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Process for Selecting Engineering Tools – Applied to Selecting a SysML Tool

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Abstract

Process for Selecting Engineering Tools outlines the process and tools used to select a SysML (Systems Modeling Language) tool. The process is general in nature and users could use the process to select most engineering tools and software applications.

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NOMENCLATURE

SNL	Sandia National Laboratories
SysML	Systems Modeling Language
COTS	Commercial off-the-shelf
UML	Unified Modeling Language
SRN	Sandia Restricted Network
SCN	Sandia Classified Network
TcSE	Teamcenter Systems Engineering
CSU	Computer Support Unit
NTK	Need To Know
CASA	Common Adaptable System Architecture

1. INTRODUCTION

This process for Selecting Engineering Tools will give the reader an understanding of the process the authors followed to select a SysML software application tool. SAND2006-0478 "COTS Software Selection Process" was used as a starting point. The authors extended the previous methodology and chose to use two Six Sigma tools, Pugh Matrix diagram and Pairwise Comparison diagram, to aid in the selection of the SysML tool.

In addition to selecting a SysML tool for use at Sandia National Laboratories (SNL), the authors were tasked with implementing and managing the tool on both the unclassified and classified computer networks at SNL.

2. BRIEF HISTORY

The use of SysML at SNL had its start more than four years ago when Regina Griego, in the Weapons Systems Integration Department, recommended the use of SysML to characterize some of the system level analyses being conducted in Mark Bleck's Use Control Systems Department. Up to that time, Regina had been using UML (Unified Modeling Language), which is a close sibling and progenitor of SysML, to analyze stakeholder requirements and system constructs.

Some four years ago, shortly after taking a course in UML since there was no strictly SysML related classes being offered at that time, the Telelogic Rhapsody UML tool with a SysML module was purchased to perform systems modeling and analysis. From that time up to the initiation of the SysML tool selection process nearly a year ago, the use of SysML proceeded sporadically within SNL.

After Mark De Spain moved into 2123, the Advanced and Exploratory department, where the objective was to apply modern analytic and modeling tools to analyze and define systems, the decision was made to pursue a more structured and better supported approach to selecting and maintaining a SysML tool. This decision led directly to the SysML tool selection project that was led out of 2998.

Mark saw a rise in the interest of engineers in SysML tools and potential fits for the SysML approach for some Advanced & Exploratory projects (e.g., CASA, Reentry Systems Transformation and Air-delivered Systems Transformation). From our experience with previous tool deployments, the team saw the need for a more rigorous trade study process, including exploring the needs of users, identifying the applications best suited for SysML, understanding the costs of tools and their range of features, and understanding the systems engineering processes that underlie the use of SysML.

Our other immediate need was to take the burden of administering our existing Rhapsody licenses from individual systems engineers. Department 2998 is experienced in administering systems engineering tools, as well as providing training and consulting;

therefore, a transition of responsibility made sense and would improve the support provided to all users.

3. METHODOLOGY

The following subsections describe the process the team used to select a SysML tool.

The team referenced the methodology outlined in SAND2006-0478, "COTS Software Selection Process." The team extended the methodology used in the previous SAND report and used a different approach in selecting a tool.

3.1 Team

Mark De Spain requested that Department 2998 manage his Rhapsody software licenses. Mark also asked 2998 to investigate the use of Rhapsody and possibly other SysML tools at Sandia. It became apparent that a team needed to be formed to investigate the future use of SysML tools.

The following team members were chosen:

Kent de Jong, 2998, Information Services for Product Information
Mark De Spain, 2123, Advanced and Exploratory Systems (A&E)
Marjorie Hernandez, 2998, Information Services for Product Information
Debbie Post, 8248, Program Analysis and Integration
Jeff Taylor, 2998, Information Services for Product Information

Kent was chosen because of his systems and requirements engineering experience. The team felt this experience would be valuable in defining requirements for a tool and selecting a tool.

Mark was chosen because of his experience and knowledge of SysML and Rhapsody. In addition, he could represent the user community by being the voice of the customer.

Marjorie was chosen because of her Six Sigma Green belt training and organizational skills.

Debbie was chosen because of her systems and requirements engineering experience and could represent the California user community.

Jeff was chosen because of his experience with choosing and deploying engineering applications on the classified and unclassified networks.

3.2 Management Approval

The team received management approval from Fran Current, manager, 2998, and Steve Harris. In addition to management approval, the team had two champions, Steve Harris,

manager, 2123, Advanced and Exploratory Systems (A&E), and Bob Oetken, 8244, CA Advanced & Exploratory Systems.

