National Aeronautics and Space Administration

Using Model-Based System Engineering to Provide Artifacts for NASA Project Life-cycle and Technical Reviews

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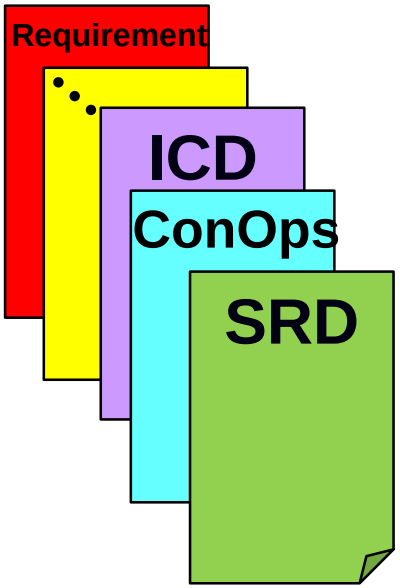
My Background

My experience:

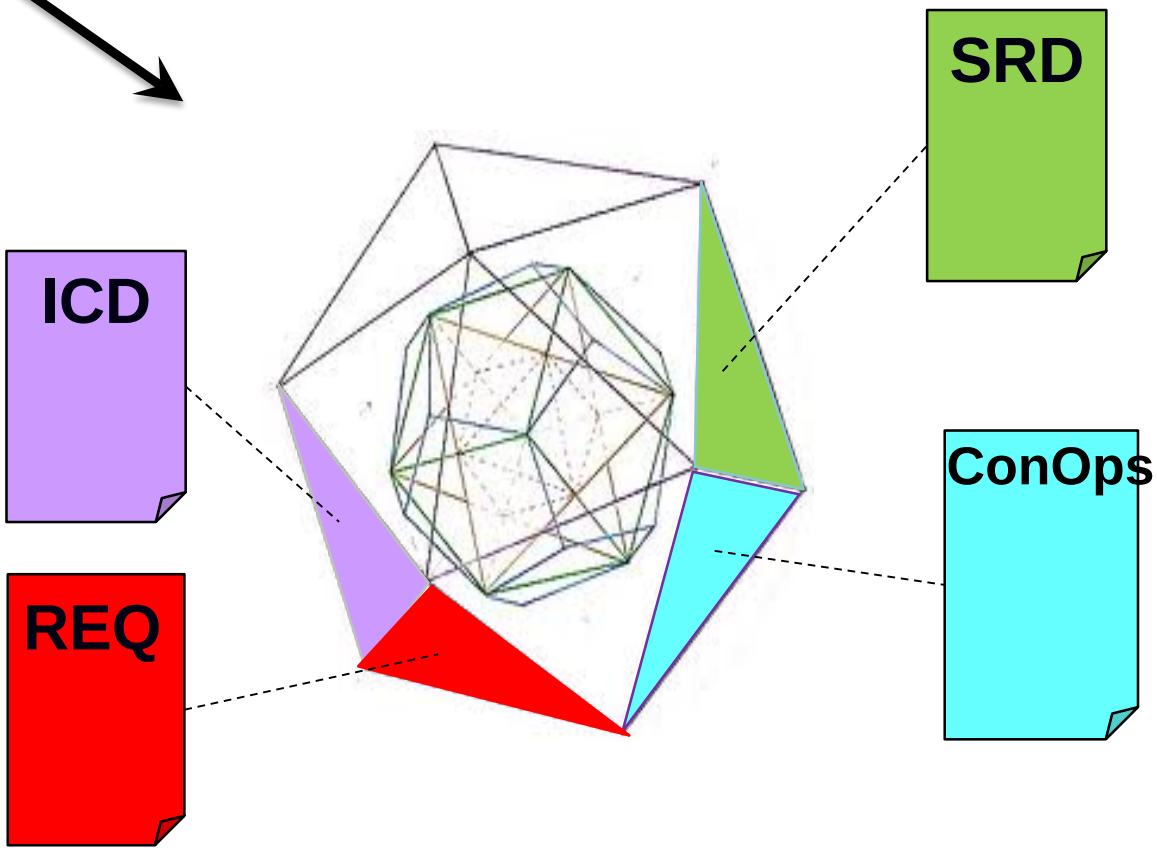
- 10+ years as a system engineer
- 8 years working with Model-Based System Engineering (MBSE)
- Utilized MBSE across various projects on multi-center teams
- Taught basic MBSE classes

What is Model-Based System Engineering



Stand alone documents

Model shows the interrelationship of the data defining the system.



