Model Based Systems Engineering using SysML

Overview and Status
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Topics

- MBSE Motivation and Scope
- System Modeling Using SysML
- System Model as an Integration Framework
- SysML Status
- MBSE Observations
- Summary
MBSE Motivation and Scope
SE Practices for Describing Systems

**Past**
- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

**Future**

Moving from Document centric to Model centric
Model-based Systems Engineering (MBSE)

- Formalizes the practice of systems engineering through use of models
- Broad in scope
  - Integrates with multiple modeling domains across life cycle from SoS to component
- Results in quality/productivity improvements & lower risk
  - Rigor and precision
  - Communications among system/project stakeholders
  - Management of complexity
System Description

• **Document-Based System Engineering:**

  Where is truth?

- Document 1
  - A<B

- Document 2
  - A=B

- Document 3
  - A>B

Inconsistencies within and among documents

• **Model-Based System Engineering:**

  Model enforces consistency

Model Repository
System Modeling Using SysML
System Modeling

Functional/Behavioral Model

Start → Shift → Accelerate → Brake

Performance Model

Requirements

Control Input → Power Equations → Vehicle Dynamics

System Model

Engine → Transmission → Transaxle

Structural/Component Model

Other Engineering Analysis Models

Mass Properties Model
Structural Model
Safety Model
Cost Model

Integrated System Model Must Address Multiple Aspects of a System
What is SysML?

- A graphical modeling language in response to the UML for Systems Engineering RFP developed by the OMG, INCOSE, and AP233
  - a UML Profile that represents a subset of UML 2 with extensions

- Supports the specification, analysis, design, verification, and validation of systems that include hardware, software, data, personnel, procedures, and facilities

- Supports model and data interchange via XML Metadata Interchange (XMI®) and the evolving AP233 standard (in-process)
SysML Diagram Taxonomy

- **Behavior Diagram**
- **Requirement Diagram**
- **Structure Diagram**

- **Activity Diagram**
- **Sequence Diagram**
- **State Machine Diagram**
- **Use Case Diagram**
- **Block Definition Diagram**
- **Internal Block Diagram**
- **Package Diagram**

- **Parametric Diagram**

- **Same as UML 2**
- **Modified from UML 2**
- **New diagram type**
4 Pillars of SysML – ABS Example

1. Structure

2. Behavior

3. Requirements

4. Parametrics
System Model as an Integration Framework
MBSE Must Integrate across Modeling Domains
System Architecture Model Provides an Integration Framework

Requirements Mgm’t Repository

Analysis Models

System Architecture Model

Verification Models

Hardware Models

Software Models

Req’ts Allocation Design Integration

Analysis Models

System Architecture Model

Verification Models

Hardware Models

Software Models
Using the System Architecture Model to Flowdown Requirements

System-of-System Level
- 1st Level Of Decompositions
- How Our System Contributes to the Overall Mission

Mission Concept of Operations

System Level
- Derives Subsystems
- Allocates Requirements to Subsystems

Element Level
- Derives Hardware and Software Components
- Allocates Requirements to Components

Component Design & Implementation Level

Trade Studies, Simulation, Specification Reviews, etc.

Behavior, Structure & Requirements

(from John Watson/LMC SysML Info Days presentation)
System Decomposition Process

1. **Analyze System Level Requirements**
2. **Analyze System Services**
3. **Identify the Subsystem**
4. **Analyze Subsystem Collaboration to Satisfy the System Services**
5. **Incorporate Additional Analysis as Needed**
6. **Derive and Allocate Requirements to Subsystem**

- **Yes**: Continue?
- **No**: Complete Subsystem Specs

- **Trade Studies, R&D, Simulation, Specification Reviews, etc.**
- **Derived Requirements**

(from John Watson/LMC SysML Info Days presentation)
Integrating SysML with Simulation

GIT Project

Modelica Lexical Representation (auto-generated from SysML)

[Johnson, 2008 - Masters Thesis]
Typical Integrated Tool Environment

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<thead>
<tr>
<th>Project Management</th>
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<tbody>
<tr>
<td>SoS/Enterprise Modeling</td>
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<tr>
<td>UPDM</td>
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<tr>
<td>System Modeling</td>
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<tr>
<td>SysML</td>
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<tr>
<td>Software Modeling</td>
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<tr>
<td>UML 2.0</td>
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<td>Hardware Modeling</td>
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<td>VHDL, CAD, ..</td>
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<th>CM/DM Product Data Management</th>
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<td>Requirements Management</td>
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<td>Verification &amp; Validation</td>
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<th>Simulation &amp; Visualization</th>
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<th>Engineering Analysis</th>
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SysML Status
OMG SysML™ Status

- **Specification**
  - OMG Beta Specification in May ’06
  - Available Specification v1.0 in Sept ’07
  - Available Specification v1.1 in Nov ‘08
  - Revision task force for v1.2 in process

- **Adoption**
  - Multiple vendor implementations available
  - Increasing number of early adopters across industry
  - Being introduced into academia
  - Books available (4)
  - SysML Certification being planned
  - DISR Emerging Standard (March 26, 2009)

- Information can be found on the OMG SysML Website at [http://www.omgsysml.org/](http://www.omgsysml.org/)
OMG SysML™ Status (cont.)

- **On-going Efforts**
  - SysML/AP233 Integration
  - SysML/Modelica WG
  - Model interchange WG

- **Leveraging SysML in other OMG Specifications**
  - UPDM, MARTE

- **University Courses**
  - Fachhochschule Vorarlberg
  - George Mason University
  - Georgia Institute of Technology
  - University of Arizona
  - University of California at San Diego Extension
  - Others …
Observations and Summary
MBSE Observations

- Transition from document-centric to model-centric is a cultural change
- Well defined MBSE method is essential
- Multiple tool vendors providing a range of price point, capability, and standards conformance
- MBSE training should include language, method, and tools
- Employ pilots to validate your MBSE approach
- Scope model based on program objectives and constraints
- *A lot has been learned, but much more remains*
Summary

- MBSE is a key practice to advance complex systems development
- Standards such as SysML are critical enablers of MBSE
- Multiple tool vendors implementing the standard
- System architecture model and standards based approach facilitate Integration across modeling domains
- Growing interest and application of MBSE
- INCOSE MBSE helping to advance and promote MBSE