NDIA 2017

20th Annual Systems [<] Engineering Conference

MBSE to Address Logical Text-Based Requirements Issues

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The Truth is in the Models™

About Me





SysML Model Builder Intermediate



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CATION



Saulius Pavalkis

- **Chief MBSE Solutions Architect**, training and consulting companies as: Ford, SGT, Abbott, Raytheon, UTAS, NYTA, Orbital ATK, SMEE, GMTO, BAH, DRAPER, LSST.
- PLM Product Integrations Manager, working with all major PLM vendors.
- Former **Analyst** on the MagicDraw R&D team for over 10 years.
- Major expertise area is MBSE, Requirements engineering, PLM, Traceability.
 - **Ph.D.** from Kaunas University of Technology (KTU) in model traceability area. Former **researcher** at Kaunas University of Technology on multimillion projects. Master and Bachelor in telecommunication and Electronics
- **Research and technical articles** in model-based solutions presented at INCOSE IS, NDIA. Check modeling community blog (blog.nomagic.com) for more.
- Representative at INCOSE CAB.

Agenda



- Requirements Quality Problem
- Systems Engineering (MBSE) Solution
- Application Case with Samples from Actual Projects
- Full Picture Framework and Method
- What next?
 - \circ $\,$ Validation and Verification
 - Documentation Generation
 - Traceability
- Conclusions

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Requirements Quality Problem

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Poor Requirements Impact on Cost



Source of program failures is the result of poor requirements definition. This increase cost significantly which result in program delay or fail if program is with fix cost.



Source: Defense Acquisition University, 1993. Cost of defects increases disproportionately after the design phase.

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- A new modern Spanish submarine S-80 Cost of 2.2 billion euros.
- Discovered to contain a serious design flaw - it is 75-100 tons overweight.
- **Calculations mistake** in beginning by putting comma in wrong place noticed before production.
- Now have to be lengthened. Would take two years - \$9.7 million per meter.
- **Priority project** which failure created problems for government and company.
- Engineering mistakes can happen for any system. In document based system engineering big problem is disconnection between design and analytical models and in general between different design artifacts.





Source: http://www.dailvmail.co.uk: http://www.huffingtonpost.com/



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Requirements Management Theory



Requirements quality can be improved through these approaches:

- Visualization. Using tools that promote better understanding of the desired end-product such as visualization and simulation.
- Consistent language. Using simple, consistent definitions for requirements described in natural language and use the business terminology that is prevalent in the enterprise.
- Guidelines. Following organizational guidelines that describe the collection techniques and the types of requirements to be collected. These guidelines are then used consistently across projects.
- Consistent use of templates. Producing a consistent set of models and templates to document the requirements.
- Documenting dependencies. Documenting dependencies and interrelationships among requirements.
- Analysis of changes. Performing root cause analysis of changes to requirements and making corrective actions.

Systems Engineering Theory





Source: Systems Engineering Fundamentals Defense Acquisition University Press, 2001

Traditional Requirements Visualization Method



Text based requirement e.g. Excel + Drawing

- Producing text based artefacts
- Multiple unconnected sources of information: non traceable, non consistent, hard to change.
- Generally not machine readable
- Verification done by manual inspection

në ni dans leur légende qui puisse justif as mari et femme (comme Zeus-Héra, P Charis), ni frère et sœur (comme Apoll nère et fils (comme Aphrodite-Éros), ni Athéna-Héraclès). Quel lien unissait do neu et une déesse qui semblent étrange illéguer une fantaisie personnelle du so ruvre sacrée, l'artiste ancien est tenu de s on initiative s'exerce dans le cadre des ion. Hestia – nom propre d'une déesse mant le foyer – se prêtait moins qui eprésentation anthropomorphe. On la vo 'est, c'est souvent, comme Phidias l'avi Hermès³. De règle dans l'art plastique



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MBSE



"Model-Based Engineering (MBE): An approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition life cycle."

