Advantages of using SysML Compatible with ISO 10303-233 for Product Design and Development based on STEP Standard

Omid Fatahi Valilai and Mahmoud Houshmand

***Abstract*—Product development can be defined as the process by which the inception, conception, development, realization, maintenance and demolition/decommissioning of a facility (constructed works) can be described and managed. A crucial problem in the development of new products is to reduce the time required for their design and manufacture while still maintaining high quality and minimum development cost. To achieve this, inputs are needed from experts in a multitude of disciplines as well as from customers and suppliers. The Systems Modeling Language (OMG SysML™) is a general-purpose modeling language that supports the specification, design, analysis, and verification of systems. ISO 10303, also informally known as the Standard for the Exchange of Product model data (STEP), is a family of standards defining a robust and time-tested methodology for describing product data throughout the lifecycle of a product. This paper describes the compatibilities of SysML for product design and development based on STEP standard. The use of this languages increases reusability of product design data. These data are compatible with STEP standard based on Application Protocol 233 and describe the product specification and requirements. Ensuring the main specifications of the product, product development process will satisfy the STEP standard. This is necessary for integration of product data during its lifecycle.**

***Index Terms*—STEP standard, AP233, System Modeling Language (SysML), Product Design and Development.**

I. Introduction

Product development can be defined as the process by which the inception, conception, development, realization, maintenance and demolition/decommissioning of a facility (constructed works) can be described and managed [1].

The importance of new product development (NPD) has grown dramatically over the last few decades, and is now the dominant driver of competition in many industries. In industries such as automobiles, biotechnology, consumer and industrial electronics, computer software and pharmaceuticals, companies often depend on products introduced within the last five years for more than 50 percent of their annual sales. However, new product failure rates are still very high. Many R&D projects never result in a commercial product, and between 33 and 60 percent of all new products that reach the market place fail to generate an economic return [2].

New product development has become central to achieving meaningful differentiation. NPD cycles get shorter as the innovations of the others render existing products unnecessary [3]. A crucial problem in the development of new products is to reduce the time required for their design and manufacture while still maintaining high quality and minimum development cost. To achieve this, inputs are needed from experts in a multitude of disciplines as well as from customers and suppliers. The overall design process must be well orchestrated and integrated [4].

A. STEP Standard (ISO 10303)

Since the mid-1980s, the international community has been developing the ISO 10303 set of standards, well known as STEP (ISO 10303-1 1994), which has its foundations in many of the earlier aforementioned standards. The STEP standard is divided into many parts, i.e. Description Methods, Information Models, Application Protocol (AP)s, Implementation Methods, and Conformance Tools. The Information Models and Application Protocols describe the data structures and constraints of a complete product model [5]. The use of STEP language can help the enterprises to have to somehow the integration of data for product design activities. STEP has led to improvements in exchange and sharing of simple CAD information, product models and complete product structures. Furthermore, STEP has improved communications within the extended enterprise (including suppliers, business partners and customers) and helped to support global collaborations [6]. With the help of this standard the design information can be managed in an integrated environment.

The first parts of STEP to achieve International Standard status were published in 1994, but many other parts have since been published or are under development and will eventually be added to the standard. Recent updates (and other relevant details) can be found at the following websites: http://www.nist.gov/sc4,www.tc-184-sc4.org, and http://www.iso.ch/iso/en/ISOOnline [7].

ISO 10303, also informally known as the Standard for the Exchange of Product model data (STEP), is a family of standards defining a robust and time-tested methodology for describing product data throughout the lifecycle of a product. STEP is widely used in computer-aided design (CAD) and product data/lifecycle management (PDM/PLM) systems. Major aerospace, automotive, and ship building companies

Omid Fatahi Valilai was with department of industrial engineering as a Msc student, Sharif university of technology, P.O.Box : 1155-9414, azadi road, Tehran, Iran. He is now the president of Parsian Information Architecture ltd, University of Tehran Science and Technology park, Tehran, Iran(omidfatahi@gmail.com).

Mahmoud Houshmand is with the department of industrial engineering as an associated professor, Sharif university of technology, P.O.Box : 1155-9414, azadi road, Tehran, Iran (hoshmand@sharif.edu).

have proven the value of STEP through production implementations resulting in actual savings of $150M per year in the US (and potential savings of $928M per year) [8].

STEP is a proactive effort, the focus being placed on developing a standard that caters for various user groups. These user groups are usually associated in an industry or according to a common application such as CAD data, which can be used throughout multiple industries [9]. STEP is an international effort that goes beyond geometry and aims to represent product data throughout a product's life cycle [9].

The STEP standard categorizes the various types of product data around APs. An AP includes at least three formal documents:

1) The Application Activity Model (AAM) describes the activities in the lifecycle of a product;
2) The pieces of product information that are needed for the activities are called the Application Reference Model (ARM);
3) The Application Interpreted Model (AIM) is formed by using an EXPRESS information model to capture everything in the ARM and to tie it to a library of pre-existing definitions [5].

