Towards the emerging Systems Engineering data exchange standard – AP233

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Das europäische IST Projekt SEDRES-2 (Systems Engineering Data Representation and Exchange Standardisation – 2), das seit Januar 2000 durchgeführt wird, beschäftigt sich mit der Weiterführung der Entwicklung eines neuen Datenaustauschstandards basierend auf STEP (Standard for the Technical Exchange of Product Data, ISO-10303), welcher die Domäne des Systems Engineering unterstützt. Dieses Projekt ist der Nachfolger des SEDRES Projektes und der Aktivitäten innerhalb der ISO 10303 – STEP - AP233 "systems engineering data representation" Arbeitsgruppe. Das Hauptziel des Projektes ist es, das vorhandene Systems Engineering Informationsmodell auszubauen, zu validieren und zu standardisieren, sowie die praktische Implementation und die Anwendung in der industriellen Umgebung über viele Bereiche zu pflegen. Dieser Artikel faßt die Hauptaussagen, die Methodik und den Anwendungsbereich zusammen und erläutert die Bedeutung von AP233 für die Domäne des Systems Engineering.

In January 2000 the European IST project SEDRES-2 (Systems Engineering Data Representation and Exchange Standardisation - 2) started in order to go on to continue the production of a neutral data exchange standard based on STEP (Standard for the Technical Exchange of Product Data, ISO-10303) supporting the Systems Engineering (SE) domain. This project is a follow on of the SEDRES project and the ongoing activities within the framework of ISO 10303 – STEP - AP233 "systems engineering data representation". The projects mission is to extend, validate and standardise the Systems Engineering data model and nurture its practical implementation and multi-sector exploitation as a key enabler for industry. This article describes the main objectives, the approach and the scope of SEDRES-2. It explains the importance of AP233 for the systems engineering domain.

1 Introduction

Contemporary complex projects and their corresponding products are never produced by just a single company, but by many companies working together, either as partners, or within a complex supply chain. The challenge is always to work together in a coordinated way. One of the significant methods to do this is Systems Engineering (SE), which 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" /7/ within this context. A lot of the projects using this discipline are mainly located in the area of aeronautics, and aerospace industry like the Eurofighter 2000 or the Ariane 5 project, but it will also be applicable to other domains like transport systems, telecommunications, civil engineering etc. as the tunnel link project shows us. These were all projects in which systems engineering has been playing a significant role. The size and the complexity of these projects leads to a significant number of partners and therefore in fact to a much larger number of current systems engineering and design tools used on any one project.

This leads usually to distinct problems with the exchange of data between all the different tools used in the systems engineering process. These tools are not limited to special system engineering tools, but also to other tools which are used within the process, i.e. control engineering, structural engineering, electrical engineering, power- and hydraulics- distribution and generation tools. It is so far indispensable to improve the interoperability between on one hand SE-tools themselves and on the other hand between SE-tools and engineering tools in order to reduce time and costs and increase quality of the system engineering process.

The relation with the solution of this problem and the SEDRES-2 project will be presented in this paper. The main objectives of the project will be described and illustrated as well as the interrelationship with the AP233 (systems engineering) working group at ISO level. An overview of the current status of the data model will be given and a more detailed view of the SEDRES-2 project work will be presented.

2 The benefits of a neutral data exchange

In order to improve the interoperability between different system engineering design tools a set of different tool to tool interfaces could be one solution to this problem. On the other hand, a standards based approach to the exchange of design information has some more advantages for the organisations, that use a set of multiple design tools in the systems engineering process as well as for the tool vendors.

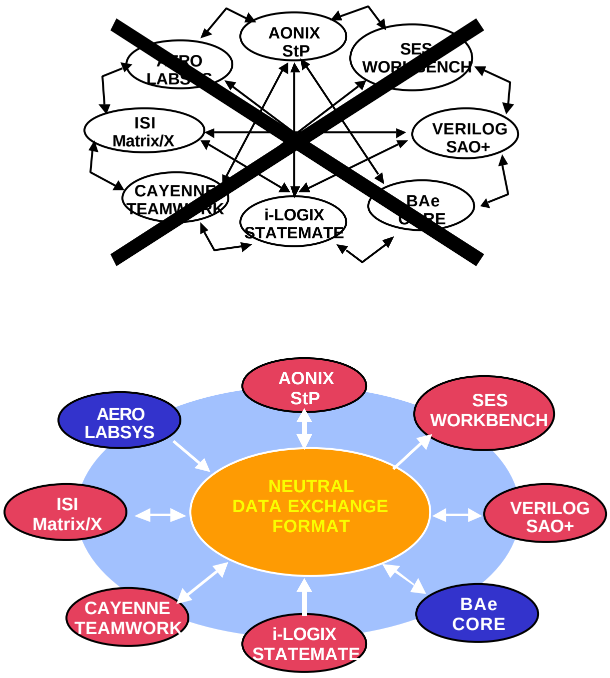

Figure 1 The difference between tool-to-tool exchange and a standards based exchange (the given tools represent the ones which were used in the SEDRES-1 scenarios

