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NEW WAYS OF DATA PROCESSING FOR INCREASING OF THE EFFICIENCY WITHIN THE PRODUCT DEVELOPMENT

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ABSTRACT
Future development processes need measurability of the development quality and of the product properties considerable before the beginning of the production and assembly process. This checkup can at least take place with virtual examinations (simulations). These virtual examinations should reflect the degree of maturity and should be used for the release of production. However, the benchmark of the whished product properties and the product behavior requires a coherent dataset, which can be additional usable for a multitude of possible simulations, which has to be strongly integrated in the product development process (PDP).

Moreover the increasing mass of information caused by complex and mechatronic products as well as the interdisciplinary work and globalization lead to the need of finding and analyzing new ways of data processing for increasing of the efficiency within the product development

Keywords: Benchmark of properties, Degree of maturity, CAx-integration, Product model

1 INTRODUCTION
Modern products must be efficiently developed and have to fulfill premium standards technically as well as qualitatively. Additionally those products must be adjusted individually to the customers.
But this ability of the individual configuration causes a steadily growing mass of variants, what becomes apparent in the vehicle-dynamics-actuator-system in the automotive industry. The different combinations of engines and gear versions as well as the drivelines and actuator systems create up to 100 different car variants [1].
Thus it is easy traceable that the steadily growing complexity stands in opposite to the area of conflict existing of costs and quality and time. To fulfill the aim of cost effective design some procedural, organizational, methodical, technological adjustments have taken place, especially in the earlier phases of the development process, where up to 80% of the whole costs were assessed [2].
Thus additionally economization potential could be unlocked through matrix organization or the teambuilding. Moreover the rearrangement of the working organization from sequential to parallel or simultaneous engineering has led to shorter development periods. But next to methodical enhancements, the already described mass of variants and reduction of development periods can only be reached by the widely application of computer assistance [2].
Therefore a completely checkup of all variants with hardware tests isn't accomplishable financially as well as temporarily and can only be realized with tests based on simulations, which are designed on the so called Digital Mock-up (DMU) [3]. Those should guarantee an already real time validation of the product properties and functions as well as an estimation of the degree of development advances [4; 5].

Despite of the already accomplished improvements within the development process the increasing complexity of the products and organization structures leads to new problems and difficulties. On the one hand the evaluation of an overall domain project or product advance is very difficult just because of this complexity and networking [5]. On the other hand the synchronization and especially the data logistic of the simulation methods and operations, which should monitor this product advance have

become more and more complicated [7]. Although the results of those simulations are strategically important for each enterprise, the single operating departments are information and data technical islands. Simulation supporting product data management systems aren't nearly wide spread as the design supporting product data management systems (PDMS) [7]. Investigations and rogations of engineers in the company AUDI AG shows, that the integration of the simulations and computations in the strongly connected development process is on the one hand very important and hasn't on the other hand been done until now [8].
This can be also be backed by a study done by KRASTEL, who investigated the needs of simulation engineers for the functions of PDMS (Figure 1) [6].

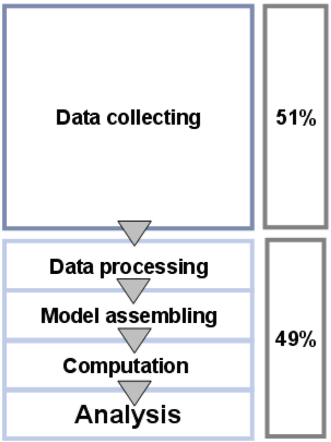

Figure 1: Time effort during simulation [6]

The basic results of these studies are that the simulation engineers must on the one hand be better supplied with data and pieces of information and on the other hand those data have to be characterized in order to enable a transparency and reliability and to avoid the misinterpretation of those information.

Therefore the aim of this work has to two aspects. Firstly the product advance should be displayed by a degree of maturity, which is based on simulation methods. Secondly a concept should be created, which can ensure the data technical integration of simulation and computation departments with a computer assisted reference process as well as a method to ensure the transparency and the reliability of those data.

2 DEGREE OF MATURITY WITHIN THE PRODUCT DEVELOPMENT

To measure and consider the advances in the product development process a transparent quality defining criteria for all in the development process involved persons and engineers is needed. Moreover it should describe the degree of maturity of the product at each level of the development process [9]. This degree of maturity was originally defined in the context of project management and should now be used to identify and present the current advance and status of the product. This enables the product managers in case of a loss of product advance to react and to counter steer in order to insecure a steadily increase of product advancement and to avoid unessential, cost intensive or even deceptive iteration loops (Figure 2).

