Developing fluid technical mechatronic systems with increased efficiency using the principles of Lean Innovation

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ABSTRACT

An integrated development environment for fluid technical mechatronic systems has a significant relevance due to the collaboration of different disciplines and the resulting complex system structures. Therefore, such an integrated development environment for fluid technical mechatronic systems using the principles of Lean Innovation was developed and implemented within the BMBF Project Fluidtronic.

1 CHALLENGES

Today innovations in many technical industries are no longer being developed as single rather than "systemic" innovations, due to the intelligent interaction of the disciplines involved. This applies in particular to fluid technical mechatronic systems, as the electronics and software proportion in particular rises continuously. It results in a strong increase of the complexity having to be controlled within production development over the last years /Eig08/.

In Order to achieve a better control of the complexity, whilst obtaining a simultaneous demand for an increasingly shorter time to Market larger attention is drawn to intelligent structuring of the "early stages" in the development process /Jac06/. It is essential to closely link the disciplines already involved at that stage of the process in order to enable a system design that is approved and optimized in an interdisciplinary manner. In order to realize this requirement an integrative development environment that integrates all disciplines and activities as well as all assigned methods, simulation models and product- and process information, starting from the collection of requirements up to the initiation, was designed within the project Fluidtronic *(Figure 1).*

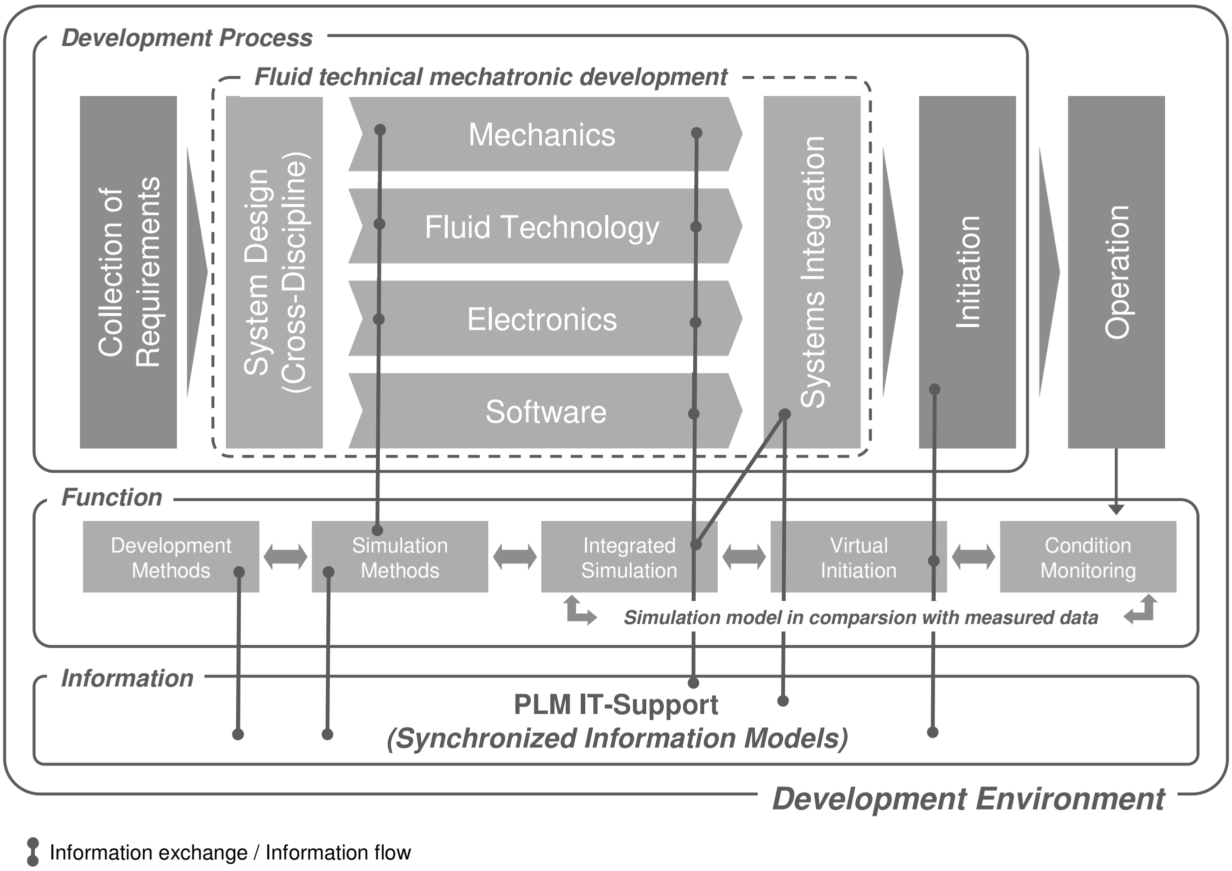

Figure 1: Integrated development environment for fluid technical mechatronic systems

Development environments as the one shown above are to be seen as a reference for company specific interpretations. They help to control the complexity of the development process /Gau06/. This allows the interdisciplinary cooperation to unfold its innovative effect during the development of fluid technical mechatronic systems /Fel07/.

2 LEAN INNOVATION - GUIDELINES FOR AN EFFICIENT AN EFFECTIVE PRODUCT DEVEOPMENT

Waste in forms of iterations, waiting periods or suboptimal technical concepts for the overall system, results in the interaction of the disciplines during the development of fluid technical mechanical systems. The understanding of the Lean Management approach meaning to focus on all value generating activities from the customer's point of view and therefore eliminating waste, is still underrepresented in today's product development. A survey of 143 companies has shown that only one third has already begun to systematically identify waste in their product development /Sch08a/.

