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A NEW APPROACH IN PRODUCT DEVELOPMENT, BASED ON SYSTEMS ENGINEERING AND SYSTEMATIC PROBLEM SOLVING

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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 [Albers 2004]. 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 [Marz 2005]. 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 and innovation processes

The topics product development and innovation processes are being researched by several different special fields. 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 [Cooper 2002]. From these two branches 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

[Prasad 1997]. 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 [VDI 2221]. 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 [Gierhardt 2001]. 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 Basics of Product Development

The basics of the systems engineering-oriented perspective were founded by Patzak [Patzak 1982] and Daenzer/ Huber [Daenzer 2002]. Ehrlenspiel takes on the systems engineering approach and transfers it to the product development [Ehrlenspiel 1995]. When describing a product, he refers to it as system of objectives, which is the sum of the objectives (requirements) and their relation. 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 [Ehrlenspiel 1995]. 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 [Negele 1998]. 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 [Steinmaier 1999]. 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 (Figure 1).

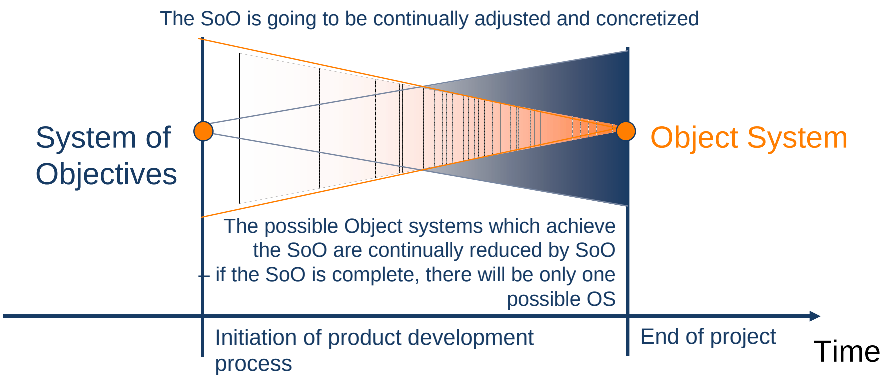

Figure 1. System of objectives, object system in the product development process

2 .2 Product development and product development processes

Die VDI-guideline describes the process for the development and design of technical systems model in seven steps [VDI 2221]. The process model of Pahl and Beitz reduces the process to four main stages [Pahl 1997]. 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 [Ehrlenspiel 1995] resumes this approach and integrated the personal, informatory, 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.

