Additional Background Material

- Recent work with SysML/MBSE/MBX
  - SysML history and usage in industry/government
  - Short courses
  - Research and applications
  - Key techniques

OMG SysML 1.0 Participants

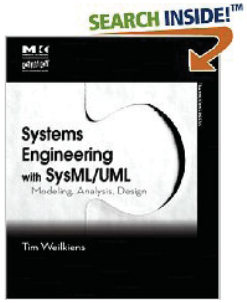
Spec Released Sept 2007

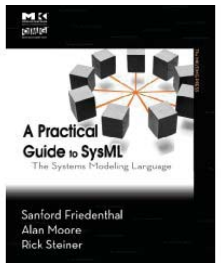
- Industry & Government
  - American Systems, BAE SYSTEMS, Boeing, Deere & Co, EADS-Astrium, Eurostep, Lockheed Martin, Motorola, NIST, Northrop Grumman, oose.de, Raytheon, THALES
- Vendors
  - Artisan, EmbeddedPlus, Gentleware, IBM, I-Logix, Mentor Graphics, No Magic, PivotPoint Technology, Sparx Systems, Telelogic, Vitech Corp
- Academia
  - Georgia Institute of Technology
- Liaison Organizations
  - INCOSE, ISO 10303 AP233 Working Group

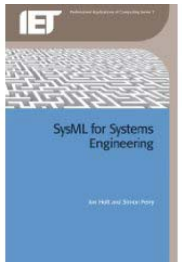
SysML Technology Status & Viability

www.omgsysml.org

- Spec v1.0: 2007-09 v1.1: 2008-11 v1.2: 2010-06 v1.3: WIP
  v2.x: RFI preparation workshop - 2008-12
  http://www.omg.org/spec/SysML/
- Strong vendor support
- Good learning infrastructure
  - Books, short courses, academic courses, INCOSE/OMG tutorial, public examples, etc.
- OMG Certified Systems Modeling Professional
  - http://www.omg.org/ocsmp/
- Expanding production usage
  - http://www.pslm.gatech.edu/events/frontiers/: 2006, 2007, 2008, 2011
  - OMG SysML Info Days: 2008-12; IC-MBSE 2008, 2009, 2010
  - INCOSE MBSE Workshops: 2007, 2008, 2009, 2010
- Overall Status: Healthy and Growing ☺



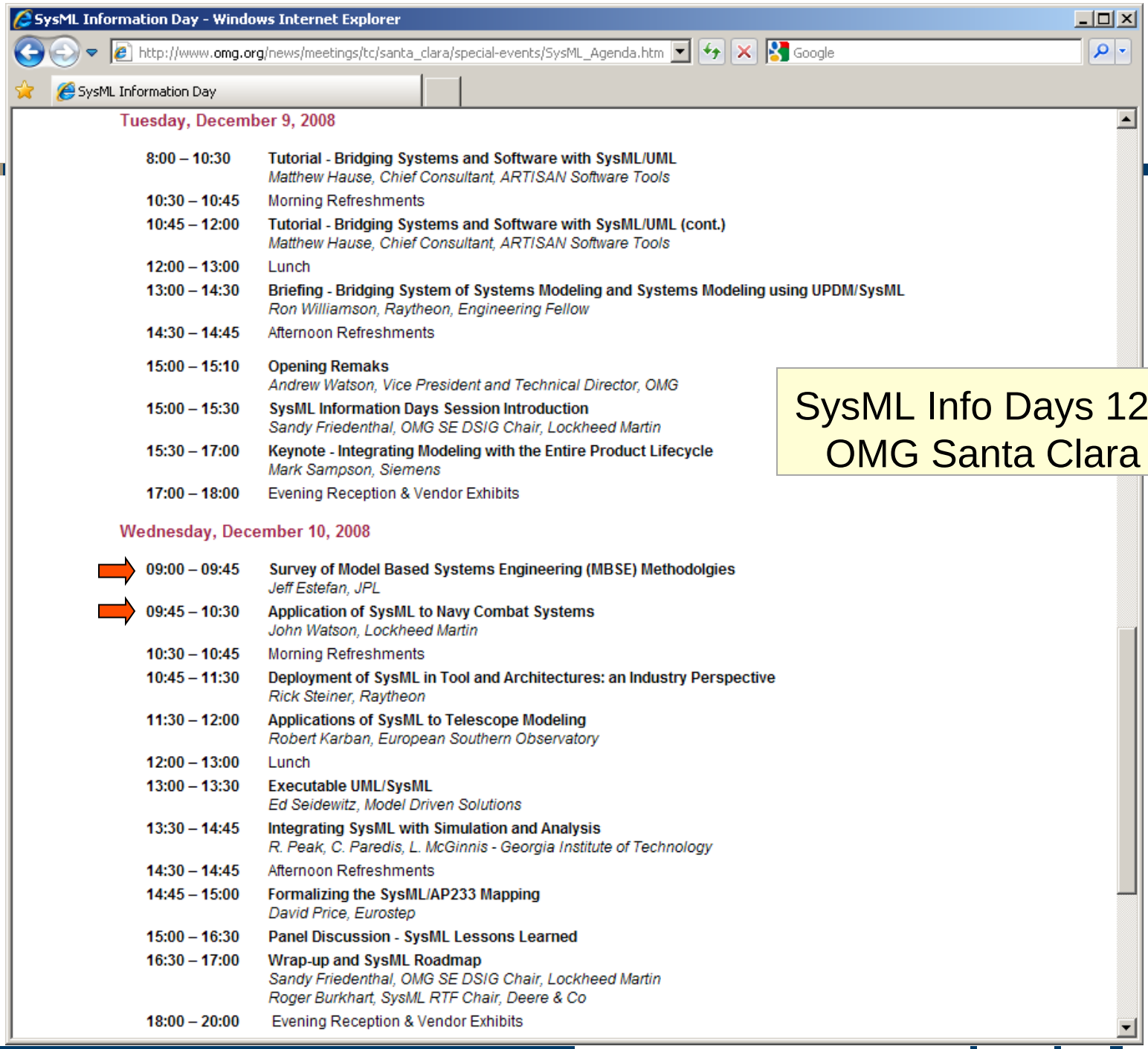




See next slides

Examples of SysML/MBSE Usage in Gov/Industry

- OMG SysML Info Days – 2008-12*
  - Application of SysML to a Navy Shipboard Combat System by J. Watson (Dec 10), and others
- SysML RFI Survey – 2009
  - Results summary by R. Cloutier at 2009-12 OMG mtg in Long Beach (OMG document syseng-09-12-04 — http://syseng.omg.org/)
  - SysML 2009 Request for Information (RFI) Response Summary. Bone M and Cloutier R, 8th Conference on Systems Engineering Research (Mar 2010). *
- INCOSE INSIGHT MBSE Special Issue 2009-12*
  - www.incose.org
  - Telescope article by Karban et al., space systems article (FireSat study) by Delp et al., and others
- Plus others emerging at an increasing pace
  - See www.omgsysml.org for links to asterisked(*) items and others.



Tuesday, December 9, 2008

8:00 – 10:30	**Tutorial - Bridging Systems and Software with SysML/UML** *Matthew Hause, Chief Consultant, ARTISAN Software Tools*
10:30 – 10:45	Morning Refreshments
10:45 – 12:00	**Tutorial - Bridging Systems and Software with SysML/UML (cont.)** *Matthew Hause, Chief Consultant, ARTISAN Software Tools*
12:00 – 13:00	Lunch
13:00 – 14:30	**Briefing - Bridging System of Systems Modeling and Systems Modeling using UPDM/SysML** *Ron Williamson, Raytheon, Engineering Fellow*
14:30 – 14:45	Afternoon Refreshments
15:00 – 15:10	**Opening Remaks** *Andrew Watson, Vice President and Technical Director, OMG*
15:00 – 15:30	**SysML Information Days Session Introduction** *Sandy Friedenthal, OMG SE DSIG Chair, Lockheed Martin*
15:30 – 17:00	**Keynote - Integrating Modeling with the Entire Product Lifecycle** *Mark Sampson, Siemens*
17:00 – 18:00	Evening Reception & Vendor Exhibits

Wednesday, December 10, 2008

09:00 – 09:45	**Survey of Model Based Systems Engineering (MBSE) Methodolgies** *Jeff Estefan, JPL*
09:45 – 10:30	**Application of SysML to Navy Combat Systems** *John Watson, Lockheed Martin*
10:30 – 10:45	Morning Refreshments
10:45 – 11:30	**Deployment of SysML in Tool and Architectures: an Industry Perspective** *Rick Steiner, Raytheon*
11:30 – 12:00	**Applications of SysML to Telescope Modeling** *Robert Karban, European Southern Observatory*
12:00 – 13:00	Lunch
13:00 – 13:30	**Executable UML/SysML** *Ed Seidewitz, Model Driven Solutions*
13:30 – 14:45	**Integrating SysML with Simulation and Analysis** *R. Peak, C. Paredis, L. McGinnis - Georgia Institute of Technology*
14:30 – 14:45	Afternoon Refreshments
14:45 – 15:00	**Formalizing the SysML/AP233 Mapping** *David Price, Eurostep*
15:00 – 16:30	**Panel Discussion - SysML Lessons Learned**
16:30 – 17:00	**Wrap-up and SysML Roadmap** *Sandy Friedenthal, OMG SE DSIG Chair, Lockheed Martin* *Roger Burkhart, SysML RTF Chair, Deere & Co*
18:00 – 20:00	Evening Reception & Vendor Exhibits

SysML Info Days 12/2008
OMG Santa Clara Mtg

MBSE in Industry & Government

Selected Publications from IC-MBSE 2010

IC-MBSE 2010 - 3rd International Conference on Model-Based Systems Engineering

September 27-28, 2010. George Mason University, Fairfax, Virginia. http://seor.gmu.edu/mbse2010/

- Complex Product Family Modeling for Submarine Combat System
  Steven Mitchell (Lockheed Martin)
- Bridging the Gap: Modeling Federated Combat Systems
  Danielle Robinson, Brandon Gibson, Steven Mitchell (Lockheed Martin MS2)
- End to End Maritime Surveillance Architecting using Model Driven Engineering
  Thomas Wheeler, Sara Orr, William Wong (MITRE)
- DoDAF System Architecture Linkages to Modeling and Simulation
  Matthew Carmona, Sean McGervey (Northrop Grumman Electronic Systems)
- Improving the Design Quality of Complex Networked Systems Using a Model-Based Approach
  Stephan Marwedel, Nils Fischer (Airbus Deutschland), Horst Salzwedel (Mission Level Design GmbH)
- We can Change the Culture of Systems Engineering with MBSE!
  Robert Healy (Raytheon)
- MBSE Process Using SysML for Architecture Design, Simulation, and Visualization
  Gundars Osvalds (Northrop Grumman)
- Developing a Strategy and Roadmap for Advancing the State-of-the-Practice of MBSE within Your Organization - Jeff Estefan (NASA Jet Propulsion Laboratory)
- Model-based Systems Engineering (MBSE) Using SysML
  Sanford Friedenthal (Lockheed Martin)
- Models as a Foundation for Systems Engineering - Should We Expect a Breakthrough?
  David Long (Vitech Corp.)

MBSE in Industry & Government

Other Selected Publications, Trends, Anecdotes, Etc.