Investing in MBSE

NASA Glenn System Engineers have investigated MBSE through:

- Training
- Exploratory uses
- Working Groups
- Implementing on projects over the past 4+ years: multi-center

Realization of Gap

System Engineers are trained to use a modeling tool but still are asking themselves . . .

- How can I use this on my project?
- Where do I start?
- What information is required for the model?
- How do I capture the data within the model?
- How do I show this information?
- What types of products am I trying to produce from the model?
- How do I know that I have all the right information and at the correct level?

The guidelines provided help to answer the above questions for developing review products.

Review Products

NASA Procedural Requirements 7123.1B "NASA Systems Engineering Processes and Requirements," which outlines:

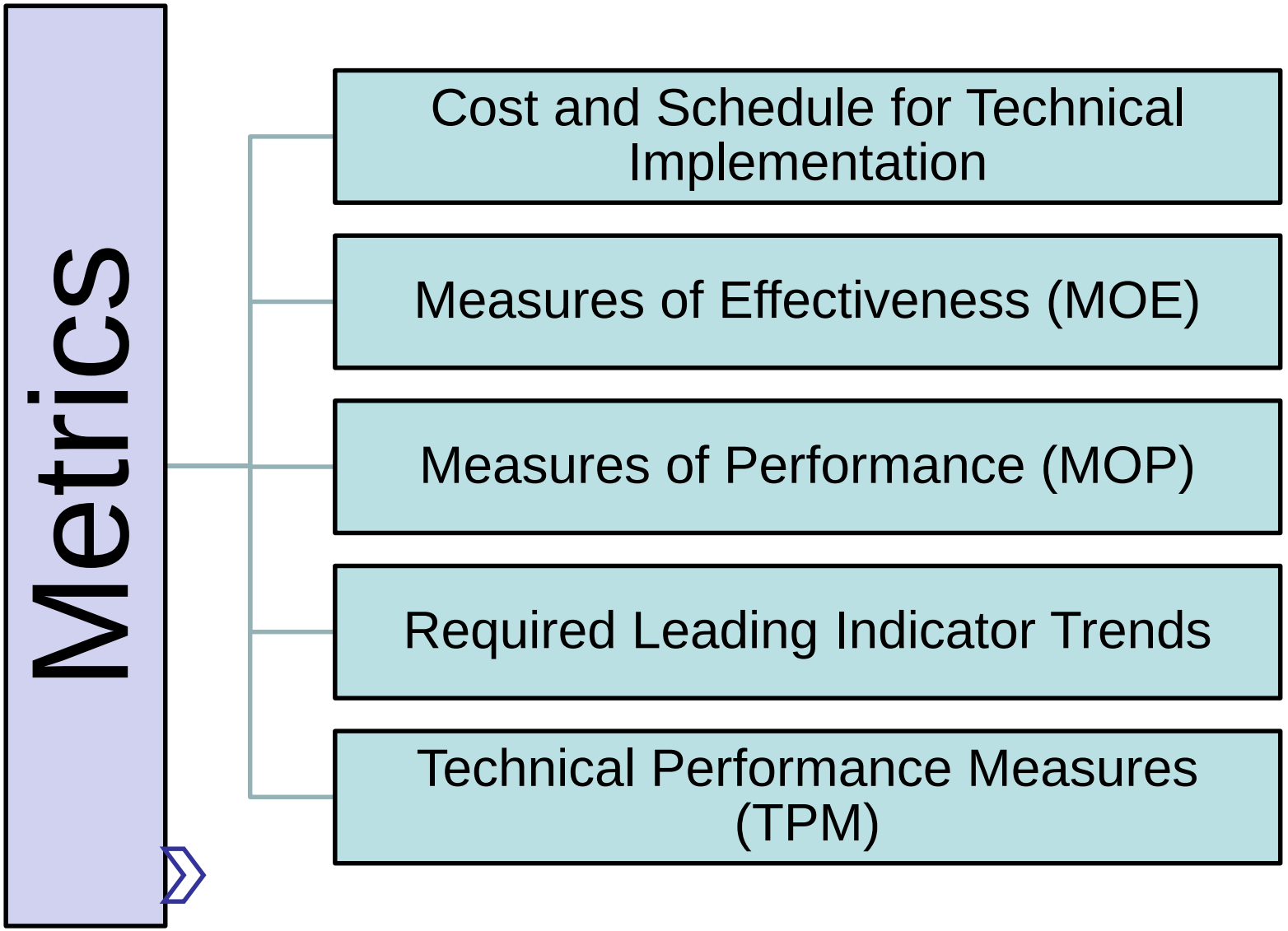
- Required products
- Required reviews
- Maturity of the products

