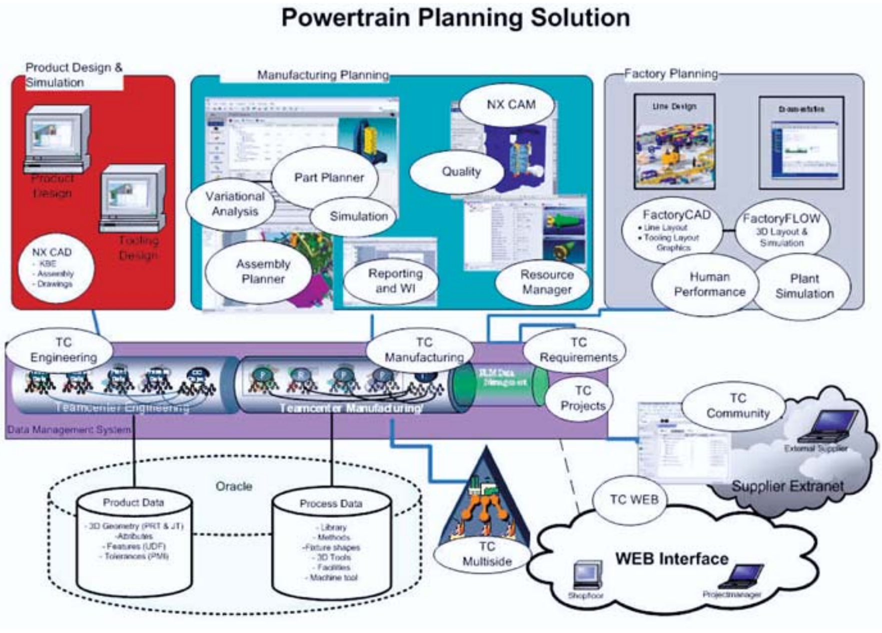

Fig. 2: Cross Disciplinary collaboration in an integrated Product Development and Manufacturing Environment

Given the economical challenges the industries face today, global outsourcing becomes a part of any production, introducing additional aspects of supplier integration. Issues of compliancy, IP-Protection needs, and fast delivery requirements need to be considered to streamline this major process. Multi-site capabilities of product, process, plant and resource information management is required with higher emphasis in these customer-supplier and supplier-supplier collaboration scenarios. Not only the management functionalities need to consider IP-protection issues in these scenarios but also multi-system architectures need to introduce methods of controlled information reduction for the exchanged models.

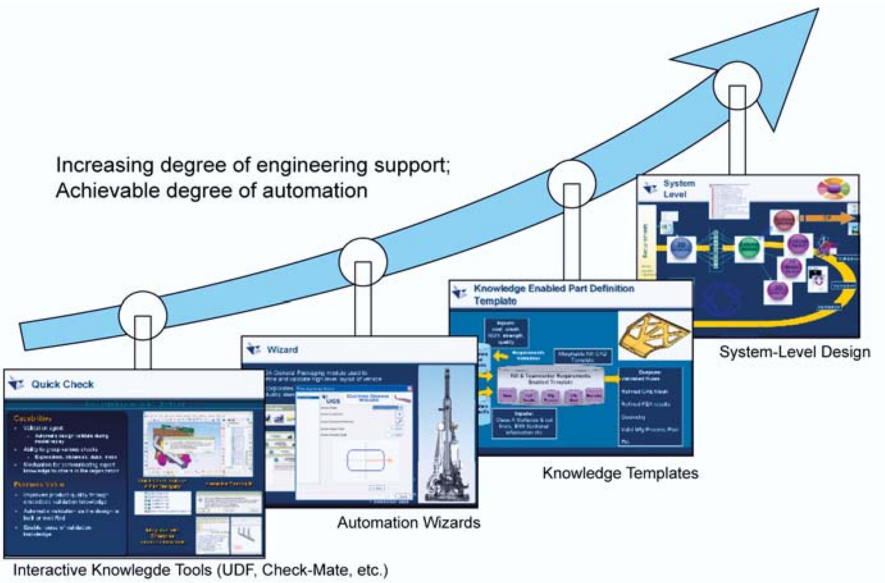

Fig. 3: Knowledge Driven Automation Strategy

The comprehension of the business processes in the target industries help the IT product and service providers to create process dedicated software solutions. The process awareness while designing IT tools opens the possibilities for knowledge driven automation strategies. The wide range of achievable automation and the degree of engineering support is provided by the diverse capabilities implemented for the specialized applications. The capabilities may range from user defined functions up to the utilization of wizards and knowledge templates, assistant software for product development. Thus a significant amount of room and time remains to introduce innovation in the processes. The path to creating innovation leads to cooperation between its creators, providers and users. Academic research, a responsive IT development team, as well as well defined and maintained business processes are therefore prerequisites for new successful practices.

Advances in PLM Methodologies Driving Needs for New Competencies

X. Fouger

Dassault Systemes, PLM Academy, Paris, France

Abstract
The daily practices in engineer's professions are a function of new work methodologies implemented by industrial companies as increments in their way to manage the lifecycle of their products. Such methodology innovations often find their first full scale implementation in business environments, as opposed to academic institutions. It becomes then a challenge for educational designers to develop the learning content that provides engineering students with the knowledge and skills required to operate, drive and evolve new practices in product creation. For technology providers, who contribute to the concurrent invention of new methods and new enabling tools, there are several ways to contribute to accelerate the transfer of their generic aspects from industry to education environment.

Keywords
Engineering education, Product Development Process, Process Innovation, Best Practices, global engineer, design in context, digital manufacturing

1 Introduction

Vendors of technologies that enhance the management of product lifecycle ("PLM") traditionally focus on improving various engineering methods and processes for industrial companies. Beyond this natural destination of their innovation effort, their potential contribution in helping educational institutions to increase their responsiveness in producing appropriate competencies is often underexploited.