Lean Innovation systematically transfers the principles of Lean Management into the product development. Results are, that "Lean Innovation Champions" obtain a remarkably high degree of innovation in comparison with other companies of the same industry. The survey also shows that these companies handle certain principles very well. Therefore the four guidelines for Lean Innovation are derived from these principles:

1. ***Strategic positioning of Innovation activities:*** Innovation activities are clearly positioned strategically in order to not lose track of time in the multiplicity of possible options. The implementation of the strategic positioning starts in the production development by emphasizing product advantages from the customer's point of view that are easy to communicate. Resulting trade-offs are being made more transparent at an early stage and prioritized in the sense of the customer value. This goal hierarchy is the basis for an integrative product development.

2. ***Structuring development projects at an early stage:*** Development projects are to be structured at an early stage, in order to give the production development the "right direction". A systematic Solution-Space Management as part of that helps to identify the complete interdisciplinary solution range of important product functions. The cross-discipline system design supports the description of the product architecture at an early stage in the project. The practice shows that intelligently structured, modular product platforms still hold significant potentials in most cases.

3. ***Easy synchronization of development processes:*** The synchronization of different disciplines is as essential to the development of fluid technical mechatronic systems as it is to a symphony orchestra. If one discipline gets out of step the whole project success is in danger. The multiplicity of processes is therefore synchronized by a certain collective step regarding all disciplines. Therefore individual processes are designed by optimizing the value stream in terms of minimum turn-around times.

4. ***Adapting Innovation Management:*** Innovation Management does not end with the commercial launch of a product. Often it's the little things like electronic features that decide if the product is still a success after a couple of years. A systematic Release-Engineering helps maximizing the life cycle turnover with comparatively small measures.

3 ACCELERATION OF THE PRODUCTION DEVELOPMENT BY SOLUTION-SPACE MANAGEMENT

The intention of a systematic Solution space management is to control the size of the solution range for each product function and to plan the convergence of the solution space limit systematical in the project over time /Len09/. A solution space limitation made too early is critical, as an often resulting late expansion of the pre-limited solution range comes at high costs (*Figure 2*).