- Navy CANES project [http://www.public.navy.mil/spawar/Press/Documents/Publications/3.4.10_CANES.pdf etc.]
  - SysML model used in generating RFP
  - SysML model required as a deliverable
- NASA JPL study: Piloting Model Based Engineering Techniques for Spacecraft Concepts. Bjorn Cole, Chris Delp, Kenny Donahue, INCOSE IS 2010, Chicago.
  - Received INCOSE Best Paper Award. Available at www.omgsysml.org
- Agile Systems Development - Bruce Douglass (IBM Rational)
  - PLM Road Map 2010, CPDA, Plymouth MI.
- Emerging Anecdotes ...
  - Practically all DoD 1st tier and many 2nd tier contractors have some type of MBSE effort underway
    - » Ranging from grassroots interest groups to major internal initiatives
    - » Similar to adoption of CAD/CAM/CAE (~'70s/'80s to present)
  - Other US gov usage: NASA, DOE (Sandia), ...
  - Growing demand for courses and consulting
  - Example business impact: A DoD contractor (who had SysML model) won a program over another contractor (no SysML model). Feedback was that their SysML model gave DoD more confidence their proposal would work.

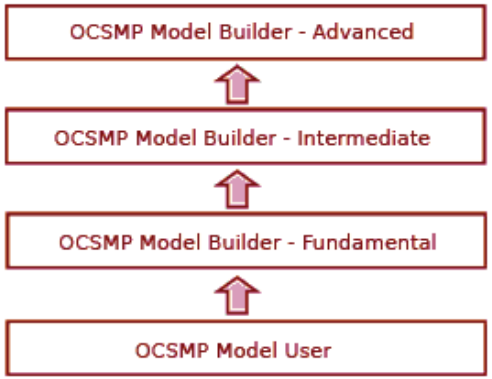
OMG Certified Systems Modeling Professional

Certification Program Overview

The OCSMP™ Certification Program is currently entering the early stages of development. The program is will award four levels of certification, arranged in a single hierarchy, and corresponding multiple-choice examinations. Our committee of SysML domain experts will define program details including the exact array of exams, their levels, names and topical coverage.

When the domain experts have defined the coverage limits, OMG will assemble a larger group of experts to write the exam questions and multiple-choice answers, which will be subject to psychometric verification before being published world-wide by our test delivery company, Pearson VUE, in their worldwide network of testing centers.

The Exams



The program will award the OMG Certified Systems Modeling Professional certification at four levels. The first level, OCSMP Model User, covers a wide range of essential MBSE and SysML knowledge and skills and so enhances the résumé of those who contribute to a model-based systems engineering project. Building on this foundation, since all lower levels will be prerequisites for the levels above, are three levels targeted at model builders and advanced model users.

These levels, termed OCSMP Model Builder - Fundamental, Intermediate, and Advanced, cover advanced topics with an emphasis on the interconnectedness among the different model viewpoints that gives MBSE its advantage over conventional engineering methods.

www.omg.org/ocsmp

Status as of Oct 2010:
- Beta testing done for Levels 1-3 (Level 4 beta in Nov 2010)
- Regular testing started for Level 1 (Sept 2010)

OCSMP Program

If you're a Systems Engineer, an OCSMP Certification at a suitable level represents a significant credential that differentiates you from your peers. Your superiors will think of you when they assign responsibility for projects based on MBSE, and when they make decisions on promotion or compensation. If you're making a hiring decision, or awarding a promotion or a raise, you know that the OCSMP Certified candidate stands out - he or she has studied the material and practiced the skills required for his level, and will bring the benefits of MBSE to the projects that they work on. And, if your company sells engineering services to clients on contract, your certified staff sets you apart.

OMG certification examinations - for OCSMP for System Modelers, and our programs OCEB™ for BPM, OCUP™ for UML, and OCRES™ for Real-time and Embedded - are administered by Pearson VUE at their world-wide network of secure testing centers.

OMG Certified Systems Modeling Professional

OCSMP Model User (Level 1) Coverage Table (p1/2)

Models of Requirements:	
Interpreting Requirements on Requirement Diagrams Concept of "requirement"; key relationships including derive, verify, satisfy, refine, trace, containment; Requirement Diagram description, purpose, and benefits;	7%
Interpreting System Functionality on Use Case Diagrams Use Case Diagram description, purpose, and benefits; use case structure encompassing use case, actor, and subject; basic relationships including association, include, extend, and generalization.	7%
Models of System Structure:	
Interpreting Model Organization on Package Diagrams Package Diagram description, purpose, and benefits, aspects of packages including ownership of elements, and defining a namespace; relationships including containment and dependency; concepts of view and viewpoint.	7%
Interpreting System Structure on Block Diagrams Block definition and description, including definition vs. usage; valuetype (with units), block features including value properties, parts, references, and operations. Block Definition Diagram description, purpose, and benefits; compartments; relationships between blocks including specialization and associations; multiplicities. Internal Block Diagram description, purpose, and benefits; enclosing block; flow ports and standard ports; connectors and item flows; representation of parts.	22%
Interpreting System Constraints on Block Definition Diagrams and Parametric Diagrams Interpreting constraint blocks on Block Definition Diagrams; Parametric Diagram description, purpose, and benefits; constraint properties, constraint parameters, and constraint expressions; connecting constraint properties and value properties with binding connectors.	7%

OMG Certified Systems Modeling Professional

OCSMP Model User (Level 1) Coverage Table (p2/2)

Models of System Behavior:	
Interpreting Flow-Based Behavior on Activity Diagrams Activity Diagram description, purpose, and benefits; I/O flow including object flow, parameters and parameter nodes, and pins; control flow including control nodes; activity partitions (swimlanes); and actions including decomposition of activities using call behavior action; send signal action; and accept event action.	**13%**
Interpreting Message-Based Behavior on Sequence Diagrams Sequence Diagram description, purpose, and benefits; lifelines; asynchronous and synchronous messages; interaction references (to elements outside the diagram).	**7%**
Interpreting Event-Based Behavior on State Machine Diagrams State Machine Diagram description, purpose, and benefits; states and regions including state, regions, initial state and final state; transitions including trigger by time and signal events, guard, and action (i.e. effect); and behaviors including entry, exit, and do.	**10%**
Cross-Cutting Constructs:	
Interpreting Allocations Across Multiple Diagram Types; Other Topics Allocation description, purpose and usage; AllocatedFrom and AllocatedTo; representation including callouts, compartments, allocate activity partitions, and tables; special notations for comment, rationale, problem, and constraint. Some concepts relating to diagrams: diagram frames, ports, parameters, and anchors on diagram frames; diagram header, and diagram description. Stereotype.	**20%**
Total	**100%**

OMG Certified Systems Modeling Professional

OCSMP Authors

JD Baker No Magic	**Alan Moore** The MathWorks
Manas Bajaj InterCAX	**Russell Peak** Georgia Institute of Technology
Graham Bleakley IBM	**Jon Siegel** OMG
Roger Burkhart John Deere	**Ernest Stambouly** Cephas Consulting Corp
Sanford Friedenthal Lockheed Martin	**Rick Steiner** Raytheon
Robert Lario Visumpoint	**Tim Weilkiens** oose
Sam Mancarella Sparx Systems	**Joe Wolfrom** Johns Hopkins APL

http://www.omg.org/ocsmp/authors.htm (2010-10-12)

Additional Background Material

- Recent work with SysML/MBSE/MBX
  - SysML history and usage in industry/government
  - Short courses
  - Research and applications
  - Key techniques

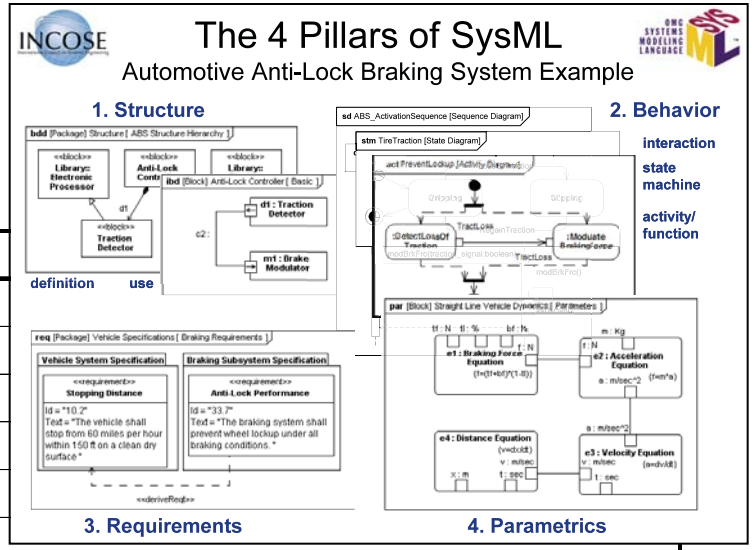
Curriculum History & Formats Offered

Statistics as of Sept 2010 — www.pslm.gatech.edu/courses

- Full-semester Georgia Tech academic courses
  - ISYE / ME 8813 & 4803: Since Fall 2007 (~95 students total)
- Industry short courses
  - Collaborative development & delivery with InterCAX LLC
  - Multiple [offerings,~students] and formats since Aug 2008
    - » SysML 101 [14,~260]; SysML 102 (hands-on) [12,~205]
  - Modes: » Onsite at industry/government locations
    - » Open enrollment via Georgia Tech (Atlanta, DC, Orlando, Vegas, ...)
    - » Web-based "live" since Apr 2010
  - Coming soon: 201/202, 301/302 (int/adv concepts, OCSMP prep, ...)
- Georgia Tech Professional Masters academic courses
  - Professional Masters in Applied Systems Engineering *www.pmase.gatech.edu*
  - ASE 6005 SysML-based MBSE course - Summer 2010
  - ASE 6006 SE Lab (SysML-based system design project) - Fall 2010

Industry Short Course Contents

SysML 101: Tool-Independent Concepts Focus (1 day)