This paper examines a selection of engineering activities that underwent significant transformations during the last recent years: (1) the accelerated use of composite technologies in large aircrafts, (2) generative design practices, (3) collective innovation practices, (4) multi-cultural engineering collaboration and (5) overcoming the cultural divide between product and production engineering.

2 The Accelerated Use of Composite Technologies in Large Aircrafts

With its 787 'Dreamliner" model, the Boeing company significantly accelerated the use of composite material in a large aircraft. This evolution is clearly driven by a competitive objective of reducing cost of ownership through reduced weight. Very large portions of the aircraft are impacted: all the primary structure, including the fuselage, wing box, and empennage boxes, are carbon laminates (a composite). The wing control surfaces are also carbon laminates, instead of the more traditional carbon sandwich.

This sudden acceleration has driven a strong need to retrain a large workforce from metal work to composites engineering and manufacturing. [3] Many aspects of engineering required to design appropriate curricula, including the design of new types of shapes for structure parts, dynamic analysis of skins, design of new manufacturing processes and resources, such as autoclaves capable to contain complete sections of fuselages.

Among this population, were several thousands of engineers using digital product / process creation technology (CATIA / DELMIA) and a shared collaborative infrastructure (ENOVIA). The competency transformation led by the manufacturer with the help of involved vendors had to target at the same time the employed workforce and students in academic education institutions. A vast training program was deployed for Boeing's employees and their program partners. This program also reached initial education curricula in numerous higher education institutions within an extended ecosystem interested in aerospace education.

The revision of existing aerospace engineering curricula has taken several paths including some exemplary active learning [4] based projects as described by Leonhardt-Western Washington University and O'Charoen-Boeing Commercial Aircraft Group.

3 Generative Design Practices

3.1 The Extended Definition is at Work

A first level of understanding generative design describes the practice of computer aided derivation of similar parts from a generic instance through simple mechanisms such as parametric dimensional variations. This version of generative design, while interesting for accelerating routine or standard design, does not have significant organisational impact within product development organizations.

The extended understanding of the practice has been formulated in the late 80'ies by the Chrysler Company under the term "morphing". Morphing, in the context of vehicle design, was specifically targeting the body-in-white definition process that relates to internal body structures which are determined by a broad set of technological – sometimes empirical – knowledge rules, on one hand, and by the external (visible) body shape, on the other hand. The capability to change the outer shape definition as late as possible in the development schedule is a factor of competitiveness since it enables car makers to adjust the appearance of their product to a more accurate forecast of the market's aesthetic expectations. However, late changes in the outer shape of a car are only possible if all downstream processes can adjust quickly. Among these processes, body-in white design is one of the most costly. Therefore, the capability to automate the production of updated computer models of body-in-white structures that are technologically valid becomes a key competitive advantage. This level of generative design is already implemented in a large scale by some automotive companies. It implies deep transformation forces towards more specialization between two classes of professionals:

- "Build Time" engineers, focusing their work on innovation, new ways to assemble body frames, new materials, etc... Their task is to provide validated generic models of body in white structures. These models become the generative material for the other type of professionals:
- "Implementation" engineers -or "designers"- who focus on the design of the car currently being developed. Their task is to reuse generative definitions and to instantiate them as fast as possible within the contest of the latest version of the outer body shape.

Not all organization may want to establish this dual specialization scheme. Smaller companies may choose to prevent specialization of engineering work. However some large car makers have clearly reinforced the polarization of competencies. (Fig. 1)

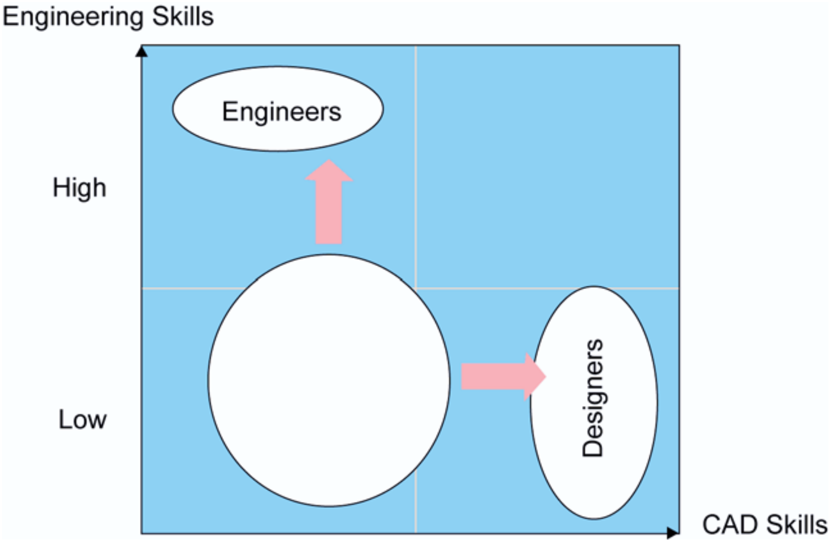

Fig. 1: Generative design practices, when deployed on a larger scale, determine two specializations of engineering profiles.

3.2 Teaching “Morphing” or Morphing Teaching?

A first challenge that generative practices pose to educational institutions is about reflecting the specialization of profiles. One could think that the “designer” profile is prepared in college studies while the task of creating generative knowledge is more relevant at Master level. In any case there is a need for future “build-time” engineers to understand the role of “designer” profiles and vice-versa.

The development of specific competencies such as knowledge-based modelling of generative objects requires students to be put in the situation of creating practical examples of realistic generative products. In many cases, it is therefore necessary to design substantial curricula evolutions. To help educators doing so, Dassault Systemes, as a vendor involved in the first industrial deployments of “morphing”, provides academic users with start up teaching material to be inserted in their personal courseware.