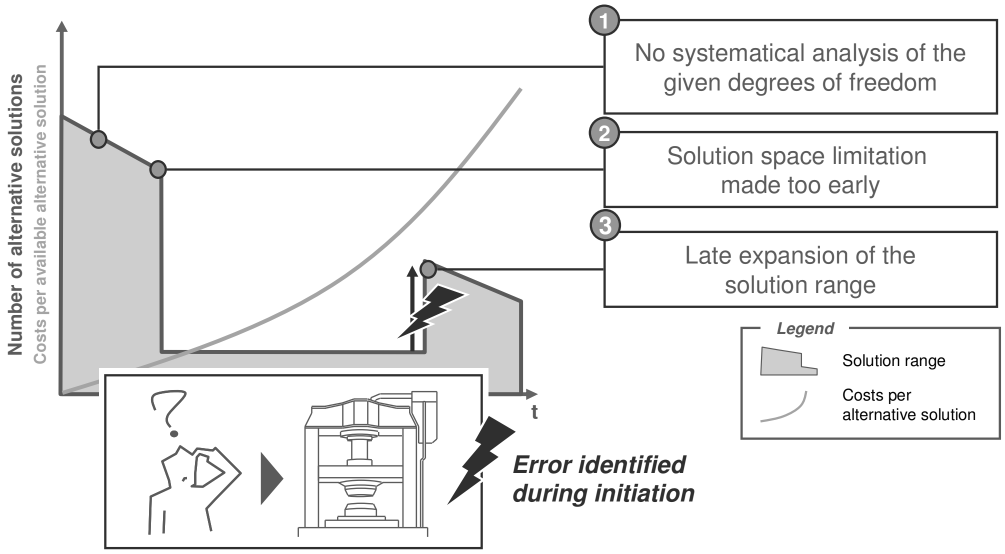

Figure 2: Late expansion of the solution range due to a solution space limitation made too early leads to high costs

A systematic Solution space management allows a continuous limitation of the solution space range. It is enabled by a validation on the basis of defined milestone reviews that take place at different stages throughout the development process and therefore prevent uncoordinated proceedings by a single discipline *(Figure 3).*

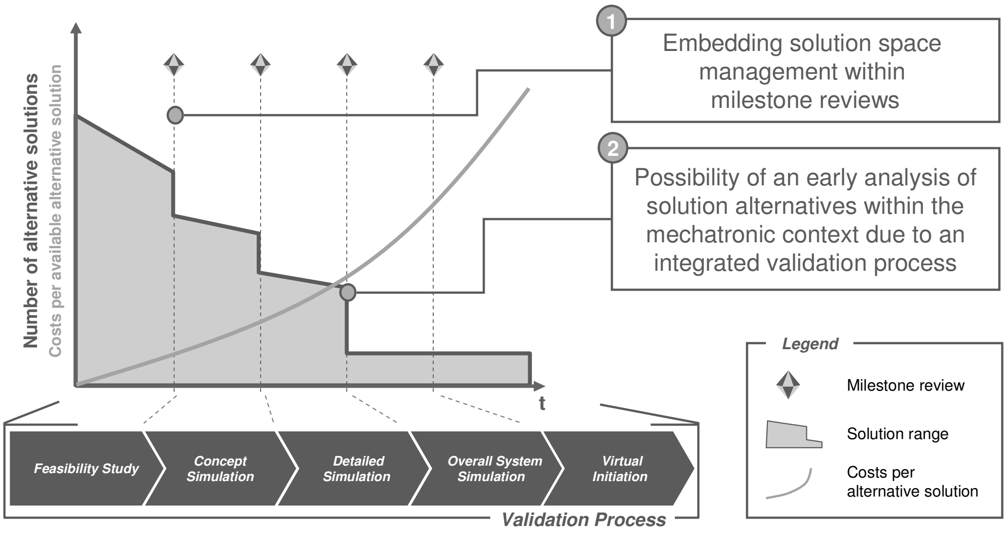

Figure 3: Continuous limitation of the solution space range by a systematic validation process

An early validation of alternative solutions and evolutional milestones is to be performed within the development process starting from the feasibility study up until the initiation of the system. This includes a continuous exchange of information between the disciplines and development partners involved taking place over a shared, server-based platform. The course of the information exchange is represented by the case shown in *Figure 4.*

