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POTENTIALITIES OF APPLICATION OF THE EMERGING SYSTEMS ENGINEERING STANDARD AP233

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1. Introduction

Nowadays complex products are never produced by a single person or company, but by many companies working together either as partners or within a complex supply chain. For this reason terms like "collaborative engineering" or "concurrent engineering" gained in importance. Disciplines like these try to solve the challenge to work together in a coordinated way to increase the impact on a nearby perfect system solution. For various reasons the "hype" on these disciplines in industry decreased in the recent past. These disciplines don´t seem to get evident acceptance in industry since they may not be mature and sophisticated enough to solve real industrial complex projects. One more siginificant methodology to cover all aspects of a product during its complete life cycle and match industrial requirements on their perfect system solution is Systems Engineering (SE), which is well known since several decades. Systems Engineering can be defined as "An interdisciplinary collaborative approach to derive, evolve and verify a life cycle balanced system solution that satisfies customer expectations and meets public acceptability" [IEEE, 1995]. Examples for application of Systems Engineering are mainly found in the areas of aerospace and aeronautics industry like for instance the Eurofighter or Ariane projects can show. But this methodology can also be applied in other industry sectors like telecommunications, railway- and transport-systems, mechanical engineering and others. This has been shown by the tunnel link project between Great Britain and France. A major issue for application of systems engineering is the interoperability of the software tools used in system design context. This article describes the possible solution to the lacking tool interoperability by providing a standards based interface approach and how the relating information model can be used within other domains.

2. The history of the emerging standard

Since 1996, significant research has been performed in the area of the standardisation of a systems engineering data model. It started with the European Commission co-funded project SEDRES in 1996 (Figure 1). The main objective of this project was to produce a neutral data exchange standard for the systems engineering domain. This standard will take place in the ISO – STEP 10303 (Standard for the Exchange of Product Data) activities. The corresponding standardisation activities were launched in 1998 as a particular ISO working group AP-233 (application protocol 233 – systems engineering). The AP-233 working group used the SEDRES data model and extended it further until today. During this time there have been more influences from other projects like KARE [Heimannsfeld and Judith, 1998] and SEDEX. The KARE project for instance has had major contributions in the area of requirements management. The main objectives of the SEDEX project, which was performed at the University of

Linköping in Sweden, was to improve and mature the capabilities of the datamodel in the areas of system architecture, functional behaviour, configuration management and object oriented analysis UoF´s (Units of Functionality), see [Johnson et. al, 2000]. During this time the systems engineering data model became more mature and the interest of people involved within ISO activities increased.
The recent SEDRES-2 project was pieced together by a number of leading enterprises in aeronautics and aerospace industry: EADS Launch Vehicles (France), SAAB Technologies (Sweden), BAE Systems (UK), EADS-GE (Germany), Alenia and SIA (both Italy). The University of Loughborough (UK) is responsible for the evaluation of the projects achievements. The Linköping University (Sweden) is responsible for modelling of the AP-233 data model. The project consortium is completed by Eurostep (UK), a consultancy company with experience and activities in the area of standardisation and STEP and the Technical University of Clausthal (Germany), experienced in engineering design, data management and advanced computer aided information systems.

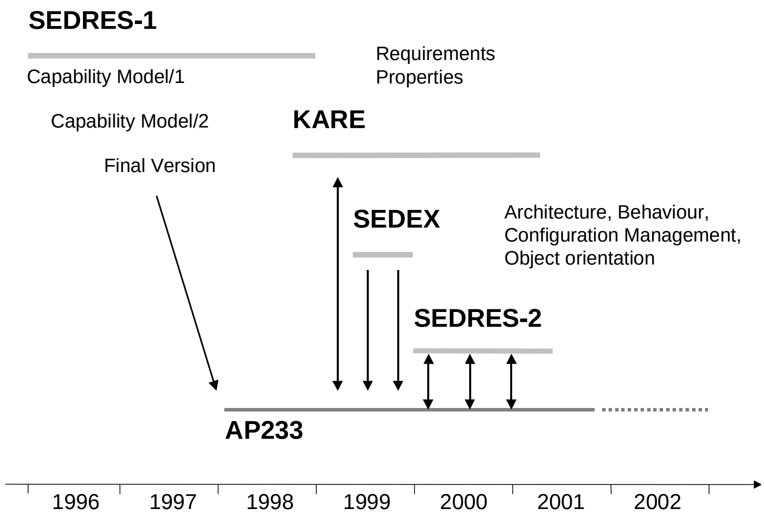

Figure 1. Interrelationships between AP-233 and different projects

The SEDRES-2 project had influence on ISO STEP "systems engineering" activities. A particular operating point of this project will be illustrated in a following section. More detailed information about the objectives and current results of SEDRES-2 can be found in [Johnson et al., 2000]. Any additional information about the project is located at the projects web-site at http://www.sedres.com.