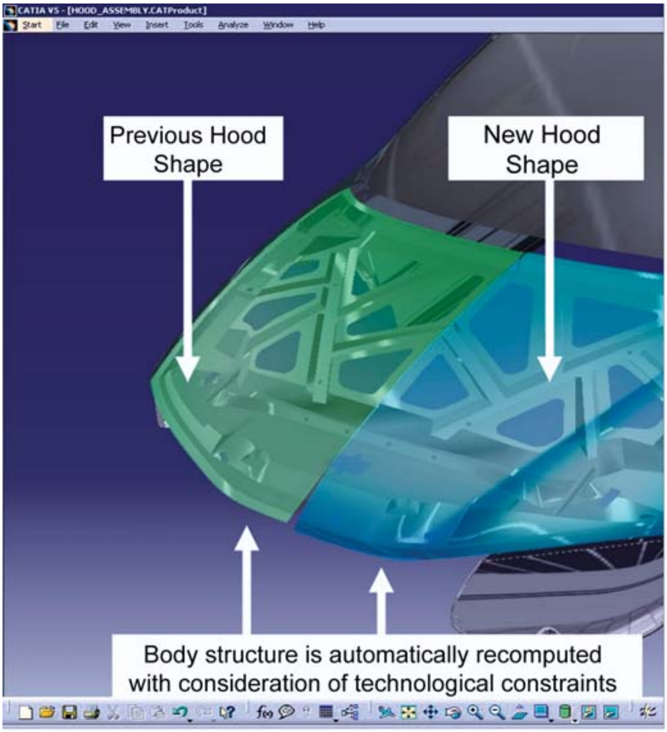

Fig. 2: An example of morphing: the complex geometry of the hood structure is determined by it's outer shape. When it changes, the new shape of the structure is recomputed with respect to knowledge rules that are active within the model. These rules guarantee that the geometry change of the structure still complies with the company's knowledge

3.3 Collective Innovation Practices

As soon as multiple players are simultaneously involved in developing a new product, typical project management issues arise, such as:

- Ensuring the consistency of the complete product while not over constraining individual's creativity,
- Creating the conditions for uniform progress of all involved engineers,
- Remove the cost of waiting for other team member's input?

A modern response to these issues was first implemented by the Bombardier aerospace company and was deployed for the first time in the automotive industry by BMW as part of their "Digital Car" project. This response was articulated around "design in context", a collective innovation practice that builds on the premises that all participants within a project publish their results daily. The technological enablers of this process include advanced publishing capabilities, complex query ("by zone") functions, as well as appropriate tools to perform local assembly consistency diagnosis.

3.4 Teaching the Social Aspect

The working dynamics created by design in context are various but the most spectacular is that it establishes "pull the input" forces (as opposed to "wait for output"), since it provides collective visibility on what are the most needed results a any time.

The social implications of establishing this effect are significant:

- Engineers must accept to publish preliminary ideas
- Engineers must accept to build on preliminary results from others.

To accelerate teaching of not only the technology but also the managerial aspects of such kind of practices, Dassault Systemes provides partnering institutions with specialized Master level conferences resulting from actual implementation projects.

4 Multi-cultural Engineering Collaboration

Globalization of product related businesses drive the need for a new kind of engineer's profile that reflects among other skills the competency of producing results in a collaborative effort that involves engineers, from one or several other countries or cultures. This has been recently articulated in a report [1] commissioned by the Continental company to several world class Universities. The first among four conclusions developed by the report is that "Global competence needs to become a key qualification for engineering graduates". This constitutes a general challenge for any institution willing to produce "global engineers".

During the 2006 Global Colloquium on Engineering Education of the American Society of Engineering Education, around 60 students were invited in Rio de Janeiro from various places to participate in the first Engineering Students forum associated to the colloquium. Most of the invited students had experiences of international relationships in an engineering context. Dassault Systemes conducted a survey of their perception of efficient education practices when developing competencies of a "global engineer". In one of the questions, students were asked to rank education practices from the most to the least efficient in developing skills for international collaboration in engineering. The results (fig. 3) reflected two trends:

- Students considered that the most efficient practices are those that immerse them into a foreign context,
- Student considered as efficient those practices that produce results within joint project.

Dassault Systemes has encouraged several international collaborative experiences that are characterized by the observation that was underlined in the survey: to create realistic conditions for concurrently learning the aptitudes and the attitudes of the global engineer, curricula that lead to joint realizations are highly efficient.

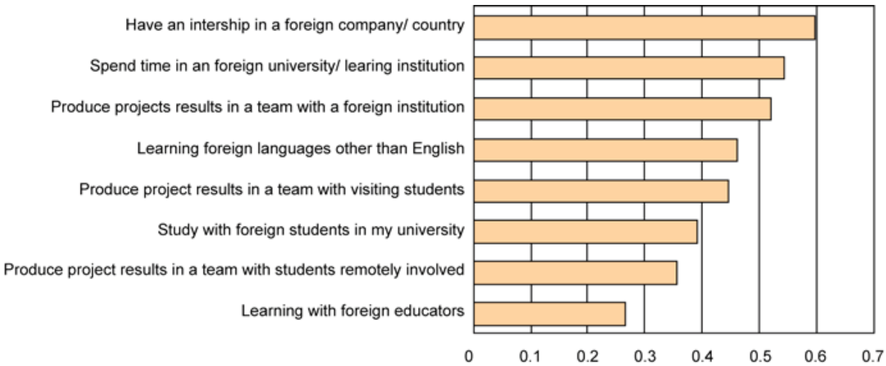

Fig. 3: The Rio survey was capturing a perception by which students could rank several education practices. Practices could score from 0 (least efficient) to 1 (most efficient)

4.1 An Indo-French Example or Result-oriented Project

An example of interesting multi-cultural experience involved an Indian and a French institution (college type). The actual project was to design and manufacture a mobile soft drinks vending machine. The students not only executed the project in the context of distant teams and shared content, they could also analyse their interaction within the network (Fig. 4) of interdependent tasks. The resulting learning experience is now inspiring further developments.

