NDIA 2017

20th Annual Systems Engineering Conference

MBSE to Address Logical Text-Based Requirements Issues

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About Me

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**.

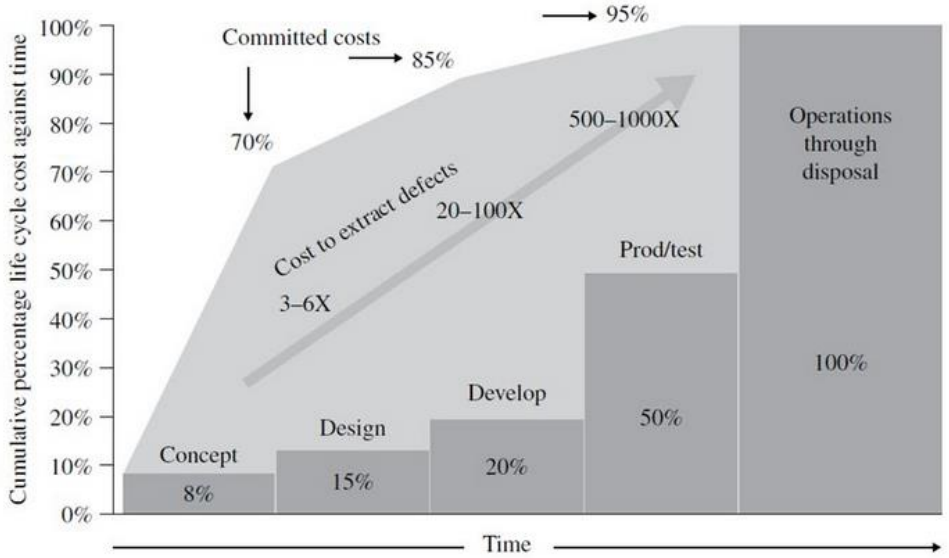
Agenda

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

Requirements Quality Problem

Poor Requirements Impact on Cost

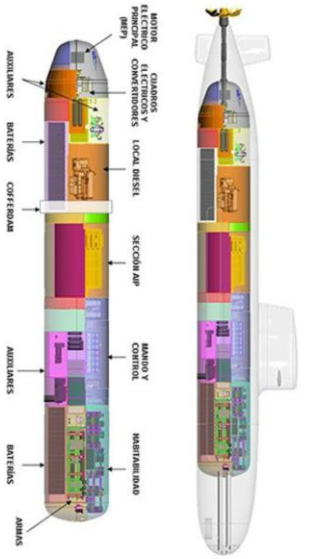
Source of program failures is the result of poor requirements definition. This increase cost significantly which result in program delay or fail if program is with fix cost.



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

Recent Case

- 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.dailymail.co.uk; http://www.huffingtonpost.coml

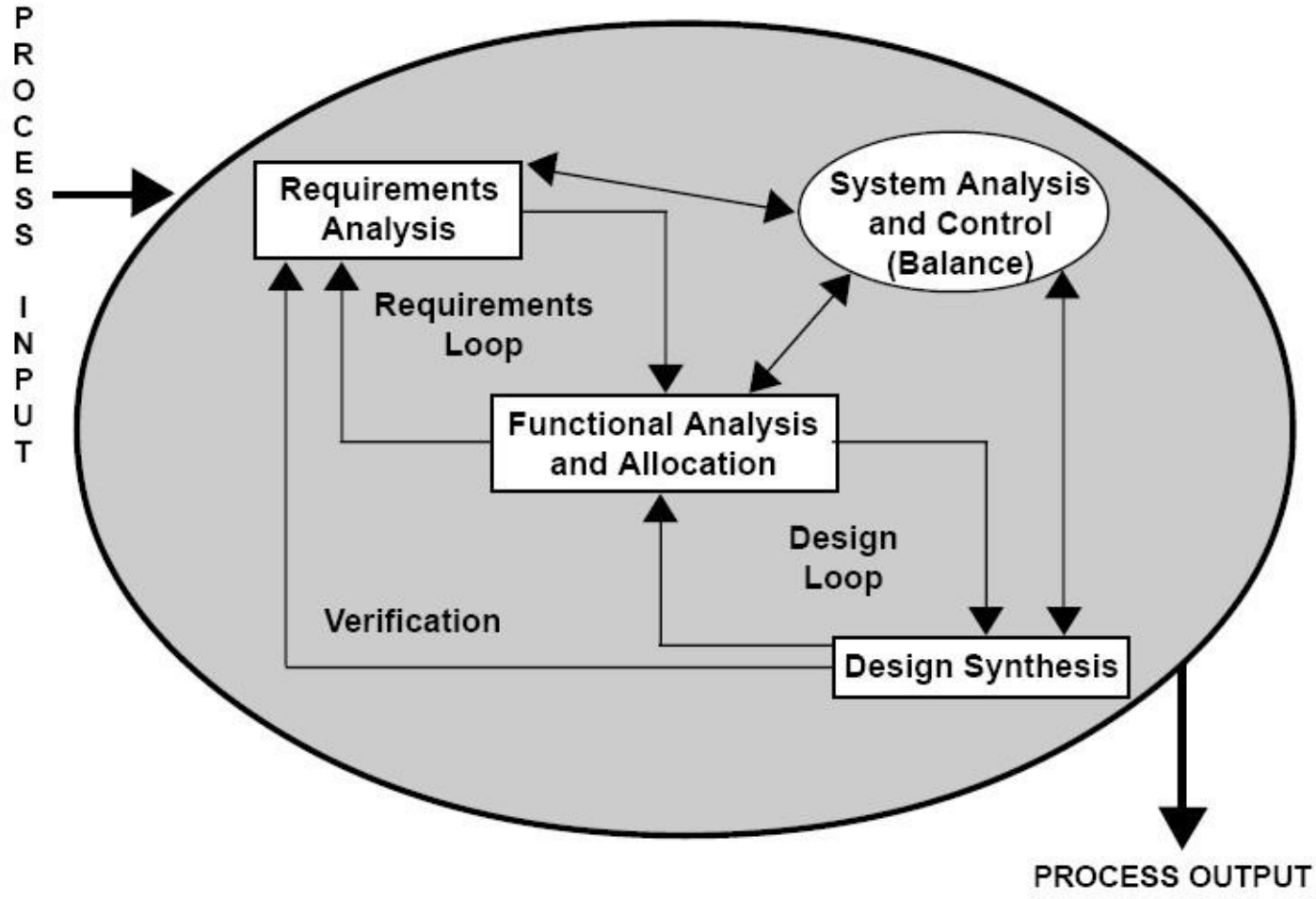
Requirements Management Theory

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.

Source: "PMI Requirements CoP Webinar on Requirements .Quality"

Systems Engineering Theory

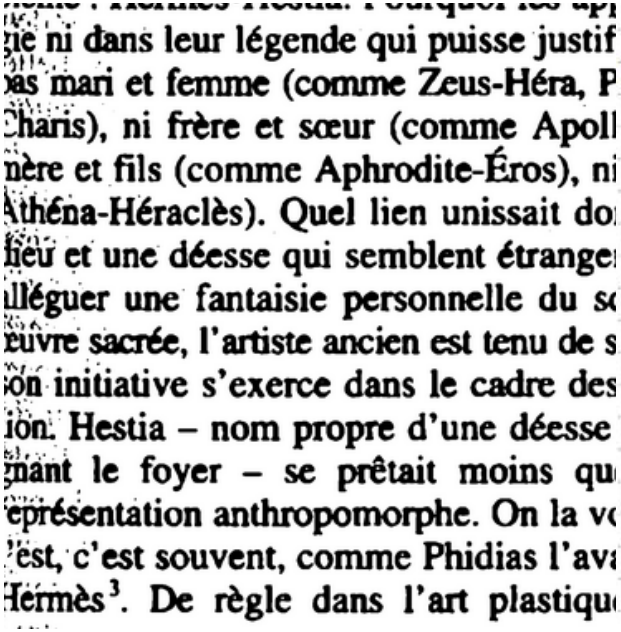


Source: Systems Engineering Fundamentals Defense Acquisition University Press, 2001

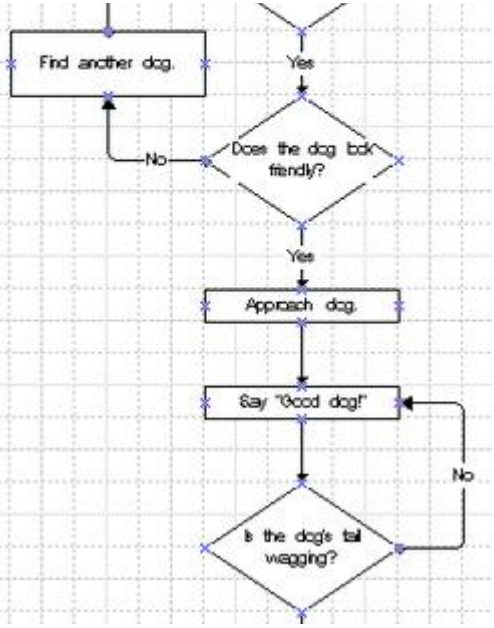
Traditional Requirements Visualization Method

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



ie ni dans leur légende qui puisse justif
as mari et femme (comme Zeus-Héra, P
haris), ni frère et sœur (comme Apoll
nère et fils (comme Aphrodite-Éros), ni
théna-Héraclès). Quel lien unissait do
ieu et une déesse qui semblent étrange
lléguer une fantaisie personnelle du s
euvre sacrée, l'artiste ancien est tenu de s
on initiative s'exerce dans le cadre des
ion. Hestia – nom propre d'une déesse
gnant le foyer – se prêtait moins qu
epresentation anthropomorphe. On la v
'est, c'est souvent, comme Phidias l'av
Hermès[3]. De règle dans l'art plastiqu



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."

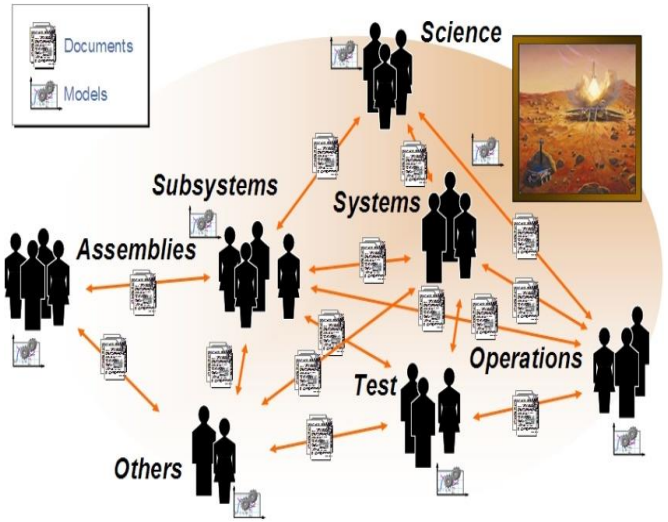
INCOSE SE Vision 2020 (INCOSE-TP-2004-004-02, Sep 2007)

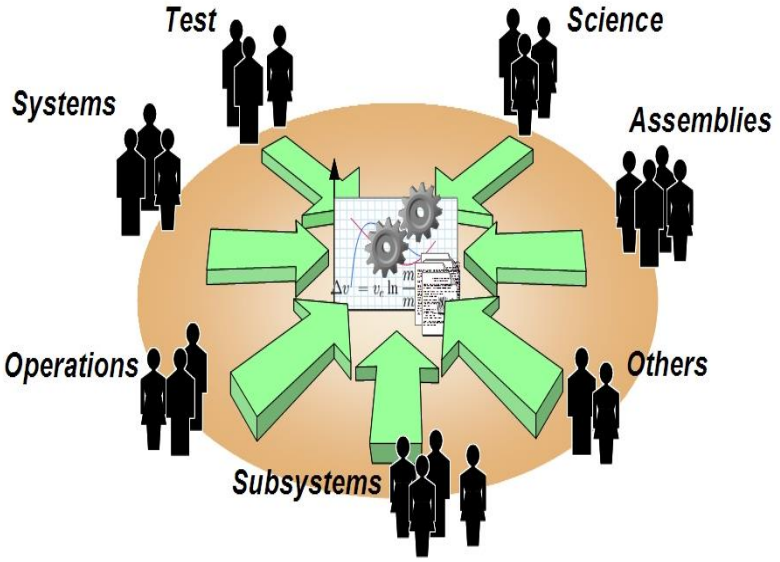
"Mechanisms to remove requirements errors up front should mitigate program risk - MBSE helps achieve this. Increasing the level and quality of systems engineering has positive effect on cost compliance, schedule compliance, and subjective quality of the programs."