Products			Formulation			Implementation					
	Uncoupled/ loosely Coupled Programs		KDP 0	KDP I	Periodic KDPs						
	Tightly Coupled Programs		KDP 0	KDP I	KDP II		KDP III		Periodic KDPs		
	Projects and single Project Programs	Pre-Phase A	Phase A		Phase B	Phase C		Phase D		Phase E	Phase F
		KDP A	KDP B		KDP C	KDP D		KDP E		KDP F	
		MCR	SRR	MDR/SDR	PDR	CDR	SIR	ORR	FRR	DR	DRR
Stakeholder identification and expectations definition		**Baseline	Update	Update	Update						
Concept definition		**Baseline	Update	Update	Update	Update					
Measure of Effectiveness definition		**Approve									
Cost and schedule for technical implementation		Initial	Update	Update	Baseline	Update	Update	Update	Update	Update	Update
SEMP[1]		Preliminary	**Baseline	Update	Update	Update	Update				
SEMP[2]		Preliminary	Preliminary	**Baseline	Update	Update	Update				

System Engineering Product Categories

Concept & Design	Requirements and Verification & Validation
Plans	Metrics

Metrics Category Product Listing



Key Focus Areas

1. **Artifacts**
   - How the traditional SE products are seen as model artifacts in the modeling world.
2. **Model elements and relationship**
   - What model elements and relationships could be used to capture the project data in order to generate the artifacts.
3. **Model validation**
   - Common questions to evaluate if your modeling task are complete.
4. **More detail**
   - Extra information associated with the SE Product

Applicability

- **Who**
  - System Engineers
  - Project Managers
  - Customers
  - Review Board members
  - Other key project stakeholders
- **What it provides..**
  - Initial guidance on where to start in order to develop system engineering products using MBSE
  - Aid in translating document-centric products into model-centric products
  - Knowledge to non-modelers about what model can do for them

Functional Examples

Walk-thru 2 examples on how document-centric products can be captured in a model, using the previously mentioned focus areas:

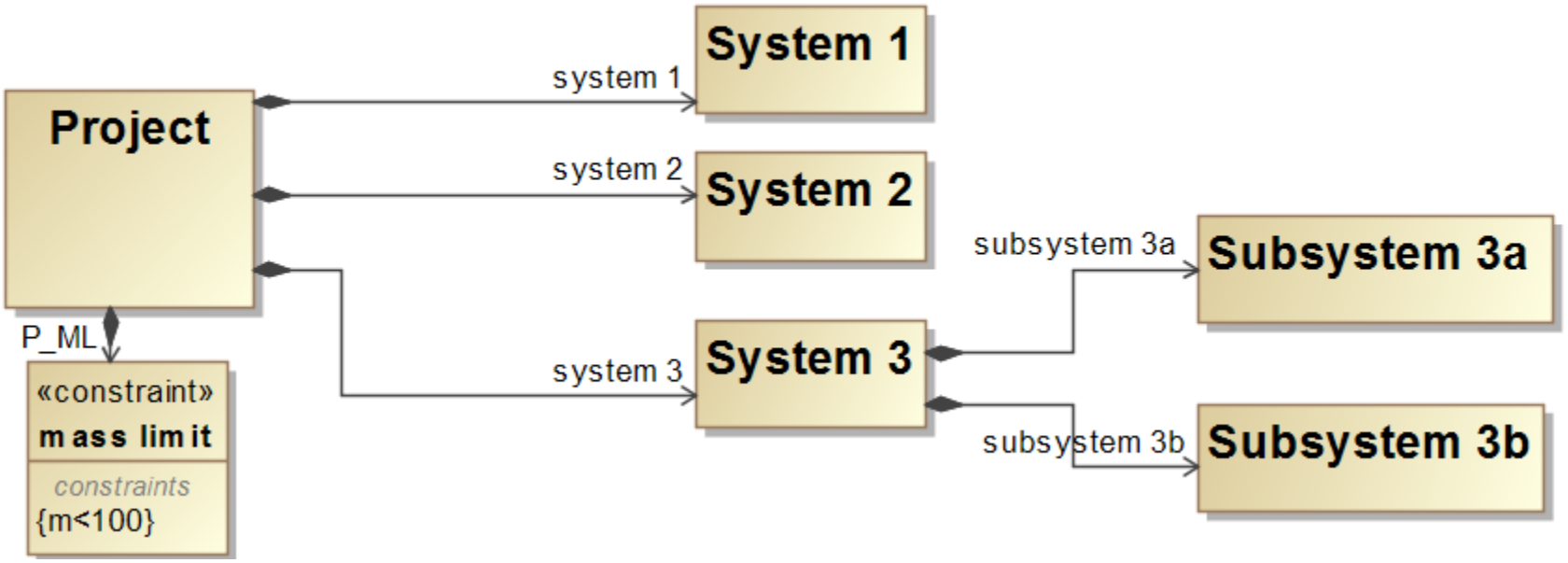
1. Metrics: using a Mass Roll-up for demonstration which is typically a Technical Performance Measures (TPM)
2. Plan: using the System Engineering Management Plan which is a living document that changes throughout its life-cycle and information used in the plan may or may not be stored inside the model