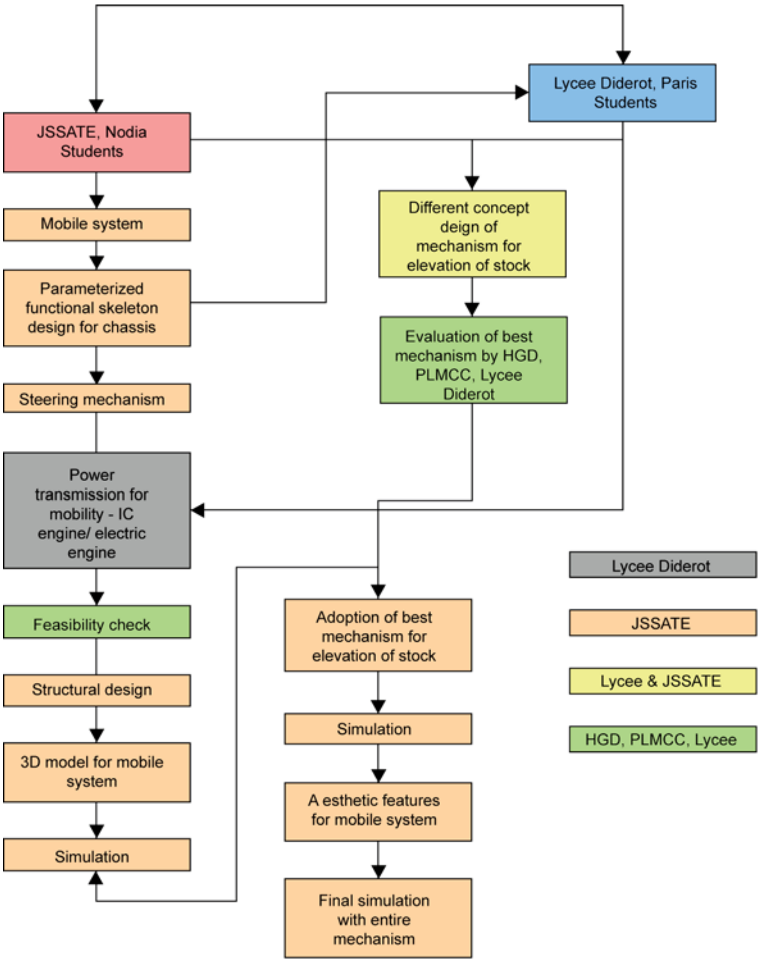

Fig. 4: Indian and French students established after the fact the actual flow of action across work packages and countries that led to the completion of the mobile soft drink vending machine

5 The Cultural Divide between Product and Production Engineering

Manufacturing industries invest considerable amount of investments and organizational efforts to establish more concurrency between product engineering and manufacturing engineering. Digital Manufacturing techniques are enabling and structuring these efforts [2].

However the cultural distance that tradition has established between these disciplines persists. Education can efficiently participate in establishing the role of engineers in a collaborative mode, while teaching the practice of concurrent definition of products and processes. Digital manufacturing provides a very appropriate framework [5] for developing this competency. The underlying principle in building digital manufacturing curricula is that it enables to import the model of the factory and its operations in the classroom. This provides product engineers with the factory point of view on the product development process and helps them conceptualize and practice concurrent product/process and resources design in teams that *simulate the different involved disciplines*.

6 Summary

Manufacturing industries provide the full scale test bench for new methodologies and processes in Product Lifecycle Management. Actual engineering practices become professional characteristics in this industrial context, even if their initial articulation originates in academic research. It becomes a frequently observed challenge for education to turn new practices into consistent elements of curricula. Technology vendors can invest in helping the transfer of this knowledge by means of specialized courseware, specialized educator's education, involvement in lectures, support of educational experiments, etc...

This paper explores *selected* examples that actually linked new industrial methods with educational practices. It outlines several key aspects of that can be implemented successfully in engineering curricula and it provides suggestions about possible contributions of vendors of enabling PLM technology to accelerate curricula construction and to help enhance educational responsiveness to industry changes.

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A Systematic Approach to Product Development Best Practises

J. Heppelmann

Executive Vice President,
Software Solutions and Chief Product Office PTC Corp.,
Needham, MA, USA

Product development today is defined by the complexity in products, processes, and a globally distributed value chain.

Product modularization and single sourcing, efficient program and project management, global collaboration and the ability to integrate mechanical, electrical and software design disciplines into one streamlined process are key success factors.

An open information backbone for integral product development is the key prerequisite for successful product development – a PLM system that will enable corporations to:

- Manage the complete product structure and product information from various sources in one integral system, leading to an optimized, lean product development process
- Enable true cross-discipline development that helps to increase product quality and reduce overall development costs.
- Efficiently manage programs, information, resources, and schedules through collaboration portals

1 An Open Information Backbone for Integral Product Development

The development processes for most of today's products - system design, detailed design, validation and configuration management – involve a complex network of disciplines, systems and individual applications from design, simulation and digital mock-up to documentation and downstream business systems for sourcing, manufacturing, and service. Isolated systems and processes today make it difficult to obtain complete and transparent view of the entire product as it is being developed.

Providing a single, integrated product development platform, enables the efficient management of design data from various sources as well as associated information like documentation, illustrations and engineering calculations. Integrating information from various sources and disciplines creates total product confidence from the first design iterations to SOP.

2 Systems Design and Mechatronics

Product development, in the past dominated by mechanical engineering principles, is undergoing massive changes and Electronics and Software engineering play a more significant role in product development.

The challenge in the system design, change management, validation, and quality management processes lies in the fact that the individual development disciplines often collaborate insufficiently, resulting in required changes being discovered late in the development process, causing unforeseen cost and quality problems.