Final Report, Model-Based Engineering Subcommittee, NDIA, Feb. 2011

"Model-based systems engineering (MBSE) is the *formalized application of modeling* to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases."

INCOSE SE Vision 2020 (INCOSE-TP-2004-004-02, Sep 2007)

"Mechanisms to remove requirements errors up front should mitigate program risk - MBSE helps achieve this. Increasing the level and quality of systems engineering has positive effect on cost compliance, schedule compliance, and subjective quality of the programs."

Honour, Eric C., et al. "Technical Report Value of Systems Engineering." (2004),



Systems Engineering (MBSE) Solution



Current Practice to Future Practice





Today: Standalone models related through documents **Future:** Shared system model with multiple views, and connected to discipline models



Document Centric v Model-Based



Document Centric

- Producing text based artefacts
- Multiple unconnected sources of information: non traceable, non consistent, hard to change.
- Generally not machine readable
- Verification done by manual inspection

Model-Based Centric

- Producing system model and generating artefacts
- Aims to minimise the sources of information and mange their relationships (acknowledges we are unlikely to ever have just one repository)
- Machine readable and thus able to query
- Verification enhanced by automatic rule checking

Systems Modeling Language (SysML)

- OMG Systems Modeling Language (SysML) is a ISO Standard graphical modeling language for specification, analysis, design, verification and validation of systems
- Dedicated for modeling complex systems that may include hardware, software, information, personnel, procedures, facilities, etc.



The Four Pillars of SysML





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SysML Diagram Kinds





Requirement Relations in SysML





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Application Case with Samples from Actual Projects

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Stakeholder Needs Import

Stakeholder Needs in



С

В 1 Bluetooth Headphones

Α

2	Id	Name	Text
3	STN1	STN1 Power source	Headphones shall charge using USB 2.0 as charging source
4	STN2	STN2 Pairng	Headphones pairing shall be intuitive and straight forward
5	STN3	STN3 Battery capacity	Battery shall last long enough to see full movie.
6	STN4	STN4 Charging time	Charging time shall be short.
7	STN5	STN5 Dynamic range	High quality dynamic range.
8	STN6	STN6 Solid material	Headphones shall look and feel as very solid.
9	STN7	STN7 Comfortable	User shall not feel weight or pressure
10	STN9	STN9 Audio source	Headphones shall play sound from bluetooth and Line-in sources



#	Id	△ Name	Text
1	STN1	E STN1 Power sou	urce Headphones shall charge using USB 2.0 as charging source
2	STN2	E STN2 Pairng	Headphones pairing shall be intuitive and straight forward
3	STN3	E STN3 Battery ca	apacity Battery shall last long enough to see full movie.
4	STN4	E STN4 Charging	time Charging time shall be short.
5	STN5	E STN5 Dynamic r	ange High quality dynamic range.
6	STN6	E STN6 Solid mate	erial Headphones shall look and feel as very solid.
7	STN7	E STN7 Comforta	ble User shall not feel weight or pressure
8	STN9	E STN9 Audio sou	rce Headphones shall play sound from bluetooth and Line-in sources

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Interface Requirements Formalization

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Functional Requirements Formalization





System Characteristics Formalization



Measurements of Efficiency (MoE)) define validation criteria for stakeholder requirements.



