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A COOPERATION MODEL FOR THE EXCHANGE OF PRODUCT DATA OF ONE-OF-A-KIND-PRODUCTS

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ABSTRACT
The strong worldwide economic competition requires cooperative design especially when one-of-a-kind-products are produced by competitors to optimize their knowledge capabilities and individual capacities. Establishing a continuous work flow between these partners demands a highly flexible network for conception, design and production. In order to set up this cooperation between the partners a flexible product data structure through which work packages containing design tasks can be exchanged and executed in different CAx-systems have to be available. Such a system was developed between three major companies, two of them being competitors in the ship building process.

Keywords: one-of-a-kind-products, system view, data exchange, cooperative engineering

1 INTRODUCTION
Taking into account identified needs and experiences of cooperating companies working together in designing and producing one-of-a-kind products such as shipyards or plant constructors and their supplying partners a general cooperation model for the design and production with different views to the product data has been developed [1]. The design results have to be available on a structured and clearly defined model and enable views to the data that support the design methods of all participating parties.
Concerning the product data model for one-of-a-kind products there was detected the necessity of some different views on the product data which represent kind of a "hull" of the product, specific "zones" or "spaces" the product can be subdivided into and the technical systems the product consists of. The "hull" view is needed for the location and description of these parts and materials the product hull is made of. The "zone" or "space" view supports the location of specific components or parts within the product hull and mainly is used by these partners who account for the design and production of the one-of-a-kind product as a whole. And, finally, the systems view supports mainly the suppliers in handling specific technical systems which often have to be installed beyond single defined zones or spaces of the product.
The product data model outlined above is one core element of the cooperation model for the exchange of product data and helps to locate specific product data describing systems, components and parts within the product structure. To get a dynamical network cooperation between cooperating partners working there is a need for an easy to handle information and communication system through which these partners can exchange defined work packages containing construction and design tasks among each other. The ICT system is the second core element of the cooperation model. This system, firstly, serves as a platform to exchange these work packages, it, secondly, makes available rules and appliances for the data exchange, and it, thirdly, supports the communication between the partners while they are doing their design and production tasks. The cooperation model allows a speedy and easy data exchange between the cooperating partners.

2 RESEARCH APPROACH
For the development of a general product data model for one-of-a-kind products, in a first step, a specific product data model especially for ships has been developed. Based on this model general patterns have been identified which could be assigned to other one-of-a-kind products as well as to other complex products so that a general product data model for these kinds of products has been deduced. The

validation of this general model is realised by a detailed description of data models of other one-of-a-kind products such as spacecrafts or plants and of highly complex products like aircrafts or automobiles. These data models show the basic structure of the general data model, they differ from each other in the number and wording of the data model elements or objects, respectively, as well as in the relations between these elements or objects. Actually, there is a German research project in aircraft industry which among other activities develops a detailed product data model for aircrafts [3].
For the development of a ship's product data model the interrelations of the ship's component parts were analysed and represented in entity relationship models [3]. These models support the derivation of exactly these views on a product that are necessary for solving a specific problem or for performing a specific task. The conceptual advisements in combination with the needs and requirements of the industrial ship building partners finally lead to a few attributes that would be used for identifying the components and parts when product data are exchanged between the partners of a shipbuilding project. The defined core attributes for identifying a ship's components and parts in combination with the needs and requirements of concurrent shipbuilding enterprises (cp. [4]) lead to that attributes or objects, respectively, which can be used for the exchange of product data. Some key attributes for identifying ship component parts are (a) the name/notation of the part, (b) the cross-company ID-number which gets assigned through the communication platform and (c) the basic metrics like dimensions, volume and weight. Further more, there should be a reference connecting these attributes to documents giving some additional information about the part.
Taking into account the identified needs and experiences of shipyards and supplying partners working together as concurrent shipbuilding enterprises, in a further step, a cooperation model for shipbuilding has been developed. According to this cooperation model, the design results have to be made available in a structured and clearly defined data model and must enable views to the data that supports the design methods of all participating enterprises. To meet these requirements, the developed data model represents a ship in its state of delivery in different views. For this data model there have been chosen three prime views on the ship's design data which are the so called "hull" view, a "room" view and the view on the ship's technical systems. These views on the ship give the opportunity to establish a task oriented design environment which is needed to solve a specific problem or to carry out a specific task. A second element of the ship's cooperation model which is an ICT system supporting the access to product related data as well as the communication between the cooperating partners is a platform for data exchange and communication. This platform ensures that a shipyard or a supplier exactly receives that data or work package, respectively, which is destined to be finished by him, and that the executing partner can give his work results to exactly that partner who put out the work package. Further more, there is a communication feature installed on the platform which informs the involved shipbuilding partners about new work packages to be executed and the finishing of already executed work packages.
Also, the general cooperation model for one-of-a-kind products includes an ICT system as one important element. The realisation of such a system mainly depends on the individual needs of the cooperating partners rather than on the specific product. There are some basic features the ICT system has to contain which is a data base for saving the exchanged work packages and their executed results, an import and export function from and to arbitrary CAx systems and a communication feature for informing the shipyards and the suppliers about new work packages or executed results in the data base. The import and export function needs a converter which changes the forma of the data created via specific CAx systems into a universal format and vice versa. The processing of data exchange by using the communication model described is extensively presented in chapter 5.