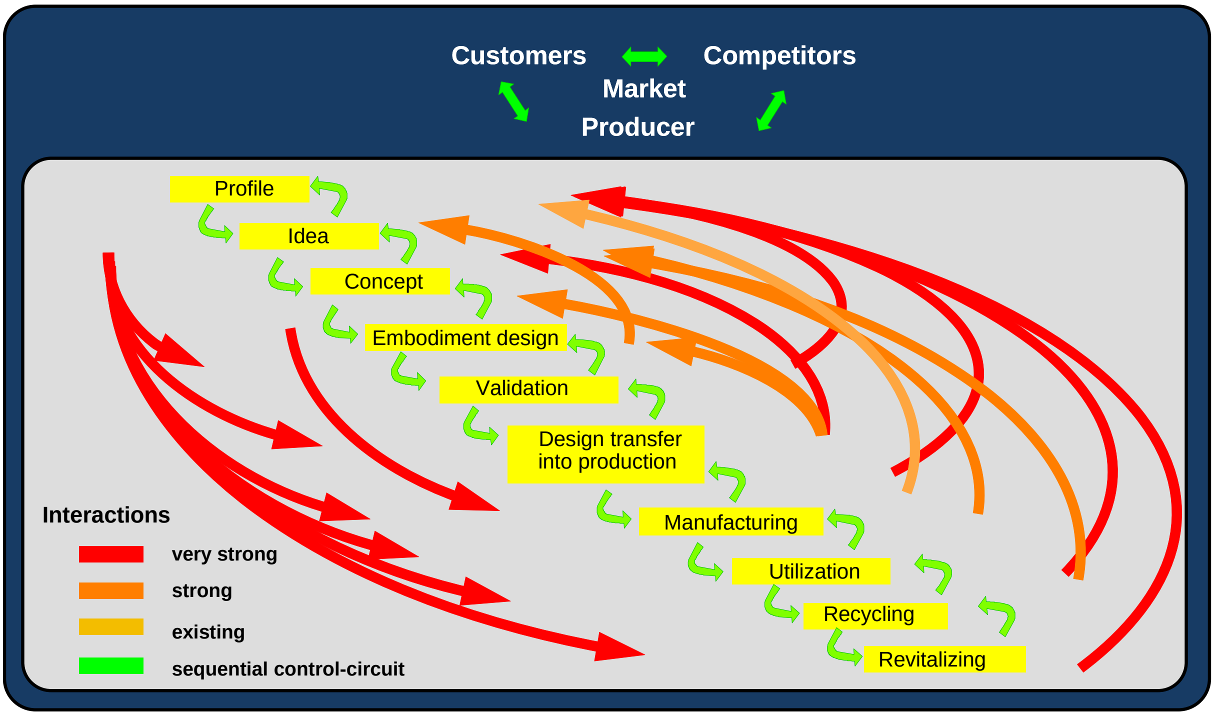

Figure 2. Stages of the product lifecycle [Albers 2004]

The process model of Albers (Figure 2) displays the single stages of the life cycle and emphasizes the overlapping and parallelization of the stages, thereby describing the interaction of the single stages [Albers 2004]. 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.

2.3 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 [Albers 2003] (Figure 3).

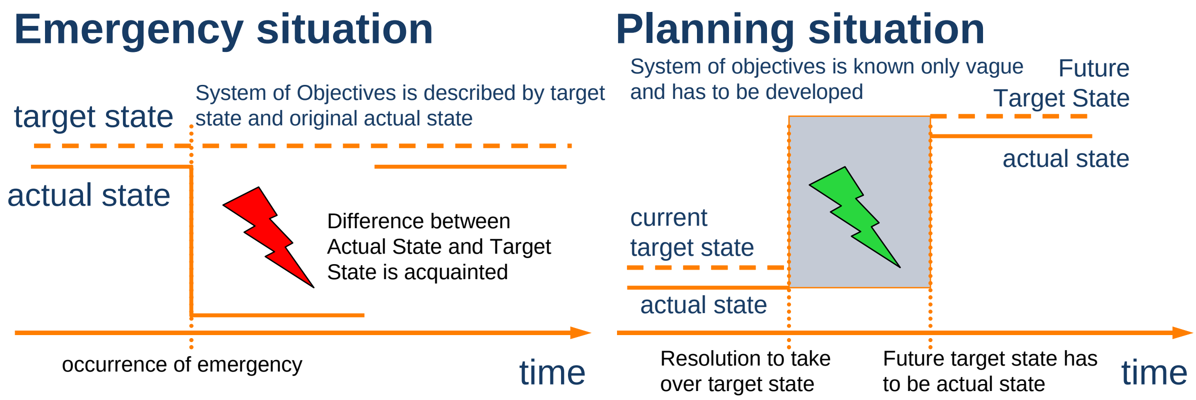

Figure 3. Problem situation

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 [Schregenberger 1980]. 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 [VDA 2006]. It supports e.g. SAP systems as standard process for customer complaints [SAP 2006].

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) [Albers et al. 2005] (Figure 4).