3. The scope of the systems engineering data model

This section briefly describes the data model philosophy and the current capabilities. An overview about the possibilities of implementation, which can be derived from it, is presented.
Figure 2 shows the main elements of the current working draft (WD#5) of the systems engineering data model in UML syntax. For a more detailed description of the content of the model please refer to [Herzog and Törne, 2000].
At the top of the figure an overview of the entities is given, which are used as support information within systems engineering discipline. Each box summarises a set of related entities. The entity sets, presentation information, configuration management, administration information, external documents (and their references) as well as the support for data types, classification and properties represent the baseline for systems engineers work as an information-container. This information is used to support systems engineering processes.
In the lower part of the figure, the specification elements are captured, like namely requirement representation, functional- and physical architecture. The object oriented representation extends the scope of the specification of a system by the area of software systems and their current methodologies. Requirements, functions and objects can be allocated to physical components of a system via specified allocation entities. The engineering process block contains entities for recording the activities performed in the systems engineering process. The system architecture block contains entities for grouping all information related to a system or a view of a system. It is defined by the specification elements and uses the information elements.
Though this data model is intended to be used in the systems engineering processes, it may also be applicable to other domains. As per the figure rendered, the data model covers many aspects, that are also relevant for other disciplines, such as mechanical engineering, electrical engineering etc.. Since

the systems engineering data model is process-independent, it can be applied by substitution of the engineering process as shown in the figure with the process applicable to the other domain.