Leveraging Model Traceability

Legend			Ξ	🖻 🛅 11 Stakeholder Needs					eds				
[▶] Refine					E STN1 Power source -	STN2 Connectivity	🔳 🔳 ETN3 Battery cap	E STN4 Charging time	E STN5 Dynamic range	E STN6 Solid material		SysML enables to link with relations to traceability	elements facilitate
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			ncv[h	ertz] 1					7				
		m dynamic range low : frequen	icy[he	ertz] = 1	1				7		_		
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			#	Id	1				Nam	e		Text	Refined By
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		m weight : mass = 11.0 oz	2	STN2		[E	STN2	2 Pain	ng		eadphones pairing shall be intuitive and straight forward	1 Pair With Device
		<u>m</u> weight : mass = 11.0 oz <u>m</u> weight balance between ear	2 3	STN2 STN3]	E	STN2 STN3	2 Pain 3 Batt	ng ery o	apacity	eadphones pairing shall be intuitive and straight forward Cattery shall last long enough to see full movie.	> 1 Pair With Device
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		 m weight : mass = 11.0 oz m weight balance between ear Operational : Bluetooth Audio Device : Headphones : Line In Audio Device : USB Charging Source USE Cases [12 User Needs] 1 Pair With Device 2 Battery Low Shutdown 3 Listen to Paired BT Device 4 Adjust Volume Charge 	2 3 4 5 6 7 8	STN2 STN3 STN4 STN5 STN6 STN7 STN7]]]]]]]		STN2 STN3 STN4 STN4 STN6 STN6 STN6	2 Pairi 3 Batt 4 Cha 5 Dyn 5 Solid 7 Corr	ng rery o rging amic amic d mat forta	apacity time range erial ble urce	leadphones pairing shall be intuitive and straight forward Image: Comparison of the set of the se	 1 Pair With Device operation time : time = 4.0 charging time : time = 2.0 dynamic range low : frequent dynamic range high : frequent dynamic range hig

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MBSE at Bombardier Transportation

Change Analysis on Different System Hierarchy Levels





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Interface System Requirements



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Requirements



10.06.2015



Full Picture - Framework and Method





You always end-up using an architecture framework whether you want one or not, or whether you intend to or not



An Approach: MBSE for RM

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MagicGrid



				Pillar		
			Requirements	Behavior	Structure	Parametrics
straction	ication	Concept	Stakeholder Needs	Use Cases	System Context	Measurements of
ayer of Ab	Specif	Problem	Goals & Objectives	Functional Analysis	Logical Subsystems	Effectiveness (MoEs)
	Design	Solution	Component Requirements	Component Behavior	Component Assembly	Component Parameters

Requirements Traceability





Validation and Verification

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GUI Mockups for System Validation



Requirements Verification: Vocabulary





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Step 1: Formalize Requirements

Thirty Meter Telescope



Verification reports





Variables X o [©] Breakpoints X	
2 ≌ ≧ 16	¢ -
Name	Value
🗉 🔜 Vehicle UT	Vehicle UT@255ef3ed
grossWeight : lbs [1]	3201.0000
💷 numberOfWheels : Integer [1]	5
requiredStopDistance : ft	Requirement 4 - "The vehicle weight shall be equal to or less than 3200 pounds." is not satisfied.
SD Verification : VerdictKind	pass
💷 speed : mph [1]	65.0000
stoppingDistance : ft [1]	163.6277
💷 stopTime : sec [1]	0.0000
🖭 💷 engine : Engine	: Engine@51427148
🗄 🎞 transmission : Transmission	: Transmission@30a84857
🗄 🍱 wheel : Wheel	: Wheel@d130ab0

🛠 Run Test 🕴 🕨

	nstance Table ×					⊲ ▷ 🗉
+ +	🖹 🗄 🖹 Add New 🖺 Add Existing 📋	Delete	» 🗈 Export 🛛 😴	0	• • • •	»
#	Name		Testcase1 verdict		Testcase2 verdict	
1	Test at 2014.05.02 19.36	pass		pass		
2	Test at 2014.05.02 19.49	pass		pass		
3	Test at 2014.05.03 09.28	fail		fail		
4	🖃 Test at 2014.05.03 09.33	pass		fail		

	Α	В	С
1			
2	Test	testcase1 verdict	testcase2 verdict
3	Test at 2014.05.02 19.49	pass	pass
4	Test at 2014.05.02 19.36	pass	pass
5	Test at 2014.05.03 09.28	fail	fail
6	Test at 2014.05.03 09.33	pass	fail

External Analytical Model Integration for Requirements Verification





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Validation and Verification (more)



- OMG standard UML Testing Profile (UTP) based test case definition
- Test cases recording based on system design
- Test cases execution