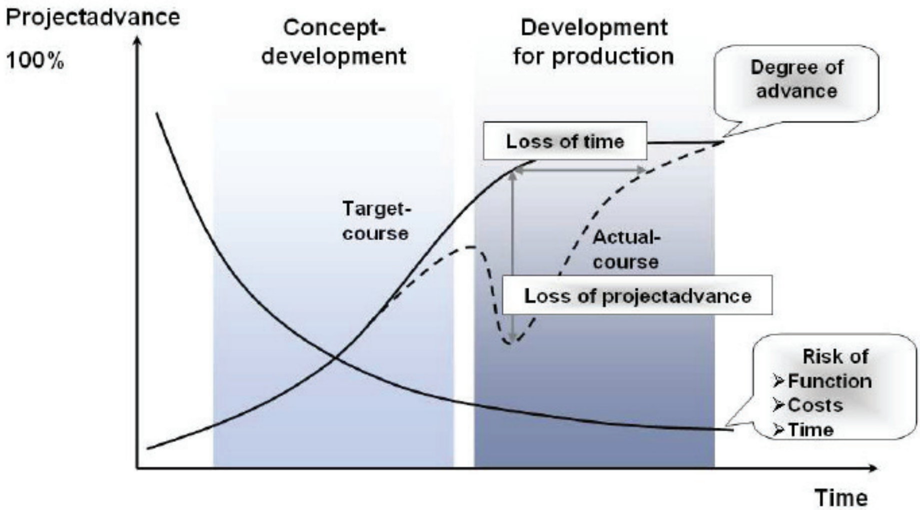

Figure 2: Course of the degree of maturity during the development process [5]

Additionally this degree of maturity should conduce to the communication and synchronization of the development departments concerning the product and should be attached as quality criteria for the data and information, which accrues during the development process. This is primly necessary, because a lot of data and information concerning the properties of the product are generated during the design process from very different sources, which can't be handled and described with current methods of version and iteration management.

Some definitions of the degree of maturity are already described by PFEIFER-SILBERBACH and MÜLLER and KREHMER [4; 5; 9]. Common is therefore the intention to compare the actual fulfillment of a property $P_{jActual}$ with the target fulfillment of that property $P_{jTarget}$. However for this consideration a definition of the term property is imperatively necessary. The approach of the character property modeling (CPM) as well as the following approach of the property driven development (PDD), developed by WEBER ET AL. makes a difference between characteristics C_i and properties P_i to combine the physically characteristics of a product with the resultant properties and functions. Characteristics are the structure or the appearance or the consistence of the product in this context. Otherwise properties describe the behavior and the function of a product and can't be accessed by the designer in contrast to the characteristics [10].

According to MÜLLER the degree of maturity can now be described as the sum of those single comparisons. Based on the strongly dependency of the properties and therefore of the degree of maturity this approach must be expanded according to MÜLLER at a term σ_j, which describes the fuzziness of the X-System as well as the interference of the X-System with the property (1). The X-System describes as well the actual occurrence of the data processing system as the boundary conditions influencing the data quality.

$$R_{Overall}(t) = \frac{1}{n} \cdot \sum_{j=1}^{n} (1 - \frac{P_{jTarget} - P_{jActual}(t)}{P_{Target}} \cdot \sigma_j) \quad (1)$$

Resultant of this consideration the degree of maturity isn't presentable without the investigation of the different process steps. The different information and data, which appears during product development process are influenced by the X-System and must be (according to MÜLLER) connected with a fuzzy-factor σ_j (2). This factor or factors have the duty to characterize the dataset and to generate a transparency and reliability for the involved persons and designers during the development process. Those influences and interferences can be combined in an overall phenomenological model, the so called engineering information management system (EIMS) (3).

$$R_{Overall}(t) = \frac{1}{n} \cdot \sum_{j=1}^{n} (1 - \frac{P_{jTarget} - P_{jActual}(t)}{P_{Target}} \cdot \sigma_j) \tag{2}$$

$$\sigma_j = \sigma_j(X - System; EIMS) \tag{3}$$

This consideration, which has a very process oriented focus, leads to the extension of the definitions of WEBER and MÜLLER. The fuzzy factor can now be seen as the influences of the process and can therefore be described by the single process steps.
The classical process sequence of simulations is defined as the three essential steps preprocessing, solving and finally post processing (Figure 3).
All relevant and needed data and information are ascertained during the preprocessing for the simulation. This dataset is the base for the generation of a simulation model. This can be done with one ore more input files, which are saved as the simulation model in the system. Additionally constraints must be defined.
The solver executes afterwards the computation on the basis of the simulation model and the constraints and calculates the actual properties [10].