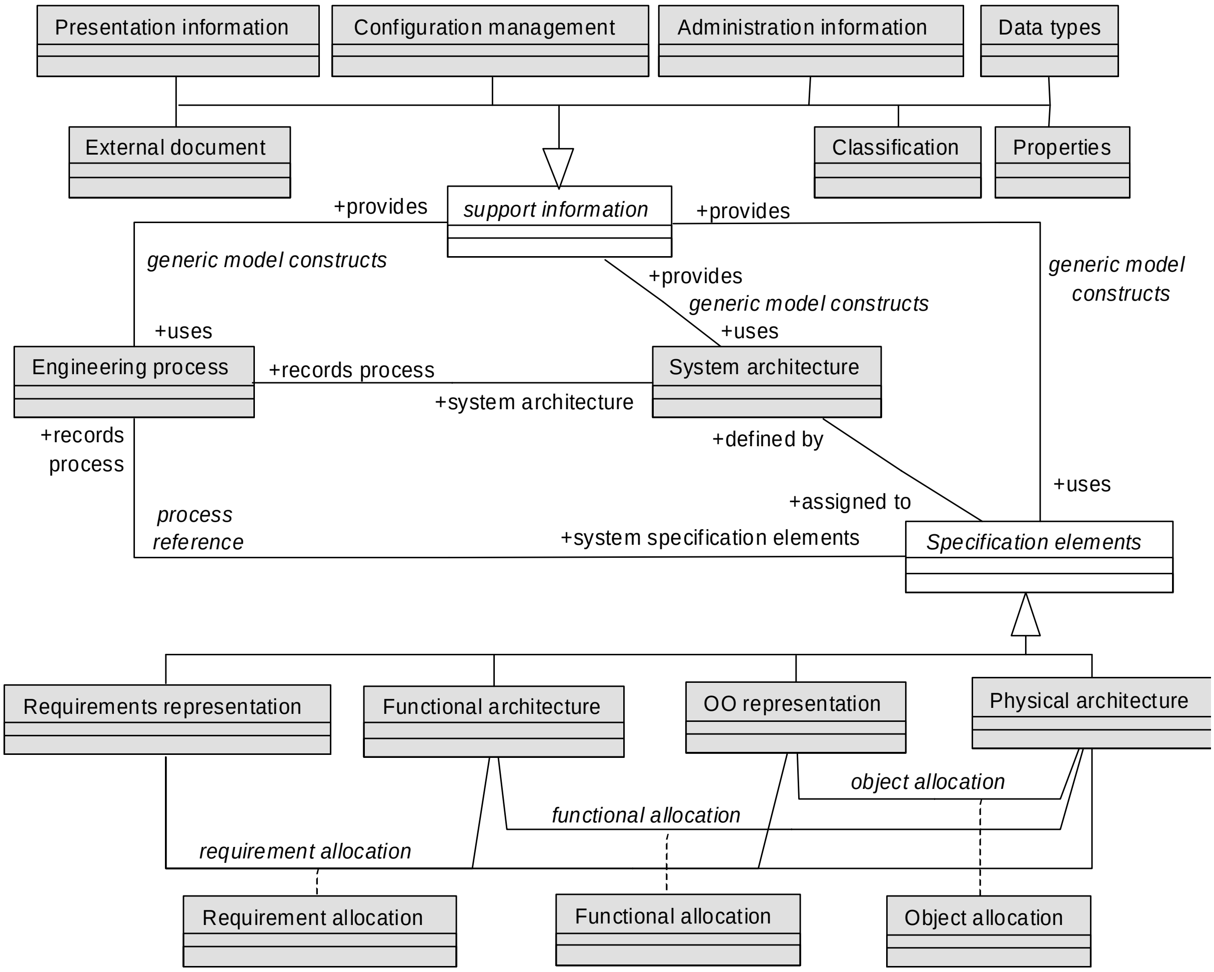

Figure 2. Conceptual view of the data model WD#5 [Herzog et al. 2001]

In the following sections, the approach of the use of the systems engineering data model as a central data-repository for different systems engineering tools is be illustrated and an example on how the data model can be used outside systems engineering is presented.

4. Applicability to other domains

The systems engineering data model is also relevant for other domains because of its high coverage level. In this section, a concrete example of the applicability of the model to the mechanical engineering domain will be shown.

The example relates to the early design phase of a hub-shaft connection. Hub-shaft connections are in use in any area of drive systems technology. Research in the area of hub-shaft connections is so far getting more and more important, basically because of two reasons:

- Prevention and examination of damage events
- Optimisation with respect to geometry, mass and power enhancement

The continuously increasing demands from industry and users lead to a significant number of requirements. The engineers of hub-shaft connections have to manage all these requirements with respect to the above written research goals. The example describes the approach of capturing and managing requirements in one tool and the simultaneous design in a CAD tool.

The mechanical engineer usually starts to capture all the requirements of the desired solution, in our

case a hub-shaft connection. Basic requirements like geometry, masses etc. are going to be captured, normally as textual requirements. These requirements are picked up and processed in a requirements management tool.
For this example, the requirements tool demanda II has been employed. This software has been developed at the Technical University of Clausthal (TUC). The main functionalities are:

- Capturing textual requirements
- Formalising requirements
- Managing requirements

demanda II is completely based on the AP-233 data model as its internal underlying database. This means, all entities of the model and therefore also all functionality provided can be used.