STEP will enable us to iterate designs based on manufacturing suggestions, then evaluate and analyze the results before manufacturing the pieces. It also offers a tremendous benefit for exchange and managing information from several engineering and manufacturing disciplines in an effective way [10].

Some of the most relevant APs used in the CAD/CAM domain include, Part 203: Configuration controlled 3D designs of mechanical parts and assemblies (ISO 10303-203 1994), Part 214: Application protocol: Core data for automotive mechanical design processes (ISO 10303-214 1994) and Part 224: Application protocol: Mechanical product definition for process plans using machining features (ISO 10303-224 2001) [5].

B. ISO 10303-233(AP233)

AP233 is targeted to support the needs of the systems engineering community. It provides neutral data models as communications pipelines to exchange and integrate information between systems engineering tools. It is built from a set of reusable information model "modules" for compatibility across application domains [11]. Since 1999, STEP has extended its scope from the product design phase to additional lifecycle phases, such as maintenance and repair, including AP239 (Product Lifecycle Support [PLCS]) and AP233 (Systems engineering data representation) [6]. AP233 is designed as a neutral information model for the exchange of data between Systems Engineering, Systems Architecture Description and related tools. In most cases, the specifications within this site are the definition of mappings between the schema or metamodel of an application, database or standard and the AP233 XML Schema. This documentation is self-contained so that readers need no knowledge of the AP233 ISO standard itself or the ISO EXPRESS language in which AP233 is standardized [12].

AP233 is a STEP-based data exchange standard targeted to support the needs of the systems engineering community, consistent with emerging standards in CAD, structural, electrical, engineering analysis and support domains. Application Protocol (APs) parts address specific products and processes. AP 233 is addressing Systems Engineering and Design using a combination of modules the systems engineering team has developed and modules that other teams have developed. The scope of AP 233 includes:

1) System behavior
2) System structure
3) System modeling
4) Decision support
5) Requirements, analysis, trade studies
6) Program and project management
7) Verification and validation
8) Risk management
9) Issue management

AP233 was proposed aiming to support the exchange and sharing of systems engineering data [6]. This helps the system analyzers to gather and develop the main properties of product successfully.

AP233 and several other STEP application protocols are being built using a modular architecture. This enables the same information model to be reused across disciplines and life cycle stages. In the STEP Modular Architecture these reusable information models are called application modules, or informally called "modules". AP233 will consist of a number of modules that together will satisfy the scope of the requirements stated above, which are shown in Fig 1 [13]. So using AP233 for gathering product specification along the modules will be used for other parts in later product lifecycle part. Support for several of systems engineering viewpoints within the scope of AP233 already exist as the result of the development of other application protocols and will simply be reused in AP233. When existing STEP modules do not provide needed capabilities, new modules are being defined as part of AP233 development. Since AP233 is part of STEP, it is easy to relate systems engineering data to that of other engineering disciplines over the lifecycle of a system and to related product models [13]. These modules will be used for other APs in product design and product process design.

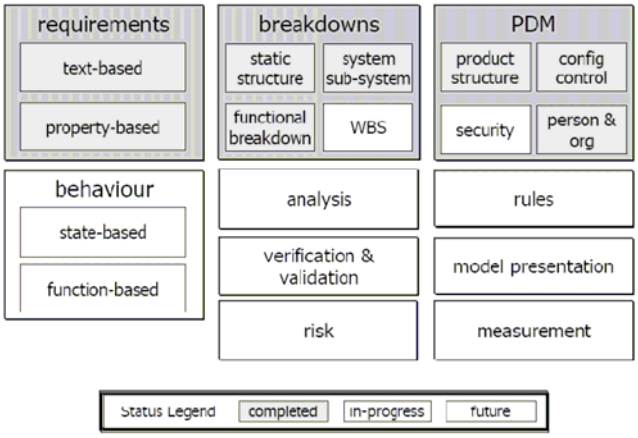

Fig 1. AP233 modules [13]

C. SysML

The Systems Modeling Language (OMG SysML™) is a general-purpose modeling language that supports the specification, design, analysis, and verification of systems. These systems may include hardware, software, data,

personnel, procedures, and facilities. SysML is a graphical modeling language with a semantic foundation for representing requirements, behavior, structure, and properties of the system and its components. The modeling language is intended to model systems from a broad range of industry domains such as aerospace, automotive, health care, and so on [14].

SysML diagrams contain diagram elements (mostly nodes connected by paths) that represent model elements in the SysML model, such as activities, blocks, and associations. The diagram elements are referred to as the concrete syntax [15].