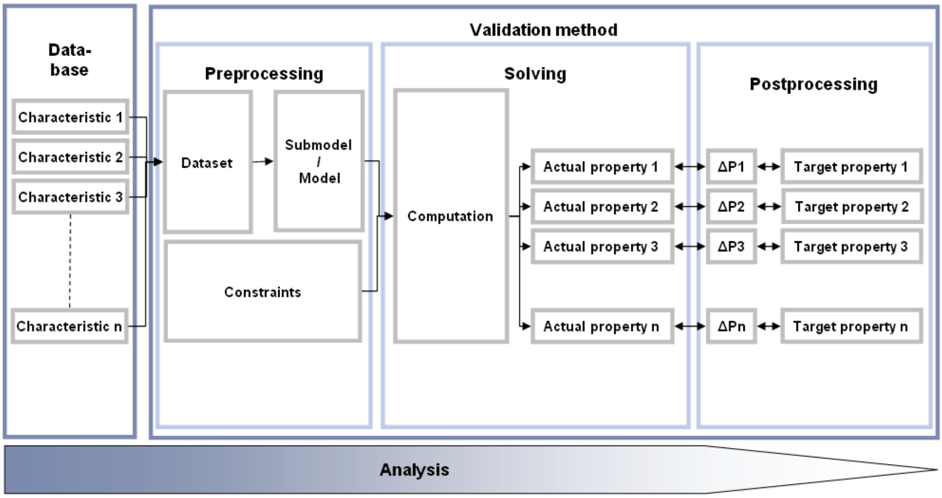

Figure 3: The simulation process in context of the PDD

Considering only the simulation process in this paper four fuzzy factors (leaned on the arising information during the process) can be defined in this context: the fuzzy factor of the dataset, the fuzzy factor of the model, the fuzzy factor of the constraints and the fuzzy factor of the simulation method itself. In this first investigation only the fuzzy factor of the dataset should be considered.

One of the main difficulties is the non existing homogeneity of the data, because the information has very different backgrounds and sources. On the one hand a lot of information sources exist on the other hand the information are generated over a large range of time during development process. This leads to the danger of misinterpreting and of misusing those data.

Therefore the user needs to know how the information is created, when they were created and what the intention of the creation was to handle and to use this information in a right way. For example the weight of a complex product like an engine in a automobile differs if it is measured in reality or it is calculated in a CAD-system. This can be leaned back to the fact that it is almost impossible to specify the right density for each single part. Another example is that the aimed weight of a car differs up to 80 kilos from the early planning phases up to the start of production.
Especially for tests or investigations which are based on measurements, the underlying *measurementmethod* is a very important parameter for the discussion of the test results. For example a lot of methods exist for the measurement of tires and their results often diverge. So the user of these measurement results can't discuss the simulation result, which was computed on the base of these measurements, without knowing the underlying measurement method. The *generationsystem* is also a very important parameter. It defines how the data were created, for example, if the mass of tire was measured or if it was calculated or if it is a target value.
The period or the *Development status* (*PDP-status*) during the development process is the next important parameter to know, because it defines which milestone is targeted. This enables a substantial estimation of the design and the project and the validation level of the information source, because these milestone are often very strictly described and have predefined aims. Finally data, which aren't officially released, must be used for simulation. This is necessary because in the context of the concurrent or simultaneous engineering the synchronous usage of data and therefore the quick providing of data have an increasing impact. But this requires possibilities to mark the provided data with a kind of *releasestatus*, which declares the data as released, in usage, in the checking process or inactive (Figure 4).

