

Model Based Systems Engineering NASA PM Challenge 2009 February 25, 2009

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Topics



- MBSE Motivation and Scope
- System Modeling Using SysML
- System Model as an Integration Framework
- INCOSE MBSE Initiative
- 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 the 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

Life Cycle Support



MBSE Benefits

- Improved quality
 - Early identification of requirements issues
 - Enhanced system design integrity
 - Improved specification of allocated requirements to HW/SW
 - Fewer errors during I&T
 - More rigorous requirements traceability
- Increased productivity
 - Improved impact analysis of requirements changes
 - Reuse of existing models to support design/technology evolution
 - Auto-generation of documentation

Reduced risk

- Improved cost estimates
- Early/on-going requirements validation & design verification





System Modeling Using SysML



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 is Critical Enabler for MBSE

4 Pillars of SysML – ABS Example



3. Requirements

4. Parametrics

OMG SysML™ Specification



Specification status

- Adopted by OMG 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
- Multiple vendor implementations available
- Information can be found on the OMG SysML Website at <u>http://www.omgsysml.org/</u>



System Model as an Integration Framework





System Architecture Model Can Integrate Across Domains





Typical Specification Tree



Space Vehicle Doman



Space Vehicle Context External Interfaces



Typical System Use Cases



Translate Vehicle Activity Diagram



Space Vehicle Hierarchy



Space Vehicle Internal Block Diagram



Georgia Tech Research Project

Integrating System Design Model with Simulation & Analysis Models



System Objective FunctionExcavator SysML ParametricsGIT Project $f = \sum_{i=1}^{n} k_i moe_i + \sum_{i=1}^{n} k_{ij} moe_i moe_j$



 $i, j=1; i \neq j$

Excavator System Breakdown GIT Project





Typical Integrated Tool Environment



Project Management													
CM/DM Product Data Management Requirements Management	ement	tion	SoS/Enterpri UP	ation									
	nents Manag	tion & Valida	System I Sys	on & Visualiz	ring Analysis								
	Requirer	Verifica	Software Modeling UML 2.0	Hardware Modeling VHDL, CAD,	Simulati	Enginee							



INCOSE MBSE Initiative

INCOSE MBSE Initiative Charter



- Promote, advance, and institutionalize the practice of MBSE to attain the MBSE 2020 Vision through broad industry and academic involvement in:
 - Research
 - Standards
 - Processes, Practices, & Methods
 - Tools & Technology
 - Outreach, Training & Education





Challenge Teams



- Telescope System Modeling Robert Karban (ESO)
- Space Systems Chris Delp *
- Mechatronics / Model Interoperability Team Russell Peak (GIT)
- GEOSS Architecture Modeling Larry McGovern
- Intelligent Enterprises Jack Ring *
- INCOSE Enterprise Model Michael Dee (Regina Griego)
- MBSE Applied to Urban Transportation Larry Head (UofA)
- Avionics Systems and Software Integration Leon Corley

INCOSE Telescope Modeling Challenge Team Robert Karban – Lead APE Project





APE will be installed at the telescope in the Chile desert.

Model Organization



Telescope MBSE Challenge Team Site http://mbse.sysmod.de/



MBSE Observations

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

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

MBSE References (there are many more)



- INCOSE MBSE Connect Site
 - http://www.incose.org
- Multiple INCOSE Journal/Insight Articles, Symposium Papers
- OMG SysML Website
 - http://www.omgsysml.org
- SE^2 Telescope MBSE Challenge Team Site
 - http://mbse.sysmod.de/
- Estefan, Jeff "Survey of Candidate Model-Based Systems Engineering (MBSE) Methodologies", Rev. B, May 23, 2008
- Cantor, Murray, Rational Unifi ed Process ® for Systems Engineering, RUP SE Version 2.0, IBM Rational Software white paper, IBM Corporation, May 8, 2003
- Hoffmann, Harmony-SE/SysML Deskbook: Model-Based Systems Engineering with Rhapsody, Rev. 1.51, Telelogic/I-Logix white paper, May 24, 2006
- Lykins, Friedenthal, Meilich, Adapting UML for an Object-Oriented Systems Engineering Method (OOSEM), Proceedings of the INCOSE International Symposium. Minneapolis, July 15–20, 2000
- Friedenthal, Moore, Steiner, "A Practical Guide to SysML: The Systems Modeling Language" Morgan Kaufmann, 2008
- Tim Weilkiens, "Systems Engineering with SysML/UML" Morgan Kaufmann, 2008
- Wymore, W., *Model-Based Systems Engineering*, CRC Press, 1993



Backup

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System Context





High Level Structure



Example for system structure: "Product tree" of Opto-Mechanical Bench



Traceability



Example for automatic dependency matrix between objective and user requirements:

	🚽 UserRequirement	🚽 APE laboratory [🚽 AtmosphericSensi	🚽 AtmosphericTurb	🚽 CaptureRange (A	🚽 DefocusControl [🚽 DoubleSegmentat	🚽 EdgeSensorSimul	🚽 EvaluationOfWav	🚽 FinalAccuracy [A	🚽 GlobalAberrations	🚽 IntegrationOfWa	🚽 LimitingStarMagni	🚽 OperationalTime [🚽 CalbrationTimeOf	🚽 CalibrationTimeO	🚽 MaximumTelesco	🚽 MeasurementTim	🚽 Report [APE:::AP	🚽 ResidualPSF [APE	🚽 ScallopingEffect [🚽 SegmentationErr	🚽 SensorPlatform [🚽 SimultanousContr	🚽 TestRequirement	🚽 ClosedLoopMeas	🚽 OpenLoopMeasur	🚽 UT of the VLT [AP	🚽 VerificationOnSky
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EvaluationEnvironment [\checkmark	2																									2
			2							2										4									2
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