3 STATE OF THE ART

As shipbuilding industry is the initial point of the communication model presented in the paper at hand there are several sources out of this industry which represent the state of the art of a communication model: So, in Germany there have been finished some research projects in 2005 which analysed the organisation structures of cooperating shipbuilding partners and which worked out solutions for improving the quality of data exchange by defining practicable product data models as well as by installing capable information and communication structures. So far, the research project called NET-S defined suitable attributes for identifying a ship's component parts and built up a product data model for shipbuilding industry [5]. Further more, an information and communication platform for product data exchange between concurrent shipbuilding enterprises working together on an equal level (such as

shipyards) as well as between different levelled partners (e.g. shipyards and suppliers) was built up. Similarly to the NET-S research project, the focus of the research project called ShinCoS laid in building up a comprehensive structure for storing and exchanging product data and engineering drawings for the shipbuilding industry as well [6]. The European and German research projects developing product data models for the maritime sector carried out in the 1990ies did not result in solutions suitable for solving today's tasks done in cooperating yards and their suppliers throughout shipbuilding projects. Nevertheless they give some hints and ideas for a new product data model meeting the demands of the shipbuilding industry. Using some of these established solutions as well as newly developed ones and combining these to new concepts for data exchange and communication anticipates an improvement to the efficiency and velocity of concurrent enterprises carrying out shipbuilding projects.
Other industrial sectors also make available specific product data models. Often, these models follow a simple hierarchical structure starting with the complete artefact throughout the product systems and the components down to the single parts of a product [7]. This structure makes the realisation of different views on the product structure very difficult. The paper at hand describes an approach for a general product data model representing different views on a one-of-a-kind product. The different views represented by this product data model support the exchange of product data exactly from that view a single cooperation partner prefers for his own work.

4 PRODUCT DATA MODEL FOR COOPERATION

The product data model for cooperation is a necessary basis for handling product data of one-of-a-kind products throughout the conception, design, and production of those products. It gives different views on the product structure which are adapted to the specific needs and requirements of the cooperating partners. This chapter gives an overview of the basic structure of the general product data model for one-of-a-kind products and it shows a representation of this data model in shipbuilding industry.

4.1 General Product Data Model

The general product data model for one-of-a-kind products gives three main views on the product data: The so called "hull" view, the "zone" or "space" view, and the view on the ship's technical systems. Throughout the "hull" view the materials the product hull is made of can be located and the over all dimension of the hull can be identified. The hull of a one-of-a-kind product itself is subdivided into areas which can be located throughout a coordination system with a defined zero. For each of these areas the hull material as well as the dimensions is deposited. Additionally, there can be connected some further information with these basic information, e.g. information about the surface of the hull, its age, or its chemical composition. All the further information or data, respectively, can be linked to the basic data of a specific hull area by defined attributes.
Throughout the "zone" or "space" view specific components or parts within defined zones or rooms of the product can be located. The zones or spaces of this product structure view are defined by the users of this view according to their needs. These zones or spaces are not necessarily the same as the physical ones of the product which is described by its relating product data model. The components or parts which are located through the "zone" or "space" view, respectively, are represented by data which have a defined structure with defined correlations. These data are represented by specific attributes supporting an explicit identification of the components or parts. The choice of the attributes can be matched to the needs of the cooperating partners who use the data model for identifying specific components or parts and for exchanging work packages in a defined way.
The so called "system" view gives access to all the technical systems of a complete artefact. Throughout this view components or parts will be located which are placed within the systems. The advantage of this view is access to the complete systems even if they installed beyond the defined zones or spaced. Especially, for cooperating partners who have to execute system specific work packages this view makes the handling of the relating data much easier. The representation of the components and parts is exactly the same like in the "zone" or "space" view.
Figure 1 gives a rough impression on the basic structure of the general product model for one-of -a-kind products and the defined main views explained above. If necessary and useful, further views on the product structure can be developed for specific one-of-a-kind products.