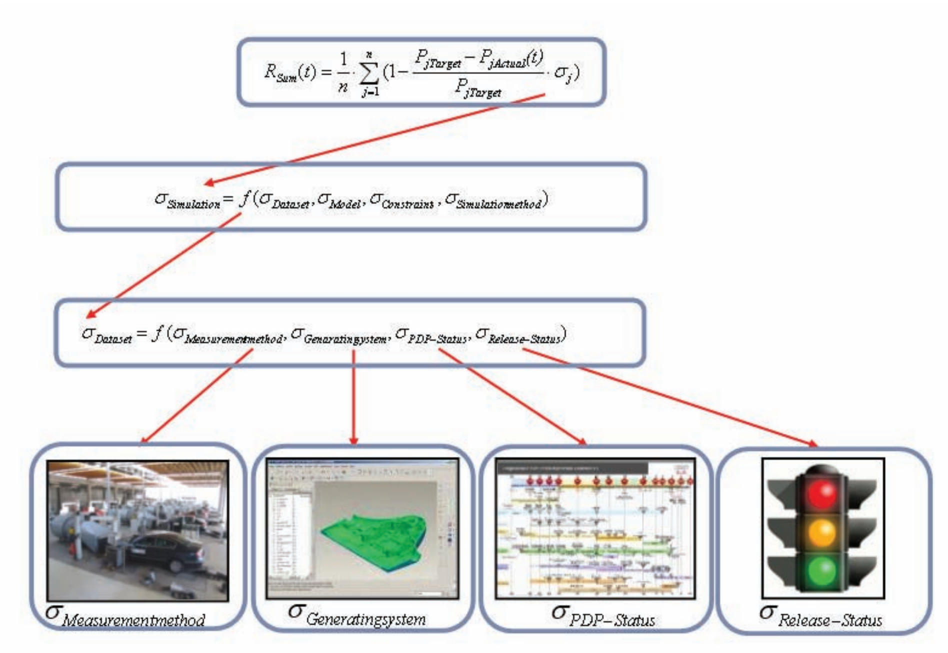

Figure 4: Fuzzy factors of the degree of maturity

The description of those factors enables the data user (in this case the simulation engineer) to estimate and to rank these pieces of information. Therefore those characterisations enable a transparency and reliability to each involved engineer, which is a fundamental need in modern networking and global engineering departments.

3 INTEGRATION OF SINGLE DEGREES OF MATURITY

Another aim of this work is to build up a degree of maturity based on the simulation results. Therefore it is necessary to combine the single simulation results. This can be done according to MÜLLER by summing up all calculated results. This integration can reflect the advance of the whole development process.

First of all to generate the target product advance course a chronological localization of the validation methods is stringently necessary. Therefore at distinct periods in the development process, the results of the simulations have to be recalled and can be combined with the actual course of the degree of maturity (Figure 5).

Summing up, every simulation is a validation method and is a part of the product degree of maturity. So it was succeeded to define a consideration of the advance of the development process, which is described by the results of the simulation methods.

On the one hand these results depend on input information and data, which are influenced through the process and the X-System. Therefore fuzzy factors have been defined which should not influence the degree of maturity but should characterize the information and their origin to enable a communication between the involved persons and engineers. So it is possible to distinguish in the case of an insufficient product advance between mirrors which are caused by an inaccurate product and mirrors which are caused by an inaccurate method or process.

On the other hand it is obvious that this consideration enables a network of properties, whereas the connection or link between two or more properties is always a simulation or rather a validation method. In other words a simulation is an analytic function which transforms input properties as the input data into output properties as output data. This description enables therefore a logical arrangement of the validation methods, because the chronological order of the simulations must be oriented after the input and output data, needed for these simulations.

In addition, such an ordering of the properties can break the simulation results down to the characteristics, which are the adjusting lever of the designers. This could enable the designers and the calculators to identify the right solution, if a simulation result and therefore the product behavior is insufficient.