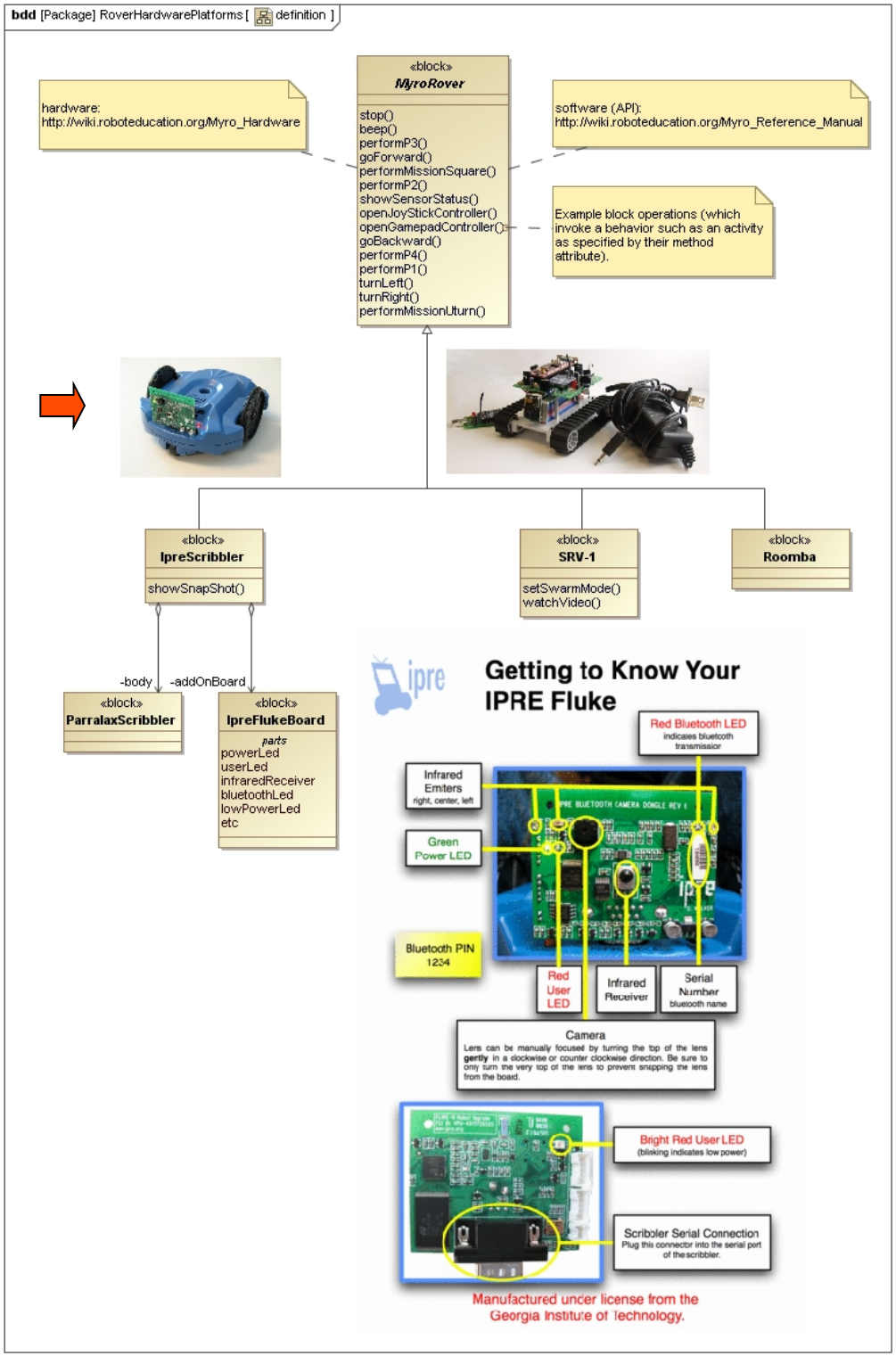
module	*topic*
Course Context	
000.01	Introduction and course overview
SysML 101: Essentials for Understanding SysML Models	
101.01	MBSE context & motivation
101.02	SysML introduction & overview; Course examples overview
101.03	Structure concepts: block basics (bdd), instances; packages (pkg)
101.04	Structure concepts: block internals, ports, flows (ibd)
101.05	Upfront concepts: use cases (uc); requirements (req)
101.06	Behavior concepts: activities, actions (act)
101.07	Behavior concepts: interactions/sequences (seq); state machines (stm)
101.08	Structure concepts: block parametrics (par)
101.09	Cross-cutting SysML concepts, methods, and processes
101.99	Wrapup — SysML 101

Industry Short Course Contents

SysML 102: Hands-on Execution-Oriented Focus (2.5 days)

module	*topic*
SysML 102: Essentials for Creating SysML Models (Hands-On for Tool Users)	
102.01	User workstation setup
102.02	Tool familiarity introduction - how to browse existing models, etc.
102.03	Structure concepts: block basics (bdd), instances; packages (pkg)
102.04	Structure concepts: block internals, ports, flows (ibd)
102.05	Upfront concepts: use cases (uc); requirements (req)
102.06	Behavior concepts: activities, actions (act) (w/ Myro rover team excercise)
102.07	Behavior concepts: interactions/sequences (seq); state machines (stm)
102.08	Structure concepts: block parametrics (par)
102.09	Cross-cutting SysML concepts, methods, and processes
102.10	MBSE processes: model-based document/report generation (Velocity, etc.)
102.11	MBSE processes: model repositories / Teamwork Server introduction for users
102.99	Wrapup — SysML 102
Approximate structure for each main concept module in SysML 102:	
	Spiral 1: How to implement basic concepts from SysML 101 in MagicDraw
	Spiral 1: Corresponding student exercise
	Spiral 1: Corresponding Q/A
	Spiral 2: How to implement other concepts (from SysML 101 and more)
	Spiral 2: Corresponding student exercise
	Spiral 2: Corresponding Q/A

(a cyber-physical system)



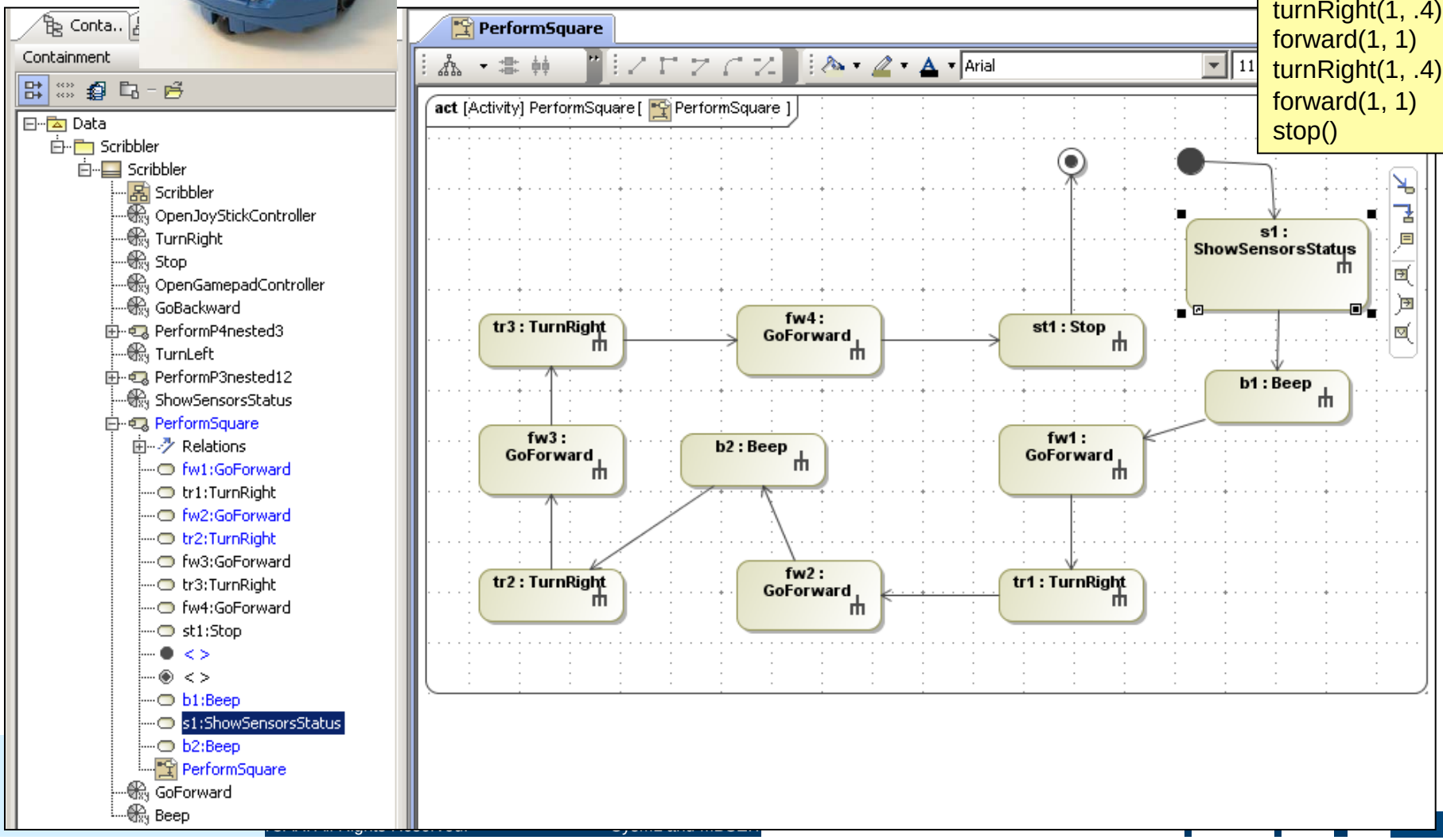
Mobile Robot Exercise

Executable SysML Activity Model [after live upd

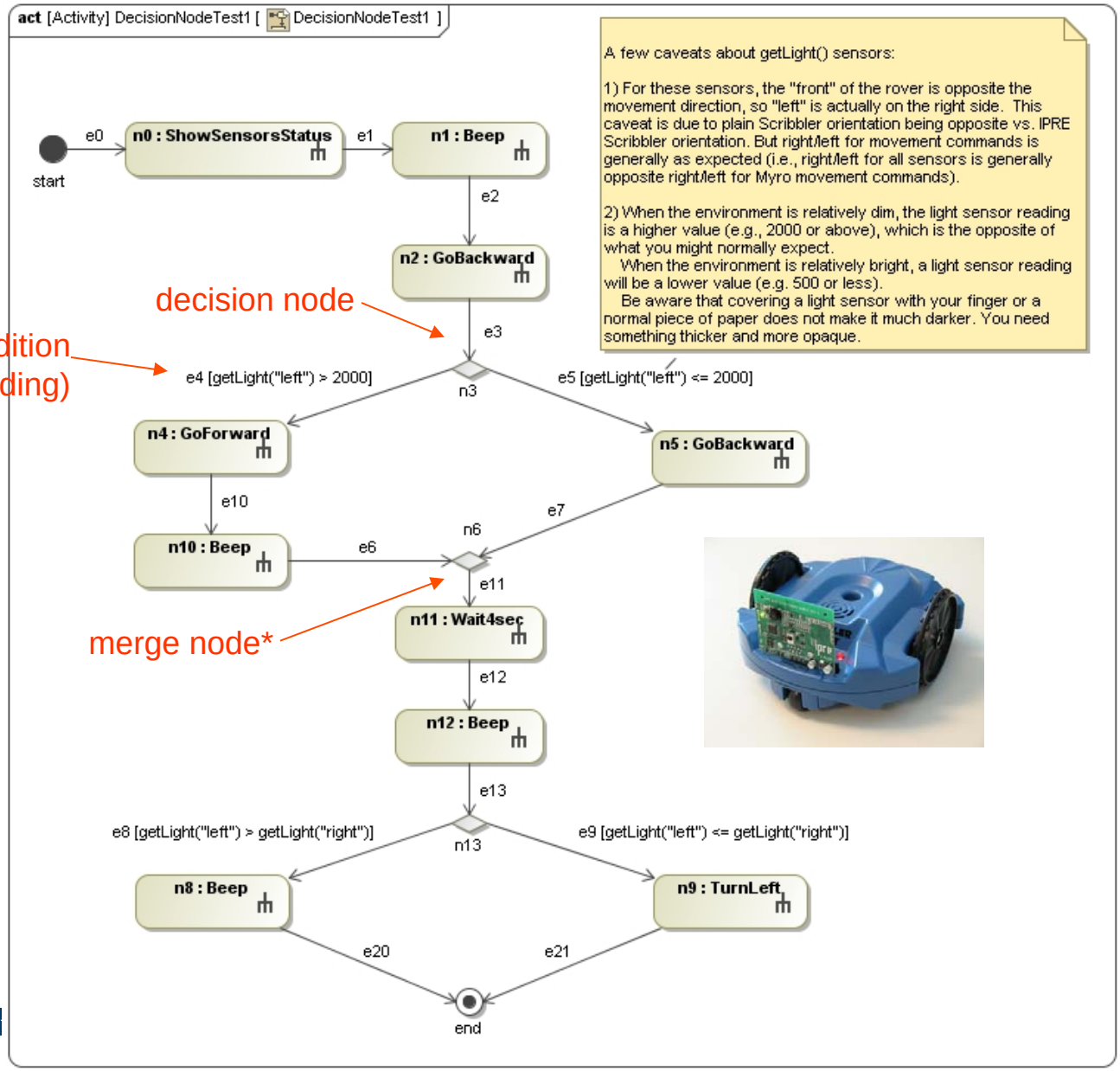
Resulting python script →

```
from myro import *
initialize("com29")

senses()
beep(1, 440)
forward(1, 1)
turnRight(1, .4)
forward(1, 1)
beep(1, 440)
turnRight(1, .4)
forward(1, 1)
turnRight(1, .4)
forward(1, 1)
stop()
```