Tool vendors can easily use the standard to develop their interfaces which will then be compliant with other interfaces. **Figure 1** illustrates the advantages of the standards based exchange of design data. In fact we have a number of N(N-1) interfaces in the upper part of the figure and a number of 2N interfaces when using the standards based exchange as shown in the lower part of figure 1. Usually all these interfaces have to be developed and maintained by the tool vendors. In our example eight different tools were used, which means that in the first case 56 interfaces have to be developed and maintained in opposition to the standards based approach where there are just 16 possible interfaces. Of course, not all combinations are either required or necessary. Practical considerations in addition increases the number of interfaces also with the number of operating systems and their derivatives. It helps also to improve the quality of interfaces and consequently the interoperability of tools, because a lot of errors in the interface - development can be avoided, as there is a smaller number of interfaces to be build. Also the structure of the interfaces is well prepared and fixed in the standard, so that every tool vendor has the same baseline for his development, which increases the interoperability of the interfaces themselves. The big advantage for the users in a systems engineering design environment is the flexibility in the use of a system. There are more advantages in too. The standard enables the storage of systems engineering data in tool neutral format, considering that a lot of the systems we are talking about have particularly more than 40 years of lifetime. Additionally you will get the possibility to pull parts of design information from multiple tools, so that you can perform consistency checking of the data. Furthermore it gives you the possibility to create views on the data which are not supported by a single tool. There is the possibility to store the data of different tools in a central repository, which could for instance include automatic consistency checking and other features.

The next section explains the interrelationship between the original SEDRES-1 project and the ongoing AP233 and SEDRES-2 activities within the standard development process.

3 The standard development activities

The European Commission co-funded project 20496 ´SEDRES´, running from 1996 to March 1999, has made significant progress in producing a neutral data exchange standard based on STEP /8/ embracing systems engineering design data. The achievements of this project after it's completion in 1999 were:

- Production of three increasingly mature data exchange information models. These are known as Capability/1, Capability/2 and Final Proposal as shown in Figure 3 and are used as a kind of baseline in the AP233 working group for the data model development, which is illustrated in **Figure 2**.
- Production of prototype interfaces for several different COTS (Commercial off the Shelf) tools used in systems engineering.

- Kick off of a healthy and vibrant standardisation activity within the ISO STEP community /8/ following a successful international ballot at the end of 1997 with a YES-vote from twelve countries.

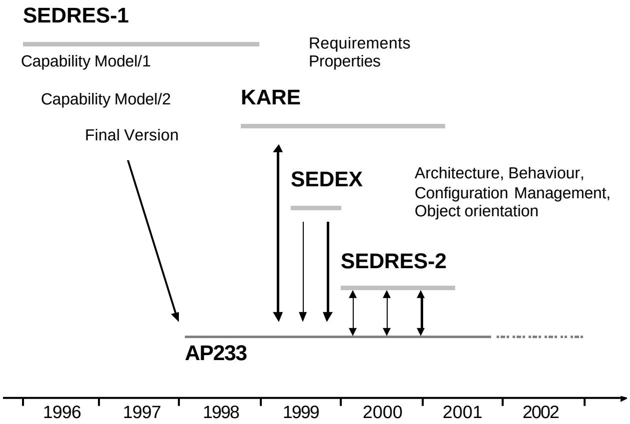

Figure 2 Interrelationship between AP233 and different projects

The ISO AP233 working group used the original SEDRES-1 data models and extended the model further during 1999. The main contributions during this period were two-fold. From the European research project 28916 KARE, there were contributions mostly in the area of the requirements UoF (Unit of Functionality). From the SEDEX project performed at the Linköping University (Sweden), contributions were in the areas of system architecture, functional behaviour, configuration management and object oriented analysis UoF´s. The main objective was not to extend the scope of the AP233 data model, but to improve and mature the capabilities of the data model itself /10/. In the following section the data model and it's single UoF´s will be described and illustrated in more detail. An overview about the AP233 information modelling philosophy will be given.