3.3 Mission/Goal/Project Objectives/Project Scope/Constraints

3.3.1 Mission

Define a process to select software tools but to also apply this method to the selection of a SysML tool.

3.3.2 Goal

Use and define a process to select and implement software tools at SNL.

3.3.3 Project Objectives

1. Choose a SysML tool for SNL
2. Centralize and manage existing and future tool licenses and installation packages in department 2998 for all users
3. Use industry best practices in Model-Based Systems Engineering to improve how to develop and communicate system specifications. For designs of sufficient complexity, users need to go beyond PowerPoint and Visio for functional analysis and allocation, interface definition, use case definition and requirement definition.
4. Reduce licensing costs by allowing users to share licenses
5. Make tools available at the engineer's desktop on the SRN and SCN
6. Educate SNL engineers on the Systems Modeling Language and its potential benefits and costs
7. Investigate systems engineering problems and processes that benefit from the use of SysML
8. Develop a process for creating system specifications with a SysML tool
9. Document commercial tool functionalities with AP233
10. Document adherence of the commercial tools to the latest SysML tool standards
11. Down select to a SysML tool for technical projects at SNL (both New Mexico and California sites)
12. Make the SysML tool available on the SCN with appropriate access controls and security plans
13. Reduce the cost of stand-alone licensing and establish floating licenses for cost sharing on both the SRN and SCN
14. Establish a collaborative website for the SysML team and SysML tool licensing and installation information for users
15. Document our SysML tool selection process and results in a SAND report
16. Investigate the integration of SysML models with the Sandia application, "Orchestra." Orchestra was written at Sandia New Mexico and is an embedded electronics design tool that can output XML files. The Orchestra users are working with SysML users to investigate how SysML might handoff to Orchestra.

3.3.4 Project Scope

1. Evaluate and select a COTS (Commercial Off The Self) software package
2. Stay within cost and schedule

3.3.5 Project Constraints

Team members must continue to meet other deadlines on other projects

3.4 Identified Stakeholder

When the project began, a large group of stakeholders was defined. These stakeholders included Sandia managers and staff from the California site's Systems, Surety, Telemetry, and Program Analysis/Integration organizations. In New Mexico, stakeholders identified include staff members and managers from the Systems, Surety, Weapon Program Integration, and Engineering Requirements organizations and the System Engineer Users Group in 2600.

Due to a cut in the project's budget, the number of stakeholders was reduced to three people. The stakeholders were all members of the team: Debra Post, Mark De Spain, and Kent de Jong. These three staff members did their best by putting on their stakeholders' hats and representing the stakeholders groups and articulating the needs and desires of these groups.

3.5 Discovery Phase

After some discussion with systems and subsystems engineers who might benefit from using SysML, the team realized that SysML is still in its infancy at SNL, and the following questions could not be answered until training classes were held and a pilot was conducted:

- What are the expectations for using a modeling tool?
- What is the work approach of systems engineering users?
- What other tools can achieve the same end?
- What kind of engineering problem can best gain value added from using SysML?
- How does SysML support an engineer's systems engineering process?

Therefore, the team decided that it was out of project scope to develop a systems engineering process for SysML. SysML is fairly new in the industry, and users are beginning to apply SysML at SNL. After the team gave several technical presentations, arranged SysML training, and acquired/deployed floating licenses, the team enabled several projects to try SysML. After these pilot projects have progressed, the team will better understand the return on investment for Model-Based Systems Engineering with SysML.

3.6 Requirements

The articulation of stakeholders' needs by the team members resulted in a list of criteria, which were then driven to requirements categories.

The team collected the criteria and placed it on the team's SharePoint site as it was identified. There were two criteria groups, mandatory and desired features. The mandatory criteria were those requirements that the team felt the tool must have for Sandia. The desired features were the discriminators between the contending tools.

Mandatory criteria:

- Floating license
- Affordable (less than $1000 including SysML plug-in)
- Supports SysML 1.0 (or later)
- Complete toolset (i.e., you can create models just with this license and don't need additional software)
- Provide formatted reports containing model information
- Provide standard output format to other applications (e.g. AP233 or XML)
- Tech Support (Monday – Friday, 8am – 5pm, Mountain Time)
- Must work on SCN with appropriate need to know controls
- Output to Microsoft Office so results can be easily communicated
- A suite of models can be independently developed, and yet can "call" each other
- Good diagnostics/test bench capability to ensure all branches of a model are exercised

Desired Features:

- Online tutorial
- Company offers tutorials, training that can be tailor for our uses.
- Easy to learn
- Does simulation
- Interfaces to Teamcenter for Systems Engineering (TcSE)
- A government or volume price discount
- Looks good to us!