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

Source : MBSE 101 by Elyse Fosse

Document Centric v Model-Based

Document Centric

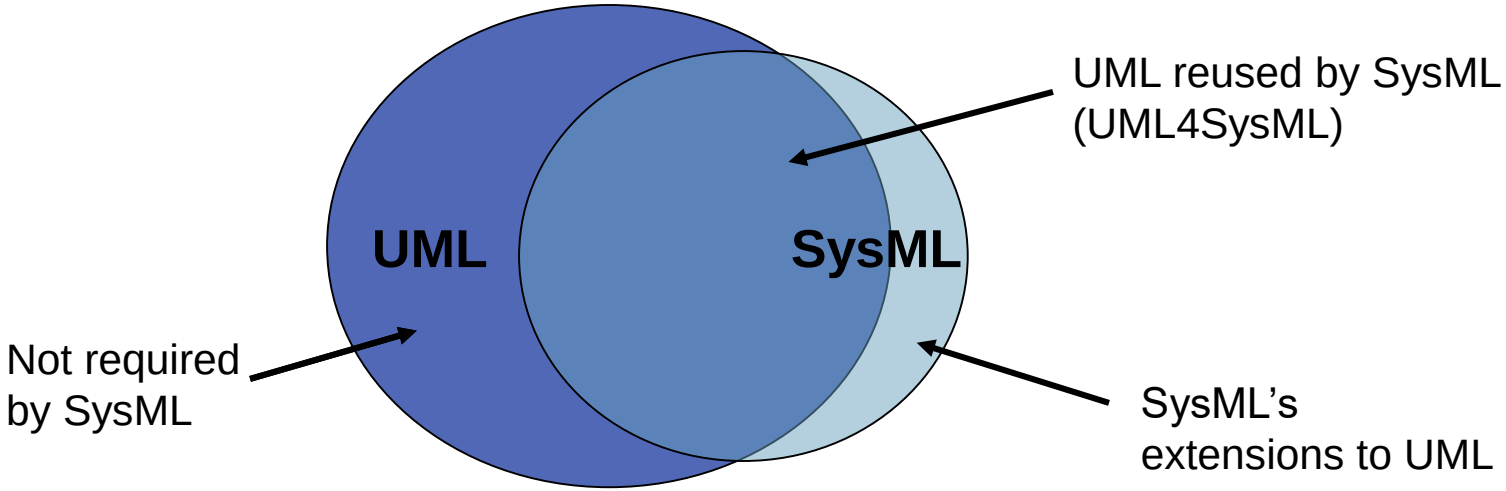
- Producing text based artefacts
- Multiple unconnected sources of information: non traceable, non consistent, hard to change.
- Generally not machine readable
- Verification done by manual inspection

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.