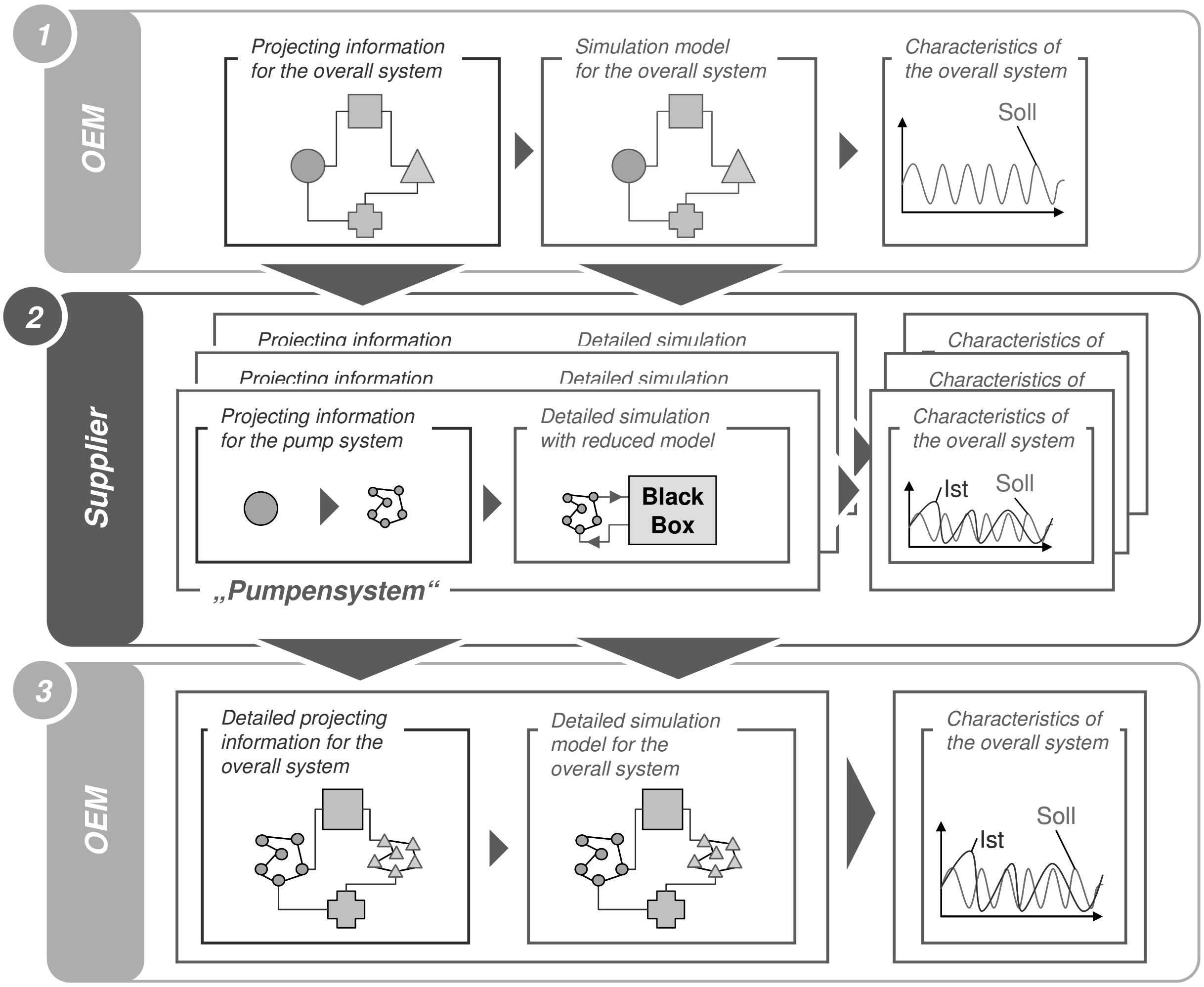

Figure 4: Information exchange between development partners

Based on this example the OEM defines the product concept with the simulations software DSHplus in the system designing phase of the development process. The requirements are translated into components maintaining the projecting information.