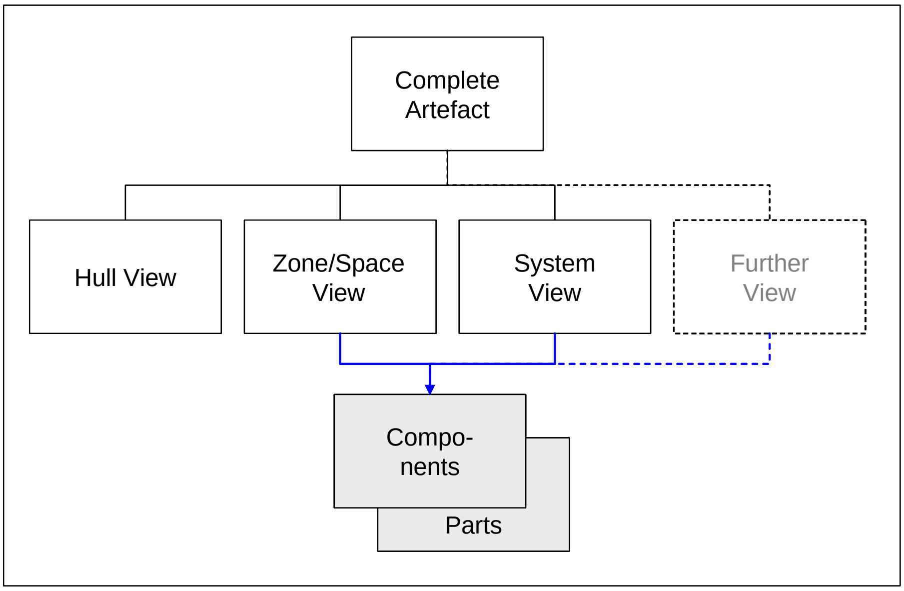

Figure 1. Basic structure of the general product data model

4.2 Product Data Model for Shipbuilding Industry

The general product data model described above has been deduced from a specific product data model for ship building industry. As for one-of-a-kind products of other industries there are the same or similar challenges, needs, and requirements for handling product data like in ship building industry it is of great use to define the three views on the product structure presented above and to give an option for extending the described model with additional views of necessary. The given views on the product structure in practice have to be implemented into the data and information management systems which are used by the cooperation partners designing and producing products together.

According to the product data model for shipbuilding industry the necessity of different views on the ship's product data which are a view on the ship's hull, a so-called "room" view and the view on the ship's systems is detected. The view on the ship's hull represents the containment of the ship itself. The room view structures the ship by dividing it into physical rooms as well as into technical rooms, which may completely differ from the physical rooms of the ship. It derives from the following two design elements: (a) the hull of the ship and (b) the main dimensions which are decks and important vertical zonings. The hull of the ship is represented by the ship's body which is created by a planar model. The definition of the planar model is realised by the NAPA system usually used by shipyards for 2-D construction. The generation of the body is realised by a CAD system to which the planar model has been transferred before. The main dimensions are defined by a grid which is valid for all persons involved in the construction process. Higher-ranking rooms, e.g. coordination areas, zone or panels are derived from this grid. By combining the hull and the main dimensions the concept model is created as a basis for the following segmentation of the rooms. By "cutting" the body along the main dimensions and the room zoning working areas could be created which are necessary for construction.

The room view of the ship's cooperation model is mainly needed by concurrent working shipyards to create complete ship units and to define work packages which can be given to engineering companies or suppliers for further elaboration. It presents a basic model for structuring a ship. To exchange data concerning this view the components, parts, or artefacts to be exchanged are described as data objects. Further more, the built work packages could include structures and arrangements. How a particular work package is integrated into the design environment of the engineering companies and suppliers is decided by themselves. Only the constraints of the work package must be checked to ensure a defined exchanged of the product model data. The results of the elaboration are returned to the principal in a similar work package only containing the results of the elaboration but none of the unchanged data from the original work package. The content covers all of the design results.