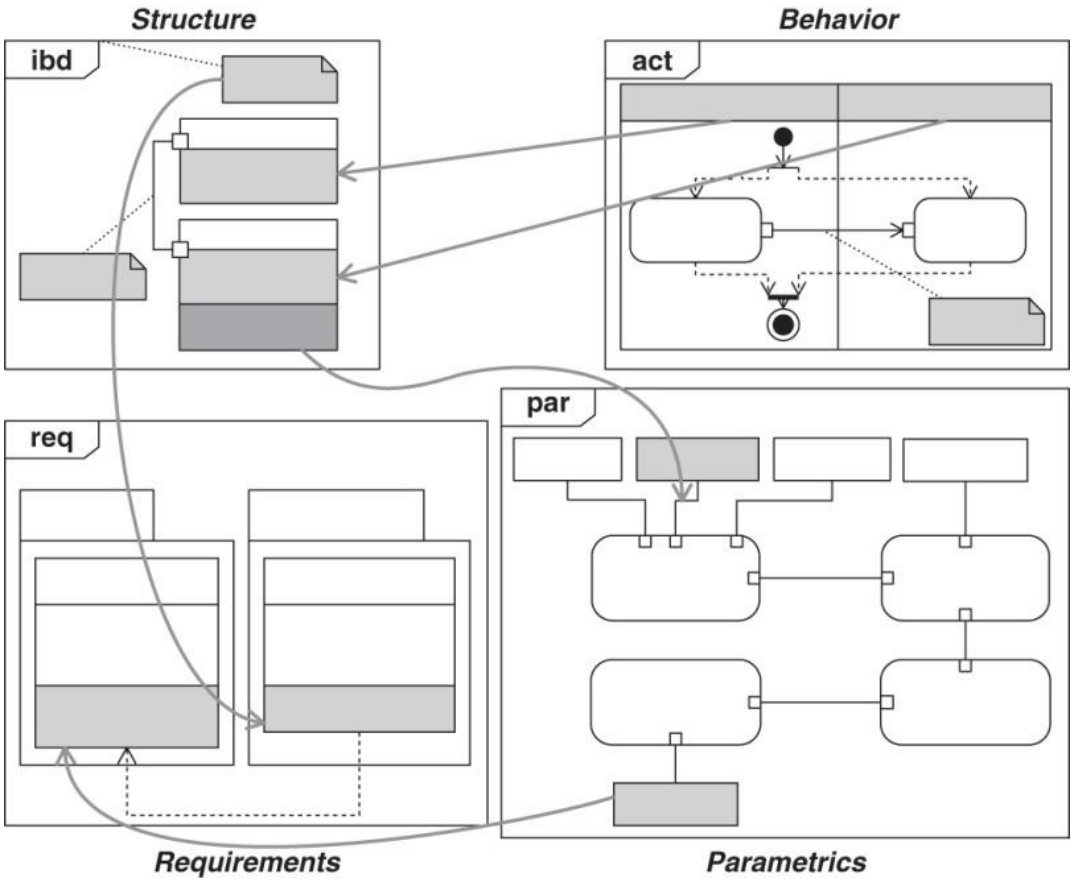


OBJECT MANAGEMENT GROUP®

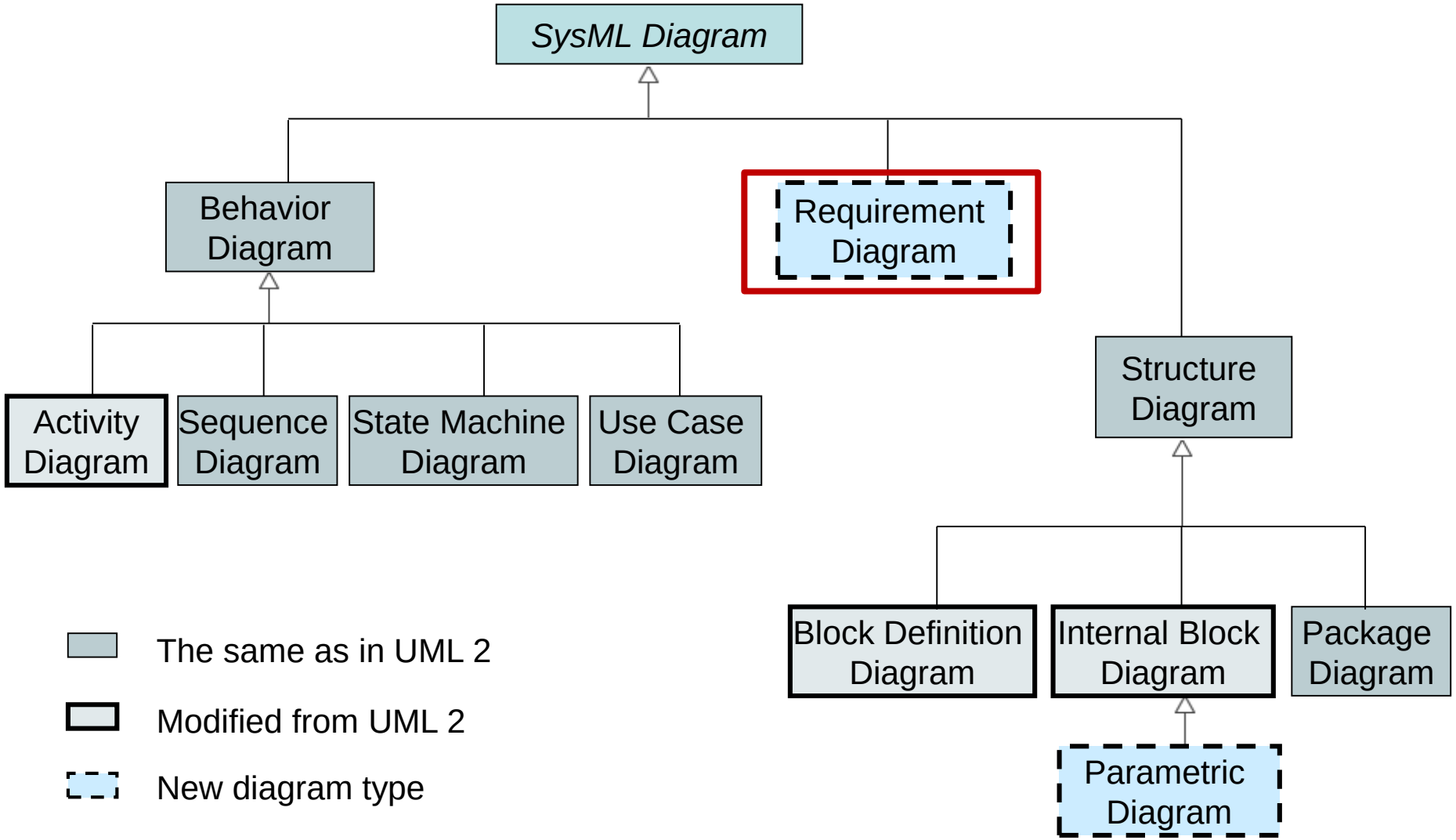
OMG SYSTEMS MODELING LANGUAGE SysML™

ISO

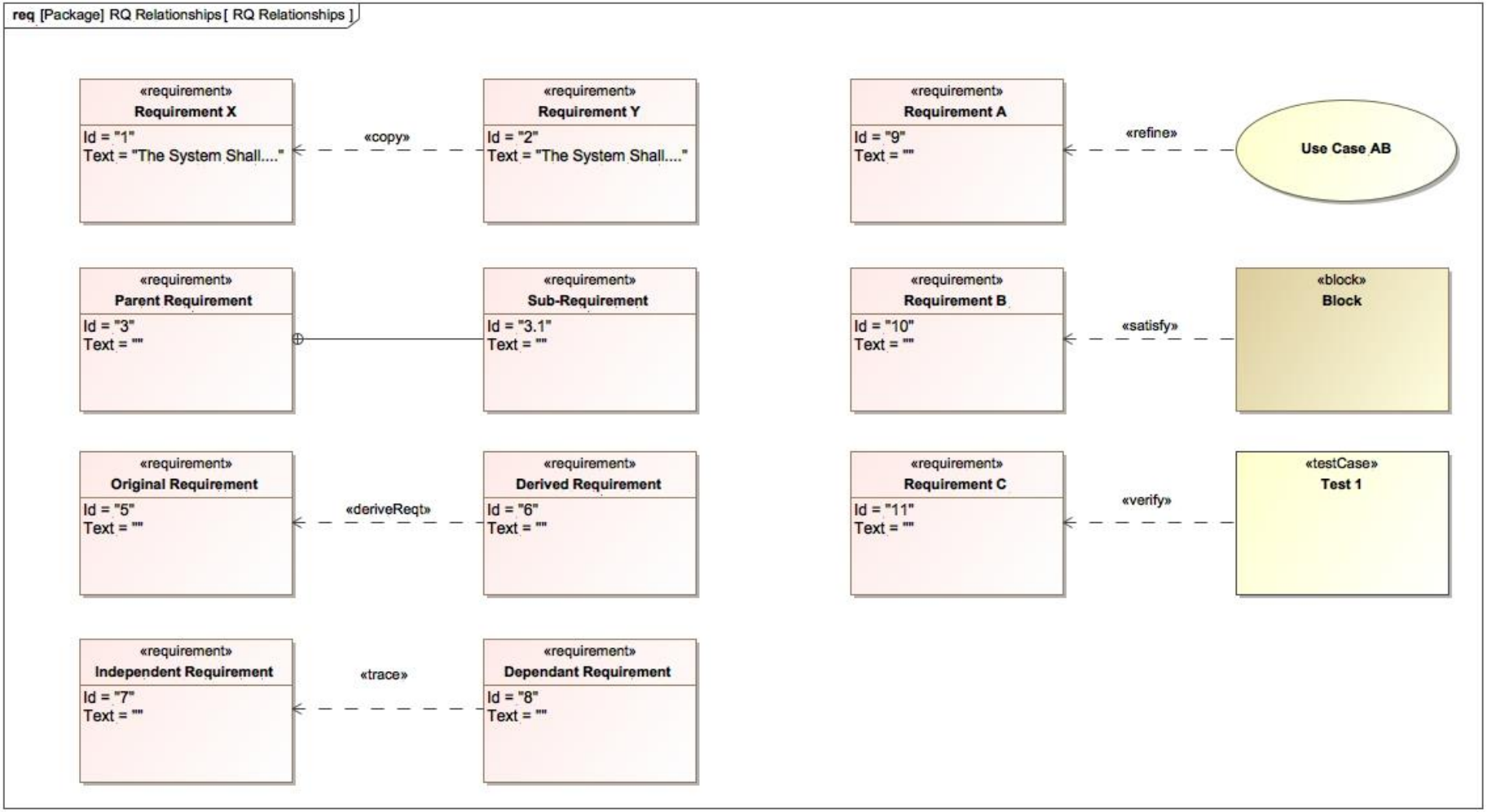
The Four Pillars of SysML



SysML Diagram Kinds



Requirement Relations in SysML



Application Case with Samples from Actual Projects

Stakeholder Needs Import

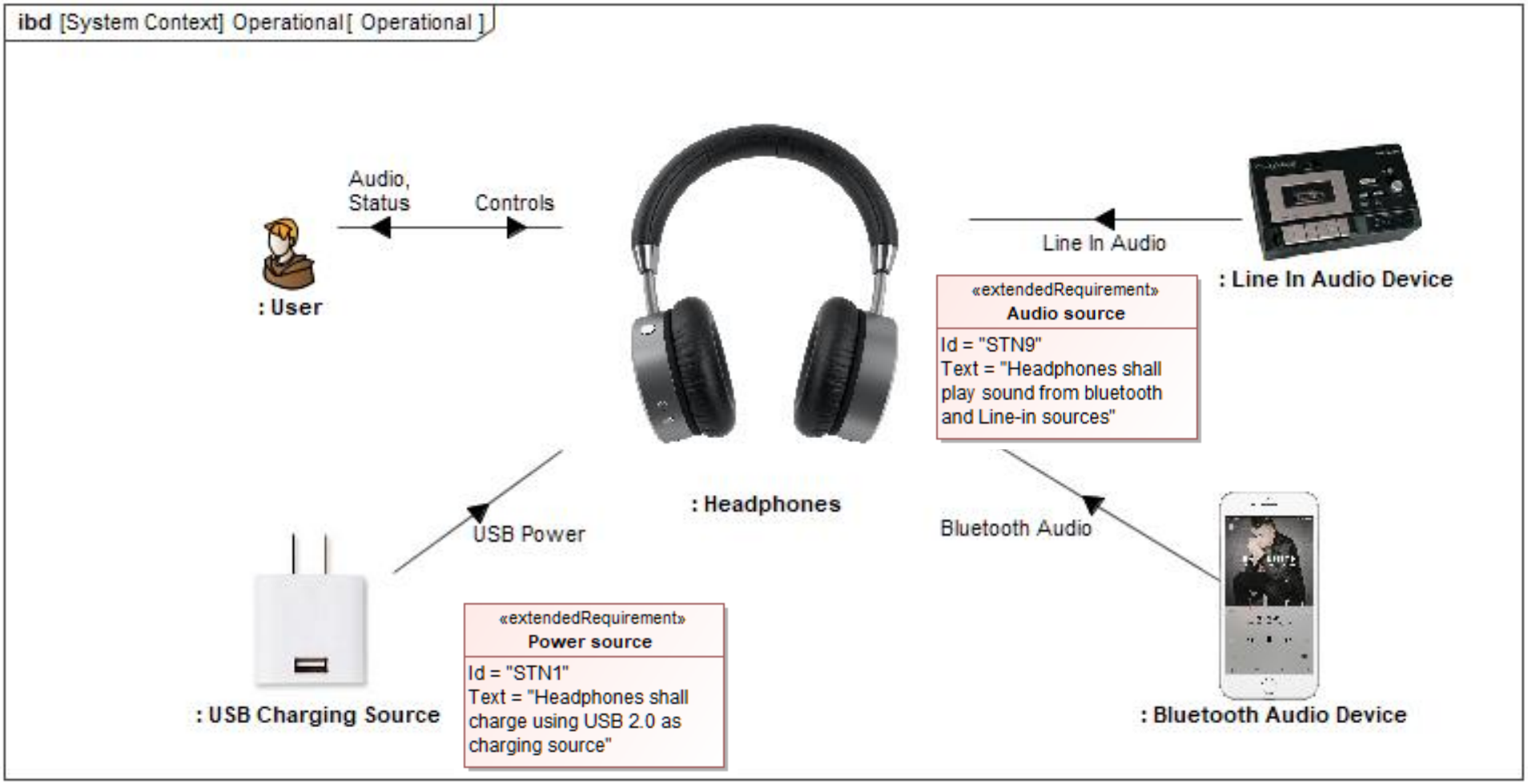
Stakeholder Needs in 

	A	B	C
1	**Bluetooth Headphones**		
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

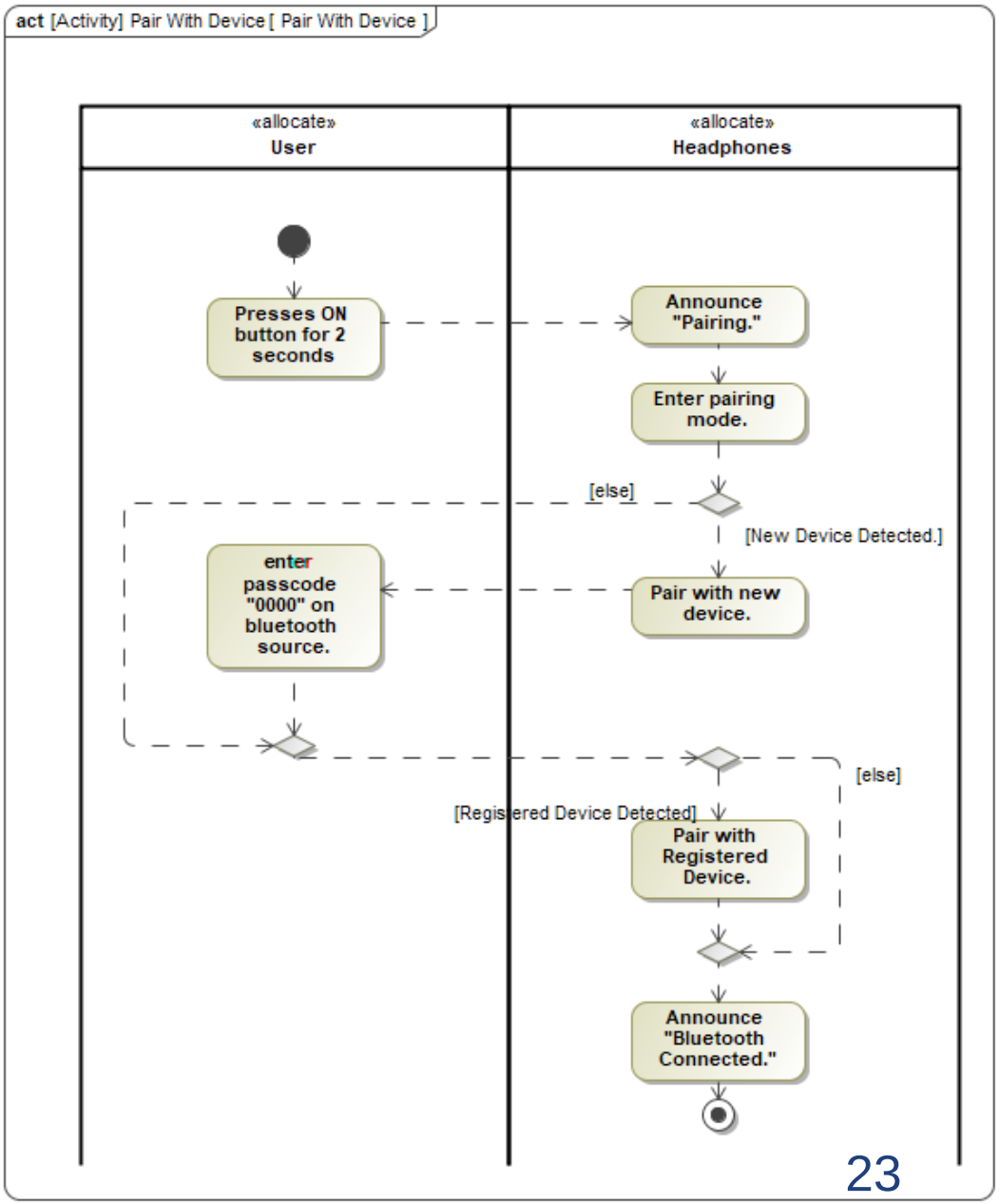
… and in Requirements Table in SysML™

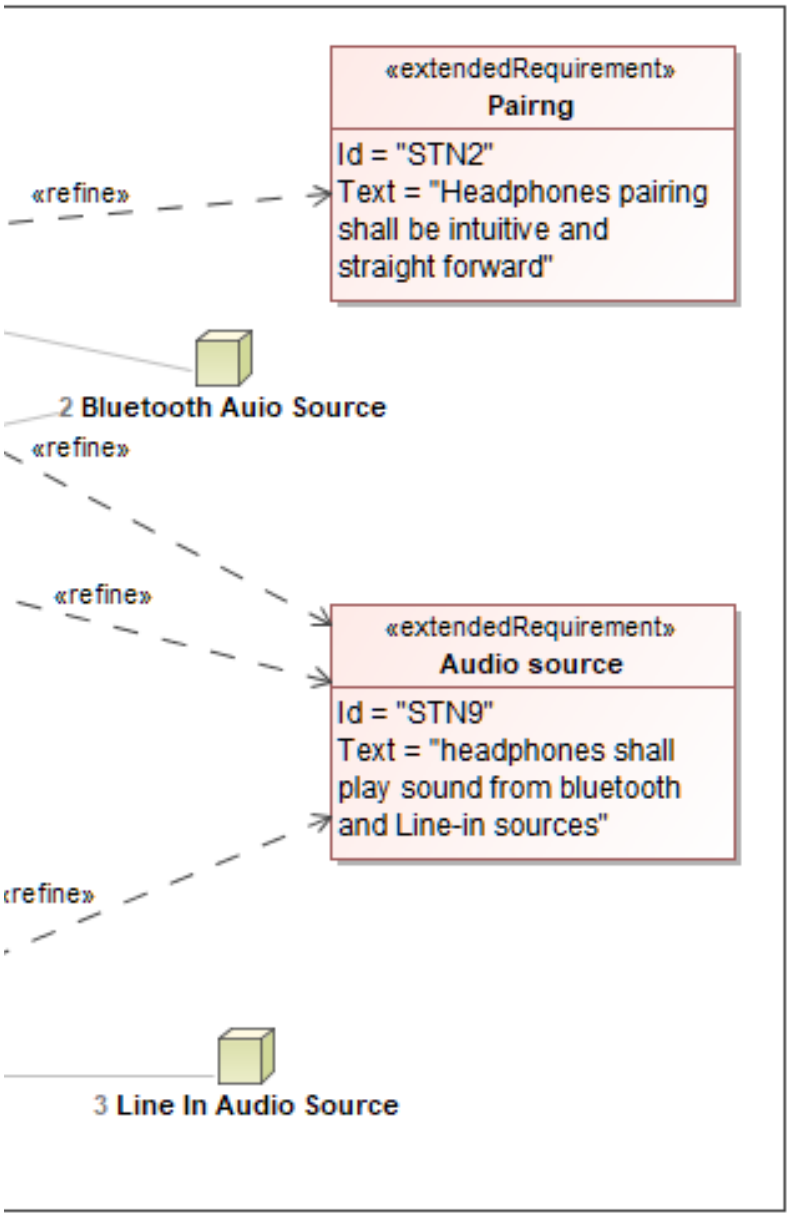
#	Id	△ Name	Text
1	STN1	STN1 Power source	Headphones shall charge using USB 2.0 as charging source
2	STN2	STN2 Pairng	Headphones pairing shall be intuitive and straight forward
3	STN3	STN3 Battery capacity	Battery shall last long enough to see full movie.
4	STN4	STN4 Charging time	Charging time shall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

