Study of Modern Modeling Techniques for Model Based Systems Engineering Methodologies

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Abstract-
The objective of this paper is to provide a brief view of modeling techniques used for Systems Engineering that might be helpful to know about Model Based Systems Engineering Methodologies to engineer the modern large, complex, interdisciplinary systems of systems and useful to system engineers in selecting and understanding the technique choices for the automation of their work. The modeling techniques used in the field have always been primarily qualitative and simple to understand based on pictorial or graphical representations instead of documentation, requiring a corresponding graphical or visual modeling language that involves syntax and semantics. The modeling languages are the just languages they must be combined with a methodology to be useful. The traditional functional decomposition techniques are being replaced by modern modeling techniques, the variant modeling techniques characteristics and their usages are described.

***Keywords*-Model Based Systems Engineering (MBSE)**

I.INTRODUCTION

Today, in the modern society is faced with the contemporary large scale, complex problems demanding a multi-faceted and interdisciplinary socio technical systems approach. These systems approaches must deal with designing of systems with robustness, adaptability, flexibility and to serve the system-of-interest needs [1].

How can a system engineer face these challenges in order to design and develop a complex, interdisciplinary system of systems in a simple way and smooth automation of their work? Systems Engineers might get the solution for the same is by using modeling techniques in systems engineering methodologies.

System Engineering (SE) deals with the all facets of computer-based development. It handles the effective transformation of stakeholder needs to fielded, sustainable development and focuses on product families, system-of-systems. SE is an interdisciplinary field of engineering that focuses on how large and complex engineering projects should be designed and managed to provide quality product to meet the customer (end user) requirements [5].

A model is a simplification of a reality and it is required for better understanding the systems being developed. The modeling techniques used in various aspects like concepts, attributes, structure, behavior, design, entities, interaction, environment, etc., to develop a system. The modeling techniques used in the field have always been primarily qualitative and simple to understand based on pictorial or graphical representations that involve semantics and syntax.

Table1. Shows the need of modeling in Systems Engineering.

S No	Need
1	To improve communications
2	To manage systems complexity
3	To improve design quality
4	To understand systems requirements
5	To address multiple aspects of system
6	To reduce risks
7	To increase productivity
8	To think about design of system
9	To generate usable products

II.MODEL BASED SYSTEMS ENGINEERING METHODOLOGY

According to J. Estefan [2] A MBSE methodology can be defined as the collection of related processes, methods, and tools used to support the discipline of systems engineering in a "model-based" environment. It can Formalizes the practice of systems engineering through the use of models

As shown in fig [1] MBSE is a model-centric approach providing a single point of truth which is reflected in a set of Living artifacts

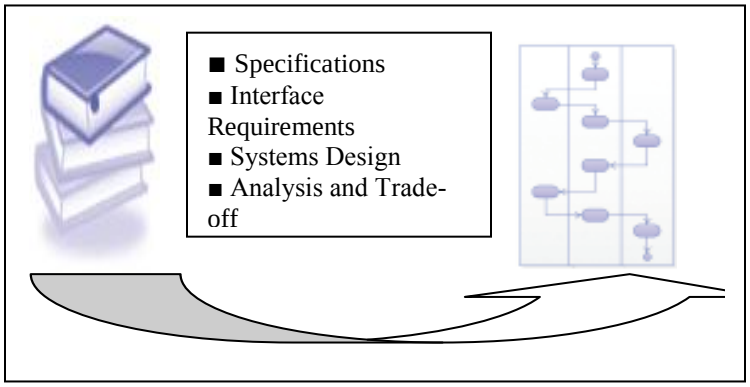

Fig. 1 : Moving from document centric to model centric

Model Based System Engineering has the model, or the models are the primary data source. Model driven development uses the activities associated with modeling to drive the whole development process.