In addition the first projecting document of the OEM, that contains the objective characteristics of the component, is transferred to the suppliers. This works in form of a DSHplus connection diagram as a rough simulation model made by the OEM. Thereby the components that do not concern the particular supplier are combined and inaccessible within a “black-box” in order to ensure know-how protection during the exchange of the projecting information. Only the module that is to be developed by the particular supplier remains alterable /Bau09/. As soon as the supplier has developed a technical solution, he endorses the given data around the additional projecting- and simulation information and uploads it on the platform, from where the OEM can retrieve it. Within the integration phase the OEM combines all the different detailed projecting documents in form of connection diagrams to one overall connection diagram containing all relevant parameters. This overall connection diagram is later being transferred into a simulation model by the OEM. With the help of the simulation model the interaction of the components as an overall system can be simulated. Thus unexpected interactions between components can be identified at a former stage in the development process. Via several iteration loops a highly detailed overall system develops /Bau09/. Due to the efficient cooperation between the customer, the OEM and the suppliers within this simulation environment a faster and more robust product development is possible /Sch08b/.

4 CROSS-DISCIPLINE SYSTEM DESIGNING AS A REQUIREMENT FOR A HOLISTIC VIEW UPON THE OVERALL SYSTEM

A fluid technical mechatronic system consists of components from different technical disciplines. This often leads to an unsatisfactory understanding for the interaction of the components results due to given discipline-specific perspectives on the overall system. Every discipline uses different terms and definitions and therefore early cross-discipline coordination is complicated in practice. It misses a defined cross-discipline system (*Figure 5*).