Interface Requirements Formalization



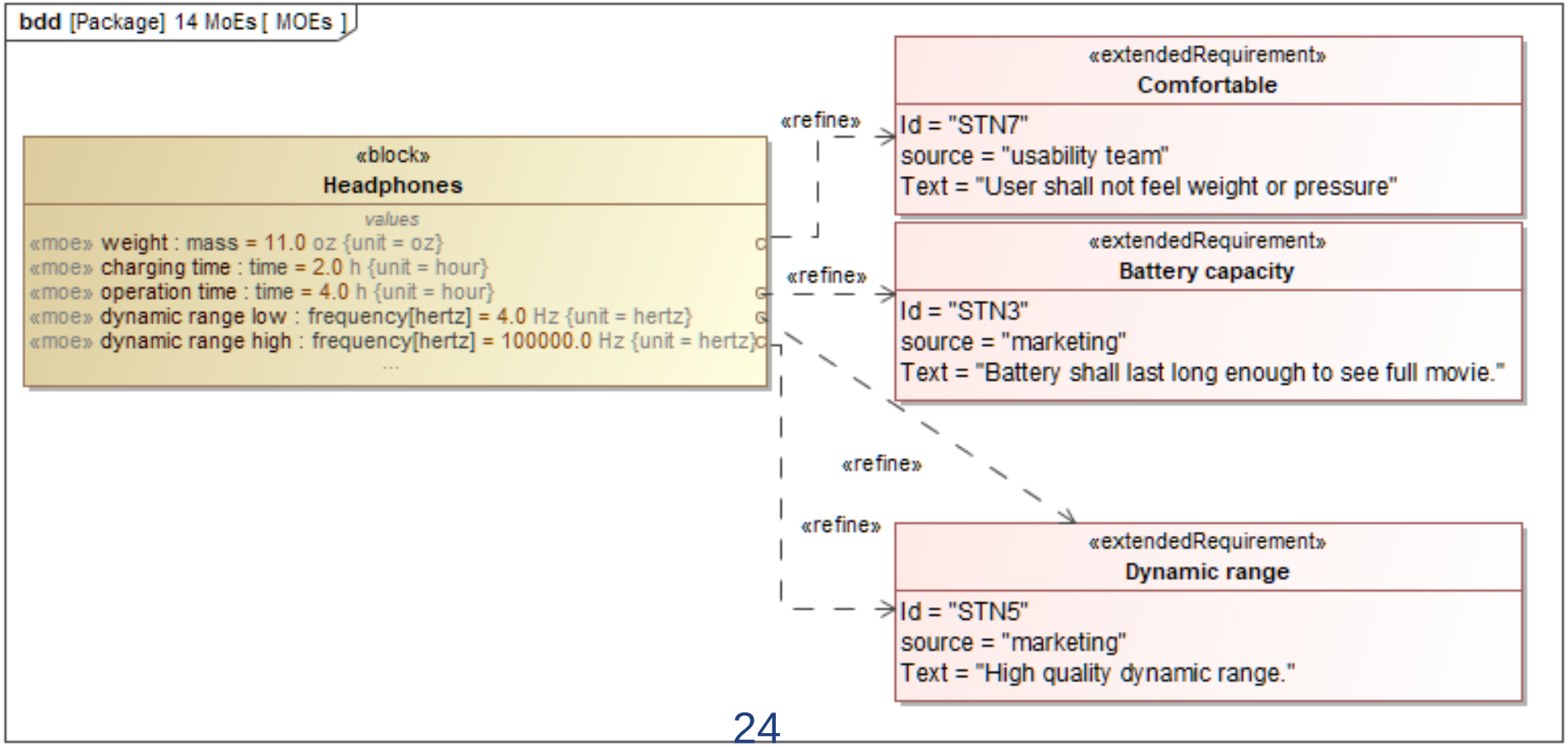
Functional Requirements Formalization



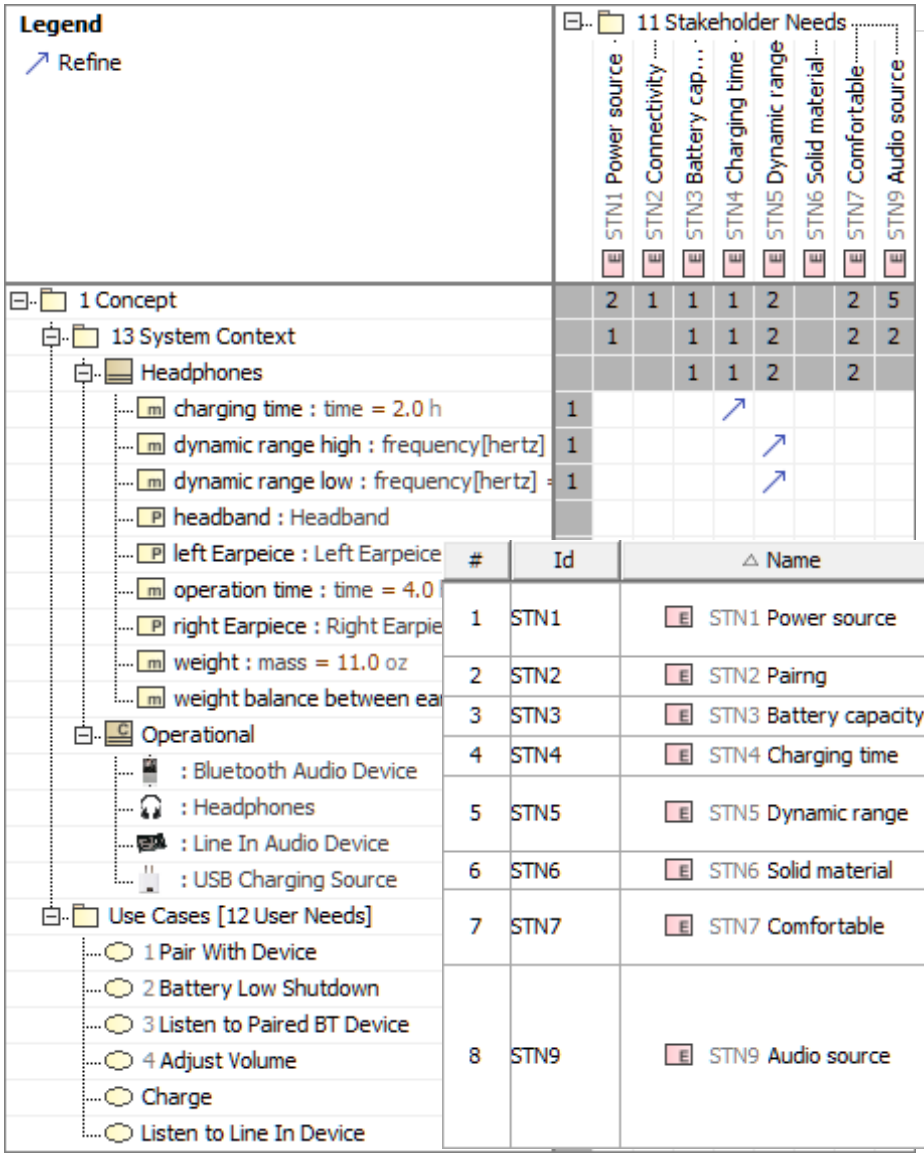


System Characteristics Formalization

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



Leveraging Model Traceability

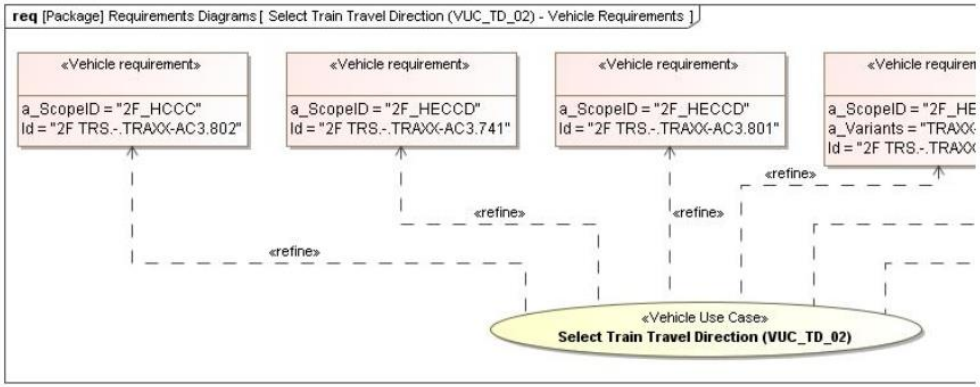


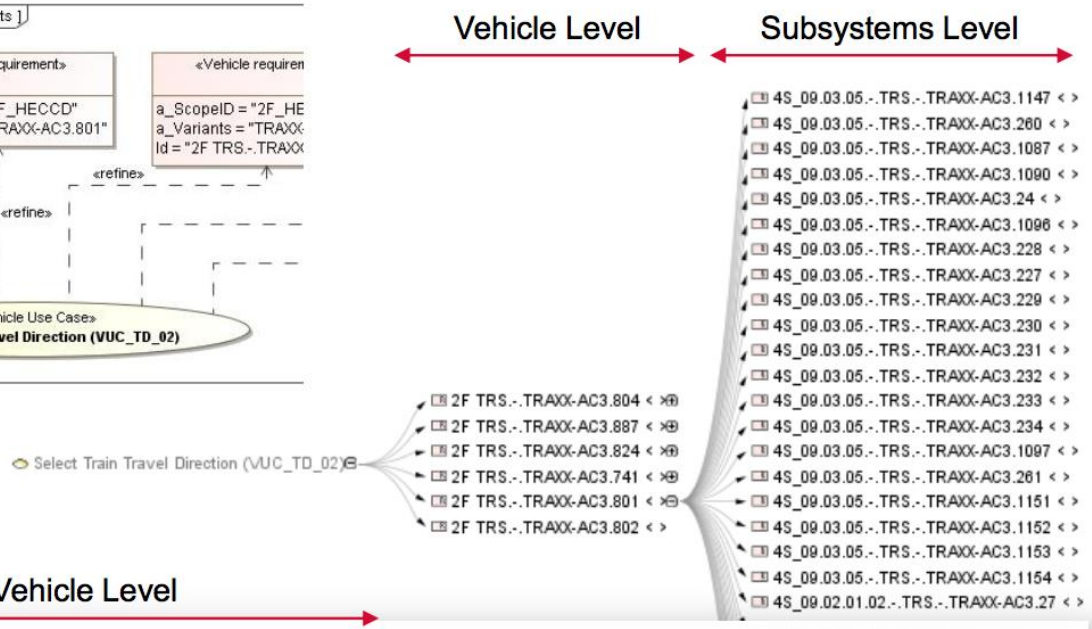
SysML enables to link elements with relations to facilitate traceability

#	Id	Name	Text	Refined By
1	STN1	STN1 Power source	Headphones shall charge using USB 2.0 as charging source	Charge : USB Charging Source
2	STN2	STN2 Pairng	Headphones pairing shall be intuitive and straight forward	1 Pair With Device
3	STN3	STN3 Battery capacity	Battery shall last long enough to see full movie.	operation time : time = 4.0
4	STN4	STN4 Charging time	Charging time shall be short.	charging time : time = 2.0
5	STN5	STN5 Dynamic range	High quality dynamic range.	dynamic range low : frequ dynamic range high : frequ
6	STN6	STN6 Solid material	Headphones shall look and feel as very solid.	
7	STN7	STN7 Comfortable	User shall not feel weight or pressure	weight : mass = 11.0 oz weight balance between e
8	STN9	STN9 Audio source	headphones shall play sound from bluetooth and Line-in sources	Listen to Line In Device 3 Listen to Paired BT Devic 1 Pair With Device : Bluetooth Audio Device : Line In Audio Device

MBSE at Bombardier Transportation

Change Analysis on Different System Hierarchy Levels



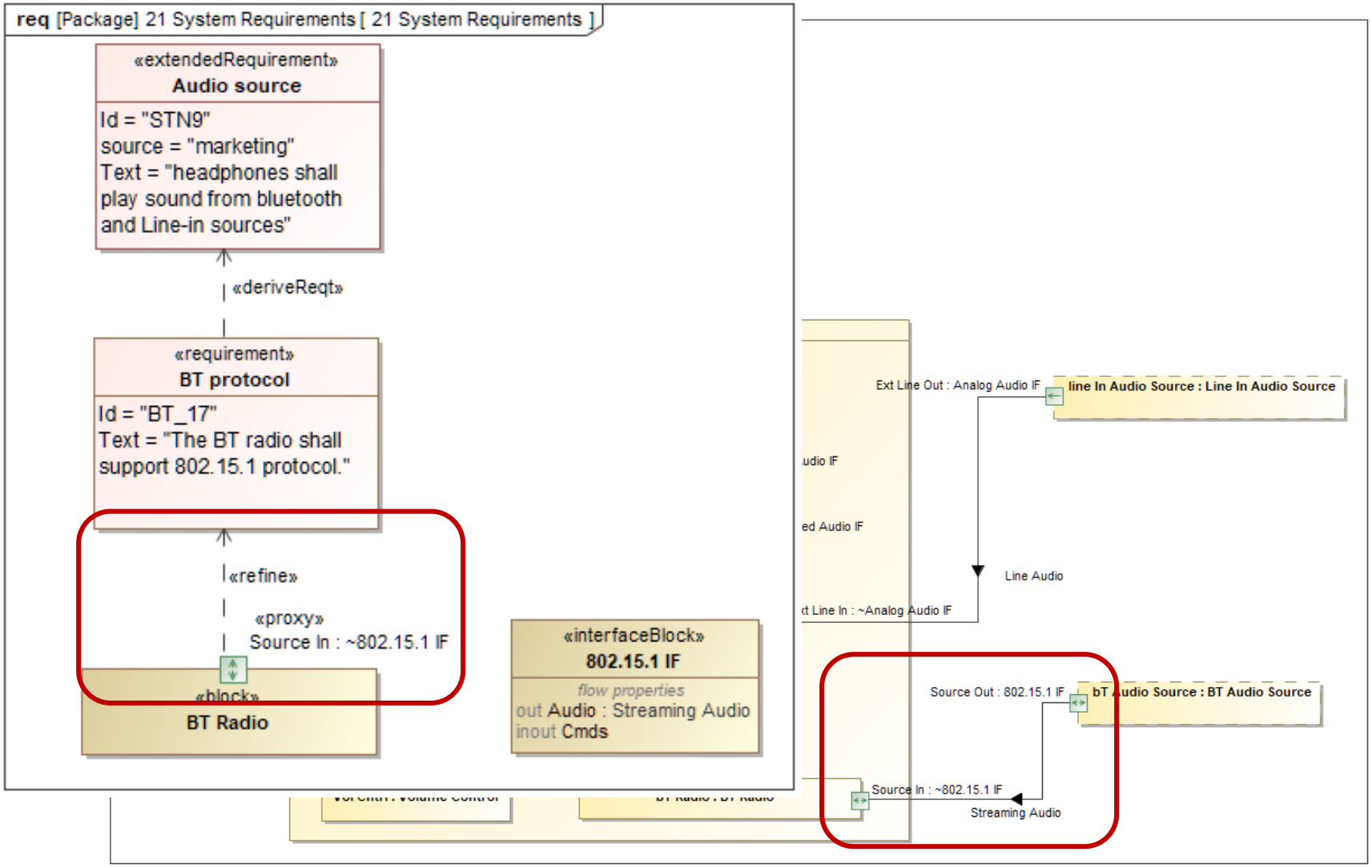


Show the described behavior (activities)

