SLIM: A Collaborative Environment for Model-Based Systems Engineering – Motivation, Status, Experiences

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◆ What is SLIM?
  - Conceptual Architecture
  - Use Cases

◆ SLIM
  - Capabilities & Tools
  - Applications

◆ Experiences

◆ Questions / Comments
**Motivation**

**Gap 1** = Disconnect between design and analysis activities across the phases, e.g. Pre-Phase A to Phase A, or Phase A to Phase B.

**Gap 2** = Disconnect between design, analysis, verification activities within a given phase.
Challenges

- Document-based or ad-hoc **point-to-point linkages** between models in different tools
- No **unified definition** of the system, analyses, V&V tasks, and MoEs that are continuous through the development process
- How does one **propagate trade spaces, uncertainties, and risk** from one phase to another?
- How do we **manage abstract**, system-level design/analysis **with detailed** sub-system/component-level design/analyses (CAD/CAE)?
Reviews, Meetings, Administration
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What is SLIM?

◆ **Systems Lifecycle Management**
  - model-based systems engineering (MBSE) with the foundations of product lifecycle management (PLM)

◆ Software environment for
  - integrated model-based (systems) engineering – MBE/MBSE
  - multi-disciplinary system development teams
  - end-to-end system design, analysis, and V&V

◆ Core philosophy
  - Use SysML as the front-end conceptual map of a system
  - Federate domain-specific tools/models from SysML
  - SysML model and domain models can “co-evolve”
Conceptual Architecture of SLIM

Primavera, MS Project, Excel,…

Requirements
DOORS, RequisitePro,…

Simulation/CAE
MATLAB, Simulink, NPSS, ABAQUS, ANSYS, SINDA/FLUINT, pSPICE, Mathematica,…

Libraries / Databases
CAD models, cost models, analysis modules, parts and material databases, supplier database, …

Manufacturing, Supply Chain
Tecnomatix, SAP, …

DE: Domain expert
SE: System engineer
SLIM is deployed in the SysML environment. It provides tools to federate (visualize, connect, execute) domain-specific models from the SysML environment.

System engineers work directly in their SysML environment - MagicDraw, Rhapsody, Artisan Studio, Enterprise Architect). SysML model is a conceptual map of the system.

SLIM connects to models in enterprise PLM environments to enable configuration control of artifacts.

SLIM allows users to wrap external model libraries (CAD, CAE, MATLAB,..) as plug-and-play SysML objects.
SLIM – Core Philosophy

- SysML-based system model is continuous through the development process

- SysML objects can
  - be “connected” to domain-specific models
  - “control” domain-specific models
  - co-evolve” with domain-specific models

- SysML-based system model
  - is not a data repository
  - is a dashboard for orchestration SE design, V&V flows
Use Cases of SLIM
Facilitate model-based…

- design and analyses
  - parametric and architectural trades
  - orchestrate simulations
  - risk analyses
  - requirements verification
- reviews
- change management
- manufacturing and supply chain management
- procurement and delivery
- verification and validation
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SLIM – Tools and Capabilities (cont.)

- **SysML Analysis Tools**
  - Parametric execution tool
  - Trade study tool
  - Risk analysis tool
  - Activity execution tool

- **SysML Integration Tools**
  - Excel interface
  - MATLAB/Simulink interface
  - Mathematica interface
  - OpenModelica interface
  - CAD (NX) interface
  - STK interface
  - Plus tailored interfaces…

- **SysML Visualization Tools**

- **SysML Libraries**
SysML Parametrics provide a foundation to…

- Represent fine-grained math relationships between SysML model elements
- Wrap and connect any external model to SysML – CAD, CAE, MATLAB/Simulink, Spreadsheets, Databases,…
- Orchestrate Simulations, Trade Studies, Optimization, Requirements Verification, Risk Assessment, and more from SysML Models
SysML parametric model

Annual cost & feature resolution for FireSat
Parametric execution and Trade study tool

- Vary operational altitudes of two FireSats
- Compute annual cost and ground coverage
- Automatically Verify cost and coverage requirement
- Results generated by SLIM’s parametric execution and trade study tool

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- COST requirement fails for these altitudes
- COVERAGE requirement fails for these altitudes
Risk Analysis Tool
Performing Monte Carlo simulations

Parametric model to compute mission response

Trials based on probability distributions of input variables

Response time (output) probability distribution
SLIM Analysis Tools

Available commercially as

- ParaMagic® for MagicDraw
  - www.intercax.com/paramagic

- ParaSolver™ for Artisan Studio
  - www.intercax.com/parasolver

- Melody™ for Rhapsody
  - www.intercax.com/melody

- Solvea™ (beta) for Enterprise Architect
  - www.intercax.com/solvea
Excel Integration Tool
Data Sync and Model Generation

Configure trade studies, specify variable ranges, generate scenarios

Connect SysML block properties to Excel spreadsheets and also generate SysML instances from spreadsheets
MATLAB/Simulink/Mathematica Integration

Wrap analysis models as SysML constraint blocks and use in the context of the system

connected to a Simulink model

SHH : SimulinkHomeHeating

{cost=xfwExternal(matlab,scriptascii, demoscriptasciisimulink, row, col, outtemp, daycyc)}

outtemp : Real
daycyc : Real
col : Real
cost : Real

OD Home : Outdoors

DailyCycle : Real
OutputRow : Real
OutputColumn : Real
DailyCost : Real

ParaSolver for Artisan Studio

Simulink model executed from SysML
SysML Activity Execution Tool

SysML activity models for controlling mobile robots

SysML – CAD Integration Tool

Data flow automated by Parametric solvers

System model

Component Z
System Model
Property A
Property B

Component Z
CAD Model
Property a
Property b

Component Z
CAD Design
Parameter a
Parameter b

B = a + b

Generated from a CAD model (Siemens NX)

Fine-grained relationships between CAD model and system model represented using SysML parametrics (instead of ad-hoc docs and spreadsheets)

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FireSat SysML model defines the context for feature coverage and interval analyses.

STK invoked at the backend to compute period of access and coverage for a given feature of interest.

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Space Systems

FireSat cost and coverage trades and reqt. verif.

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Military and Intelligence

Probability of mission success, mean response time

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Manufacturing and Supply Chain
Computing value at risk, supply-demand balance
Banking and Financial Systems
Computing risk and checking compliance
Smart Grid

Supply-Demand Balance

Daily Expense:  
SmartGrid $60,228  
DumbGrid $66,477

For more info, visit http://smartgrid.ieee.org/nist-smartgrid-framework
Case Study - MBSE of Electronic Systems

Document-based system definition

Data Flow & Control Signals

ALU OUT LO
ALU OUT HI
INC DEC VALUE +
DATA OUT
32
Model-Based System Definition
Generating Simulation Models
SysML, XML, and Java

SysML-based Analytical Model + design-analysis relationships

System Design Representation (SysML)

XML-based analytical model structure

Java-based simulation model

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DSL Plugin Environment for Designers and Analysts
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❖ Questions / Comments
Experiences

- Computing with SysML & Variable Topology
- Deployment for all 4 major SysML authoring tools
- SysML/MBSE for different applications
- SysML – X tool interoperability patterns
- Domain-specific MBSE
Contact

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- Products – www.intercax.com/products
- SysML/MBSE – www.intercax.com/mbse
- Training – www.intercax.com/training