4 The data model: evolution and status

The first information model, which was Capability/1 from the SEDRES-1 project (shown in **Figure 3**) in 1996 covered a small subset of the systems engineering domain. The intention was to support data exchange of functional models with a limited capability of supporting requirements management. The second version of the data model (capability/2) extended the scope in the areas of behavioral design, configuration management, and the support for graphics.

The final version of the data model developed within SEDRES-1 contained further information about physical aspects of a system as well as entities for tracing decisions on how functionality is allocated to physical components of a system. The final data model from SEDRES-1 is described in more detail in /9/.

The contents of all above mentioned UoF´s are summarized beneath:

Systems architecture - provides an entity to represent the system (or systems), to which other model elements can be related. It also covers relationships between systems, as well as definition of lifecycle, mode or stakeholder views on a system.

Requirements - covers essentially structured or unstructured statements about what a systems product shall comply with, be they functional, architectural, operational aspects or system properties (safety or legislative requirements, performance, cost, etc.); justification information; support for defining relationships among requirements (for instance, to distinguish *original* and *derived* requirements). There is also support for tracing requirements to functional and physical elements of a specification.

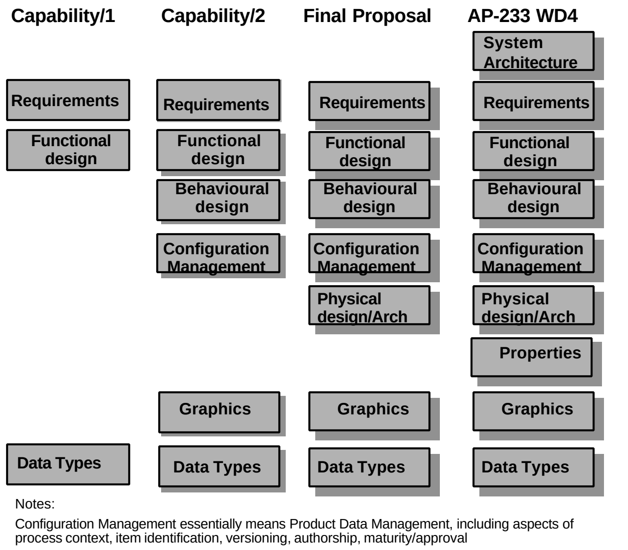

Figure 3 Evolution and elements of SEDRES data model

Functional - comprises entities to model the system functions, functional refinement (functional hierachy), flows between functions, and the functional context.

Behaviour - embraces detailed timing, sequencing and event-based behaviour. These include: data driven behaviour specifications; finite state machine concepts; a procedural or functional chain approach; a synchronous behavioural model. A 'black box' or 'stimulus-response' form is also being considered for AP-233. Many references (for instance, Ward & Mellor 1985, Hatley & Pirbhai, 1988, Oliver et al 1997) illustrate several of the concepts covered in the Functional and Behavioural areas.

Configuration Management - covers the concepts needed to manage and control the different design items, including: authorship and ownership, authorisation, work management, development process reference, item versions, product variants, item maturity through the product's lifecycle. This is building on work in other areas of STEP data exchange development, for instance, the agreement on the Product Data Management (PDM) Schema.

Graphics (Visual presentation) - covers concepts such as diagram object shape, connections, and placement within the diagram. This is to support transfer of the visual layout of notations used in SE such as: data flow diagrams, statecharts, functional flow block diagrams.

Properties – covers representation of numerical defined calculated, assessed or measured attributes of systems, physical elements or functions. Examples include cost, weight and execution time.

Physical Architecture - covers a simple node-&-link type approach for capturing architectures, where the node-elements and connect-elements are instantiated to deal with the different technology elements. This will enable the functional analysis and trade-off activities to be supported within Integrated Product Teams across multiple design tools. This generic approach enables the data model to support physical component topologies (interconnections without details of physical placement) for a variety of basic technologies including: computing; electrical; hydraulic; pneumatic; mechanical; and potentially hybrid technologies such as electrical-mechanic, and electro-optic.

Data Types – includes: strings, dates, bound and unbound number types, strings, compound data types or aggregations. Bound numbers are numbers which are constrained to a particular range, for instance Day-of-Month [1..31]. Where possible this area will be aligned with the existing data type building blocks available within the existing STEP architecture.