At the bottom of each page will show what focus area that the information can be found in.

Example 1:
Product Artifacts: Metrics

MOE/MOP/TPM Products	Model Artifact
Metric	Instance
Metric to Needs Goals and Objective(s) traceability	Table
Metric to requirements traceability	Table
MOE, MOP and TPM decomposition	Relationship Matrix
Tracking trends	Instance Tables

Example 1:
Mass Roll-up Instance



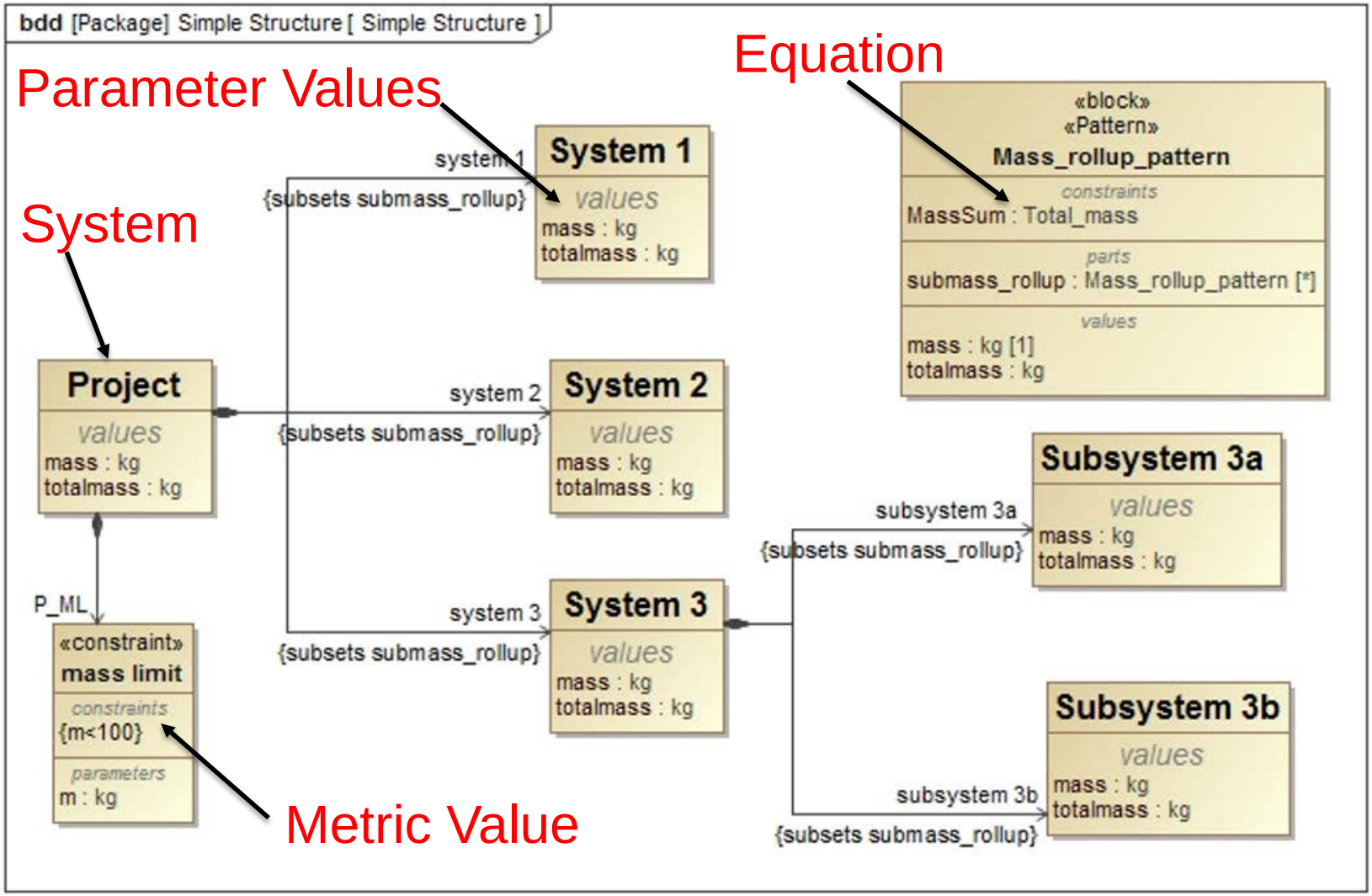
Instance Example

#	Name	P_ML : mass limit	totalMass : kg	system 1.totalMass : kg	system 2.totalMass : kg	system 3.totalMass : kg	system 3.subsystem 3a.totalMass : kg	system 3.subsystem 3b.totalMass : kg
1	project 06-01-2016	pass	75.0	10.0	15.0	50.0	25.0	25.0

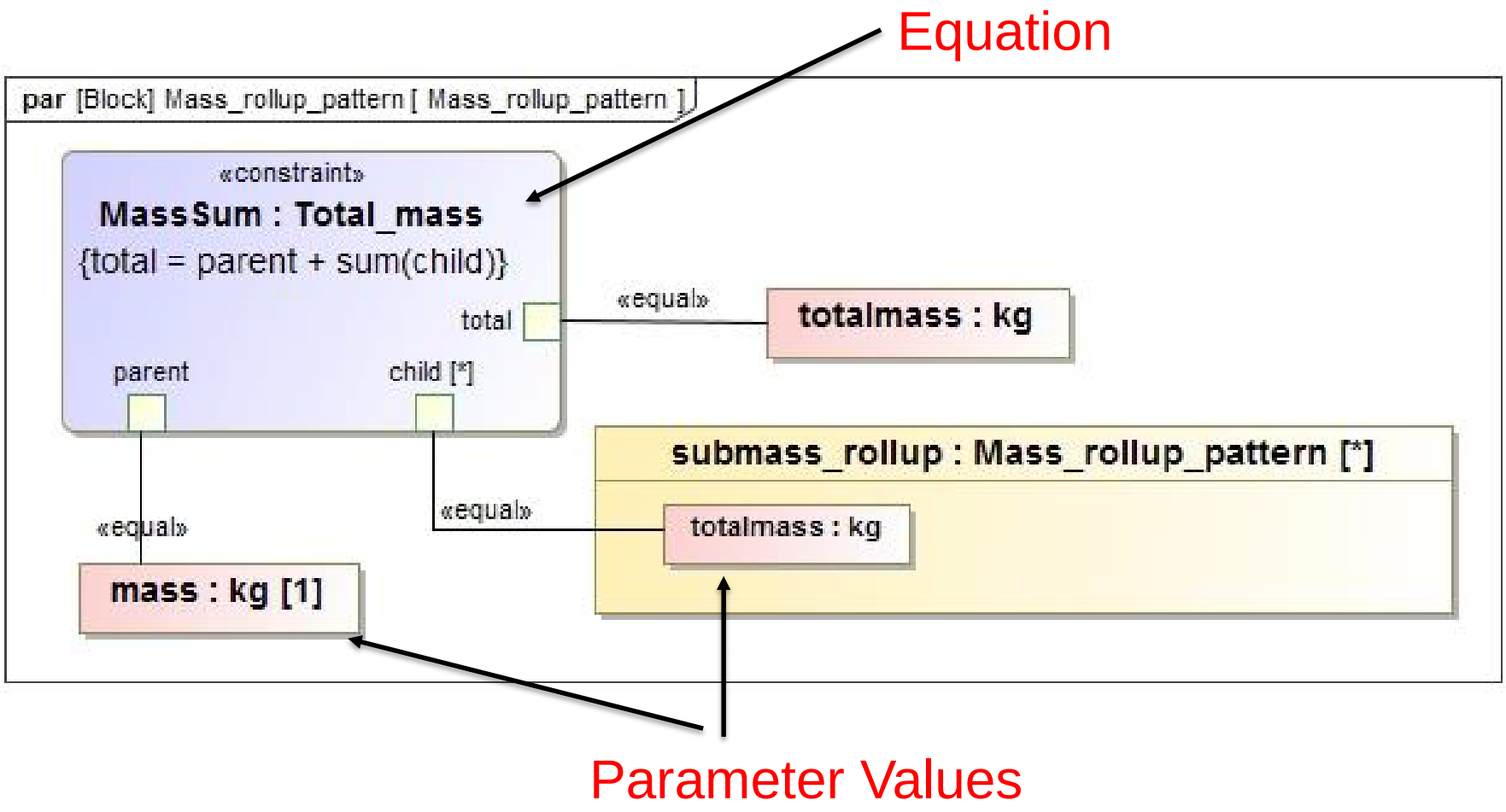
Example 1: Model Elements and Relationships: Metrics