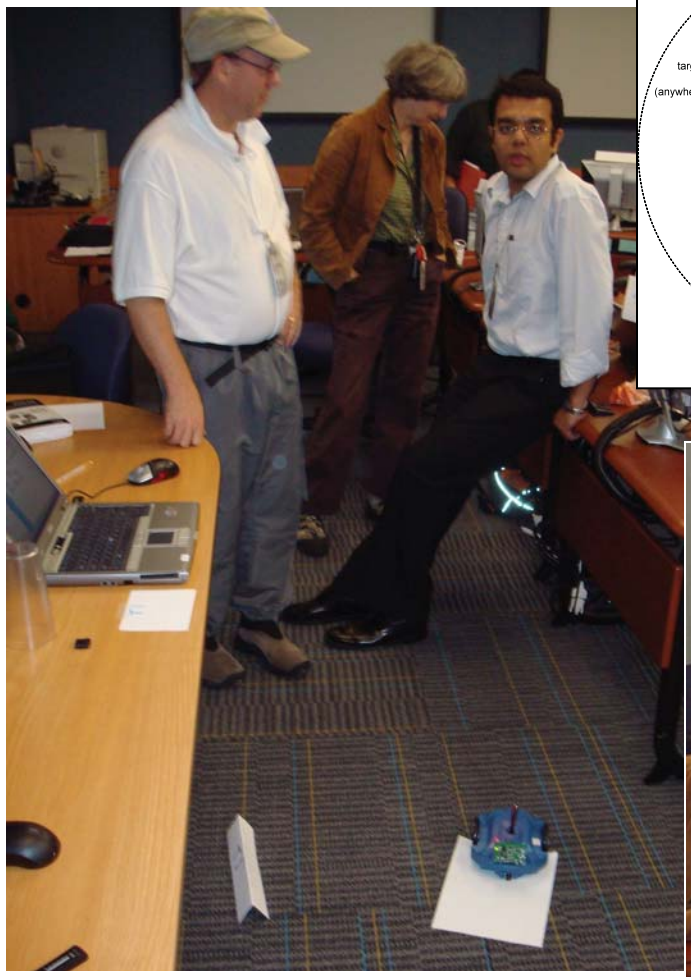


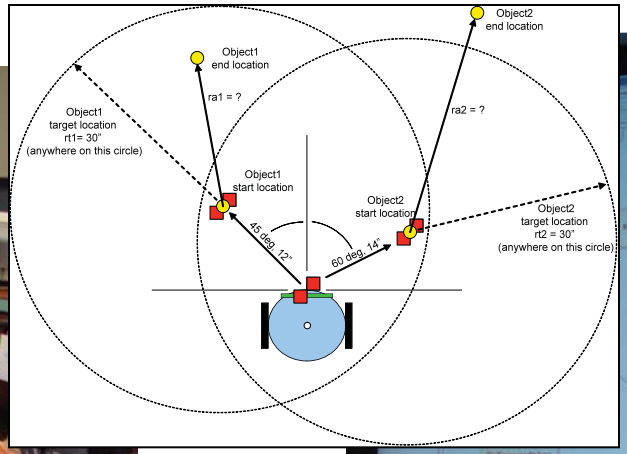
Decision Nodes / Guard Conditions and Merge Nodes

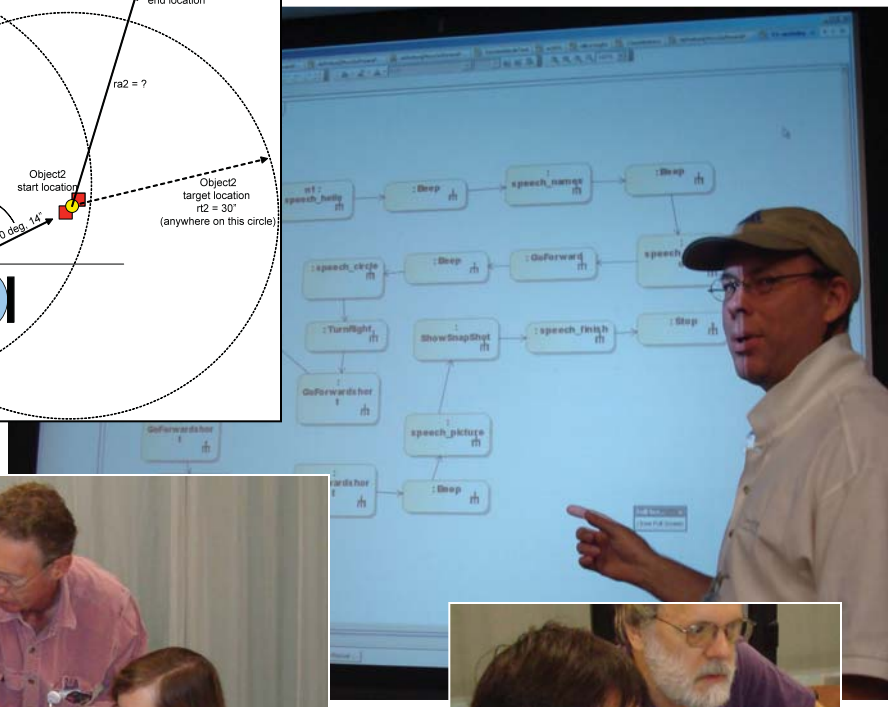


SysML Activities Exercise @ JPL

Team Contest Using MyroMagic Plugin & Scribbler Rovers







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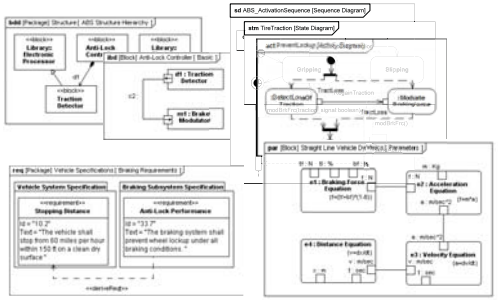
Representing System Models Using SysML

Developing, Interconnecting, and Executing Diverse Models



System

Sub-system 1 | Sub-system 2 | ... | Sub-system n

Component 1.1 | ... | Component 1.m

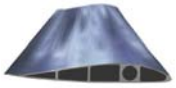
Comp 1m.1 - Structure | Comp 1m.1 – Behavior *i*

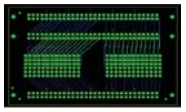
Connections | Connections | Connections

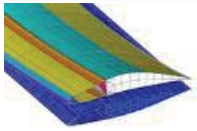
System models in SysML

External tools and models

mCAD models (NX, Pro/E, CATIA,…) | eCAD models (Board Station, CR5000,…) | CAE models (FEA, CFD,…) | ... | Other models & documents (spreadsheets, reports, DEVS, …)







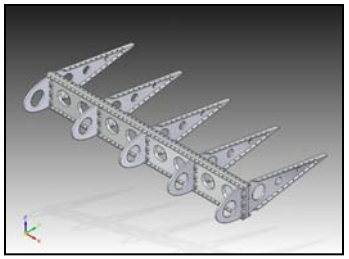
Broadly Applicable Technology
Examples of Executable SysML Parametrics

- Road scanning system using unmanned aerial vehicle (UAVs)
- UAV-based missile interceptor system trade study
- Space systems (tutorials): orbit planning; mass/cost roll-ups
- Space systems (studies/pilots): FireSat (INCOSE SSWG), ...
- Space systems (actuals): science merit function, ...
- Environmentally-conscious energy systems / smart grid
- Manufacturing “green-ness” / sustainability assessments
- Regional water management systems (e.g. South Florida)

  ...
- Mechanical part design and analysis (FEA)

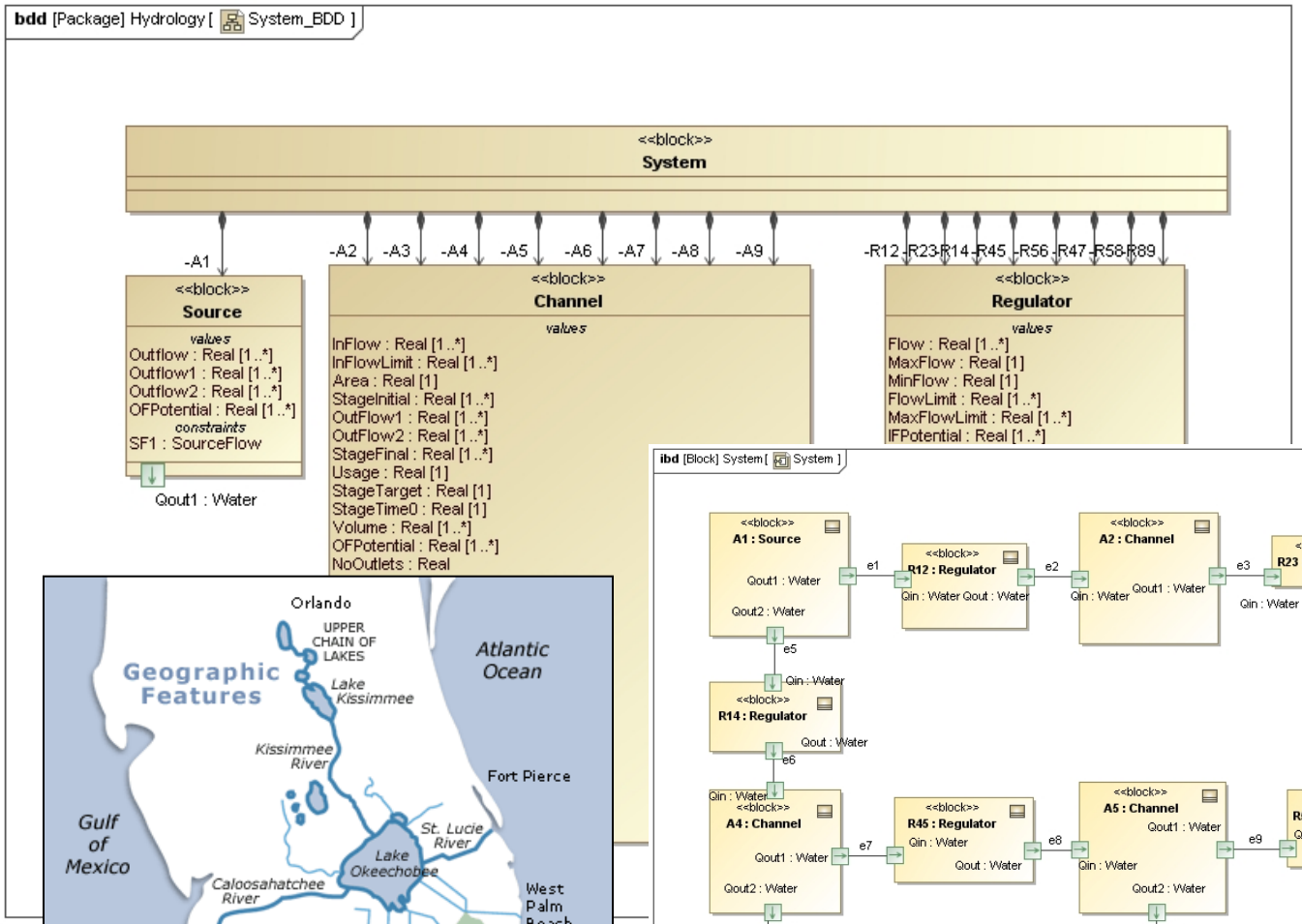
  ...
- Wind turbine supply chain management
- Insurance claims processing and website capacity model
- Financial model for small businesses
- Banking service levels model