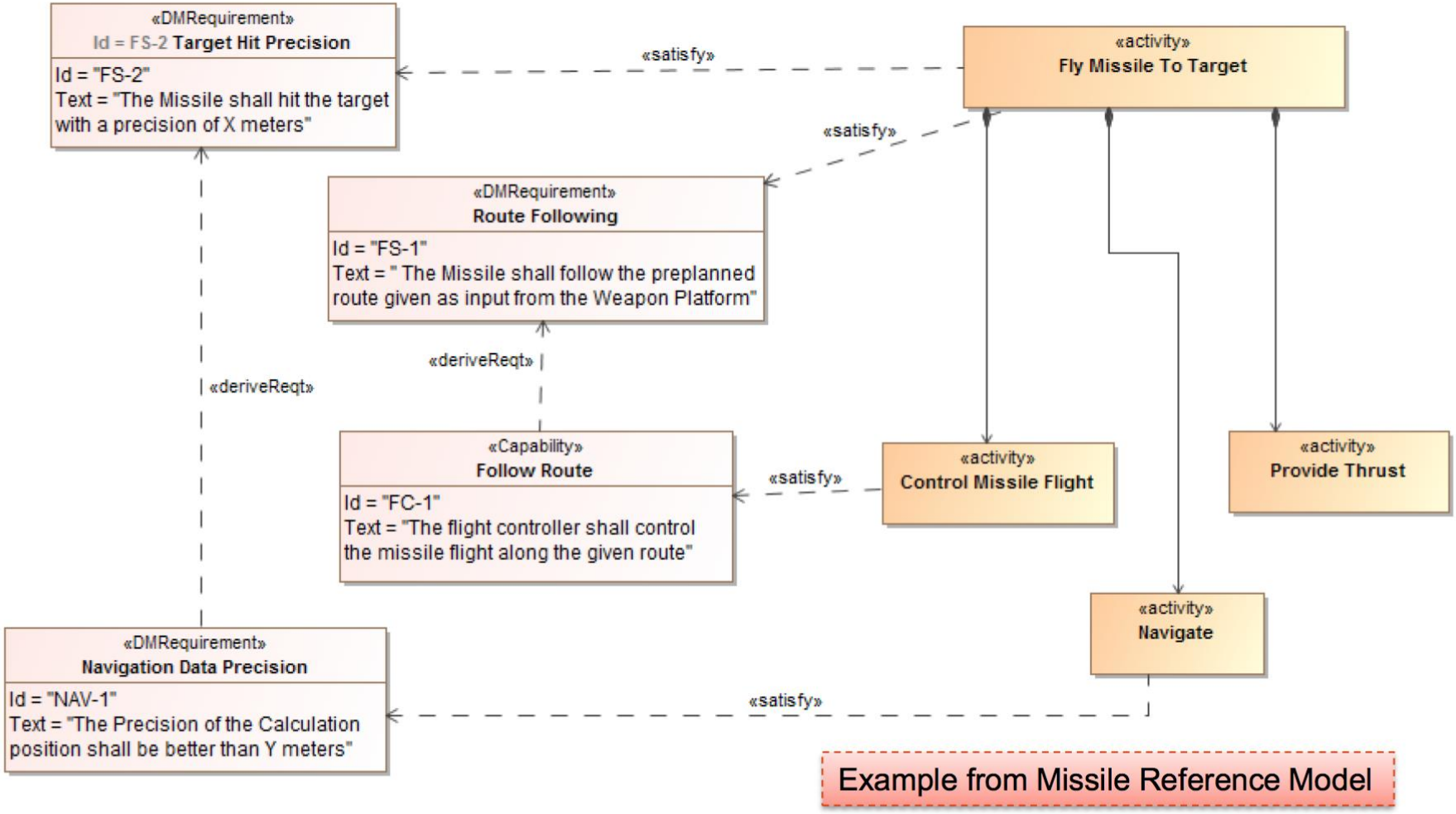
Show the allocated elements

BOMBARDIER
the evolution of mobility

Interface System Requirements



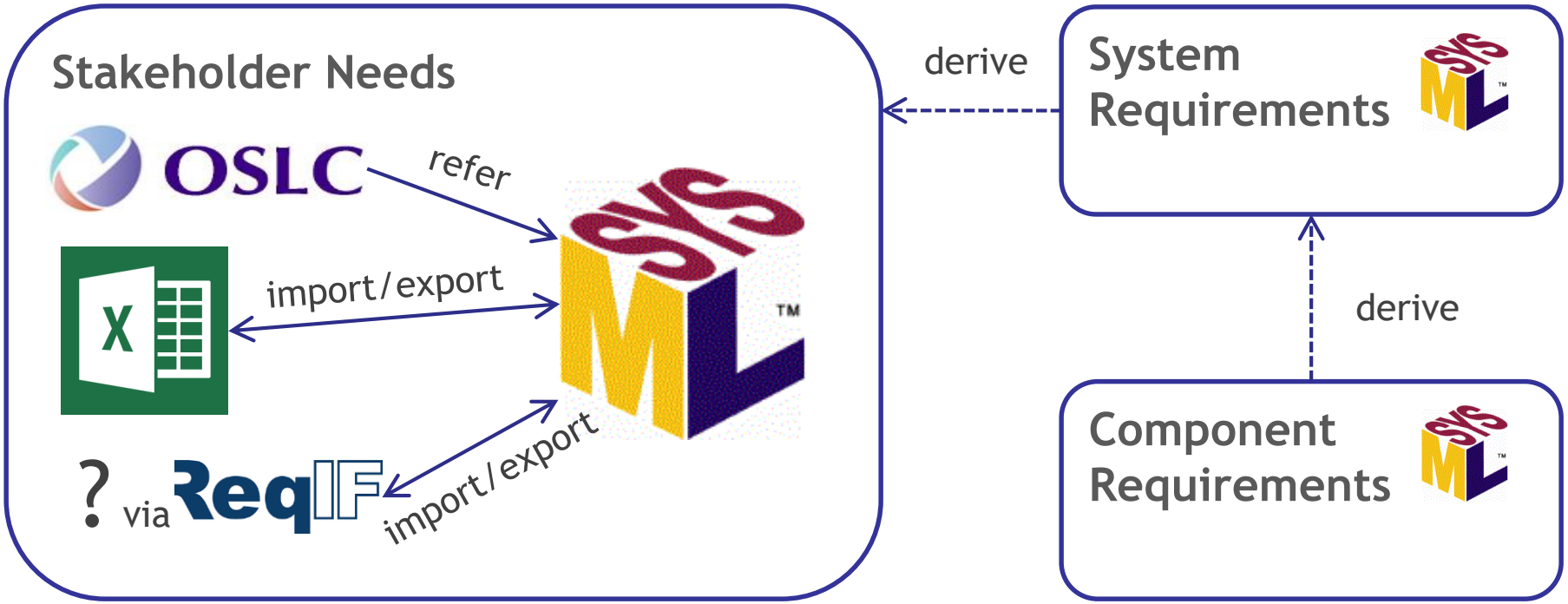
Requirements



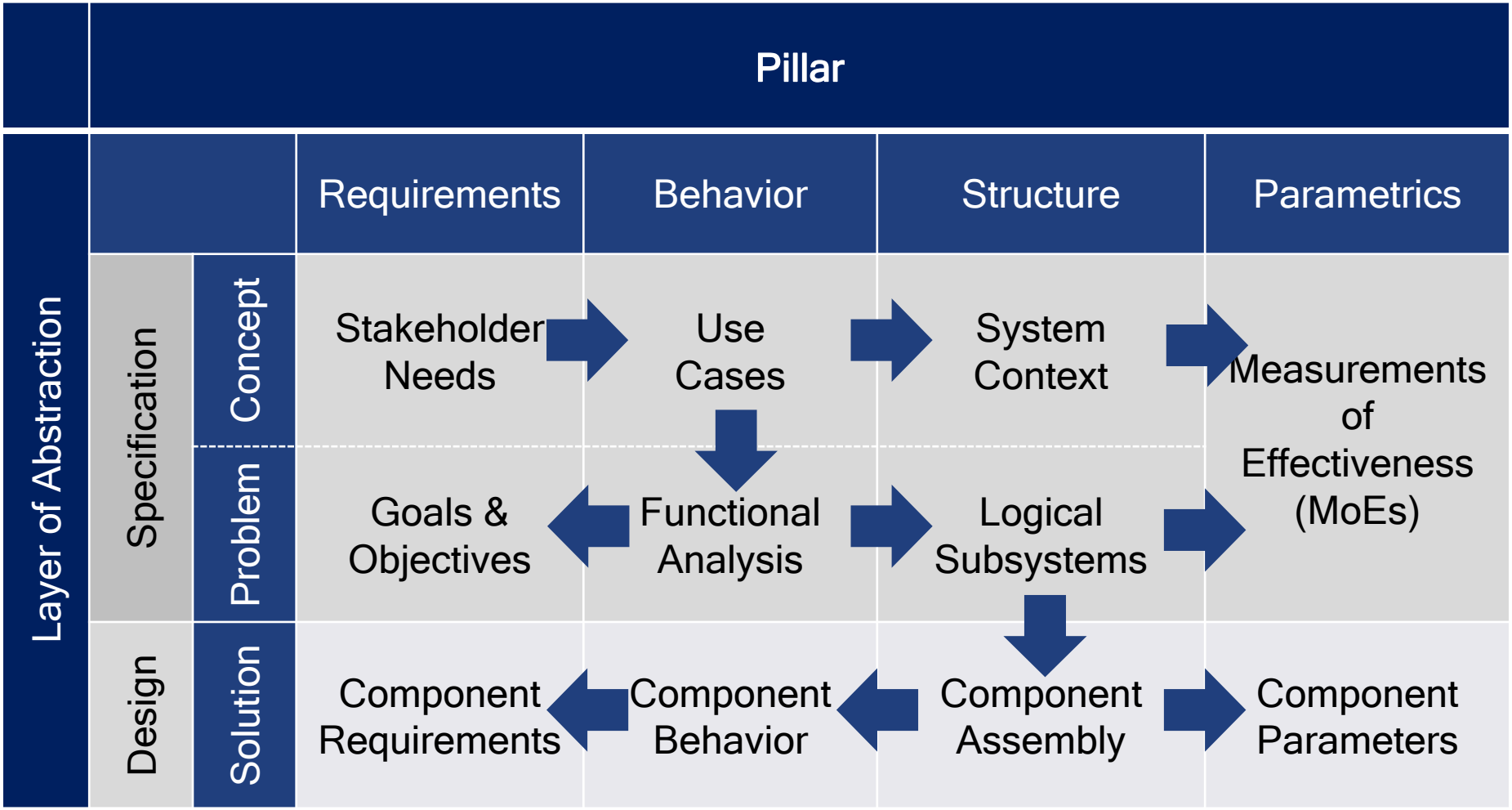
Full Picture - Framework and Method

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

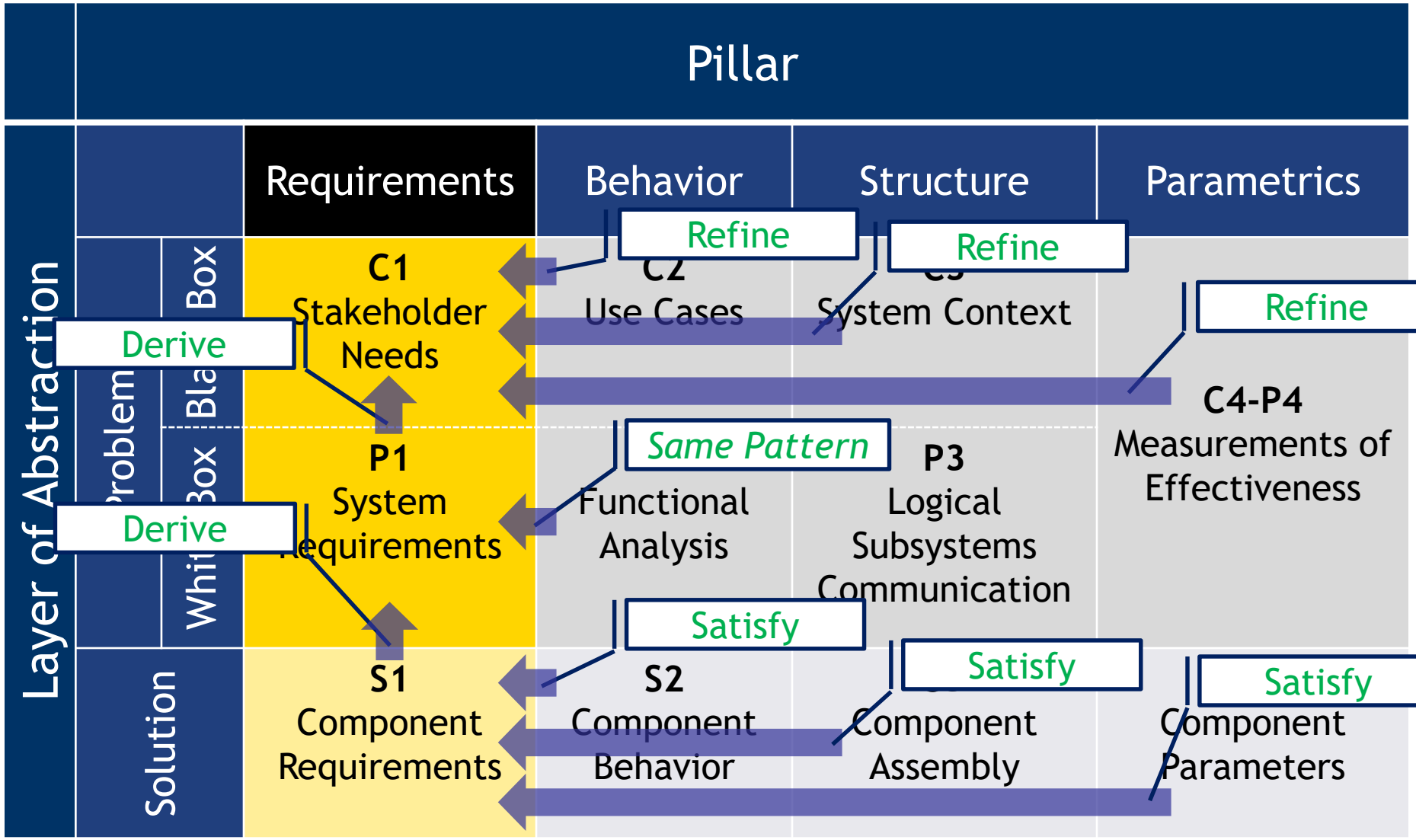
An Approach: MBSE for RM



MagicGrid

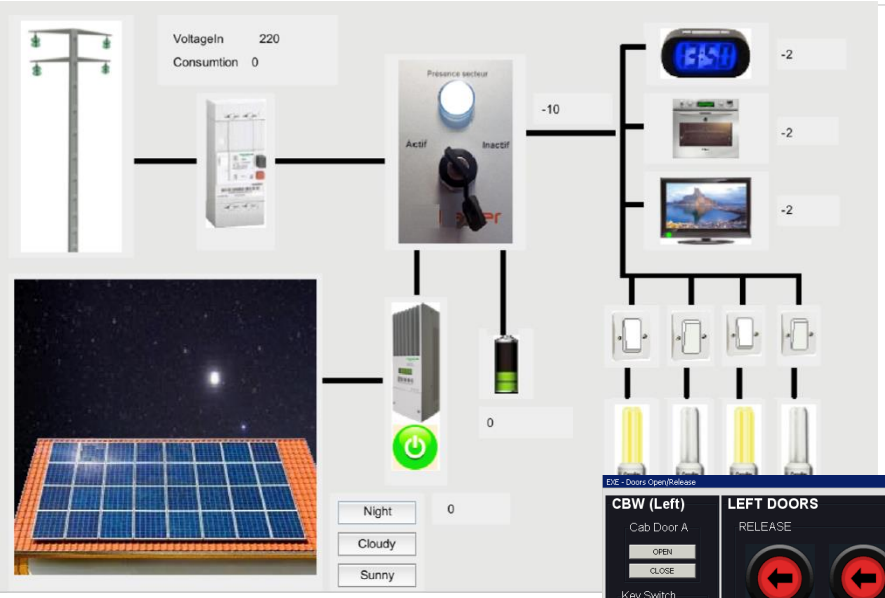

Pillar
Layer of Abstraction
Requirements
Behavior
Structure
Parametrics
Specification
Concept
Problem
Design
Solution
Stakeholder Needs
Use Cases
System Context
Measurements of Effectiveness (MoEs)
Goals & Objectives
Functional Analysis
Logical Subsystems
Component Requirements
Component Behavior
Component Assembly
Component Parameters