This allows corporations to plan for quality through cross-discipline product development and avoid late, expensive changes.

3 Collaboration

Product development today requires close collaboration with design partners, suppliers, and manufacturing.

Collaboration needs to take place in a secure environment protecting intellectual property, and must ensure that up-to-date product information is being used.

PTC provides a collaboration portal solution with role- and task-based access, enabling secure and efficient collaboration within the extended enterprise and across the supply chain.

4 Solution Capabilities

PTC today combines four core product families – MCAD, PLM, Technical Documentation and Illustrations, and Engineering Calculations - into one integral and open system differentiated by a broad footprint of capabilities, clean architecture, that is easy to use, scalable to meet the needs of a global supply chain, supports incremental adoption to deliver value quickly while reducing risk and total cost of ownership.

SPALTEN Matrix – Product Development Process on the Basis of Systems Engineering and Systematic Problem Solving

A. Albers, M. Meboldt

IPEK – Institute of Product Development Karlsruhe, University of Karlsruhe (TH), Germany

Abstract
The SPALTEN Matrix is a holistic product development process approach, which combines system engineering, the phases of the product development process and a systematic problem solving to one successful approach to handle complex product development processes. The SPALTEN-Matrix is the process backbone and cooperation, coordination and information platform for the product development process. This approach provides a long term planning and situation oriented problem solving during the product development process.

1 Introduction

Many different product lifecycle processes have been developed during the last years and the specialization of development processes is getting more and more common. Examples for this trend are the specialization of the development processes of mechatronics and micro technology [1]. The stages of these product development processes can be compared but they differ substantially with regard to the interactions and order of the single process steps. E.g. in the case of micro technology, the manufacturing method influences already considerably the ideas and the conceptual stage, because the production restrictions have to be known at this point of the development [11]. These different technologies show that there exists no general product development process. Product development processes depend always based on situation- and environment-related planning and modification. These circumstances create a demand for a reference model for the product development from which it is possible to derive specific development processes. The aim is to establish a reference model that indicates and supports optimally its adaptation to product-specific features. This paper presents a model for product development processes that is based on a continuous systems engineering approach in combination with the stage model and a team-oriented problem solving cycle.

2 Product Development Processes

Product development and innovation processes are being researched by several different domains. Thus, different domains propagate and develop continuously new approaches. The most active actuators in the field of innovation- and development processes are the management and engineering sciences. Many of these approaches have a special focus on their own domain. This fact can be clearly seen in the case of the design-methodical approaches. They start the development process with the clarification of the development task and the creation of the requirement specification. Many business management approaches, in contrast, end with the requirement definition. Especially Cooper was a decisive influence in the 90s in the change from the design-oriented development processes to business management-oriented product development processes [6]. From these two domains result two dimensions of a development process: design methodology and business management. The task of a development process is to manage the development project and to support the developers themselves during the development process. The success of a development process depends on the consistency and continuity of the single dimensions and stages. Prasad seizes this suggestion and divides the elements of a development process in different hierarchy levels – organization, product, and process [15]. These dimensions of the product development process are characterized by the stage-oriented protection, the objectives, and the navigation, by the development process itself. This view was founded by Blass, Franke, and Lindemann in the VDI-guideline 2221, in which the stages of the development process are connected to a problem solving process [20]. It is often used as the basis for the design of development processes. Gierhardt divides the model into process level, organization level, and product level, with a target and a knowledge level [10]. In brief, the development process can be divided into systems, methods, and processes, which again link targets, information / knowledge, and activities.

2.1 Systems Engineering and Product Development

The basics of the systems engineering-oriented perspective were founded by Patzak [14] and Daenzer/ Huber [7]. Ehrlenspiel transferred the systems engineering approach to product development processes [8]. Describing a product, he refers to it as system of objectives, which is the sum of the objectives (requirements) and their relations. In the system of objectives, the requirements are hierarchically structured according to their importance and the chronology of the sub-requirements. The result is the requirement list and system specification, they are the basis of the evaluation of each developing object system and of the development- or operation process. The market or the consumer that the product is manufactured for has of course also a large influence on the system of objectives [8] Ehrlenspiel defined these approaches, but he did not apply them consistently in practice. In the work of Negele, the systems engineering approach for the description of development processes was revived [12]. Negele developed the ZOPH-model (German: Ziel-, Objekt-, Prozess- und Handlungssystem, target-, object-, process-, and operation system) for the product development. He divided the operation system defined by Ehrlenspiel into process- and operation systems. Steinmaier reduces this approach and combines operation system and process system again to one operation system [18].

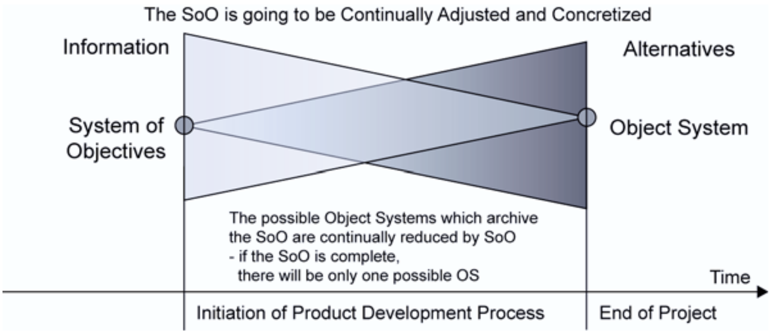

Fig. 1: System of objectives, object system in the product development process

In the systems engineering approaches, similar as in the problem solving processes, the system of objectives can be defined as target state and the object system as actual state. With these systems engineering approaches, the product development can be described as the transfer from a system of objectives, being still vague at the beginning of the product development, to a concrete object system. I.e., the core activity of the product development is the continuous expansion and specification of a system of objectives, the creation of an efficient operation system and therefore the successful realization into an object system – the product (Fig. 1).