The AP233 data model development continued afterwards in conjunction with the Swedish SEDEX project. The main focus of this project was to address identified weakness and issues and not to extend the model further. Additionally a model was developed, which shows how object oriented systems engineering and analysis can be implemented in the information model.

The current version of the data model, which is WD4 (working draft 4) covers all the aspects mentioned above and shown in figure 3 in the right column labelled AP233-WD4. Over the time a lot of requirements for the data model development have been added. Sources for requirements are for example the AP233 WG itself, the SEDRES-2 consortium, the INCOSE (International Council on Systems Engineering), the NASA/JPL other industrial companies etc.. These requirements are going to be evaluated, prioritised, and checked if they are "in scope" within the SEDRES-2 project. If they are in scope they will be implemented in the data model.

The fact that the systems engineering domain itself and the tools used within this domain are very heterogeneous, implies that there is no consistent or total view of the capabilities that shall be supported by systems engineering design tools. Figure 4 shows a conceptual view of the AP-233 information model in UML notation. The main groups of the model are: System architecture, specification elements, requirement and functional allocation, engineering process and support information.

The relationships between the groups are outlined below (see **Figure 4**). The elements of the Engineering process group can be used to capture the systems engineering process for a project and relate Specification elements and System architecture information to the process phase they were created/referenced in. Specification elements provide the structures to define requirements, functional and physical architecture of systems represented by elements of the System architecture group. The support information group provides information that can be applied to elements in the other groups. The model is structured such that there are no existence dependencies on entities involved in relationships between the groups, i.e., entities are used to represent the relationship. More detailed information about the data modelling strategy can be found in /6/.

5 The scope of the SEDRES-2 project

The goal of SEDRES-2 is set against the ultimate concept of achieving a distributed environment supporting systems engineering, building on the results of SEDRES-1 and in complement to the AP233 activities.

Therefore the top-level objectives of the project are defined as:

- To drive the on-going AP-233 activity in the areas of data modelling, test material, document preparation, to ensure that European interests are represented in the emerging systems engineering data exchange standard;
- To validate the standard by performing practical case study definition, prototyping, use and evaluation of the emerging standard within real SE activities;
- To achieve the adoption ("take-up") of AP-233 by all stakeholders, by maximising the two-way dialogue between the first two tracks of work, and between SEDRES-2 and such stakeholders, and to ensure that the vision of generic systems engineering is appropriately supported by the emerging standard.

- investigation on implementing design repositories instead of simple data exchange will be done.

An action SEDRES.*network* will be started with the main objective to manage the evolution of the AP233 standard across various stakeholders. It will ensure the cross-sector cohesion of the emerging AP233 data exchange standard, such that the standard fully supports the generic nature of systems engineering as practised across industry sectors. The SEDRES.*network* will enable you to influence the development of the standard, because it gives you the possibility to share your opinion with the project consortium of SEDRES-2. Furthermore, as a member of SEDRES.*network*, you will be kept regularly informed on events, progress and results of the project and the standardistion status.