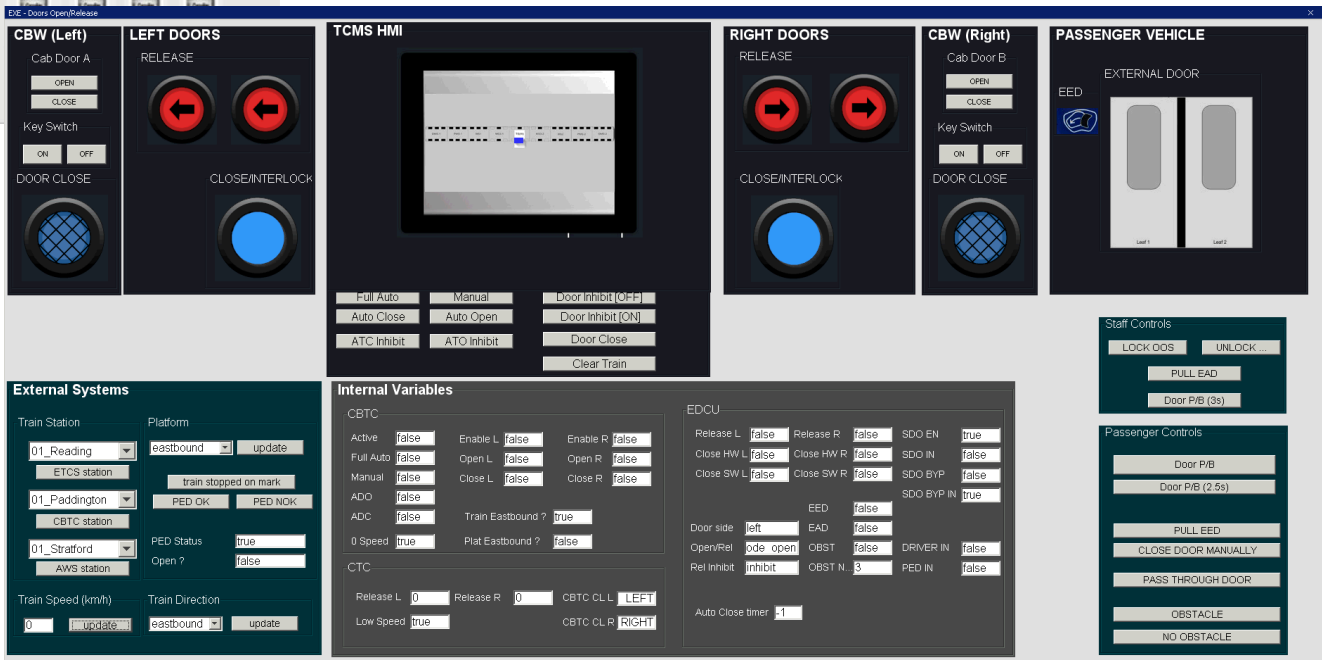
Requirements Traceability



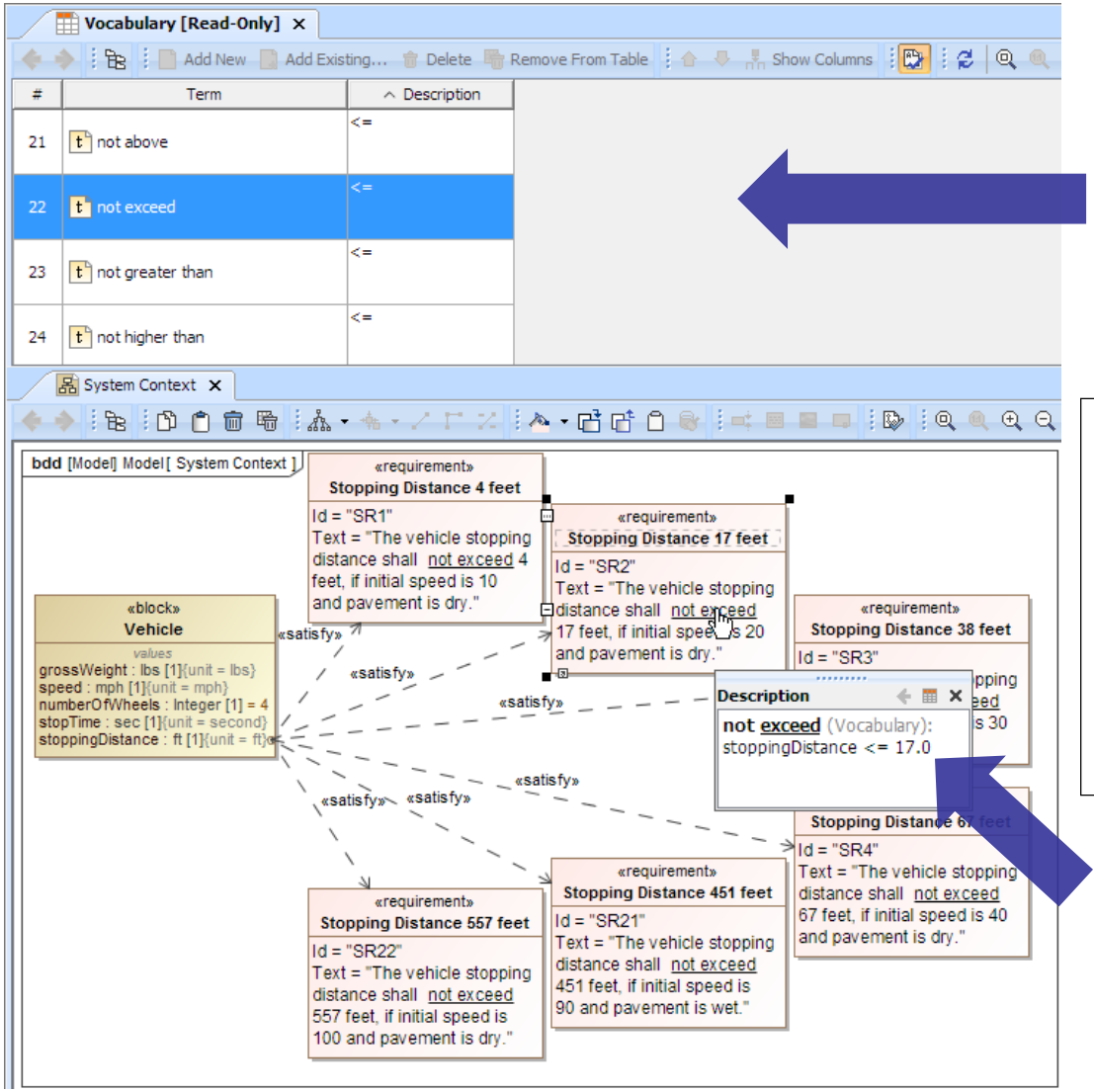
Validation and Verification

GUI Mockups for System Validation

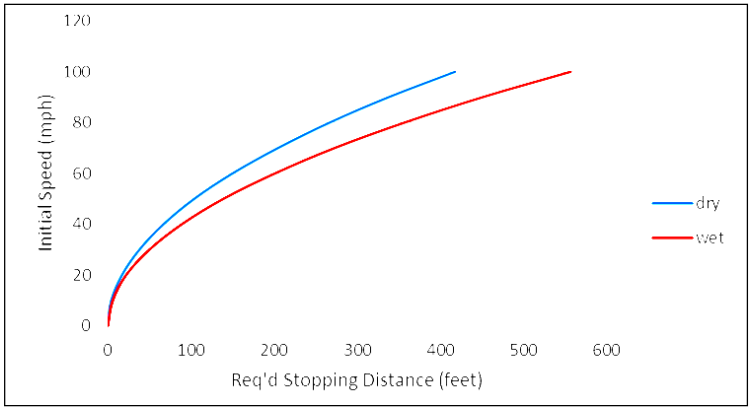




Requirements Verification: Vocabulary



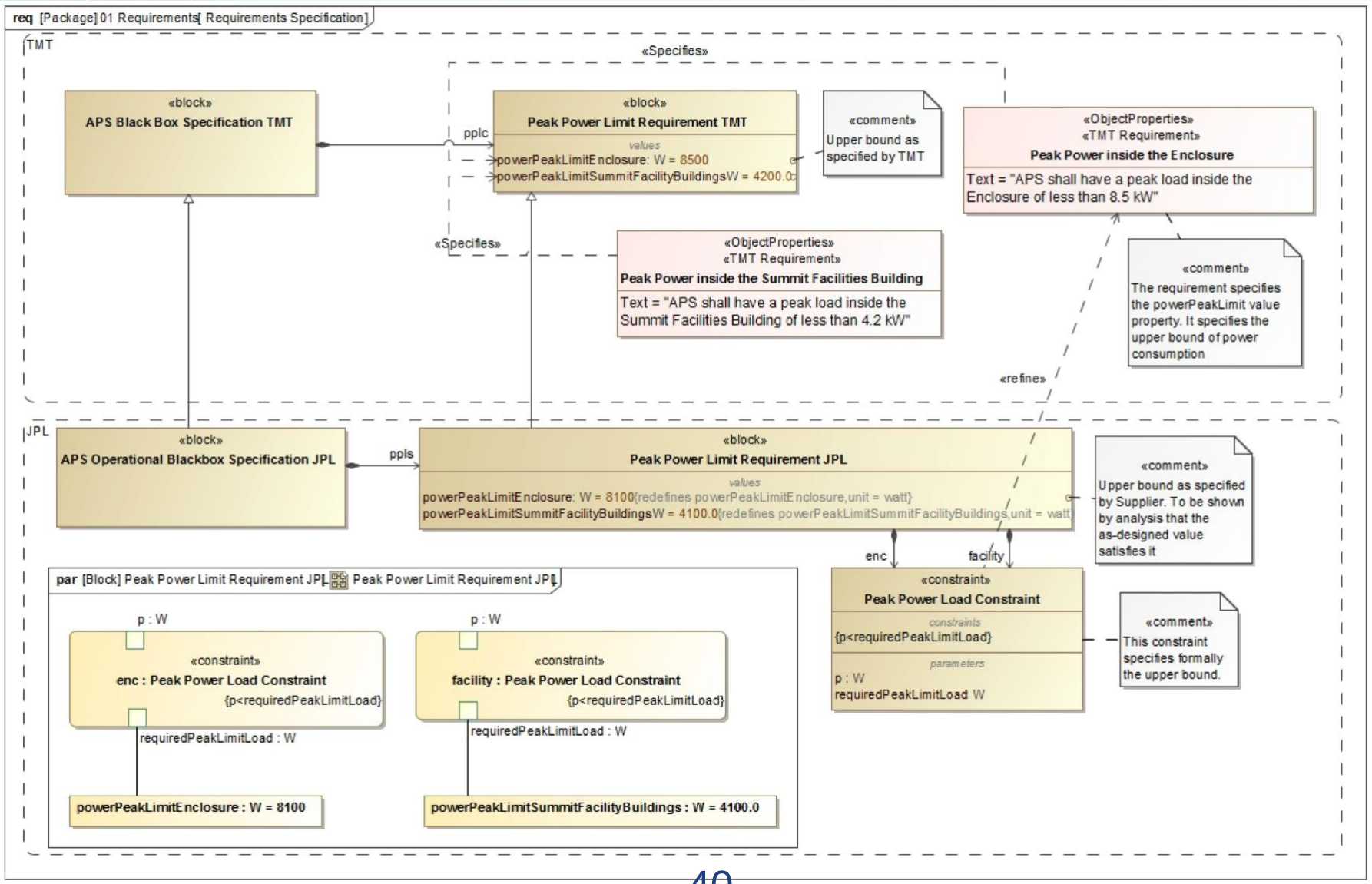
Vocabulary maps natural language phrases to mathematical expressions for automated requirements formalization