MOE, MOP and TPM	Model Element and Relationship
System & subsystem	Block
Value used in calculating parameter(s)	Value attribute within the system/ subsystem/component block it represents
Metric value associated with MOE/MOP/TPM	Parameter owned by a constraint block
Equation to calculate parameter(s)	Constraint block - The parametric diagram assigns the values for which the equation need to execute
Results from calculations	Instances (generated from the equations)

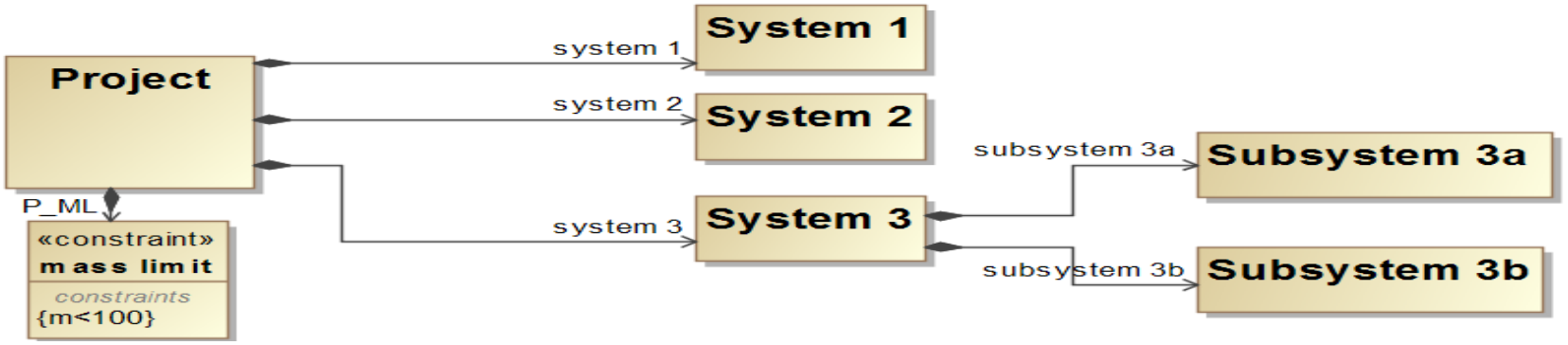
Example 1:
System level Mass Roll-up



Example 1: Mass Roll-up Equation



Example 1:
Mass Roll-up Instance Table for Trending



#	Name	P_ML : mass limit	totalMass : kg	system 1.totalMass : kg	system 2.totalMass : kg	system 3.totalMass : kg	system 3.subsystem 3a.totalMass : kg	system 3.subsystem 3b.totalMass : kg
1	project 06-01-2016	pass	75.0	10.0	15.0	50.0	25.0	25.0
2	project 09-01-2016	pass	95.1	10.1	25.0	60.0	25.0	35.0
3	project 06-05-2017	pass	93.1	10.1	25.0	58.0	21.0	37.0
4	project 06-06-2017	pass	93.1	10.1	25.0	58.0	21.0	37.0
5	project 06-10-2017	fail	110.3	22.3	28.0	60.0	21.0	39.0