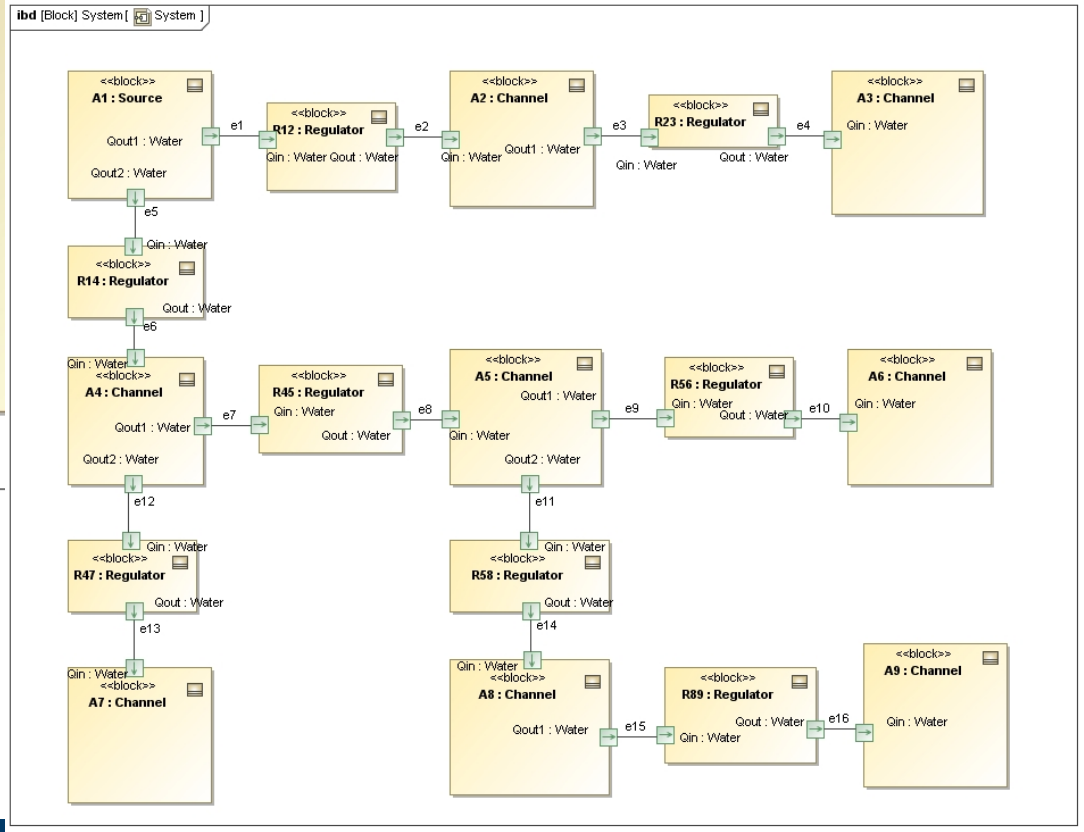
  ...



Next-Generation Spreadsheet Technology++
(object-oriented, multi-dimensional, ...)

Regional Water Mgt. System: Hydrology Model



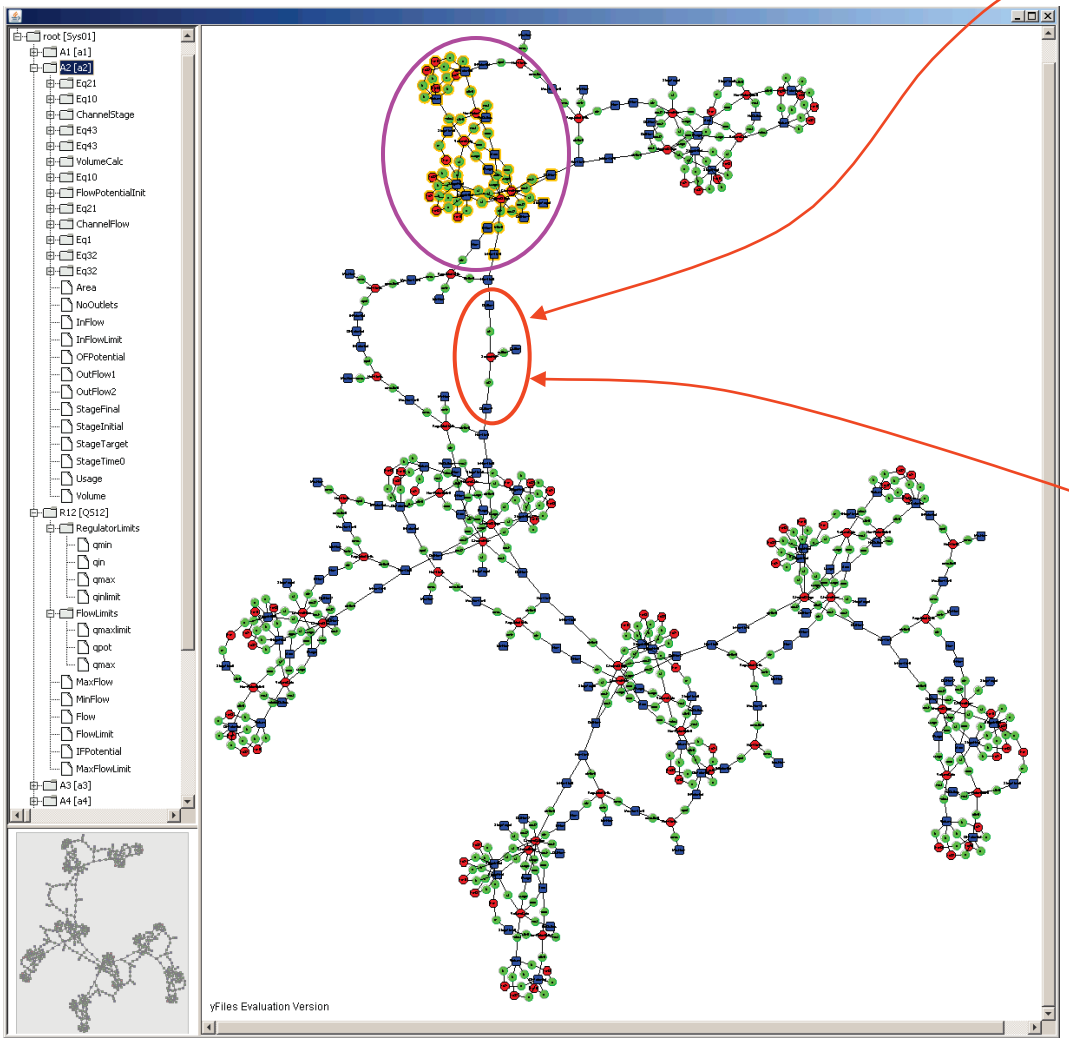


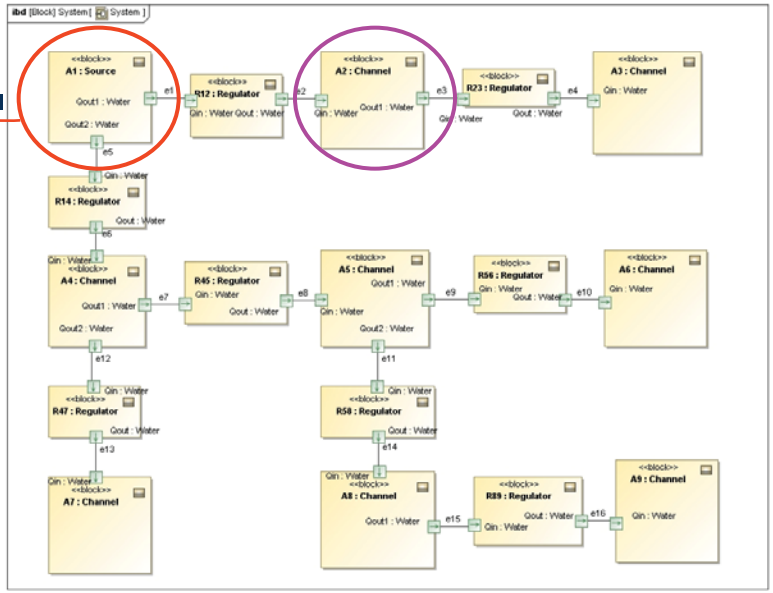
Sources:
www.sfwmd.gov and
Dirk.Zwemer@InterCAX.com

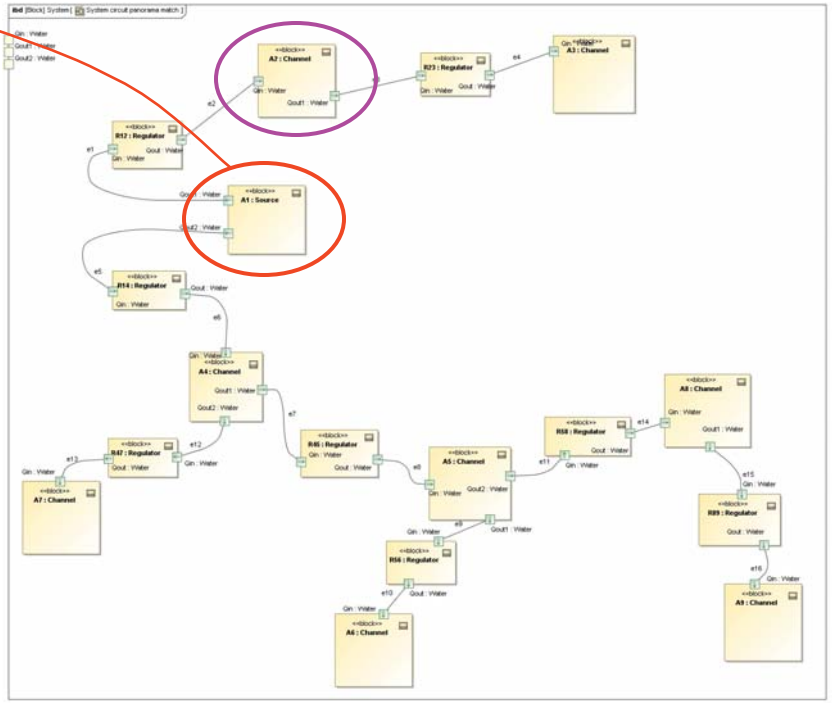
[SystemB_v2h_rsp.mdzip]

Regional Water Mgt. System: Hydrology Model

Model DNA signature (flattened graph “panorama” view)
(auto-generated from SysML parametrics model)







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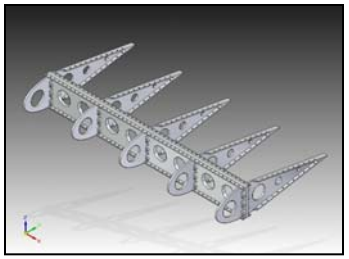
- Space systems (studies/pilots): FireSat (INCOSE SSWG), ...
- Space systems (actuals): science merit function, ...
- Environmentally-conscious energy systems / smart grid
- Manufacturing “green-ness” / sustainability assessments
- Regional water management systems (e.g. South Florida)

  ...
- Mechanical part design and analysis (FEA)

  ...
- Wind turbine supply chain management
- Insurance claims processing and website capacity model
- Financial model for small businesses
- Banking service levels model

  ...