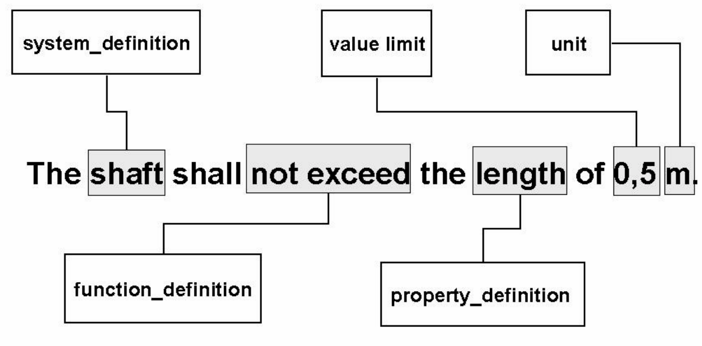

Figure 3. Formalisation of a textual requirement

After the textual requirements have been captured they are going to be "formalised". Formalisation in fact is meant here to transform text based requirements into model based requirements. This is done by mapping words or phrases of the textual requirements onto the entities of the data model as shown in figure 3. For example: An entity system_definition, (which describes a system or subsystem in the AP-233 data model) is created for the shaft. Either a definition is going to be reused or a new one has to be created for each entity in the textual requirement. At least one instance and one unique element identifier is instantiated for each key entity that is going to be used in the data model. So far each component is explicitly identifiable. Since CAD tools are currently not equipped with AP-233 import/export interfaces the following steps describe a desirable vision of the use of these tools in engineering work. The draft specification of our hub-shaft connection could be imported into a common CAD tool as shown in figure 4. From now on, the designer is able to design the parts of the system directly with use of the geometrical requirements coming from the requirements tool. This enables the engineer to check the fulfilment of the geometrical requirements within the CAD tool. It is naturally much easier to handle geometrical requirements in geometrical tools then in textual based documents. This helps the designer significantly to perform his task, because it prevents him from significant errors in the early design phase, which would inevitable lead to higher costs and lower quality of the whole system. Once the designer has finished the first improvement of the specification directly related to the according geometrical requirements, this specification can be reimported into the requirements tool.
In order to specify the system in more detail, the requirements engineer is usually refining the requirements on the system. This is now directly based on the geometrical representation of the CAD tool. Since the requirements tool mentioned here is fully AP-233 compliant, it provides all the possibilities of the data model itself. The most important ones in this design phase are explicit versioning and change management, which enables the user to iterate the process of refining and modifying the geometrical requirements in both tools, without loosing control of the process. The rational for changes in the operational model can be captured and tracked with the justification entities of the data model. So far complete traceability of each action and modification independent of the tool they are performed in, is guaranteed.
This example gave an insight into the applicability of the AP-233 systems engineering data model to a small process in the mechanical engineering domain. Though this illustration is very limited in scope, it shows how the systems engineering model can also be used for a lot of other different domains, because it covers many aspects that are common for a wide range for different domains. Further possibilities, which arise from the content of the model are described in more detail in [Heimannsfeld et al., 2000].