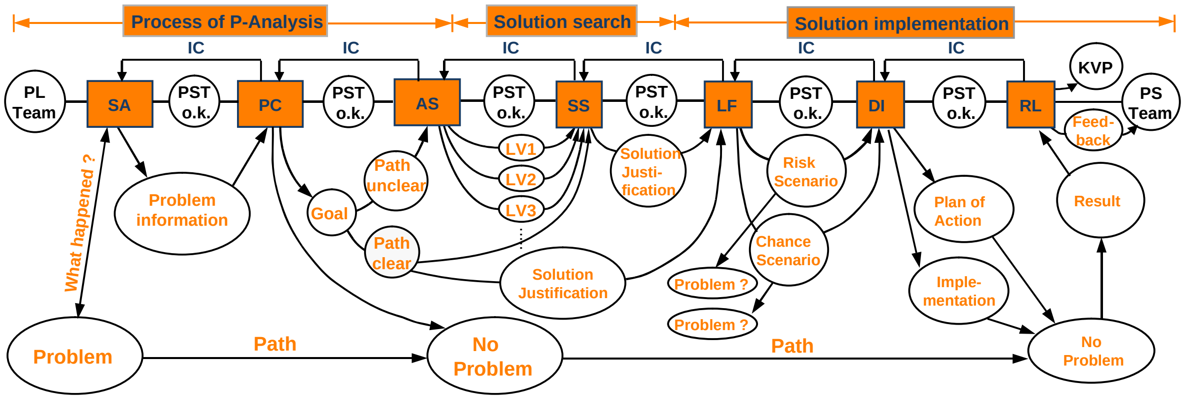

Figure 4. SPALTEN-process

3. SPALTEN-Matrix as 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 to recycling, 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 [Gerst 2002]. Based on these different approaches, a reference model for the product development was created that displays the different dimensions und combines and supports the different views and approaches.