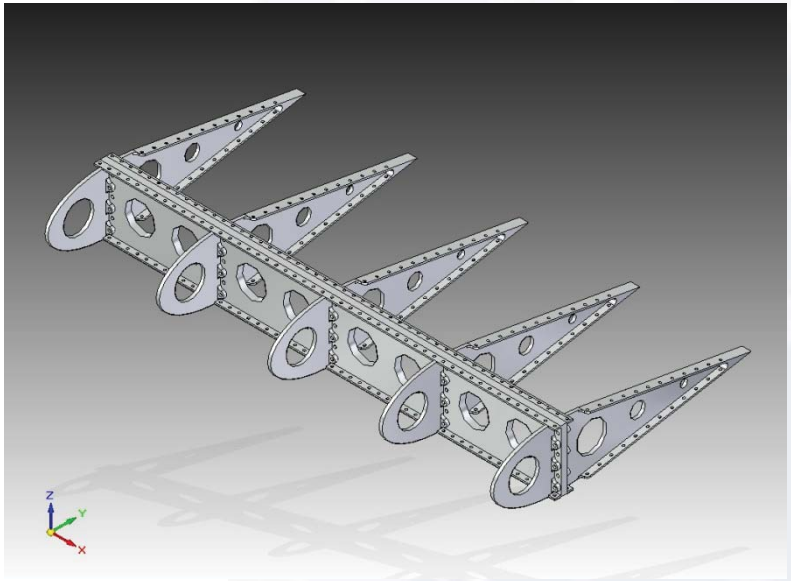


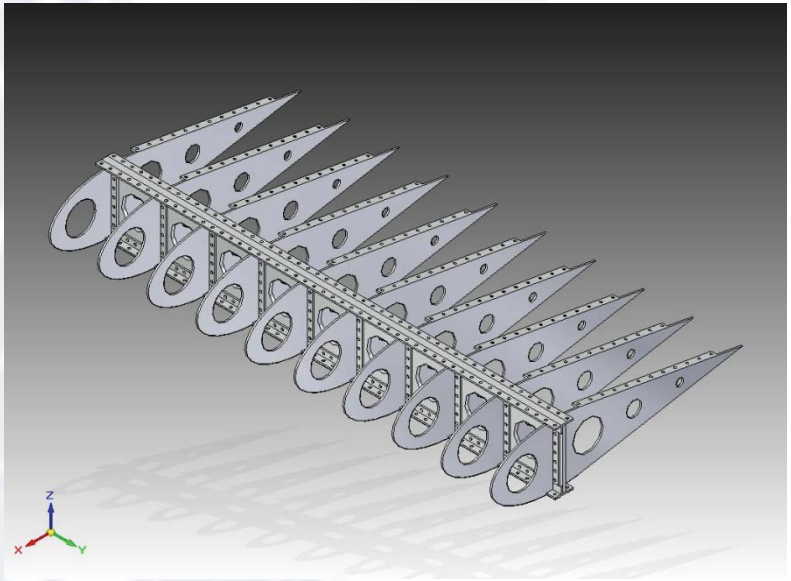
Next-Generation Spreadsheet Technology++
(object-oriented, multi-dimensional, ...)

Using SysML to Evaluate Sustainability Metrics

(similar to Other Metrics: Design Flexibility, ...)

F-86 wing section test case





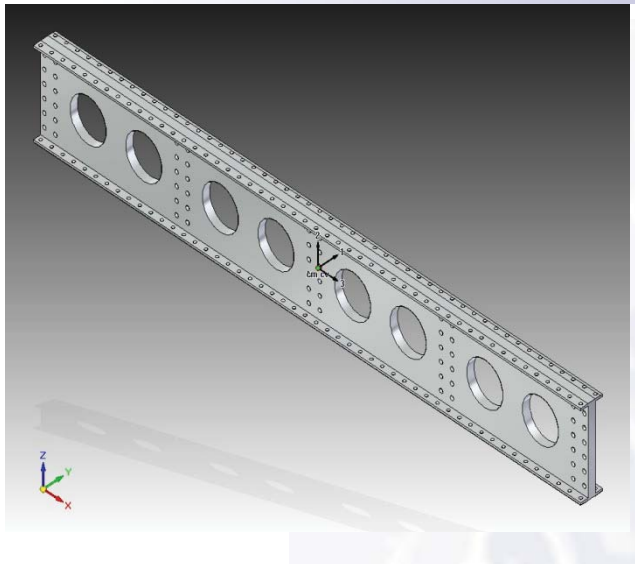
Aluminum Cast and Machined Components
More Room for Internal Parts
Fewer Manufacturing Operations
Heavier

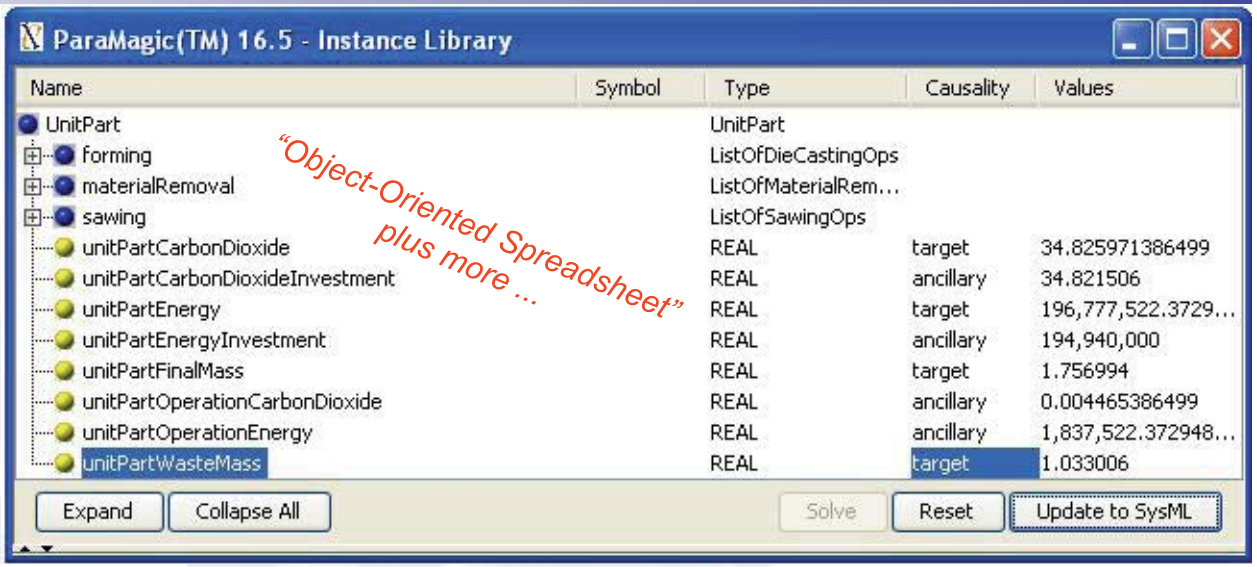
Rolled, Bent, Stamped Sheet Metal
Less Room for Internal Parts
More Manufacturing Operations
Lighter

Source: Bras, Romaniw, et al. 10/2009
www.sdm.gatech.edu

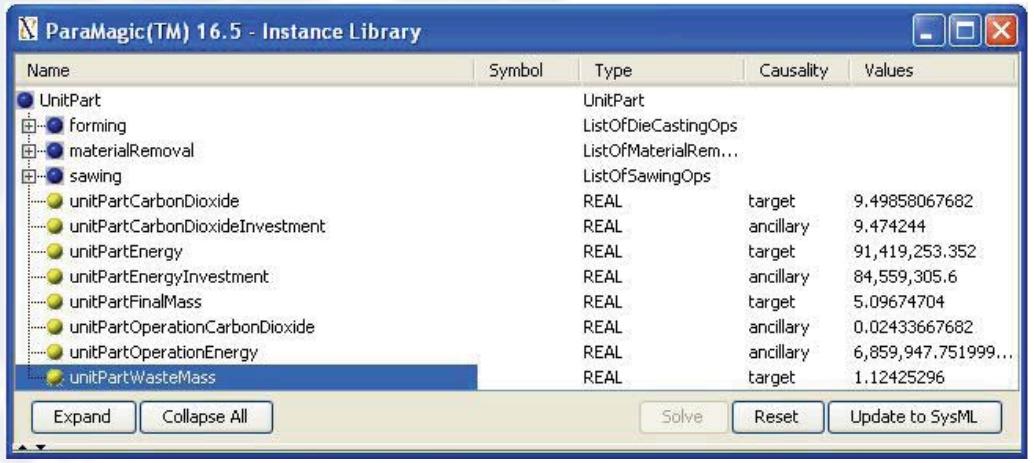
F-86 Wing Section Test Case in SysML Parametrics

Comparing Sustainability Metrics for Design Alternatives





Value	Description	Change Aluminum to Steel
Total Carbon Dioxide	Total CO2 For Life of Part (up to this stage)	-25.3 kg
Total Energy	Total Energy for Life of Part (up to this stage)	-105.4 MJ = -29.3 kWh
Invested Carbon Dioxide	CO2 in Harvesting/Refining Raw Materials	-25.3 kg
Invested Energy	Energy in Harvesting/Refining Raw Materials	-110.4 MJ = -30.7 kWh
Operation Carbon Dioxide	***Manufacturing/Fabrication CO2***	***+0.02 kg***
Operation Energy	***Manufacturing/Fabrication Energy***	***+502.2 kJ = +1.4 kWh***
Final Mass	Final Part Mass	+3.4 kg
Waste Mass	Total Manufacturing Waste Mass	+0.1 kg