The room view is represented by defined objects which give a clear description of the single components or parts the complete artefact or a system consists of. The combination of these key objects for identifying a ship's component part with the conceived general cooperation model for shipbuilding and its different views lead to a total of 13 data objects that are necessary for defining the work packages exchanged between the concurrent shipbuilding enterprises. The basic attributes valid for every of the defined objects are an identification number, the name of the object, the object description and a values list. The 13 defined objects form a hierarchical structure to organise the product data of the work packages to be exchanged between the enterprises in a well manageable manner. This hierarchical object structure is shown in figure 2. Each of these objects represents an attribute which gives a unique characterisation of the specific component or part. Further more, according the hierarchical structure there is an over all description of the specific component or part.

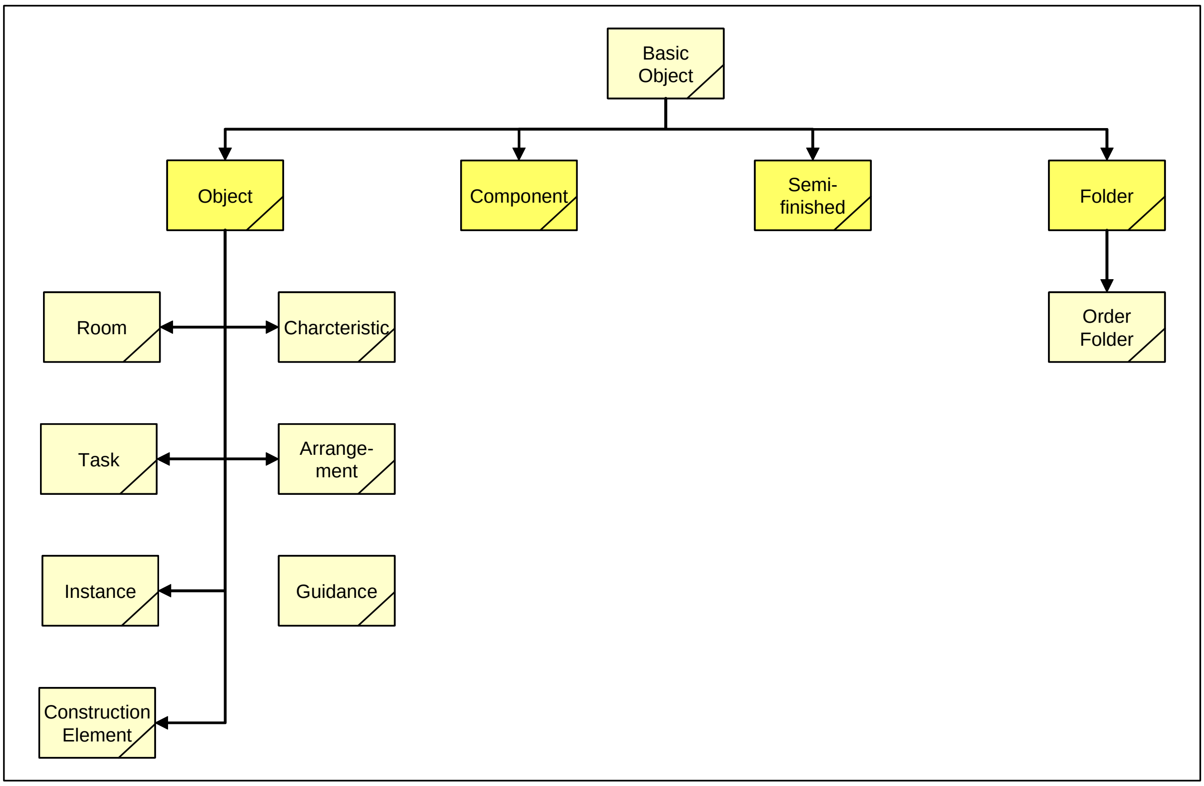

Figure 2. Hierarchical structure of the objects of the room view

Besides the room view a system view for the ship has been developed which is especially relevant for the definition of systems by the systems suppliers. It allows a representation of the ship's systems independently from the ship itself. Within this view the ship's components and parts can be classified and located along the systems of a ship like fuels, ventilation, power supply, etc. The system view allocates a defined structure for data exchange but it does not define a generalised system view for all partners of a cooperative shipbuilding project. To create the view on the ship's systems an assembly unit directory is used which gives a unique filing structure for all parties involved in a shipbuilding project. This structure supports the exchange of product data and reduces the time of searching specific parts of a ship's systems. It has to built up individually by every partner of a shipbuilding project who needs a system view for his own work.