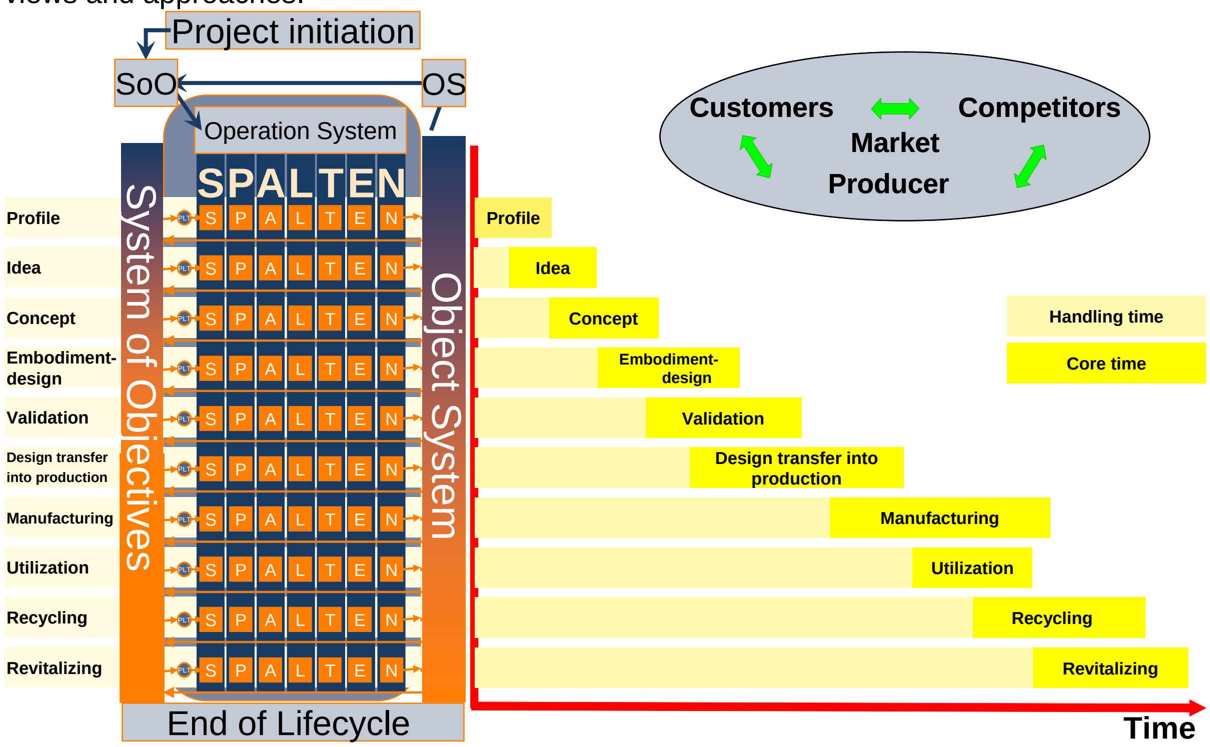

Figure 5. Reference model

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. 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 [Negele 1998]. 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 [Ehrlenspiel 2003]. The object systems 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, models, prototypes) developed in the operation system [Wenzel 2003]. 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 schema. The fractal nature of the SPALTEN-process means that the SPALTEN-process is repeatedly implemented in each problem situation of the SPALTEN-process (Figure 6.). It has been demonstrated that the SPALTEN-process is effective and successful for the implementation as well as the documentation of problems. Especially the standardized procedure enables the interchangeability. 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 the SPALTEN-process 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 and the results are replaced in all stages of the system of objectives and made available for all stages.

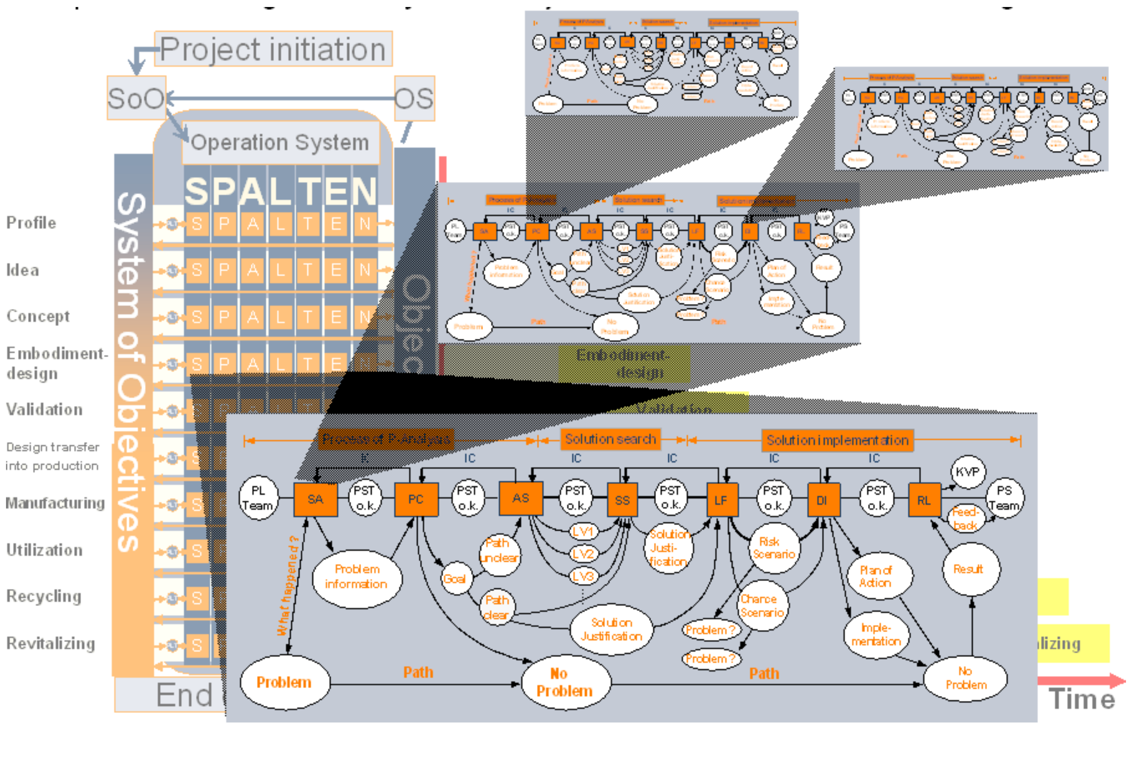

Figure 6. The fractal SPALTEN-process

3.1 Conclusion

This reference model creates a problem-oriented process control that is based on the system of objectives and therefore protects the object and operation system 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 during 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.

3.1 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 is to 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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