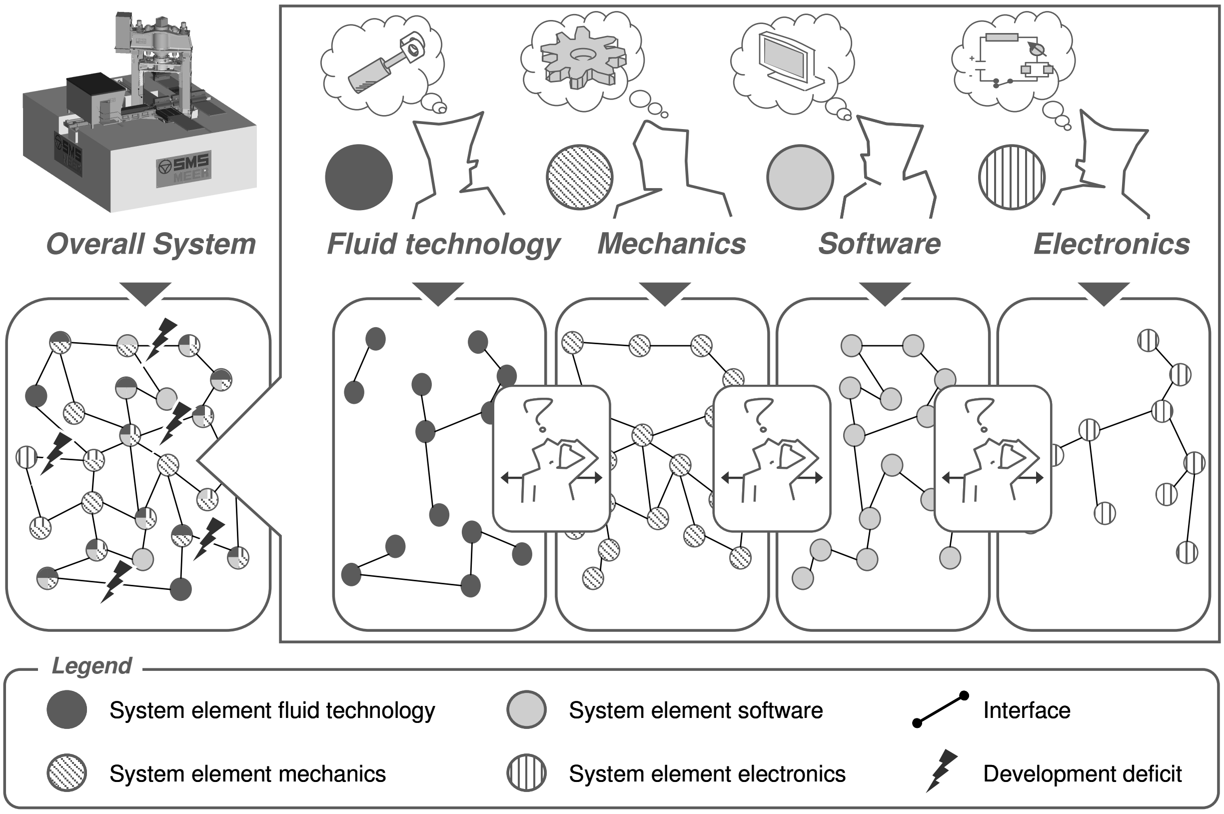

Figure 5: Lack of understanding concerning system interactions due to given discipline-specific perspectives on the overall system

A cross-discipline system design for the overall system helps identify the discipline-interfaces. The initial point is the collection of the overall system requirements. The requirements are then being translated into cross-discipline functions. The emerging functional view serves as an initial basis for a cross-discipline understanding *(Figure 6).*

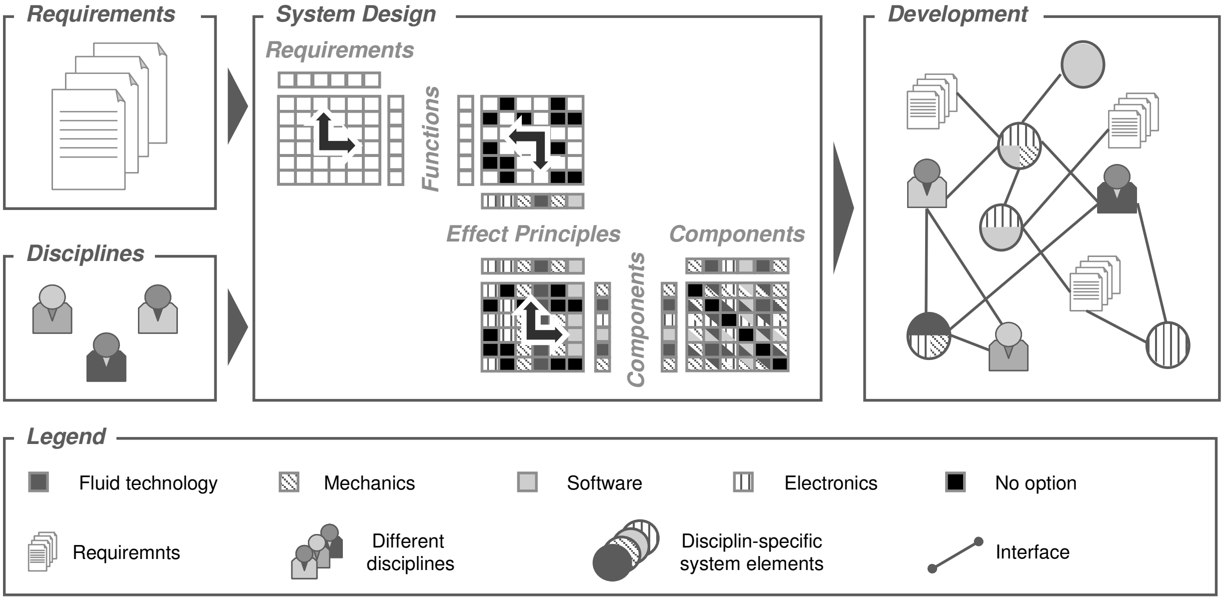

Figure 6: A functional view serves as a solution neutral initial basis for a cross-discipline system design

Product functions are not linked to any discipline. Possible active principles are assigned to the functions in a cross-discipline manner. Each active principle can be assigned to a certain individual discipline. The active principles are summarized in effect structures, where the combination of different disciplines takes place. These effect structures are later transformed into technical components. The comparison of the individual components allows identifying and defining interfaces between them. Therefore a mutual basis can already be established at a former stage in the development process, as the cross-discipline boundary conditions and interfaces in the system are specified and a cross-discipline understanding of dependencies is made possible.