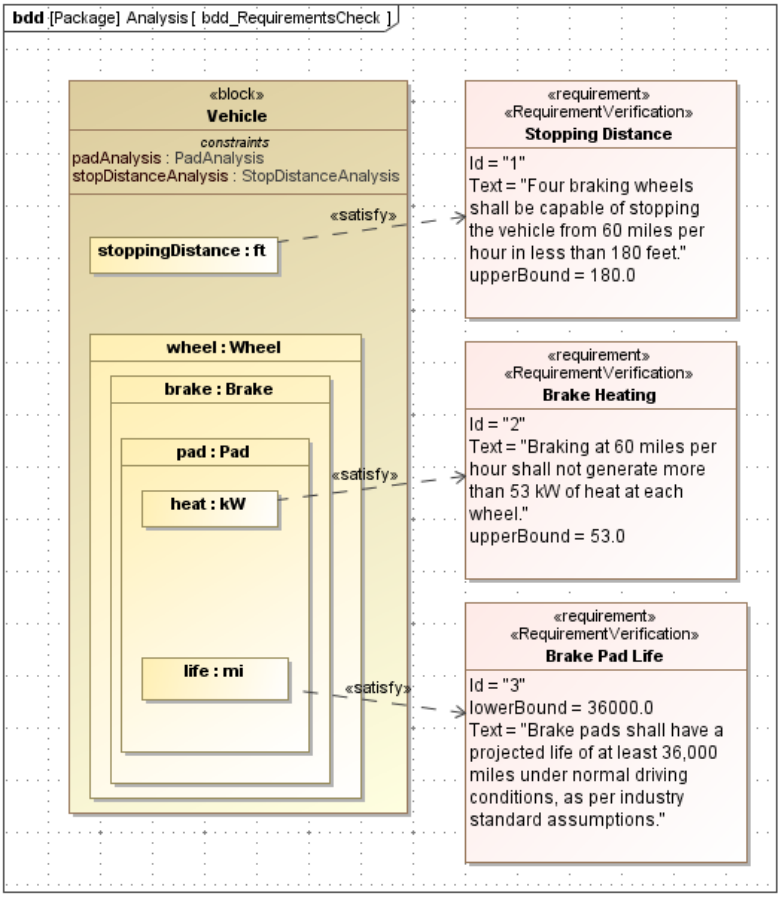
Stopping distance requirements visualization

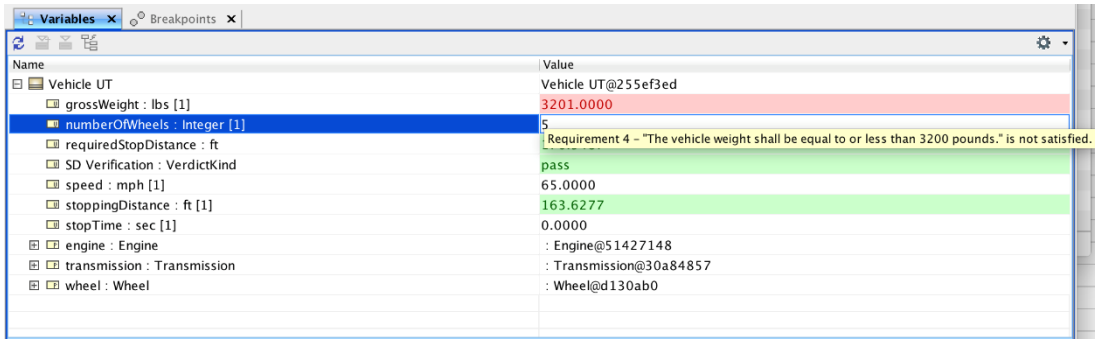
Requirement texts are automatically parsed to mathematical expressions

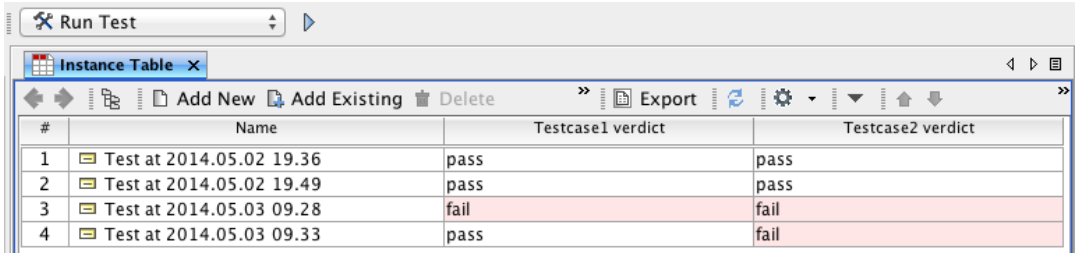
Step 1: Formalize Requirements



Verification reports



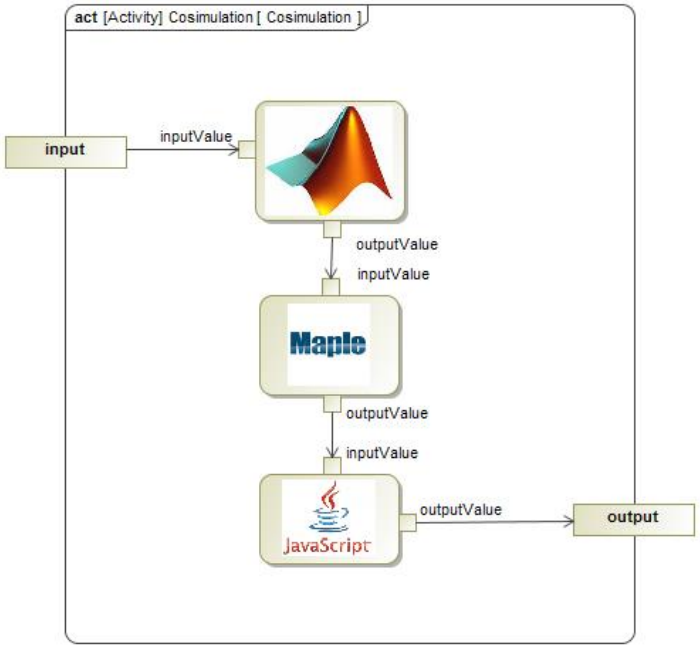


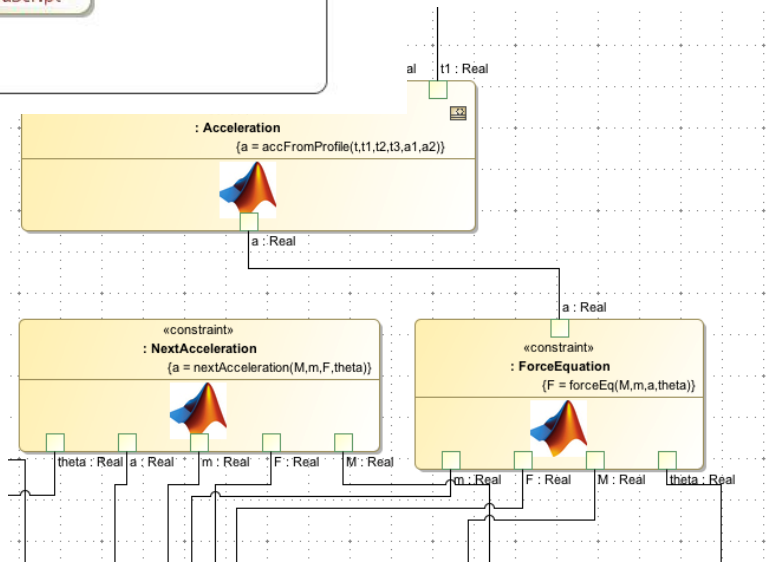


#	Name	Testcase1 verdict	Testcase2 verdict
1	Test at 2014.05.02 19.36	pass	pass
2	Test at 2014.05.02 19.49	pass	pass
3	Test at 2014.05.03 09.28	fail	fail
4	Test at 2014.05.03 09.33	pass	fail

	A	B	C
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





Math engines

- Matlab/Simulink
- Mathematica
- Maple
- Open Modelica

- Scipting
  - Javascript
  - Python
  - Groovy
  - Ruby

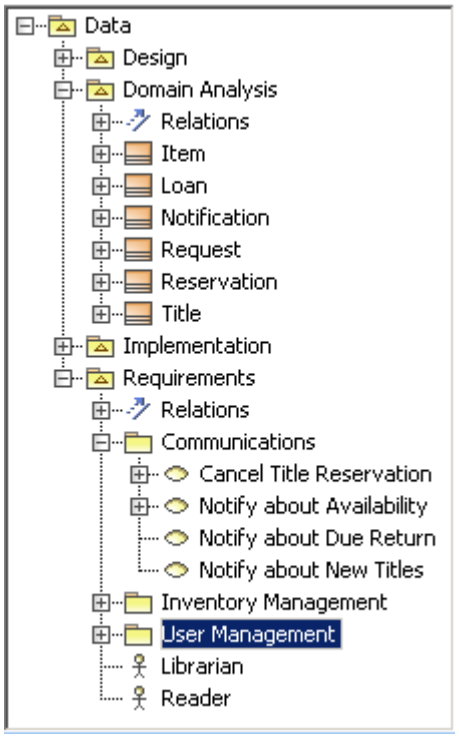
Validation and Verification (more)

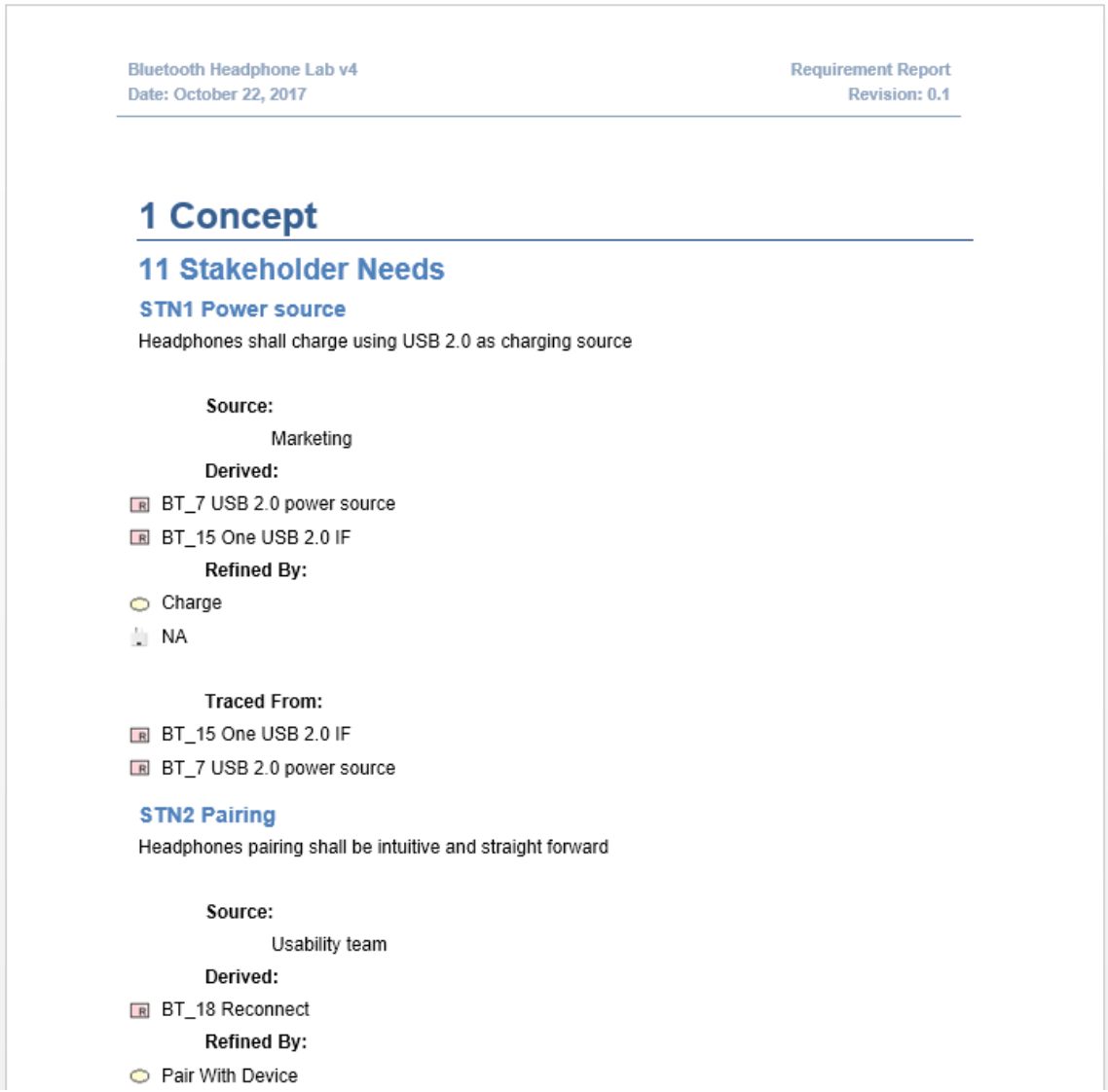
- OMG standard UML Testing Profile (UTP) based test case definition
- Test cases recording based on system design
- Test cases execution