Die VDI-guideline describes the process for the development and design of technical systems model in seven steps [20]. The process model of Pahl and Beitz reduces the process to four main stages [13]. Both process models start with the clarification of the development task; this step leads to the requirements, i.e. specifications that accompany the development process. These process models are sub steps of the product creation process and separate the development and design from the remaining product life cycle. In the nineties, it was recognized that the process steps in the development process are not sequential, but highly parallelized and with interlinking. Ehrlenspiel [8] resumes this approach and integrates the personal, informational, and organizational aspects into the product development process; he establishes the "integrated product development". The product life cycle is described by means of systems engineering. The influences of all systems on the complete system, e.g. customer, product, production, human resources, methods, etc., are examined holistically.

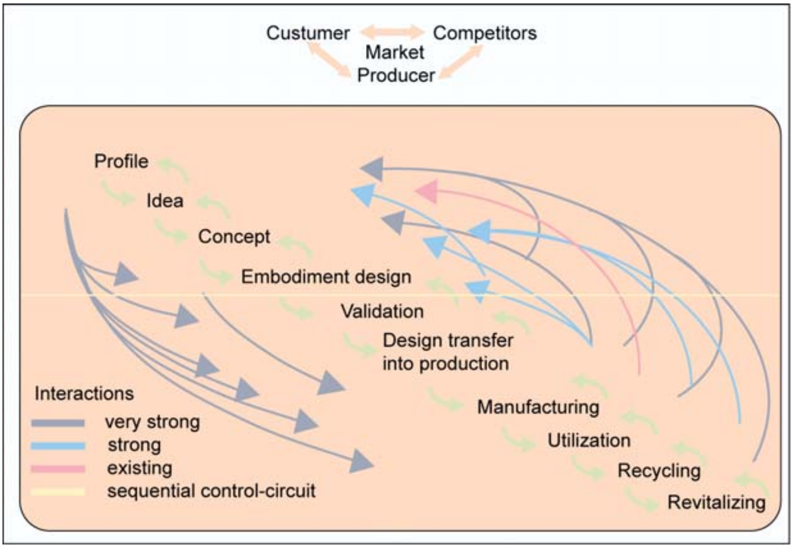

Fig. 2: Stages of the product lifecycle [3]

The process model of Albers (Fig. 2) displays the single stages of the life cycle and emphasizes the overlapping and parallelization of the stages and thereby it describes the interaction of the single stages [3]. The market and its three players (customer, competitor, and the producer himself) is the starting point. Albers incorporates the entire life cycle.

Cooper describes the change of the development processes in three generations. In the first generation, the relation of the single stages is primarily a supplier-to-costumer relation. The further development of the processes leads to the stage-gate approach of Cooper's second generation, in which the single stages are separated by gates. The approach of the third generation is Cooper's request to replace the gates of the single stages by fuzzy gates. The difficulty with a process where the stage limits are eliminated is the coordination of the complex interaction of the stages and the establishment of a clearly defined lead process [6].

2.2 Problem Solving Processes

Basically, a problem can be described as delta between the target state and the actual state. Two kinds of problems can be distinguished: the emergency and the planning situation. In the emergency situation, the actual state declines and the target state remains the same, whereas in the case of the planning situation, the target state as objective is actively changed so that the actual state needs to be adjusted [4] (Fig. 3).

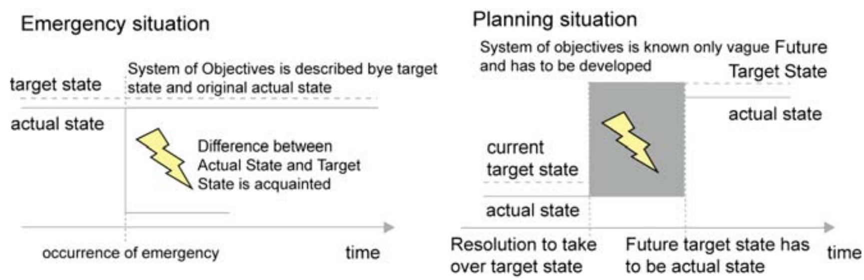

Fig. 3: Problem situations

The most elemental problem solving process is the TOTE-schema (Test-Operate-Test-Exit). The aim of this schema is to achieve the target state or objective by changes or operations of the given actual state. This schema can be considered as closed loop [17]. This closed loop is repeated in iterative steps, until the desired state is achieved. For this purpose, a variety of problem solving cycles and models were developed. Here, the problem solving process according to the VDI-guideline 2221 has to be mentioned, which is substantially adapted to the system technology or systems engineering. This process represents the stage-oriented procedure of the product development, i.e. a macro process. Most problem solving models have not been established as standard process. In practice, stringent problem solving methods for emergency situations are of a greater importance, here, the VDA 8D-report is well-tried [19]. It supports e.g. SAP systems as standard process for customer complaints [16].

The developed SPALTEN-process (German: spalten = to split, to decompose) is a holistic problem solving process. It describes a universal procedure for the solution of problems with different boundary conditions and complexity degrees. With its help, an effort and time minimization as well as a solution optimization and safety maximization for the problem solving can be achieved. The areas of application of the SPALTEN-method are the future-oriented as well as the spontaneously occurring problems. This problem-adjusted procedure enables an optimized benefit-/effort relation. Here, the procedure is not to be applied dogmatically but pragmatically depending on the boundary conditions. (The seven steps of SPALTEN: 1. situation analysis, 2. problem containment, 3. finding alternative solutions, 4. selection of solutions, 5. analyzing the consequences, 6. deciding & implementing, 7.finally recapitulation & learning) [2] (Fig. 4).