As titled in [2] and [8], The Embedded Computer System Analysis Modeling Methodology (ECSAM), Model Based Architecture and System Engineering (MBASE), The Harmony SE, Object Oriented System Engineering Methodology (OOSEM), Rational Unified System Engineering (RUP SE), Vitech MBSE Methodology , Objet Process Methodology(OPM), LITHE Methodology are the existing notable MBSE methodologies.

III.TRADITIONAL MODELING TECHNIQUES

The traditional modeling techniques follow top-down, procedural approaches and functional modeling perspective in modeling systems. Functional Flow Block Diagrams, Structured Analysis and Design Technique (SADT), State Transition Diagram, HIPO (Hierarchical Input Process Output) and IPO charts, N-squared charts, Petri nets, Integration Definition for Function Modeling (IDEF0) are the few of notable traditional modeling techniques.

The Functional Flow Block Diagrams, developed in 1950s and, with a widespread use within the community, it describes a function between inputs and outputs and should describe the system in one picture. Structured Analysis and Design Technique developed in 1970s and it follows diagrammatic notation for constructing a sketch for an application and it models technical assessment, operational assessments, economic assessment. It can be used as a functional analysis tool of a given process, using successive levels of details. The HIPO stands for Hierarchical Input Process Output developed in 1970s as a documentation technique for systems analysis and design. The HIPO charts some what named as a structure charts. The N-squared charts is used for representing functional or physical interface between system elements and the main objective is to develop software interfaces in software and however it also be used to develop hardware interfaces. The State Transition Diagrams used to describe aspects that change over time and it helps to model real-time systems like as data acquisition systems, telephone switching systems, process control, military command and control systems. The Petri nets developed in 1980s and they are good for modeling concurrency and synchronization. It can be used as a graphical and mathematical modeling tool. The IDEF0 originated in the US Air Force under the integrated computer aided manufacturing program from a well established graphical language, the SADT. It acts as functional modeling is designed to model the decisions, actions, activities of an organization or system. It includes activities of both graphical and documentation principles and it was derived from SADT.

According to Nelson, W. R [3]. The Function modeling techniques have certain advantages for various applications and have the potential to form a framework for modeling human performance throughout the system development life cycle.

The function modeling fails to design and develop the systems in a simple and easy to understood way by the stakeholders. Hence, the filed is moved to use modern techniques in design and development of large complex system of systems.

IV.MODERN MODELING TECHNIQUES FOR MBSE

The traditional modeling techniques are being substituted by the modern modeling techniques and all the modern techniques includes object oriented principles. To day in SE field it all encompasses modern object oriented practices, with in roots in software engineering.

Object Process Diagrams(OPD)/Object Process Language(OPL) , Unified Modeling Language(UML),Systems Modeling Language(SysML), GRAPHITE are few of the notable modern modeling techniques used in Model Based System Engineering Methodologies to engineer the large , complex, interdisciplinary systems of systems.

A.OPD/OPL

The OPDs/OPL techniques used in Object Process Methodology (OPM), OPM is one of the notable Model Based Systems Engineering Methodology. In order to enlarge the domain of object oriented modeling tools, The Object–Process Methodology (OPM), founded by Prof. Dov Dori in 2002. OPDs/OPL is one of the current state-of-the art modeling languages. Object Process Diagram used for graphical representations where as Object Process Language is for textual representation.OPM/OPD provides bimodality i.e both graphical, textual facilities in understanding of complexity of systems. Like as a brain it acts as a visual interpreter and language interpreter. As stated by Grobshtein and Dori [4], this intuitive dual notation provides a single model that is comprehensible to the different stakeholders (both technical and nontechnical) involved in the development process. Both these techniques available at software environment Object–Process Computer-Aided Software Engineering Tool (OPCAT).

According to its author [6], OPM "is a comprehensive novel approach to systems engineering. Integrating function, structure, and behavior in a single unifying model, OPM significantly extends the system modeling capabilities of current object-oriented methods."