Documentation Generation

Template-based Generator

You can generate an HT
XML or any other simple





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

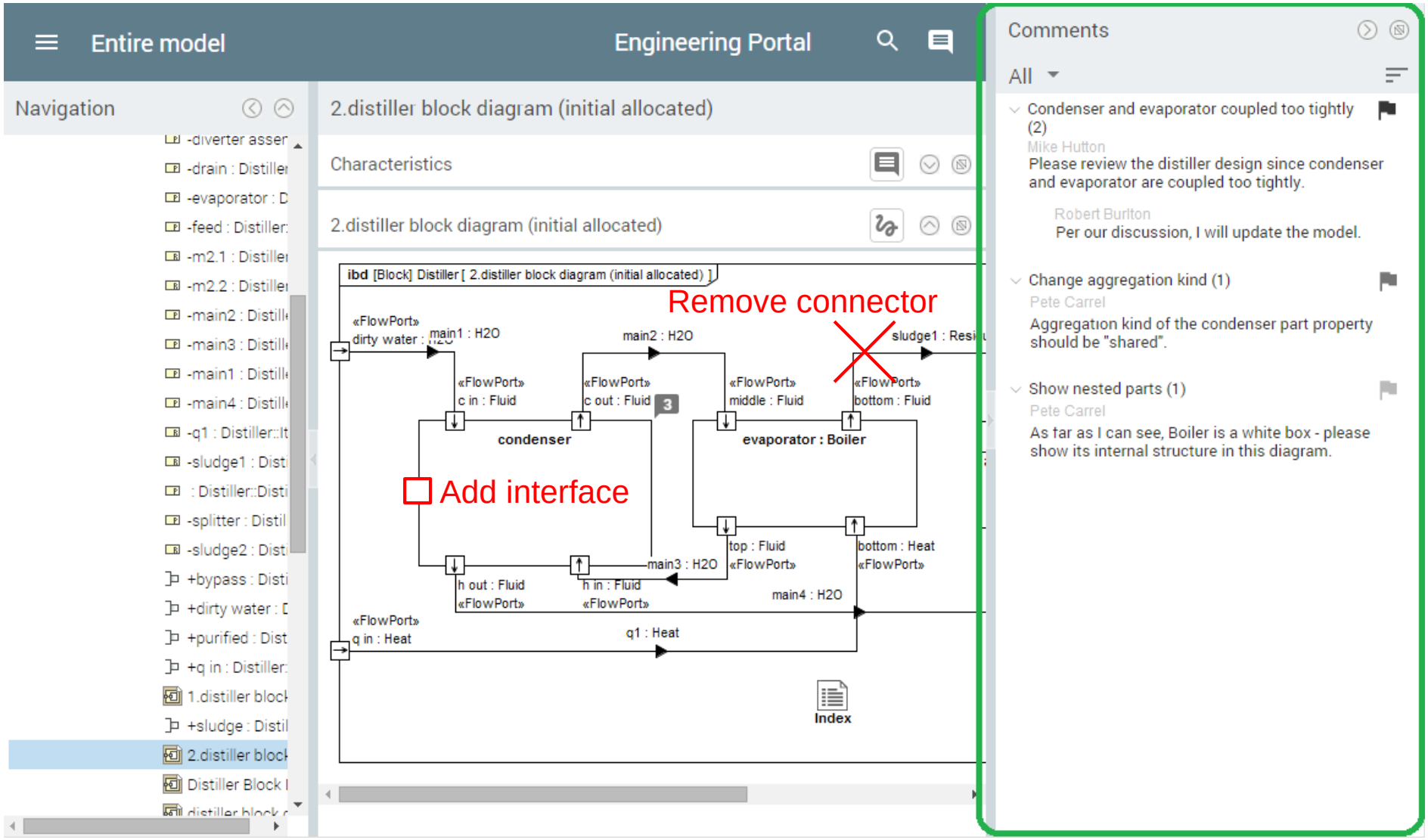
Derived:

BT_18 Reconnect

Refined By:

Pair With Device

Online Documentation And Review



Traceability

Requirements Analysis: Coverage

Use Cases | Data Metric Table | Data Metric Table1

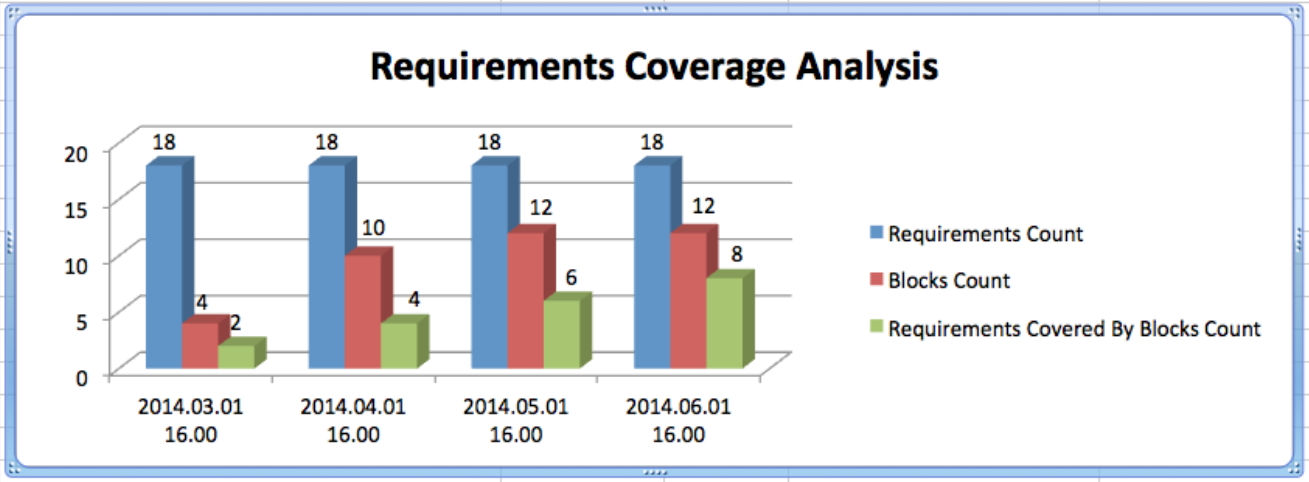
Calculate Metrics | Add Existing | Delete | Remove From Table | Show Metric Suites | Show Columns | Export

Criteria

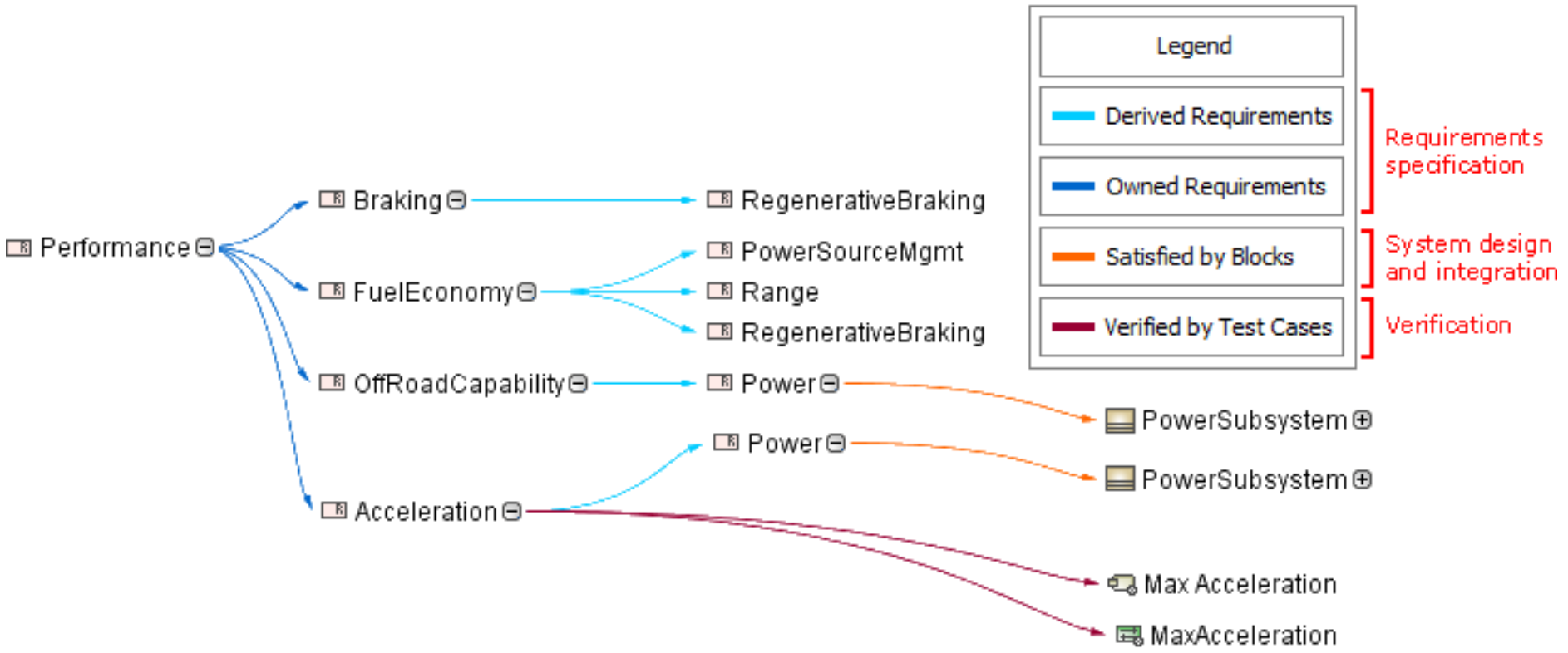
Metric Suite: Reqs Satisfied by Blocks ... Scope (optional): Drag elements from the Model B ... Filter:

#	Date	Requirements Count	Blocks Count	Requirements Covered By Blocks Count	Requiremets Covered By Blocks Percentage	Requirements Covered By Blocks Average
1	2014.03.01 16.00	18	4	2	11.11	1.00
2	2014.04.01 16.00	18	10	4	22.22	1.00
3	2014.05.01 16.00	18	12	6	33.33	1.50
4	2014.05.01 16.00	18	12	8	44.44	1.33

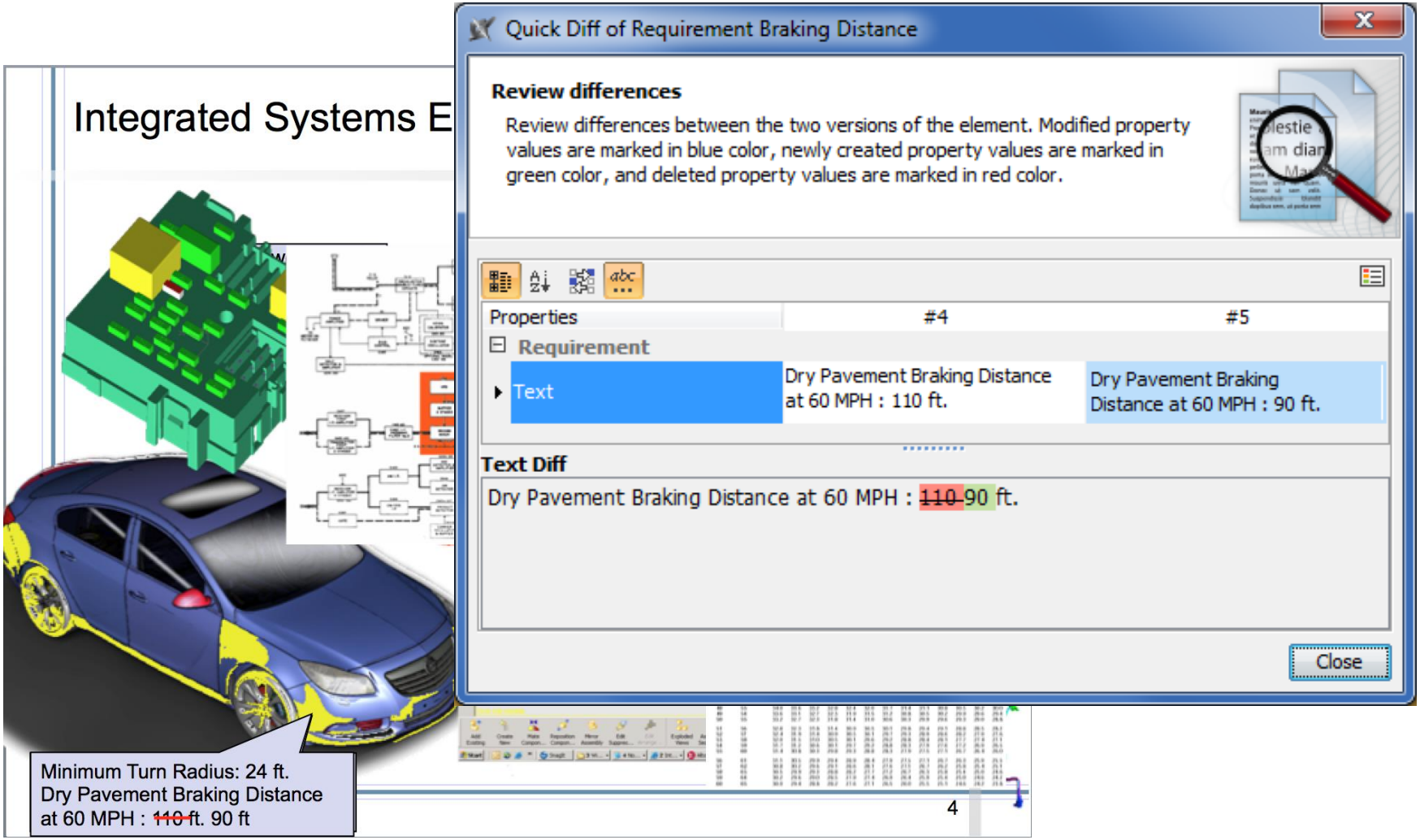
	A	D	E	F	G	H
1		Requirements Count	Blocks Count	Requirements Covered By Blocks Count	Requirements Covered By Blocks Percentage	Requirements Covered By Blocks Average
2	2014.03.01 16.00	18	4	2	11.11	1
3	2014.04.01 16.00	18	10	4	22.22	1
4	2014.05.01 16.00	18	12	6	33.33	1.5
5	2014.06.01 16.00	18	12	8	44.44	1.33



Requirements Analysis: Change Impact



Tracking Changes



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.
  - Ensures requirements traceability
  - Supports automated requirements analysis

Questions

Innovation drives success!