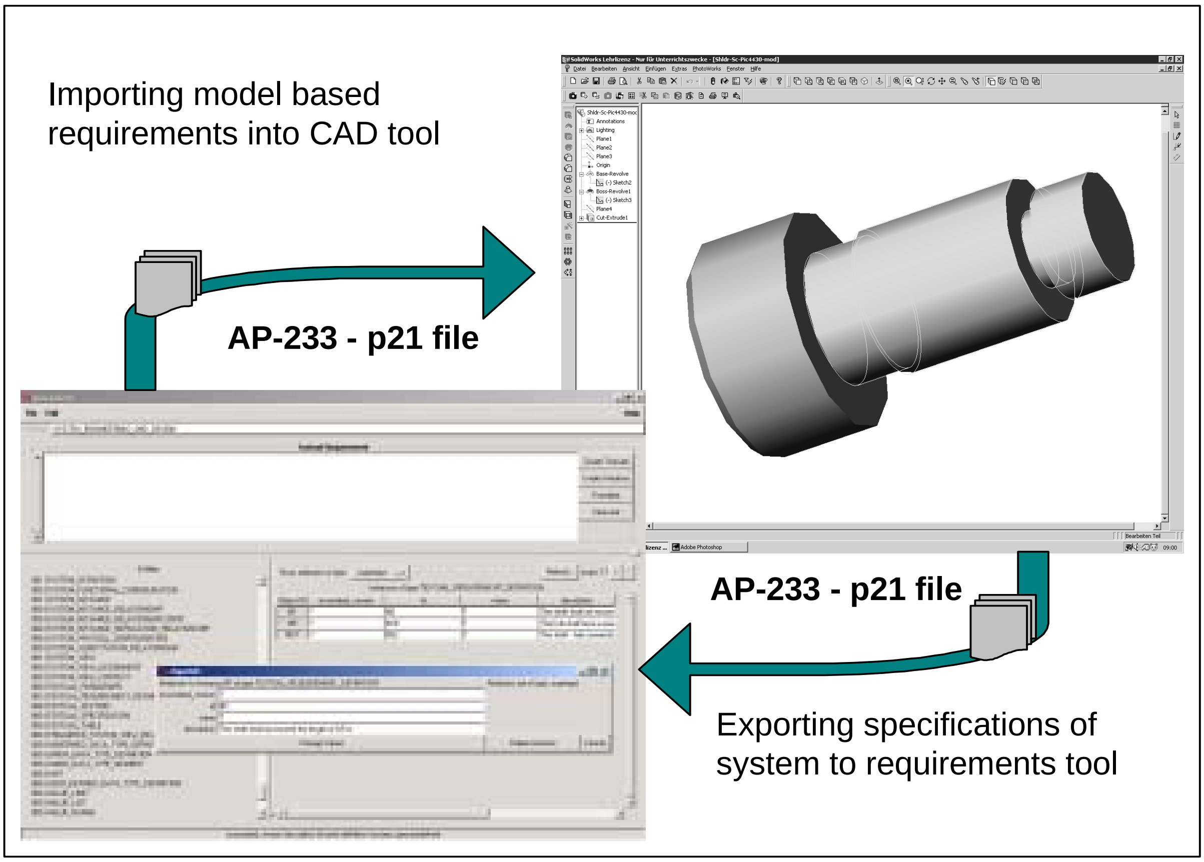

Figure 4. Data exchange between requirements and CAD tool

5. Conclusion and Outlook

This paper described the importance of systems engineering as a methodology for current complex projects. The history and the scope of the information model have been described. Obviously the coverage of the information model allows the application of the ermerging systems engineering standard AP-233 within other engineering domains. This has been shown on a concrete example from the mechanical engineering domain. The main facts which are important for the application and implementation of the emerging standard are:

- maturity
- implementability.

The maturity of the information has been verified on one hand by the two industrial driven validation scenarios performed during the SEDRES-2 project, it will published as a PAS (public available specification) within the year 2002 within the ISO community on the other hand (see Figuire 5). The publication of the standard gives the kick-off sign for implementation of the standard for tool vendors.

The implementability is mainly depending on the size and complexity of the information model, especially within applications in other domains. For application in “non-SE” domains, implementations of sub-sets of the information model are sufficient. This will be realised by providing a modularised international standard within the next two years by mid of 2004. The modularisation work started in mid 2001 and a first set of modules have been made available during autumn 2001. These can already be used for implementations like the one shown here in this paper.

With the release of the PAS and the international modularised standard the doors for implementation of the Systems Engineering information model are opened and will increase rapidly in the next years.

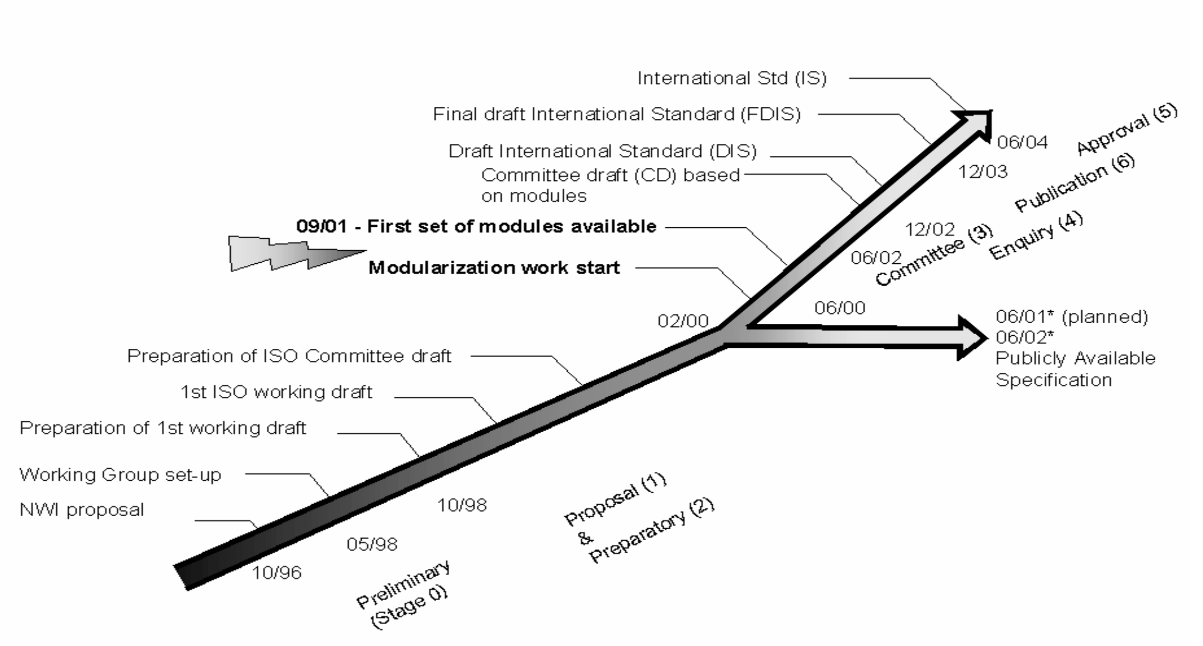

Figure 5. AP-233 status and route

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