5 INTEGRATIVE PROCESS MODEL FOR THE DEVELOPMENT OF FLUID TECHNICAL MECHATRONIC SYSTEMS

The basis of the development environment for fluid technical mechatronic systems is an integrative process model. The process model builds up on already existing development models and supports the ideal, cross-discipline development process for fluid technical mechatronic systems. All analysed development process models have in common, that they either schedule the validation of their results at the end of the development process or that they indeed mention an accompanying validation on a model basis, yet consider this insufficiently. This aspect however is considered in the presented process model as iterations in particular can be avoided during the development process by an accompanying validation. Right from the start the results are being examined and the development steps are being supported by models. Furthermore a virtual initiation is used in order to accelerate and simplify the real initiation, which represents substantial time and costs in the development of larger systems, e.g. a hydraulic Press. A Hardware-in-the-Loop-Simulation is also being used as an approach to simplify the control calibration with the aim of accelerating the initiation. Altogether this results in a three-divided structure for the process model. In this process model the development- and the validation process are located in the center. The processes accompanying the development handle tasks like planning, supervising, coordinating and steering. They are located above the development- and validation process *(Figure 7).*

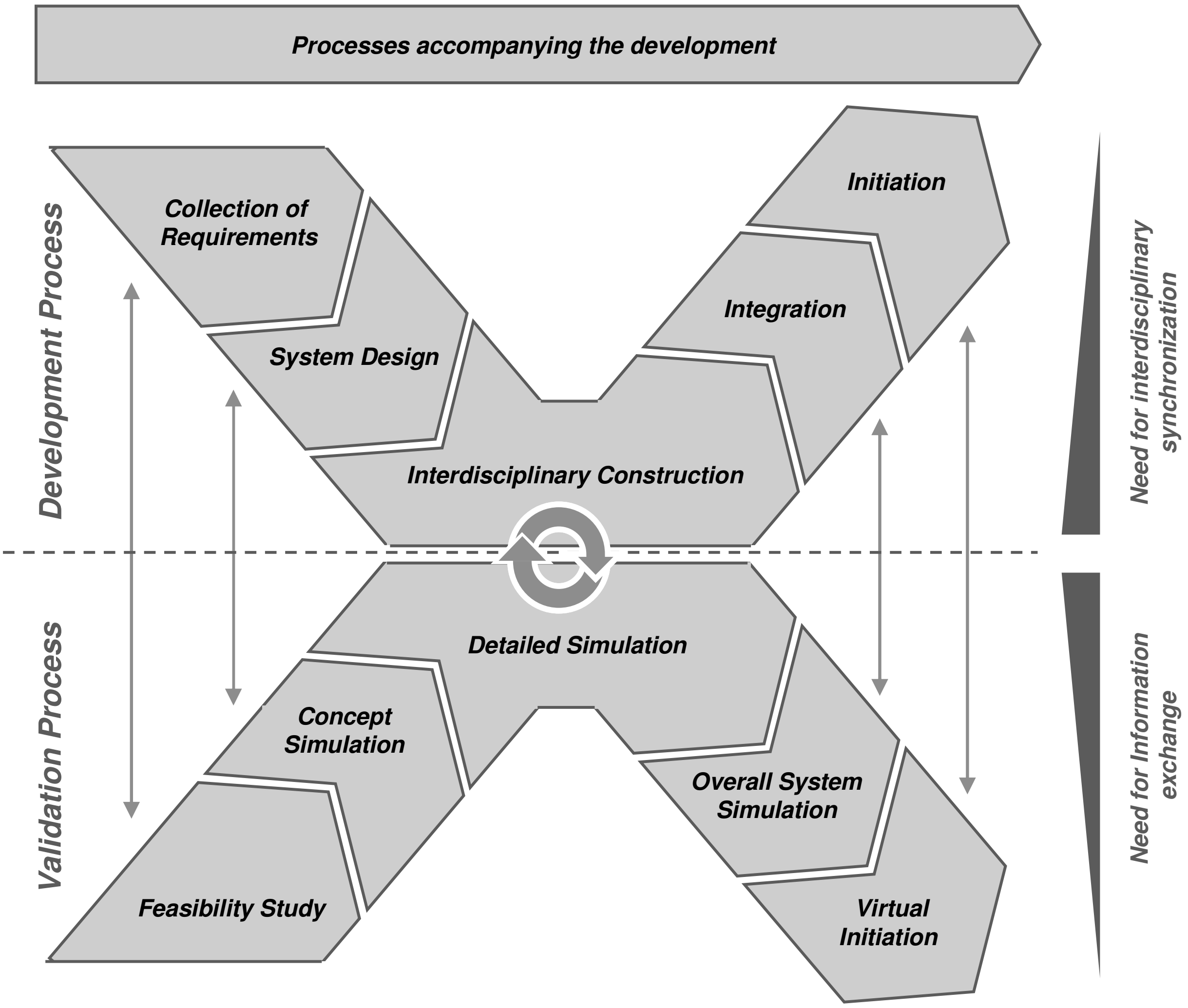

Figure 7: Integrative process model for the development of fluid technical mechatronic systems

The process model is to read from left to right. The further one moves to the right, the higher the maturity level of the developed system rises. The development process starts with the collection of requirements, being presented by the customer and other stakeholders. It is followed by the system design. The system design provides the basis for a coordinated proceeding with the different disciplines in the development process and helps to set up an overall concept for the overall system. Afterwards the interdisciplinary construction takes place and the process divides itself into the fluid technical-, mechanical-, software technical- and electrical development. Despite the partition of the process at this point a regular information exchange between the individual disciplines still takes place. As soon as the results from each developing discipline are available, the process is re-united and the results are integrated into an overall system model. The process model ends with the initiation of the overall system. The more the process elements within the process model approach the center of the process model, the higher the need for synchronization gets. This becomes apparent as the constraints between the disciplines become more visible, the further one approaches the center and continues to blur, the further one departs from it.