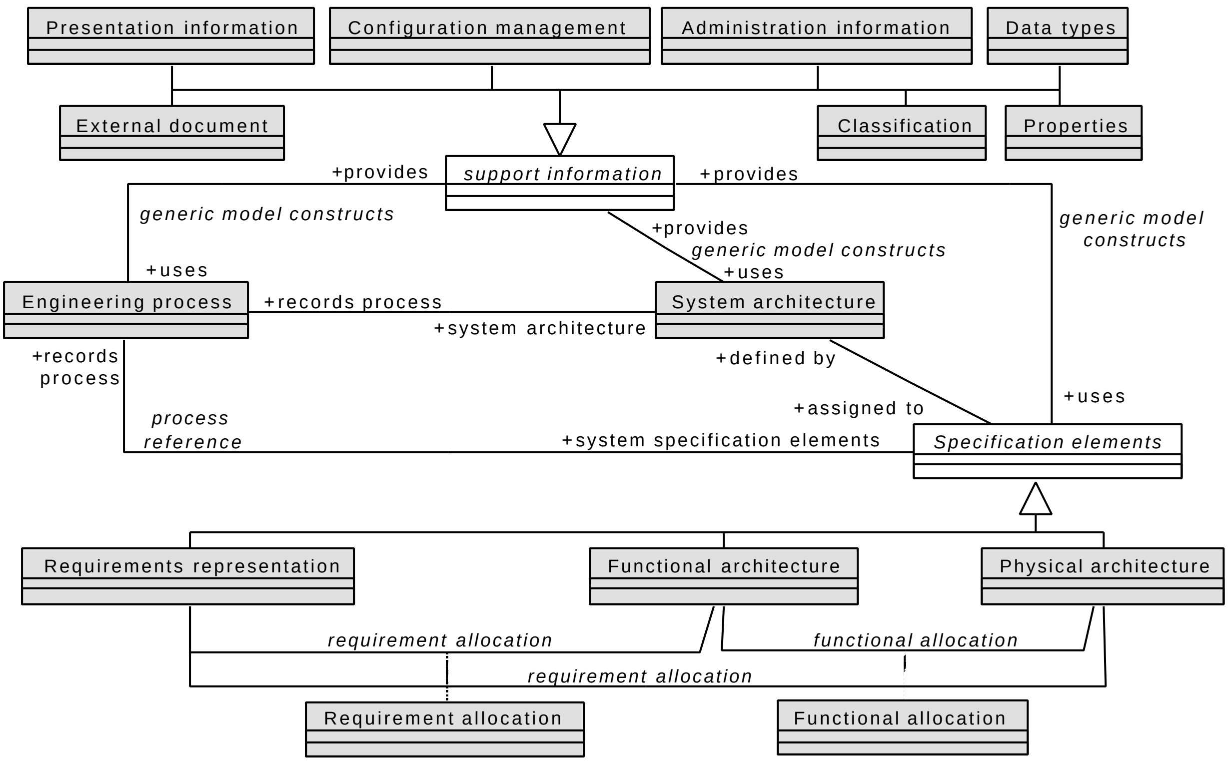

Figure 4 Conceptual view of the information model

The main aspects of the current project are so far that

- the work is complementary and supportive of AP233.
- the data model developed in the SEDRES-1 project and the ISO activities will be extended and validated
- an extended set of prototype tool interfaces will be developed

More information about the SEDRES.*network* is available directly at the SEDRES homepage (http://www.sedres.com).

The eighteen months project, which started in January 2000 consists mainly of three different phases, which are illustrated in **Figure 5**. Within the project two validation scenarios are defined, which drive the actual modelling activities and are intended to improve the quality of the information model in an industrial driven context. Both of the validation scenarios are driven by the philosophy to ensure that the refined requirements of the information model can be related to a real situation and that a mechanism exists to perform a meaningful evaluation. The data modelling work will refine existing work and extend it with new elements, which are defined earlier. Interfaces will be produced during prototyping activities for a set of different systems engineering tools.

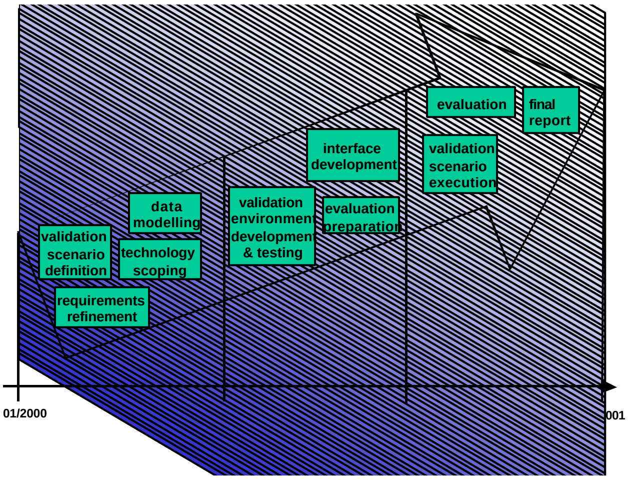

Figure 5 timescale and related content of the SEDRES-2 project

The focussing on the technical issues of data models for communication between different types of tools in the systems engineering domain leads to reduced attention on issues like human and business factors involved. In fact these factors have implications on the functioning working style of people and companies in which they work. Therefore the evaluation will especially be build in the user-system evaluation area. There will be an investigation on the implications of business effectiveness with respect to team working and business life factors. The evaluation process, which is currently in the definition phase will be performed during the application of the validation scenarios.

6 Summary

This article has presented the need for neutral data exchange standard within the systems engineering domain. It illustrated the work which has been done in several projects and activities until now and how they will fit together. The modeling philosophy and the current status of the actual systems engineering information model have been described in some detail. Finally, the objectives and the approach of the follow-on project SEDRES-2 have been explained.

7 References

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