Documentation Generation

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Template-based Generator



You can generate an HT XML or any other simple



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Bluetooth Headphone Lab v4 Date: October 22, 2017 Requirement Report Revision: 0.1

1 Concept

11 Stakeholder Needs

STN1 Power source

Headphones shall charge using USB 2.0 as charging source

Source:

Marketing

- Derived:
- BT_7 USB 2.0 power source
- BT_15 One USB 2.0 IF

Refined By:

- 🗢 Charge
- . NA

Traced From:

- BT_15 One USB 2.0 IF
- BT_7 USB 2.0 power source

STN2 Pairing

Headphones pairing shall be intuitive and straight forward

Source:

Usability team

Derived:

BT_18 Reconnect

Refined By:

Pair With Device

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Online Documentation And Review







Traceability

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Requirements Analysis: Coverage



Use	Cases 🔠 Data Metric Table	🔲 Data Metric Tabl	el X						4 ▷ [
🔶 🔶 Criteria	🕆 🗄 🗐 Calculate Metric	s 🗋 Add Existing	👕 Delete 🖷 I	Remov	/e From Tab	e 🛛 🖨 🖶 🛄 Show Metric Su	iites 👖 Show Colum	ins 📄 E	xport 🛛 🛃 🔹 🔹 📥
Metrio	Suite: Reqs Satisfied by	Blocks	Sco	ope (o	ptional): D	ag elements from the Model I	B Filte	r: Q-	
#	Date	Requirements C	ount	Blo	cks Count	Requirements Covered B Blocks Count	y Requiremets Cove Percent	red By Block age	s Requirements Covered By Blocks Average
1 20	1 2014.03.01 16.00 18					2	11.11		1.00
2 20	14.04.01 16.00	18	10			4	22.22		1.00
3 20	014.05.01 16.00	18	12			6	33.33		1.50
4 20	014.05.01 16.00	18	12			8	44.44		1.33
	A		D		E	F	G		Н
			Requiren	nents	Blocks	Requirements Covered By	Requirements Cov	ered By	Requirements Covered
1			Count		Count	Blocks Count	Blocks Percentage		By Blocks Average
2	2014.03.01 16.00			18	4	2		11.11	1
3	2014.04.01 16.00			18	10	4		22.22	1
4	2014.05.01 16.00			18	12	6	i	33.33	1.5
5	2014.06.01 16.00			18	12	8		44.44	1.33
6									
7	F				*		1)	
8		Dogu	iromont		worago	Analysis			
9		Requ	irement	su	werage	Analysis			
10						_			
11	20 18	18	18	18					
12				-		-			
13	15	10	12		12				
14		10			8	Requirements Count			
15	10		6			Blocks Count			
16	5 4	4							
17						Requirements Covere	d By Blocks Count		
18	o 🖌 🗖 🗖								
19	2014.03.01	2014.04.01	2014.05.01	201	4.06.01				
20	16.00	16.00	16.00	1	6.00				
21	:-								

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Requirements Analysis: Change Impact

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Tracking Changes





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Conclusions



- Requirements quality is big problem which causes projects to delay and be out of budget. This means a lot of money in case of complex SE projects.
- Traditional methods for requirements quality does not address semantic of system under design.
- In document based system engineering big problem is disconnection between design and analytical models and in general between different design artifacts.
- MBSE provides: methods, tools, and languages for requirements formalization and significant quality increase.
- We presented MBSE with SysML based approach (MagicGrid) for requirements formalization. It:
 - Using SysML as a language provides rich means to address requirements quality issue by formalizing them with system model. Descriptive system model represents system from behavioral, structural, and analytical viewpoints giving full understanding of requirements at any level.

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• Ensures requirements traceability

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• Supports automated requirements analysis

Questions





Innovation drives success!





This illustration is inspired by and in part derived from the work by Scott Simmerman, "The Square Wheels Guy" http://www.performancemanagementcompany.com/