The implementation of the structure described above needs a hierarchical organisation: Directly beneath the root directory of the ship are the directories of the hull view, the room view, and the system view. The directories within the room view directory show the underlying segmentation of the ship (prow, stern, deck, etc.). Lower in this structure there are the directories of the single rooms (e.g. engine room, cabins, etc.) which are structured along the categories engineering, facilities, coordination and equipment. Within the system view there are directories for the single technical systems (fuels, ventilation, power supply, etc.). Beyond this, data and information concerning devices, configurations, and foundations are filed. The connection between the room view and the system view can be realised by allocating a system to a room. Figure 3 shows the developed product data model of a ship.

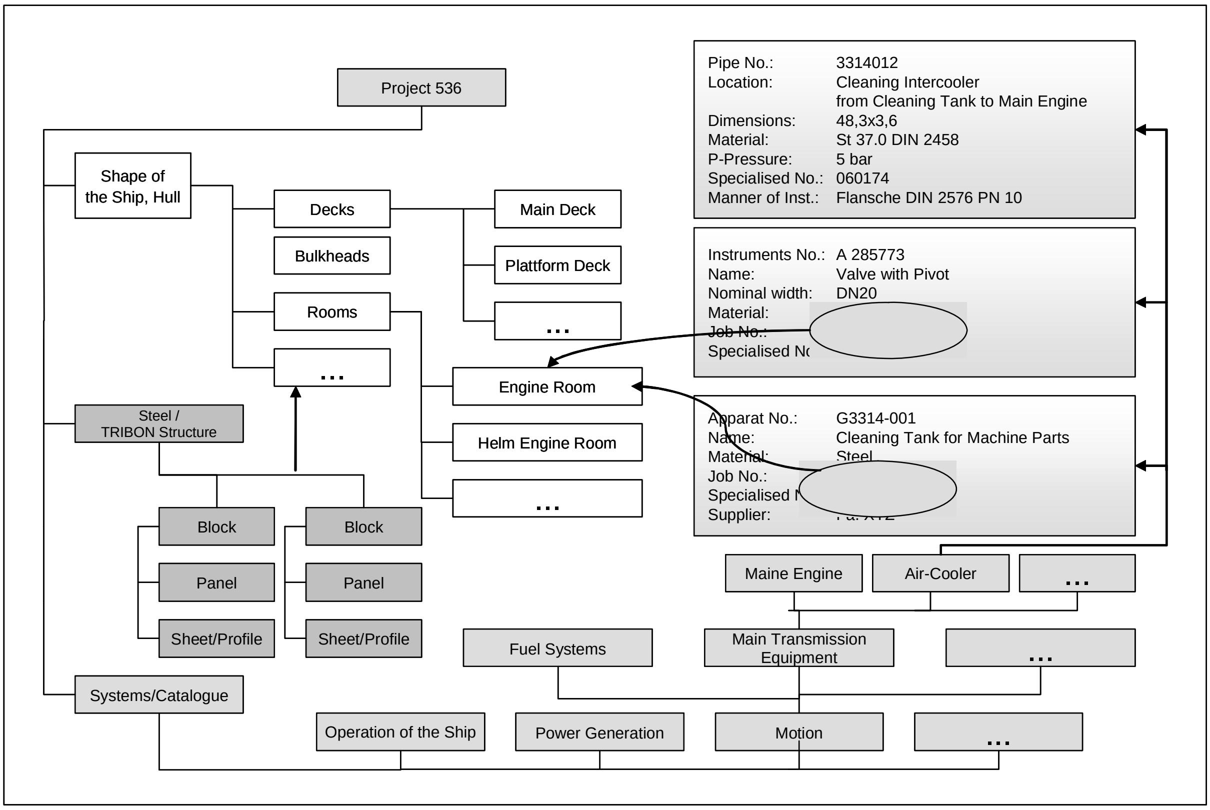

Figure 3. Product data model of a ship

The arrangement of the objects allows a delimited view of the cooperation model that exactly provides the room in which a task has to be fulfilled. To assign a task within a specific room to another enterprise, e.g. a design office or a system supplier, a work package has to be created that is being exchanged between these enterprises through an information and communication platform. On basis of the defined data objects that are necessary for defining the work packages exchanged between concurrent ship building enterprises and on basis of the conceived general cooperation model for ship building with its different views a number of exchange scenarios were set up to test the product data model. The basis for the exchange of defined product data is a XML scheme which checks for the correct layout structure of the exchanged product data arranged in the respective work package. Also the step standard would be a suitable basis for the exchange of product data; especially, AP 214 *Core Data for Automotive Mechanical Design Processes* could be used for the data exchange if its specification is transferred from automotive industry to other industries.

5 EXCHANGE OF PRODUCT DATA