Source: Bras, Romaniw, et al. 10/2009

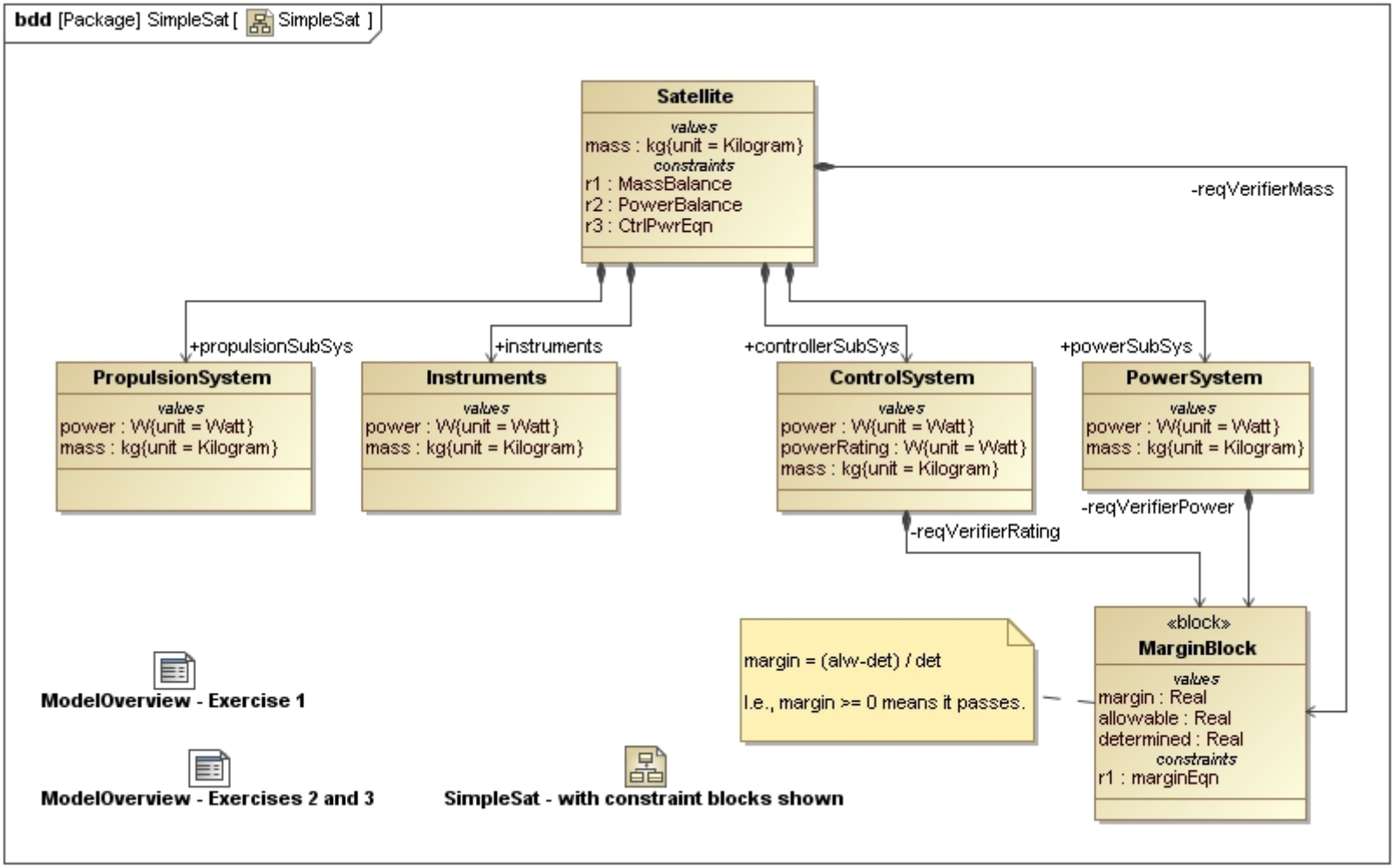
www.sdm.gatech.edu

Additional Background Material

- Recent work with SysML/MBSE/MBX
  - SysML history and usage in industry/government
  - Short courses
  - Research and applications
  - Key techniques
    - SysML parametrics (as basis for pattern implementation)
      - Ex. patterns for requirements verification
    - Model “DNA signatures”
      - Auto-created from SysML parametrics model
    - MIM patterns for modeling & simulation

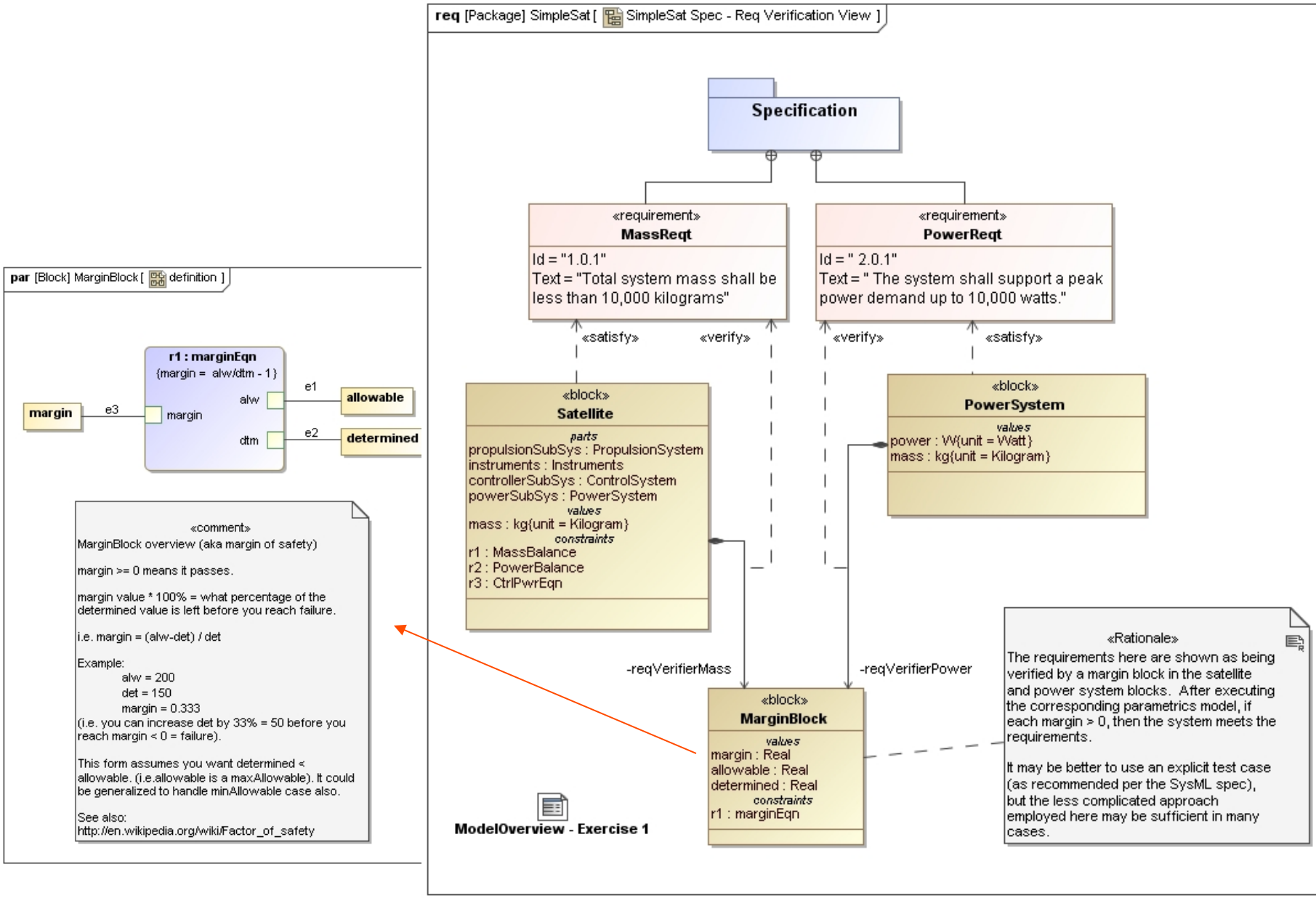
SimpleSat Parametrics Tutorial

bdd depicting model structure



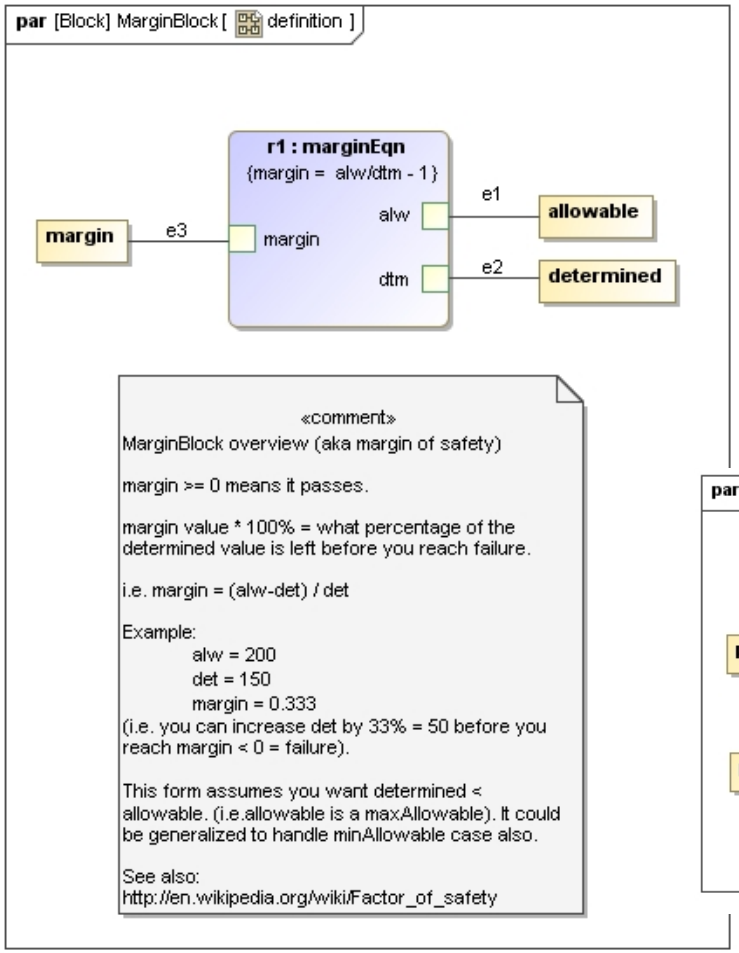
SimpleSat Parametrics Tutorial

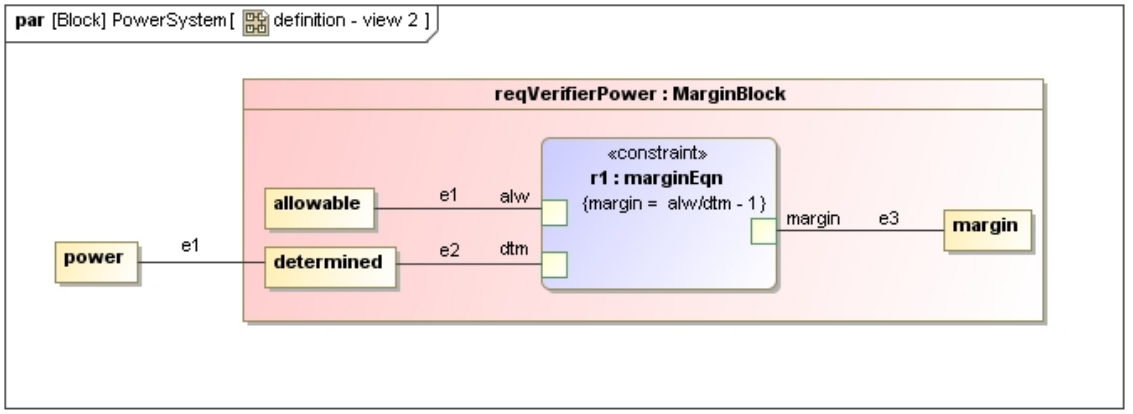
req diagram showing requirements verification pattern