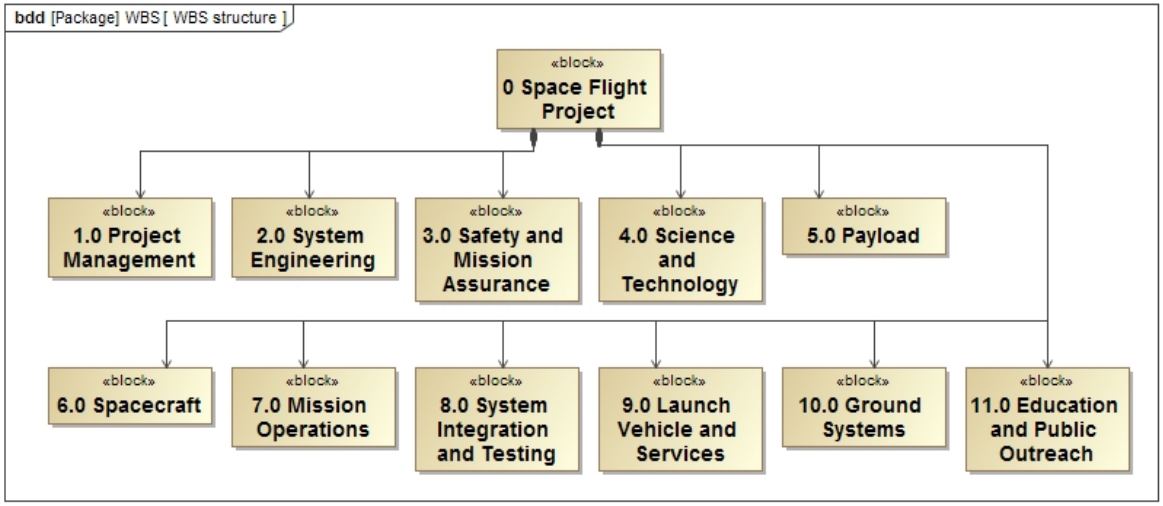
Example 1:
Model Validation Questions: Metrics

Validation Question	Validation Method
Which MOP or TPM satisfy a concern?	Table showing the MOP and TPM with their related model elements via the satisfy relationship.
Which MOP and TPM are related to a requirement, system or subsystem?	Table showing the MOP and TPM with their related model elements. The relationship used is dependent on the project.
Have the constraint equations been implemented correctly in the model?	Run a known configuration to show that the model configuration produces the expected results.

Example 2: Product Artifacts: SEMP

SEMP artifacts	Model Artifact
SEMP Document	Output from the model using information from within the model, in addition to information that supplements model-generated content
System Decomposition	Block definition diagram
Work Breakdown Structure (WBS) Layout	Block definition diagram
Technical Summary of SEMP sections	Artifact
Responsibility and organizational structure	Block definition diagram and allocation matrix
External or NASA Standard	Block that contain attributes with external hyperlink
Processes	Activity diagrams