Every element of the development process faces an element of the validation process in order to secure the results. At first the general negotiability of a development project is examined within the context of a feasibility study. Later in the process the system design is validated by the concept simulation, where rough concepts are examined regarding the requirement fulfillment and the feasibility. After that the detailed simulation, using particular tools for each discipline, follows in order to validate the specific concepts. As soon as all the developed concepts are integrated into an overall system, an overall system simulation takes place in order to validate the results. At the end the real initiation is supported by a virtual initiation. The arrows between each element of the development- and the validation process symbolize the iterations taking place between them. Thus the development has the ability to simulate a concept and to steadily improve it, whilst simultaneously simulating the effects of the modification.

A detailed documentation of the process model with a detailed display of all activities including supporting methods is available in a manual. It can be downloaded under www.fluidtronic.de.

CONCLUSION

An advancing integration of the disciplines mechanics, fluid technology, electronics and software increased the complexity of fluid technical mechatronic systems substantially in the last years. This manifests itself in an increased number of deficits in the development and unreliability on developed systems. Since the increasing interdisciplinary manner of developing systems creates new possibilities both with the realizable functions and with the miniaturization of the components, „it is understood […]

that a demarcation between individual technical disciplines is no longer possible and arising potentials can only be made accessible by a cross-discipline development“ /Win07/. Therefore it is of great importance to supplement the existing development methods by means of a continuous interdisciplinary development methodology. In this context a development environment for fluid technical mechatronic systems offers essential benefits. It allows a coordinated cooperation of the disciplines and helps companies to identify and eliminate weak points within their own processes. Furthermore it offers a balanced relationship between standardization and flexibility in the individual phases of the development process by means of configurable process components.

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