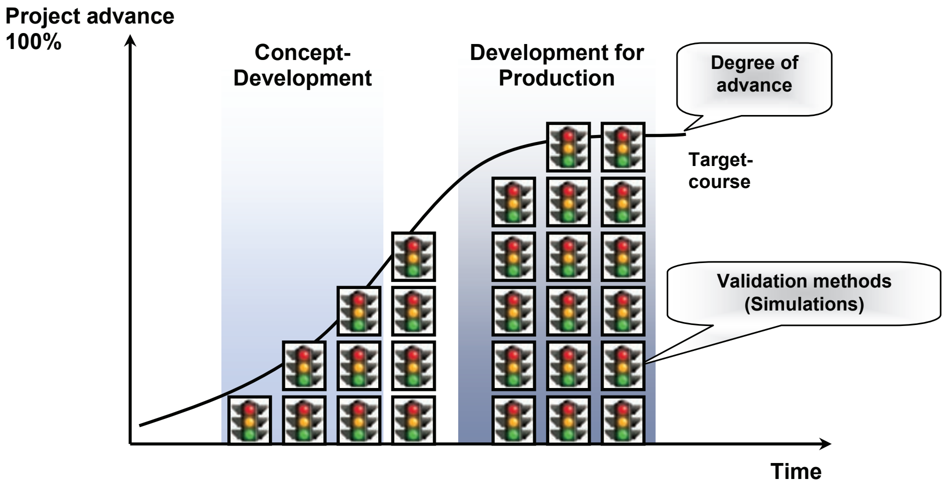

Figure 5. Integration of single simulations to a target course

4 PROCESS AND PRODUCT MODEL

The last aim of this work is to supply simulation departments with data. Therefore a process and product model should be presented.

First of all it is necessary to expand existing process and product models, to effectively integrate the simulations in the development process and to realize these theoretical considerations. Furthermore it

is necessary to create a common database which can be used as an input pool for every simulation, to avoid different versions of the datasets.
The focus of current product or data models, which are realized in modern PDM-Systems, is the detailed description of geometries and part structures and configurations and production information and reflects therefore the classical view of the designers [14].
But to effectively represent the requirements of the simulations und computations in a product model, this part orientated view must be expanded about a representation orientated view. The input and output properties are especially for this consideration relevant (Figure 6). The part itself steps back, the more as it must be the aim of future product models to support simulations in the earlier periods of the development process, where no geometries or fixed part definitions exist. Above all there lies the main usage of simulations because they are able to be the real driver of the development. And the simulation can only fulfill this function if the product model is not fixed on the part definition.
Additionally a lot of properties, which are generated by the steadily growing number of mechatronical components, can't sufficiently be described with only part oriented view. For example the effort to describe the ESP-System of a vehicle with a common product structure is only be able on the top or highest level, the whole vehicle, because the single involved components are locally and hierarchically assigned to the very different components.
This strong divergence of those two different views of design and simulation can therefore only be solved on the level of the properties, because this is the only level which is common to both. Thus the request for a process model is created, which is able to filter the data, which are relevant for the simulation to convert them and to send them to the aimed simulation department.

The need of a filter mechanism is based on the assumption that a simulation s_j needs only some of the properties of the parts, which are included in the model. Moreover this is the reason why a part oriented view can't effectively provide simulations with data, because there would be to much idle information. The conversion of the data is caused on the fact that a lot of different systems create information and data of the product. Most of these are highly specialized and don't have a direct interface to other systems.
This generates the requirement of an effective communication model, which is able to transfer and transmit meta information like the responsible person or the date of creation as well as the influences of the X-system as they are described.
Based on the product model STEP AP 214, which deals with the description of geometry as well as the description of the product structure, a product model was created, which integrates a communication model and the characteristics, which are needed to judge the dataset. Additionally the property data are linked to the part by a representation level, which describes the source and origin of the information.
A classification of the usage information, which is the essential property information, is oriented at the concept of the so called *Sachmerkmalslisten* (SML). The SML is a method to describe properties in form of a matrix and is according to the DIN 4000 a collection and ordering of characteristics and properties which are characteristic for a distinct group of parts [13]. Moreover it enables a digital documentation as well as the transmission of its content, which is independent on the influences and view of the user. The properties and characteristics are listened to, with or without a coding, in special tables [15].
Finally the properties can be accessed as input or output data to a simulation or a validation method. This allows the postulated hierarchical ordering of the properties (Figure 6).