The model elements and corresponding concrete syntax of SysML diagram are [16]:

1) Activity diagram
2) Block definition diagram
3) Internal block diagram
4) Package diagram
5) Parametric diagram
6) Requirement diagram
7) State machine diagram
8) Sequence diagram
9) Use case diagram

SysML is intended to capture actual parametric models—not just documentation—that can be solved by external tools [17]. This makes SysML capable of stating needs clear. SysML is an extension of the Unified Modeling Language (UML), version 2, which has become the de facto standard software modeling language. The Object Management Group (OMG) issued requirements in March 2003 to extend UML to support systems modeling [14]. This makes SysML suitable for software development processes.

SysML can represent systems, components, and other entities as follows [14]:

1) Structural composition, interconnection, and classification
2) Function-based, message-based, and state-based behavior
3) Constraints on the physical and performance properties
4) Allocations between behavior, structure, and constraints (e.g., functions allocated to components)
5) Requirements and their relationship to other requirements, design elements, and test cases

II. SysML Collaboration with ISO 10303-233

The requirements for AP233 and SysML have been largely aligned the OMG and the ISO teams working together. However there might be differences in breath and scope of AP233 and SysML resulting from the different development life cycles of both activities and the different nature of the modeling frameworks used to define SysML and AP233 [13].

As AP233 and SysML are defined in different modeling frameworks, the AP233 metamodel will be converted to UML to ease the mapping. OMG has started a standardization activity to capture EXPRESS semantics in UML, but a custom mapping will be used until the UML profile for EXPRESS has been adopted [15].

To avoid semantically issues in exchanging data between SysML and AP233, a neutral or mapping model of systems engineering concepts has been defined. Thus the mappings between the mapping model and SysML metamodel and the mapping model and AP233 metamodel can be maintained independently [13]. This approach has been shown in Fig 2 [15].

Fig 2. Mapping Model [15]

As seen the SysML and AP233 has similarities in metamodel structure. SysML is compatible with UML and on the side EXPRESS has a providing structure for AP233. The compatibility of EXPRESS and UML 2.0 makes the interchange of data between AP233 and SysML feasible.

One approach for SysML and ISO 10303-233 STEP AP233 Model Interchange is to use the STEP XML-based file exchange capability by simply translating the model contained in an XMI file into a model based on the AP233 XML Schema. This approach encourages systems integrators and SysML tool vendors to develop interoperable SysML-AP233 exchange capabilities. It also provides SysML tool vendors with a means to directly export AP233 XML files [16]. As STEP uses part 28 as "XML representation of EXPRESS schemas and data", AP233 can interchange with the mentioned approach.

Another approach for collaboration of SysML and AP233 can be by means of using of high-level application program interfaces (APIs) [15]. At the moment, standardized APIs for SysML- or AP233-specific models are not available, but work is underway in the industry to provide implementations of such APIs [16]. Application level developers can use the same APIs to access backend XML models serialized in either SysML XMI or AP233 XML format, depending on customer needs. When combined, standardized XML serialization formats and high-level APIs will provide a very convenient and interoperable way for SysML tool vendors and systems integrators to exchange SysML and AP233 models. These standardized capabilities will also provide the foundation needed for building a set of Systems Engineering Web Services.

III. Advantages of using SysML for product design

As mentioned earlier the product design plays an important role for a successful product development. The design time

and product capabilities that answer the needs of customers are two important successful product development factors. The SysML can greatly affect these two factors. It enables us to model and manage activities concerning product design.

A. *Product Capabilities to satisfy customer's needs*

The SysML abilities to gather product Properties requirements and specification enable this language to present the main properties of product design for next stages of product development. Product specifications declare the main needs that the product should satisfy. SysML has this ability to gather and manage the product properties to answer the customers' needs. The structure of this language can gather the information about the requirements. Requirement diagram manages the requirements (product specifications) within the SysML. The ability of the SysML to manage the requirement and relating the sub requirement – requirements that comes from another requirement- to test cases increases the product capabilities to answer the customers' needs.

If the product specification lakes to answer the customers' needs, required features will be added before product design and other proceeding ages start. This decreases the costs for changes. The changes will be declared in the first stages of product design. This makes the other stages of product development ensuring of a consistent structure.

Further, other SysML diagrams help the designers to understand the design specification and constraints in product design and product process planning in future. SysML block diagrams declare the effects and specification of the products in act with internal and external devices and environment.

The most important application of SysML for product design and development is the compatibility of this language with AP233. This is so important because STEP tries to cover all product lifecycle. So the information which comes out as the result of using SysML can easily transmitted to product design stages (AP203) and product process planning (AP214) and other stages within the integrated structure of application protocols.

B. *Time for developing product*

As said in Product Capabilities to satisfy customer's needs, the integrated information structures between SysML and Ap233 and other application protocols increases collaboration. This collaboration occurs in different product lifecycle. STEP application protocols are engaged in these stages.