B. THE UNIFIED MODELING LANGUAGE (UML)

The OMG specification states that, The Unified Modeling Language is a open standard, general purpose visual modeling language for specifying, visualizing, constructing, and documenting the artifacts of software systems, as well as for business modeling and other non-software systems

UML was developed by Grady Booch, James Rumbaugh and Ivar Jacobson at Rational Software in an effort to simplify and consolidate the large number of object-oriented development methods that had emerged and released in 1997 after successful unification of three modeling methods namely OOAD, OMT, OOSE and these are good at low-level, high-level, middle-level designs respectively. Hence, UML is used to design in every level.

The objectives of UML are general purpose modeling language and to be simple as possible as while still being capable of modeling the full range of practical systems that need to be built. The authors found in their study that UML lacks support from aspects like the decomposition, requirement engineering, the performance analysis, or the trade studies.

C. THE SYSTEMS MODELING LANGUAGE (SYSML)

The Systems Modeling Language (SysML), which has been released in 2007 because UML not has enough support from aspects like decomposition, requirement engineering, the performance analysis, or the trade studies. In order to incorporate these and other additional features, the International Council of Systems Engineering (INCOSE) and the Object Management Group have joined efforts and developed an extension of UML for SE, the Systems Modeling Language (SysML) [7].

SysML is a graphical language which supports the specification, analysis, design, verification, and validation of systems that include hardware, software, data, personnel, procedures, and facilities and also supports model and data interchange via XML Metadata Interchange (XMI®) and the evolving AP233 standard (in-process). It is a methodology and tool independent and it is a critical enabler for model driven SE.

The relation ship between the UML and SysML has shown in fig.2 SysML is an extension to UML and it is a domain specific such as automotive, aerospace, communication and information systems, where as UML used for general purpose. SysML is compatible with UML and it abandons some of the software centric aspects of UML. As per the authors point of view the combination of UML and SysML improves communication among the various stakeholders in the systems development process and SysML makes UML better.

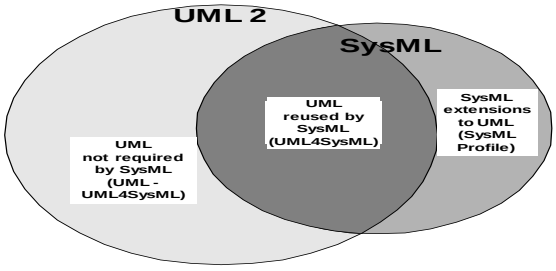

Fig.2.Relationship between UML and SysML

D. GRAPHITE TOOL

The GRAPHIcal Tools for StakEholders' interactions (GRAPHITE) is developed to support LITHE (An Agile based methodology). This tool is an integration of the state-of-the art models like

SysML and OPD/OPL to provide significant added value to the engineering process. It supports graphical representations.

According to Anu Lusa Ramos [8] it consists set of matrices with the rows standing for the "type" of stakeholders involved in the development process, the columns standing for the activity to perform, and the entries symbolizing the model(s) more suitable for that given circumstance. The matrices intend to be a graphical representation that is "easy to use" in MBSE cooperative development environments where the systems engineer is the "glue" central person.

V.CONCLUSION

This study of modern modeling techniques provides a rational way to view the techniques for model based systems engineering methodologies and to know about their significance and usage for systems engineers in understanding to engineer the complex, large and interdisciplinary systems of systems and aiming to support the development of successful systems. The techniques noted above specify its importance in implementation of methodologies to support the development of successful systems. According to the authors point of view the modeling languages or modeling techniques are the just languages or techniques they must be combined with a methodology to be useful. In this study authors found that OPD/OPL, SysML are the state-of-the art modeling languages and especially SysML is methodology independent. Modeling techniques plays crucial role in effective design and development of successful systems. Hence the authors says that there is high tendency for research in this aspect and authors conclude that there is a need of standard techniques or tools for MBSE methodologies which satisfy the stake holders expectations and aiming to support for the development of successful systems .

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