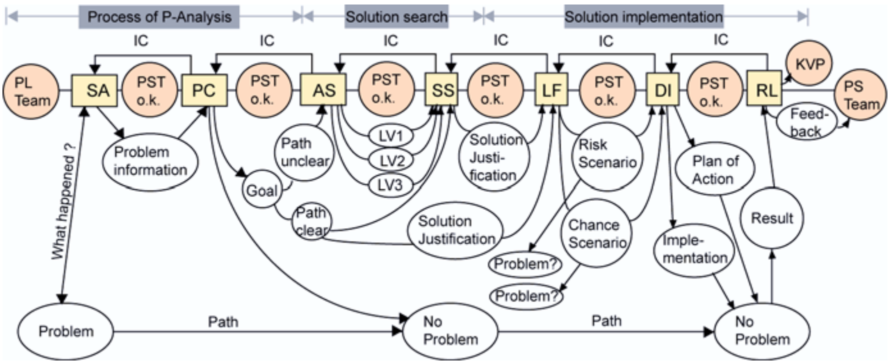

Fig. 4: SPALTEN-process

2.3 A Reference Model for Development Processes

In general, product development can be understood as problem solving. In the product development process, the problem solving has two dimensions: the life cycle from the profile phase to recycling phase, and the problem solving of the single stages from the situation analysis to the recapitulation and learning. Gerst defines theses two dimension of problem solving in the product life cycle as the macro-logic and micro-logic of the product development [9]. Based on these different approaches, a reference model for the product development was created that displays the different dimensions and supports the different views and approaches.

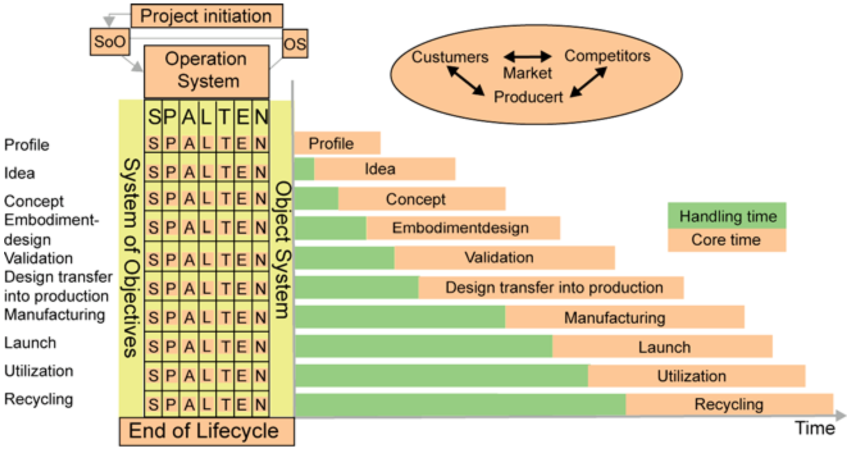

Fig. 5: The SPALTEN-MATRIX reference model

The core element of this model is the holistic referencing to the system of objectives and the fractal problem solving process SPALTEN during the entire product development process. The base of the process is the system of objectives that specifies the objectives that describe the future, anticipated or planned target state (Fig. 5). The system of objectives describes all relevant objectives and their dependencies and boundary conditions that are relevant for the development of the right solution – from the current actual state to the future actual state; the solution itself is not included [12]. In the course of the product development process the system of objectives is constantly expanded and concretized. The correct, continuous and complete collection and adaptation of the objectives is the foundation of a successful product development and a decisive part of the development activity. From this system of objectives the socio-technical operation system is derived, it includes structured methods and processes, as well as the resources involved in the operations for the achievement of the objectives. The operation system creates the system of objectives and the object system.

The result of the operation system is the object system, the implemented solution of the system of objectives. The object system is completed, when the planned target state corresponds with the actual state. Object systems are not only material systems, but also immaterial systems, e.g. in the case of software and services [8]. The object system comprehends the operation results developed for the problem solving or the achievement of the system of objectives, i.e. besides the result itself, also all intermediate results (e.g. drafts, prototypes) developed in the operation system [21]. The elements of the object system are subject or result of the operation system. The problem solving process SPALTEN is the fractal micro-logic of the operation system. All process steps are structured and documented according to the SPALTEN-process. The fractal nature of the SPALTEN-process means that the SPALTEN-process is repeatedly implemented in each problem situation of the process. It has been demonstrated that SPALTEN is effective and successful for the implementation and documentation of problems. Especially the standardized procedure enables the interchange ability. The process step is the basis for a standard language for the dealing with problem situations in different domains. The interactions of the single stages of the product development process are controlled objective oriented with SPALTEN, based on the system of objectives. If e.g. the problem containment of the idea stage identifies restrictions concerning the manufacturability, the situation analysis of the production planning is started, the results are replaced in all stages of the system of objectives and made available for all stages.

3 Conclusion

This reference model creates a problem-oriented process control during the entire life cycle. At the same time, all process steps can be development-methodologically supported. The continuous model enables a standard language on the micro and macro level in the product life cycle and standardizes stage- and domain overlapping views of the product development process. With this reference model Cooper's demand for a development process of the third generation is realized, stage changes and interactions are situation-specifically detected, implemented and protected by the problem solving process. With the documentation of the process model, the single steps of the SPALTEN-process cannot only be observed singularly in one stage, but also the entire life cycle. The reference model creates new possibilities in the methodical process support. Each step in the process, the cross point between micro- and macro cycle, can be provided with suitable auxiliary means accessible for the developers. The first studies demonstrated that the reference model offers many possibilities especially with its stringent division between system of objectives, object-, and operation system and the separation of the single steps of the problem solving.