If the work packages exchanged between cooperating partners do not follow the structure demanded by the “space” view of the general product data model the correct transmission of the product data can not be made sure. To guarantee that no incorrect structured product data achieves the ICT system for the data exchange an XML scheme has been developed that screens the layout structure of these data. Such an XML scheme, in a first step, has been developed for the example of a ship’s product data. It serves as a supervision system preventing the ICT system from accepting product data with structures that diverge from the defined structure which has been fixed for the exchange of work packages. The XML scheme scans the composition of the objects of the exchanged product data to validate the work package. It represents the reference model for the organisation of the exchanged product data. Its structure is linked to the defined structure of the work packages exchanged between the partners of a cooperative shipbuilding project. On its highest level the exchange package is subdivided into a header with the basic information about the exchange package itself, a documents part to refer to all files connected to the exchange package, a drawings part for the organisation of drawing data, a component package used to generate the system view of the product structure and the work package itself presented in the room view.

Summing up, the XML scheme represents a product data model for the exchange of a ship's product data defining an exchange package for conception, design, and production. It supports the exchange of product data independent of a specific shipbuilding project as well as the exchange of project specific data. The data exchange will be realised via an information and communication platform accessible throughout the internet which comprises three main functions to optimise the communication as well as the exchange of product data between the concurrent shipbuilding enterprises. One function already mentioned before is the screening of the layout structure of the exchange packages via the XML scheme presented above. The second function is the structured storage of the work packages and their retrieval through the respective enterprise. Thirdly, there must be a secure correlation of communication via the platform with the exchange package, e.g. if there are modifications or revisions in the work package or in the product data itself [8], or if there is additional need for information.