The information flows between these stages is integrated and the information reaches the missions fast and without losing necessary data. This makes a decrease in information transmission time between different users. The structure of SysML information and data within its diagrams is compatible with AP233 structure. The feedback from the proceeding stages in product development phases can easily transmits the information with the minimum time.

IV. Conclusion

SysML as a modeling language satisfies the needs to declare product specifications and properties. It can express the main features of product in design and manufacturing domains. This information in design and process design are compatible with STEP standard. It can results in successful product design and product process design. SysML has compatibilities with AP 233 and further can collaborate with UML and EXPRESS. These enable the integration of the data based on STEP standard and ease the information flows between different application protocols. This article studies the compatibility of SysML and AP233 to manage the requirements and features of products. Compatibility of UML and SysML and UML and EXPRESS-G diagrams improve data integration during Product design and process planning. The features of SysML to manage the product specification and requirements and its compatibilities with STEP standard help the product design and development cycle insured and fast.

Further studies can be done to apply the information gained during the application of SysML in different courses of product lifecycle other than product design.

References

[1] Kagioglou, Mike, "Product development and design management," Manchester : s.n., 2008. IGLC.

[2] Qualls W., Olshavsky R. W., Michaels R. E., "Shortening of the PLC—an empirical test," 1981, Journal of Marketing, Vol. 45, pp. 76–80.

[3] Blagoevski-Trazof, Aleksandar. "Managing new product development process." 2007, http://www.bea.org.mk /Upload/Content/Documents/Report%202007%20MANAGING%20NEW%20PRODUCT%20DEVELOPMENT%20PROCESS.pdf

[4] O. Canciglieri Junior, F. Favaretto, R.I. M. Young, "Information sharing using features technology to support multiple viewpoint design for manufacture," 2005, Produto & Produção, Vol. 8, pp. 75-86.

[5] X. W. Xu, H. Wang, J. Mao, S. T. Newman, T. R. Kramer, "STEP-compliant NC research: the search for intelligent CAD/CAPP/CAM/CNC integration," 1 September 2005, International Journal of Production Research, Vols. 43, No. 17, pp. 3703–3743.

[6] A. Ball, L. Ding, M. Patel, "An approach to accessing product data across system and software revisions," 2008, Advanced Engineering Informatics, Vol. 22, pp. 222-235.

[7] C. Dartigues , P. Ghodous , M. Gruninger, D. Pallez, R. Sriram., "CAD/CAPP Integration using Feature Ontology." 2007, Concurrent Engineering, Vols. 15, 2, pp. 237-249.

[8] R.S. Peak, J. Lubell, V.Srinivasan, S. C. Waterbury "STEP, XML, and UML: Complementary Technologies." september 18, 2004, JCISE, Vol. 59.http://jcise.eas.asu.edu:8080/ JCISE/.

[9] P. Arunkumar, Anand S. Deshpande, A. C. S. Kumar "A System for Extracting Product Features from CAD Models – A STEP Approach.". 2008, no. 3, Contemporary Engineering Sciences, Vol. 1, pp. 139 - 146.

[10] S. Ranđelović, S. Živanović. "CAD - CAM data transfer as a part of product life cycle." s.l. : FACTA UNIVERSITATIS, 2007, Mechanical Engineering, Vol. 5, pp. 87 -96.

[11] S. Rachuri, S. Foufou, S. Kemmerer. "Analysis of Standards for Lifecycle Management of Systems for US Army --- a preliminary investigation." August 2006. NISTIR 7339.

[12] [Online] [Cited: march 12, 2009.]http://homepages.nildram.co.uk /~esukpc20 /exff2005_05/ap233/index.html .

[13] SysML Merge Team. "Systems Modeling Language (SysML) Specification." April 3, 2006. OMG document: ad/2006-03-01, version 1.0.

[14] S. Friedenthal, A. Moore, R. Steiner. "A practical guide to SysML : The Systems Modeling Language." s.l. : Elsevier Inc, 2008. 978-0-12-374379-4.

[15] Object Management Group (OMG)." OMG Systems Modeling Language (OMG SysML™)," V1.0. September 2007. OMG Document Number: formal/2007-09-01, OMG Available Specification, Standard document URL: http://www.omg.org/spec/SysML/1.0/PDF.

[16] Object Management Group. "OMG Systems Modeling Language (OMG SysML™)," Version 1.1. November 2008. OMG Document Number: formal/2008-11-01, Standard document URL: http://www.omg.org/spec/SysML/1.1.

[17] R. S. Peak, R. M. Burkhart, S. A. Friedenthal, M.W. Wilson, M. Bajaj, I. Kim. "Simulation-Based Design Using SysML Part 1: A Parametrics Primer." may 2007. INCOSE Intl. Symposium, San Diego.