Based on the criteria, the team identified several requirements' groups. The team continued in the tool selection with these requirement groups rather than developing a full set of requirements due to time and budget constraints. The requirement groups were:

Floating license	Merge multiple into larger system model
Supports SysML 1.0 (or later)	Ease of Use
Provide standard output format to other applications (e.g. AP233 or XML)	Timeout feature for floating licenses
Tech Support (M-F 8a-5p MT)	Simulation capability
Works on SCN with need to know controls	Operating System
Independent development of a suite of	Model completeness or goodness checks

models	

3.7 SysML Classes

Our team attended and hosted several SysML classes in New Mexico and California. The schedule was as follows:
SysML for System Engineers in NM – August 7, 2008
SysML Class in NM – September 8, 2008
SysML for System Engineers in CA – October 7, 2008
SysML Class in CA – November 10, 2008
Beginner's SysML Class in CA – February 2, 2009
Beginner's SysML Class in NM – April 28, 2009

3.8 Consultation and Training

Upon doing some research through the International Council on Systems Engineering (INCOSE) and SysML users groups and forums, the team chose a US-based consulting firm: PivotPoint Technologies, Inc. PivotPoint Technologies is involved in the development of the SysML and UML language standards and is active in the INCOSE working group on Model-Based Systems Engineering (MBSE).

The team arranged for three classes and put a consulting contract in place so that users could continue to work with the vendor as they progressed in their pilot projects. Our team also received recommendations for criteria for comparing commercial tools that implement the SysML standard.

The team concluded a modest analysis should be done given the available funding for this team, down select to reasonable tools, and then monitor the progress of the pilot projects. SNL engineers, management, and other stakeholders do not have sufficient experience in the use of SysML to either create a highly detailed requirements document, nor to understand the value added of this tool. The team recommend that the pilot projects give seminars to share their experiences with SysML in order to help us assess whether or how to promote SysML to the SNL systems engineering community.

3.9 Project Plan/Budget

The team started doing work on the project and was working on documenting the project plan and budget when funding was cut. The team was instructed by management to use the data and knowledge they had and choose a SysML tool.

In addition to the work listed above, the team planned to schedule and take training on the Rhapsody SysML software tool so the team would be better able to evaluate the tool but had to cancel. Mark had training and experience with Rhapsody so the team relied on his expertise to evaluate Rhapsody.

4. SOFTWARE LICENSING

When Mark came to department 2998 with a need to manage Rhapsody software licenses, the department investigated how users were using Rhapsody at Sandia. Rhapsody was being used with standalone licenses. To get the best use out of the tool, the standalone licenses were converted to floating licenses and the licenses were made available on both the SRN and SCN networks.

When Magic Draw was selected as a second SysML tool for Sandia, floating licenses were purchased. Having both Rhapsody and Magic Draw available on a floating license server, reduced the cost of licensing.

Approval to place both Rhapsody and Magic Draw on the SCN was accomplished by using the CNARS process. Cyber Security provided proper procedures for placing applications on the SCN with proper NTK controls.

User procedures were written for installing both applications on the SRN and SCN for the CSU's.

A collaborative share site was established for all necessary information and instructions for using the selected SysML tools on both the SRN and SCN.
Department 9341, CSU Special Projects, will manage the SysML tools selected for use at SNL. The vendors, No Magic Inc. and IBM, will support our customers in using the products.

5. COMPUTER SECURITY APPROVALS

The applications, Magic Draw and Rhapsody, store the data in each user's diskless work station, like MS Office Products, a security plan was not needed. Users can share models by emailing or saving models to Web Fileshare, much like MS Office files.

6. LESSONS LEARNED

Since the beginning of this effort, the team has been focused on determining whether the System Modeling Language methodology could be useful for system engineers and if so, how the system engineering staff could best learn the methodology.

As part of the work of learning the methodology, members of the group took SysML classes. The team decided to host the classes with an independent vendor whose focus was on the methodology. It was during these classes the team learned of some of the challenges of comprehending and using SysML.

The learning of SysML parallels the learning of a new language. There are new elements and new constructs in SysML, which new users need to grasp. Once understood, the implication of the constructs and elements can be put together to communicate ideas and concepts.

SysML provides the capability to triangulate between diagram elements. SysML can compare the content of multiple diagrams and was very helpful in working on a couple of projects. The comparison of the activity diagram (which represents functional flow) to the structure of the product (represented in the block definition diagram) uncovered errors, misinterpretations, and miscommunications.