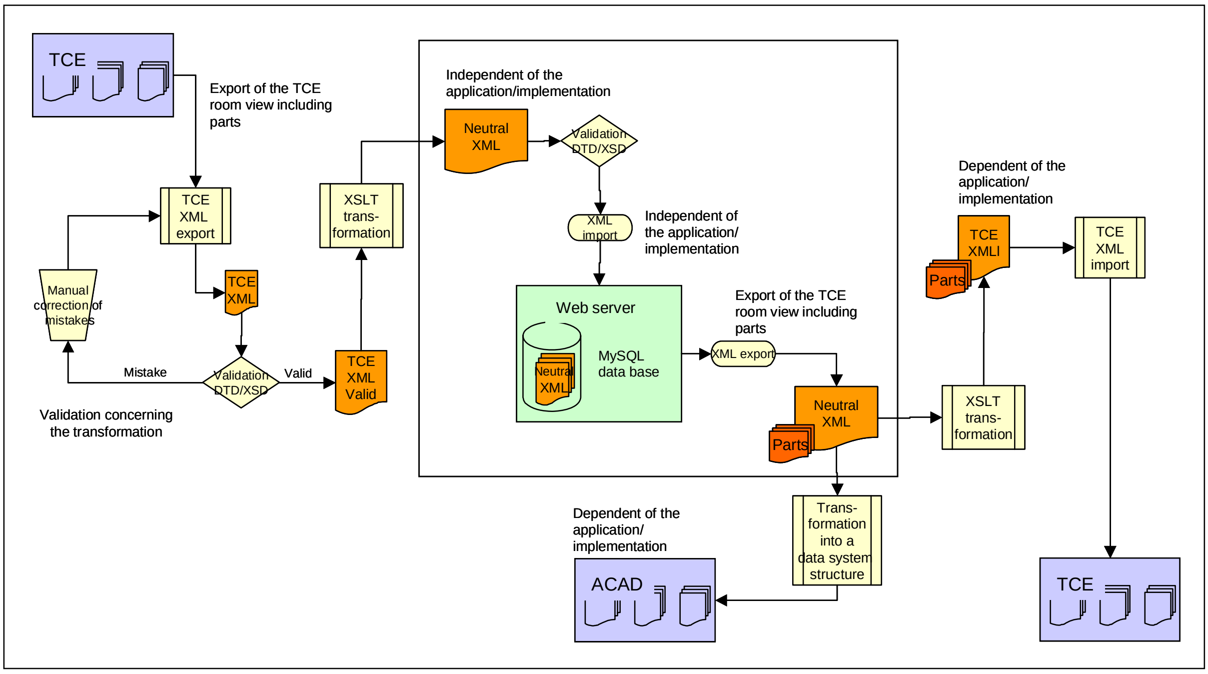

Figure 4. Product data exchange via the internet platform

The output of a product data management (PDM) system, which e.g. could be Teamcenter Engineering (TCE), towards the information and communication platform as well as the export of the product data out of the platform to another PDM system or a computer aided design (CAD) system, which is e.g. AutoCAD (ACAD), is schematically illustrated in figure 4. As shown in this figure, in the first step an export of the product data from the PDM system to a TCE specific XML document is realised. In the second step, this XML document is transformed to a neutral XML document. The layout structure of this document finally is scanned by the XML scheme and uploaded to the information and communication platform, if it is valid. The export proceeding of the product data out of the platform can be described vice versa: In the first step, the product data of a specific exchange package is rescanned by the XML scheme. The created neutral XML document then can be transformed into e.g. a TCE specific document followed by its import into the TCE PDM system or be transformed into the structure of the CAD data system which is directly imported into the e.g. AutoCAD system.
Summing up, to realise an efficient and effective exchange of product data – independent of the industrial sector they origin from – there is a need of defining specific object which describe the product data, to describe the interrelations of these objects graphically as well as by structured tables, and to deduce an XML scheme from these objects and their described interdependencies. These elements are the basis to create a system of secure product data exchange which supports the identification of exactly that data or work packages, respectively, which have to be executed by cooperative activities. Throughout this system both the original work package as well as the executed results of this work package can be identified.

6 CONCLUSION

The paper at hand gives a rough impression on a cooperation model for the exchange of product data representing one-of-a-kind products or products of high complexity, respectively. This cooperation model consists of two core elements which are a general product data model on the one hand and an ICT system for the exchange of product data and work packages on the other hand. The general product data model and the general ICT system are described on a very generic level because they have to be valid for a wide spectrum of products and industrial sectors. The model and the system must be so universal that they can always be adapted to the needs of specific industrial sectors and of the product represented by this data model as well. Especially, the developed general product data model helps cooperating enterprises to systematically categorise the complex structures of data describing a one-of-a-kind-product which are handled during the life cycle of this product. The model is of high relevance for realising information technological solutions as well as improving the information and communication structures of cooperating enterprises.

Additionally, with a suitable communication structure hosted by an ICT system, clearly distinguished design tasks can be transferred to the respective companies executing these tasks, e.g. design offices or system suppliers. The results of the work of these enterprises concerning their work packages have to be re-transferred to the work coordinating enterprise which integrates these results into the overall context. This integration automatically can be carried out through the communication structure as well. The data exchange will be realised via a neutral XML document with a well defined layout structure. This way, the aimed information and communication system can be utilised by numerous software applications without losing information.

The relevance of the cooperation model presented in this paper is founded by the fact that more and more projects for conception, designing and building one-of-a-kind products are carried out through concurrent enterprises to cope with the strong international competition. To make the cooperation of these enterprises work there is a need for exchanging data between them. As a basis for the data exchange, suitable attributes for identifying the product's component parts and a common structure for handling the exchanged product data has been found. Further more, a practical general product data model of one-of-a-kind products has been developed. The specific approach of shipbuilding industry presented in this paper was very much driven by a German corporate group which actually integrates three shipyards under its roof what indicates the high relevance for industrial practice.

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