4 Perspectives

Wikis as open content management systems in Intranet und Internet for information and knowledge platforms have reached a very high acceptance and penetration in only a short time. In a larger development project with 40 developers the IPEK used a Wiki as cooperation- and communication platform for a product development process and tested it with regard to its applicability. The potential of such Wikis is undisputable; many companies begin to build up expertise- and knowledge management systems based on Wikis. In the scope of the development project, the process support was very successful and the Wiki added substantially to the positive result of the project. The open structure of Wikis offers many advantages; however, it can also cause problems. When Wikis are used in product development processes, it is necessary to pre-define the structure, and here the reference model can be an ideal substructure. In further research projects, the reference model of the product development will be applied to an Internet-based Wiki. With this Wiki, the process navigation, -documentation, and project controlling will be carried out for the entire development.

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How to Measure the Success Potential and the Degree of Innovation of Technical Ideas and Products

H. Binz[1], M. Reichle

[1] Institute for Engineering Design and Industrial Design, University of Stuttgart, Germany

Abstract
The evaluation of innovative ideas and products with regard to their success potential – in terms of market penetration – and the degree of innovation is a special challenge for research and development departments as well as for management. Therefore a new evaluation method was developed to quantitatively determine these two characteristic values. The basis of the new method is Quality Function Deployment, which was modified and expanded to consider aspects of novelty and enhanced customer and manufacturer benefit. The evaluation of the method in five pilot projects shows that the calculated evaluation figures are very well suited for decision making in the product development process.

Keywords
Evaluation Method, Degree of Innovation, Innovation-management

1 Introduction

Innovative products are the key to success for all enterprises, especially in a competitive global market [3]. As far as economics is concerned, innovation signifies the introduction of an idea into the market or the conversion of scientific results and new ideas into a market economy-related or technical realisation [1]. In order to successfully develop innovative products, methods are necessary which are particularly related to the innovative parameters “novelty” and “successful commercialization”.

A review of the literature regarding development processes for new products indicates that there is still no quantitative appraisal and evaluation method which integrates the complex central factors “novelty” as well as “enhanced customer and manufacturer benefit” – and it is these factors which are the crucial final determinants of the success of a product.

In order to launch successful products, a detailed knowledge of customer requirements and their conversion into product requirements is necessary. The most exact possible fulfilment of customer requirements is an essential criterion for quality.

A new evaluation method should be able to identify the chances of market penetration (success potential) and the degree of innovation of technical product ideas and products. The objective of this new evaluation method is the determination of quantitative parameters to measure these two abstract items and to enable a comparison with other products (preceding models or competitive products). For the beginning, the method should focus on scientific-technical aspects.

Conventional methods, such as selection and evaluation methods, or methods for designing for quality, e. g. FMEA and QFD, are not sufficient to evaluate innovative ideas and products according to the objectives of the new method. Even if these evaluation methods of design engineering are modified accordingly, it is not possible to quantitatively determine the parameters of innovations, market penetration capability and degree of innovation.

2 The Key to the Solution

Updated definitions of genuine “(product) innovation” imply that a product not only has to be *new,* but also *successful* on the market [4]. A product can certainly be called “successful” if it offers a higher benefit than other products to both the customer and the manufacturer and if it is accepted on the market. The following definition can be derived from this analysis:

A product innovation is the successful realisation of a creative new idea or invention with an enhanced customer and manufacturer benefit.

According to this definition, the task of making innovation measurable raises the problem of how to quantitatively determine the degree of novelty and the enhanced customer and manufacturer benefit of an innovation (Fig. 1).

Since *customer benefit* can be equated with the best possible fulfilment of customer requirements, the new procedure must, as a first step, analyse customer requirements and their conversion into product requirements. To achieve this, the solution approach uses elements of the QFD method. Based on the first QFD phase, the evaluation method was enhanced by the following steps:

1. Product survey by means of the QFD method to obtain important parameters from the customer and product requirements for the evaluation algorithm.
2. Modification of the QFD matrix to record the importance of the novelty of the product.
3. Analysis and recording of influencing variables for each product requirement by modifying the QFD matrix.
4. Creation of an evaluation algorithm to determine the success potential and the degree of innovation.

These solution steps are the basis for the new evaluation method which is described in the following [5].

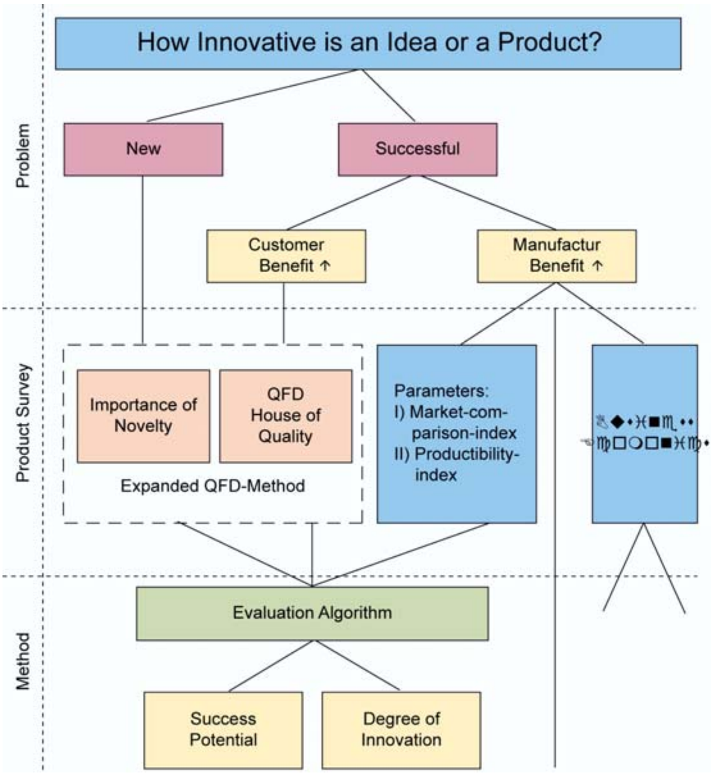

Fig. 1: Solution approach for the evaluation of innovative ideas and products