Example 2: SEMP Artifacts



WBS Structure

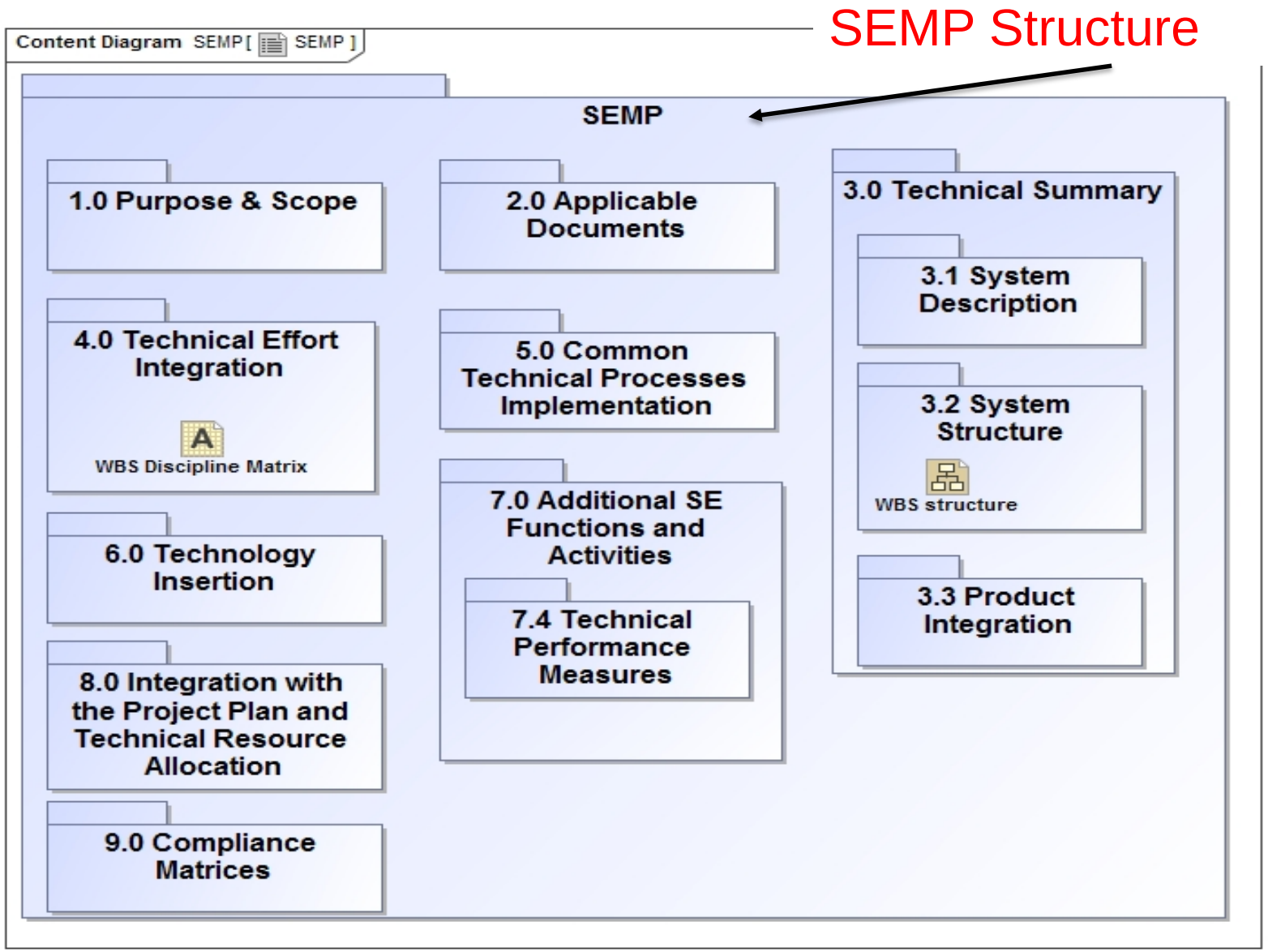
WBS Allocation Matrix

WBS		Engineering Directorate	Gound Systems Program Office	Launch Vehicle Program Office	Mission Operation Office	Project Management Office	Safety and Mission Assurance Program Office	Science Team
		5	2	2	2	2	2	3
0 Space Flight Project	7	↙	↙	↙	↙	↙	↙	↙
1.0 Project Management	1					↙		
2.0 System Engineering	1	↙						
3.0 Safety and Mission Assurance	1						↙	
4.0 Science and Technology	1							↙
5.0 Payload	1	↙						
6.0 Spacecraft	1	↙						
7.0 Mission Operations	1				↙			
8.0 System Integration and Testing	1	↙						
9.0 Launch Vehicle and Services	1			↙				
10.0 Ground Systems	1		↙					
11.0 Education and Public Outreach	1							↙

Example 2: Model Elements and Relationships: SEMP

SEMP	Model Element and Relationship
SEMP	Package or content diagram
Textual content	Artifact or comment
Personnel and organizations associated with the project	Actors
System component	Block
WBS structure	Block
Project process activities	Action block or call behavior action block
Organizational task allocation	Swim lanes
Data interactions	Activity parameter nodes and pins on the action block

Example 2:
SEMP Artifact Organization



Example 2:
Model Validation Questions: SEMP

Validation Question	Validation Method
Does the model have all the processes that are required in a SEMP?	Package diagram or content diagram and verify that all required sections contain the pertinent information.
Do the WBS elements have allocations to an organization or role?	Matrix with all the WBS allocated to an organization or role.

Summary

- Gap between learning MBSE and the application of those skills is often significant
- The information and examples in this paper are intended to increase the use of MBSE
- Work presented is limited to the primary products for project life-cycle and technical reviews based on NPR 7123.1B
- A SysML system model can contain or generate most systems engineering products to a significant extent


QUESTIONS