However, this capability comes with a significant learning curve. SysML requires a significant persistence to maintain a modicum of fluency. Without that persistence, is was and is very easy to revert back to just doing 2 dimensional lines and boxes.

Having a tool is critical to using the language, yet it was found that the tool gets in the way of learning the language. There might be a significant benefit to learning System Modeling Language without a tool in the classroom.

7. SOFTWARE SELECTION

The team used two tools: Pugh Matrix and Pairwise Comparison to help them pick the best tool to be used by engineers at SNL.

Of the three tools studied, Magic Draw was chosen as the best overall tool and was implemented on the SRN and SCN.

It was decided to implement Rhapsody too because it has advance capabilities that Magic Draw and Enterprise Architect do not have. Rhapsody was not the overall winner because its advanced capabilities are more difficult to use and learn and it is more expensive. Mark used Rhapsody before the team did the evaluation and had purchased licenses. Converting the Rhapsody licenses from stand-a-lone to shared licenses was done at a minimal cost.

Due to budget and schedule constraints, the team quickly chose 3 of the most popular SysML tools on the market per public forums found on the internet. Our study did not exhaustively evaluate every possible vendor. Our Pugh Matrix and Pairwise Comparison scores represent the qualitative opinions of our team.

8. APPENDIX A: PUGH MATRIX

Weighted Pugh Matrix

Requirements	Weight	Baseline Rhapsody	Magic Draw	Enterprise Architect
Must work on SCN with appropriate need to know controls	10	0	0	0
Simulation capability (depending on the cost and ease of use tools with and without simulation capability may be chosen)	8	0	-8	-8
Model completeness or goodness checks (do you have orphan diagram objects not connected to anything? do you have dangling interfaces?)	8	0	0	-4
Operating System (Apple, PC, Linux, etc. Engineer desktops are PC or Apple. Servers are Windows or UNIX.)	7	0	0	0
Supports SysML 1.0 (or later)	6	0	0	0
A suite of models can be independently developed, and merge into larger system model	6	0	3	3
Floating license	3	0	0	0
Provide standard output format to other applications (e.g. AP233 or XML)	3	0	-3	-3
Tech Support (M-F 8a-5p MT)	2	0	6	2
Ease of Use	2	0	4	2
Total		0	2	-8

Notes: Used the pairwise comparison for weight (listing the most important requirement to the least important)

For example, Magic Draw and Enterprise Architect was given a -1 for simulation because neither application does simulation)

9. APPENDIX B: PAIR WISE COMPARISON

Pairwise Comparison Matrix

		A	B	C	D	E	F	G	H	I	J	K
		Floating license	Supports SysML 1.0 (or later)	Provide standard output format to other applications (e.g. AP233 or XML)	Tech Support (M-F 8a-5p MT)	Must work on SCN with appropriate need to know controls	A suite of models can be independently developed, and merge into larger system model	Ease of Use	Timeout feature for floating licenses	Simulation capability (we may want tools both with and without, depending on the cost and ease of use)	Operating System (Apple, PC, Linux, etc. Engineer desktops are PC or Apple. Servers are Windows or UNIX.)	Model completeness or goodness checks (do you have orphan diagram objects not connected to anything? do you have dangling interfaces?)
	Pairwise Comparison Matrix	A	B	C	D	E	F	G	H	I	J	K
A	Floating license											
B	Supports SysML 1.0 (or later)	B										
C	Provide standard output format to other applications (e.g. AP233 or XML)	A	B									
D	Tech Support (M-F 8a-5p MT)	A	B	C								
E	Must work on SCN with appropriate need to know controls	E	E	E	E							
F	A suite of models can be independently developed, and merge into larger system model	F	F	F	F	E						
G	Ease of Use	G	B	C	D	E	F					
H	Timeout feature for floating licenses	A	B	C	D	E	F	G				
I	Simulation capability (we may want tools both with and without, depending on the cost and ease of use)	I	I	I	I	E	I	I	I			
J	Operating System (Apple, PC, Linux, etc. Engineer desktops are PC or Apple. Servers are Windows or UNIX.)	J	J	J	J	E	J	J	J	I		
K	Model completeness or goodness checks (do you have orphan diagram objects not connected to anything? do you have dangling interfaces?)	K	B	K	K	E	K	K	K	K	K	

10. REFERENCES

1. Han Lin, *COTS Software Selection Process (U)*, SAND2006-0478, Sandia National Laboratories, Albuquerque, NM, May 2006.

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