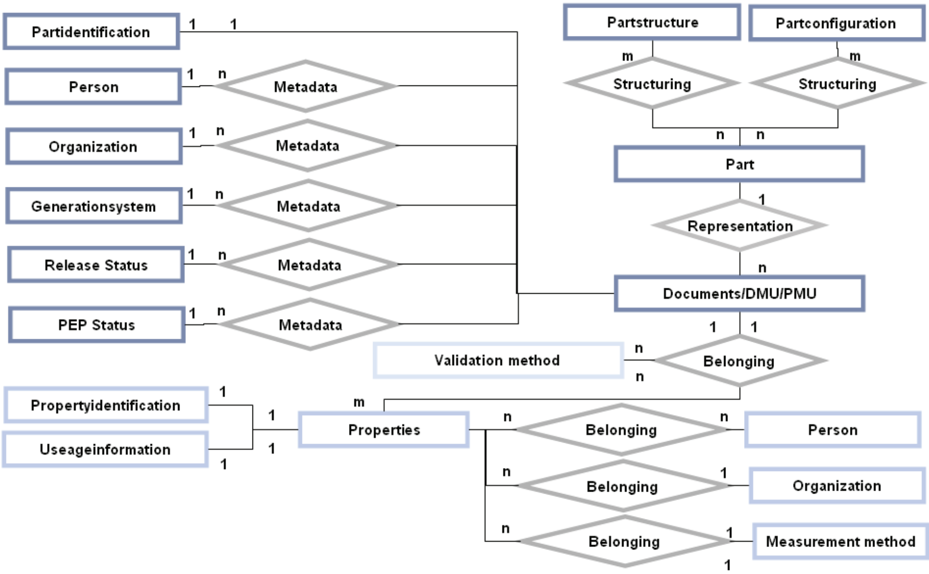

Figure 6: Enhanced product model

Secondly a process model must be created which can order and arrange the data and information transport. This reference process should be based on the data warehouse concept. According to this concept the data logistic is distinguished into the steps of taking over the data and the data delivery. Moreover these steps can be spitted into the steps extraction, transformation, loading (cp. ETL-Concept). The role of the data distributor should according to the VDA 4985 part 2 and the ISO 13584 provide knowledge and information and the data user should interact with it [16].
Designer and external sources as well as test engineers can be classical seen as data distributors. On the other side simulation engineers and managers can be seen as data users. The role of the data logistician is a kind of interface function, which is responsible for the data transport and the transformation and processing of the data. The previous described product model should storage the data.
The described meta data can now be used to control and to regulate the information transport. Therefore the simulation engineer can communicate over a dialog interface with the data warehouse and can access the data by choosing and distinguishing metadata. A data interface enables the simulation engineer to download the chosen data.

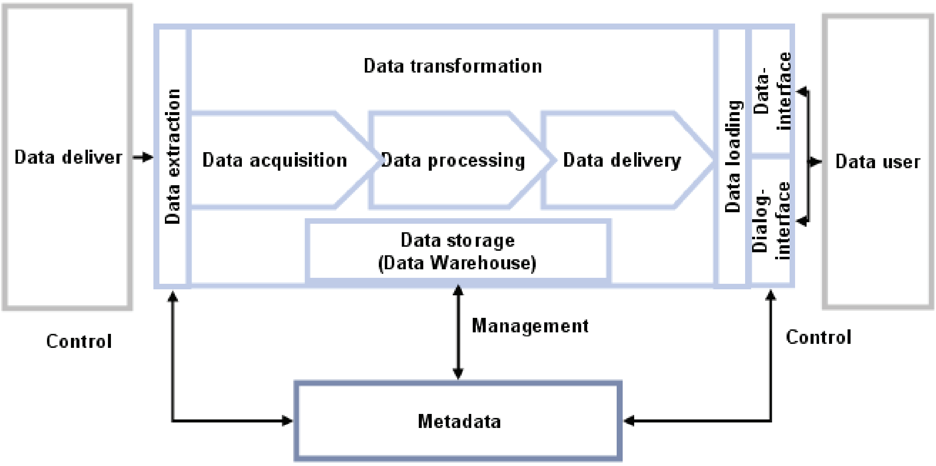

Figure 7: Data supply process

7 CONCLUSION AND OUTLOOK

The aim of this paper was to develop a concept how to supply simulation with data and how to generate a transparency and a reliability of those data.
This could be fulfilled with a theoretical concept of an enhanced product and process model. Based on the STEP AP 214 a product model was created which is able to link information as input and output data to simulation and is able to characterize them with a multitude of metadata.
Moreover a reference process based on the ETL-concept was created which enables the data user to access the information stored in such a product model.
This product and process model is the base to execute successfully simulations. Those simulations are needed to validate and benchmark the product degree during development. This can be formally monitored by a degree of maturity which is fed by the single simulation results, and aggregates them to a formal degree of maturity.

The next steps should be the further investigation of the X-System as well as its influences on the simulation results. Therefore a pilot project within the company AUDI AG, which supplies multi body simulations (MBS) with needed data and information, should be finished and evaluated, to reflect the experiences to the product and process model. Moreover this concept has to be evaluated within other simulations and disciplines like the FEM or CFD.
Finally the feedback of the simulation results and of the current degree of maturity to the designers should be the concluding part of this work. Therefore ways of conversion and transmitting the output data must be found und must be integrated in the design systems.

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