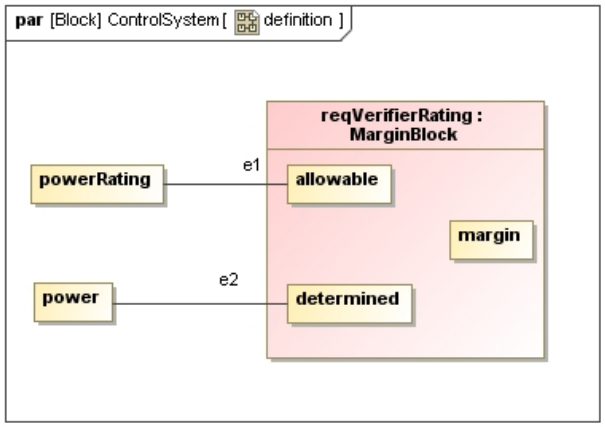


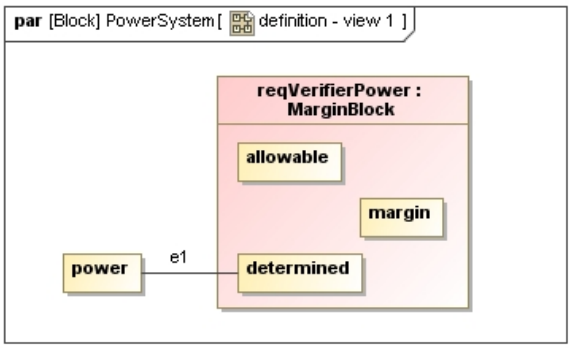
SimpleSat Parametrics Tutorial

par structure of building blocks and subsystems



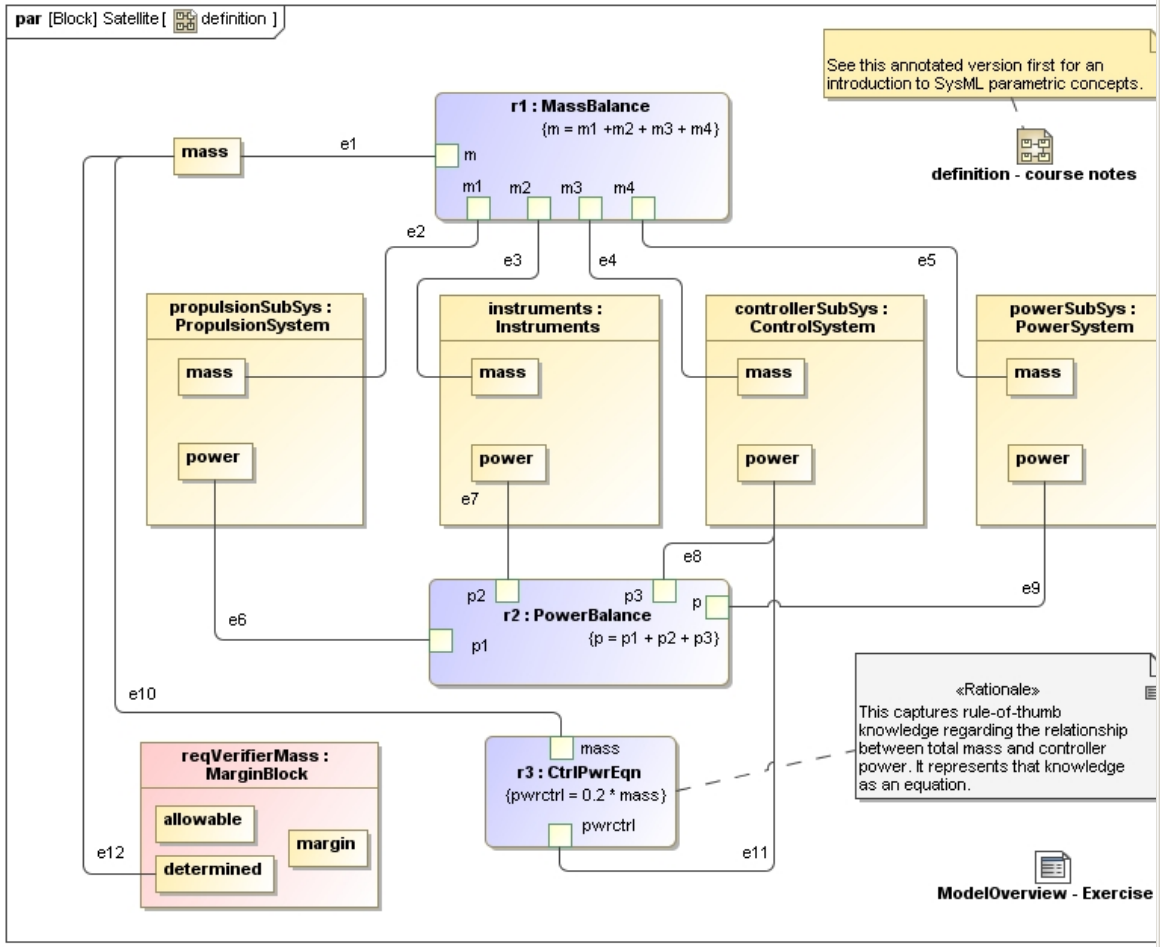


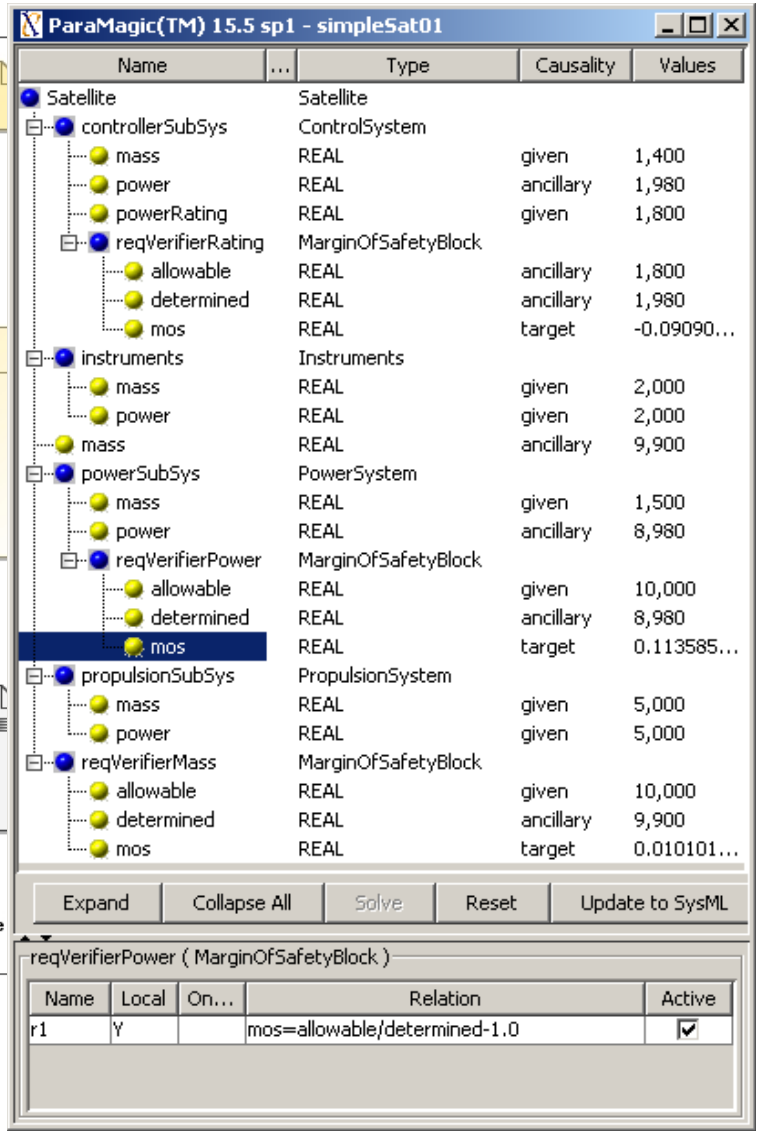




Satellite Tutorial Highlights: SimpleSat

SysML par view and ParaMagic tool for execution

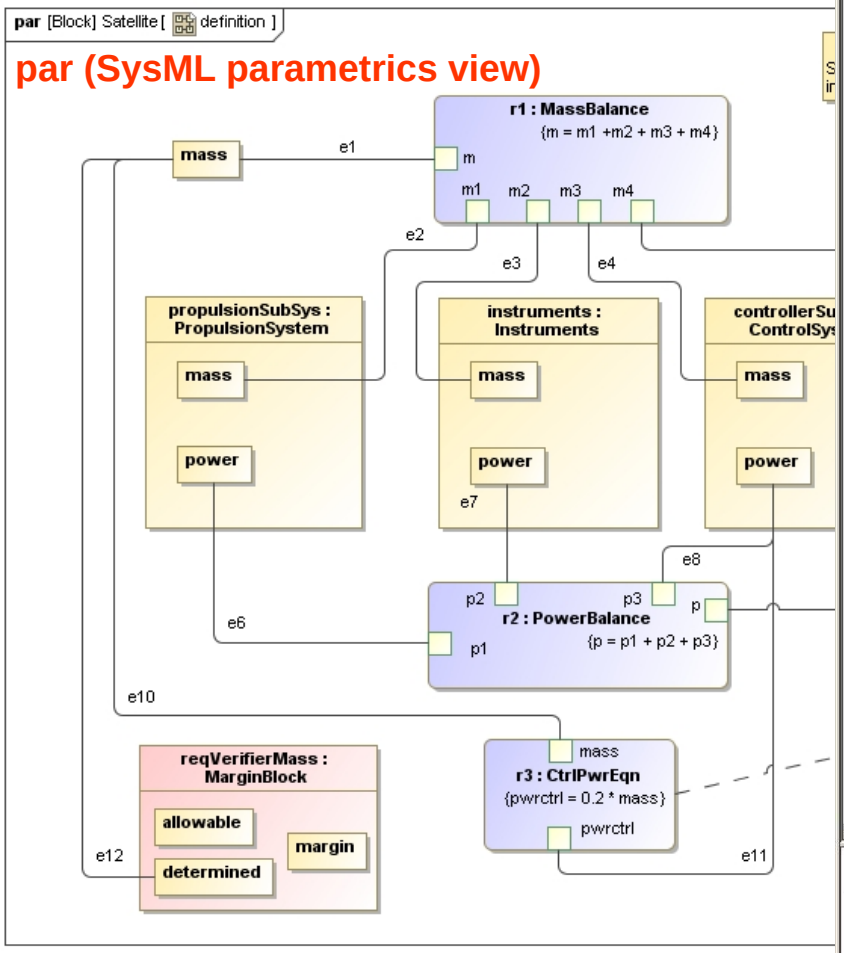


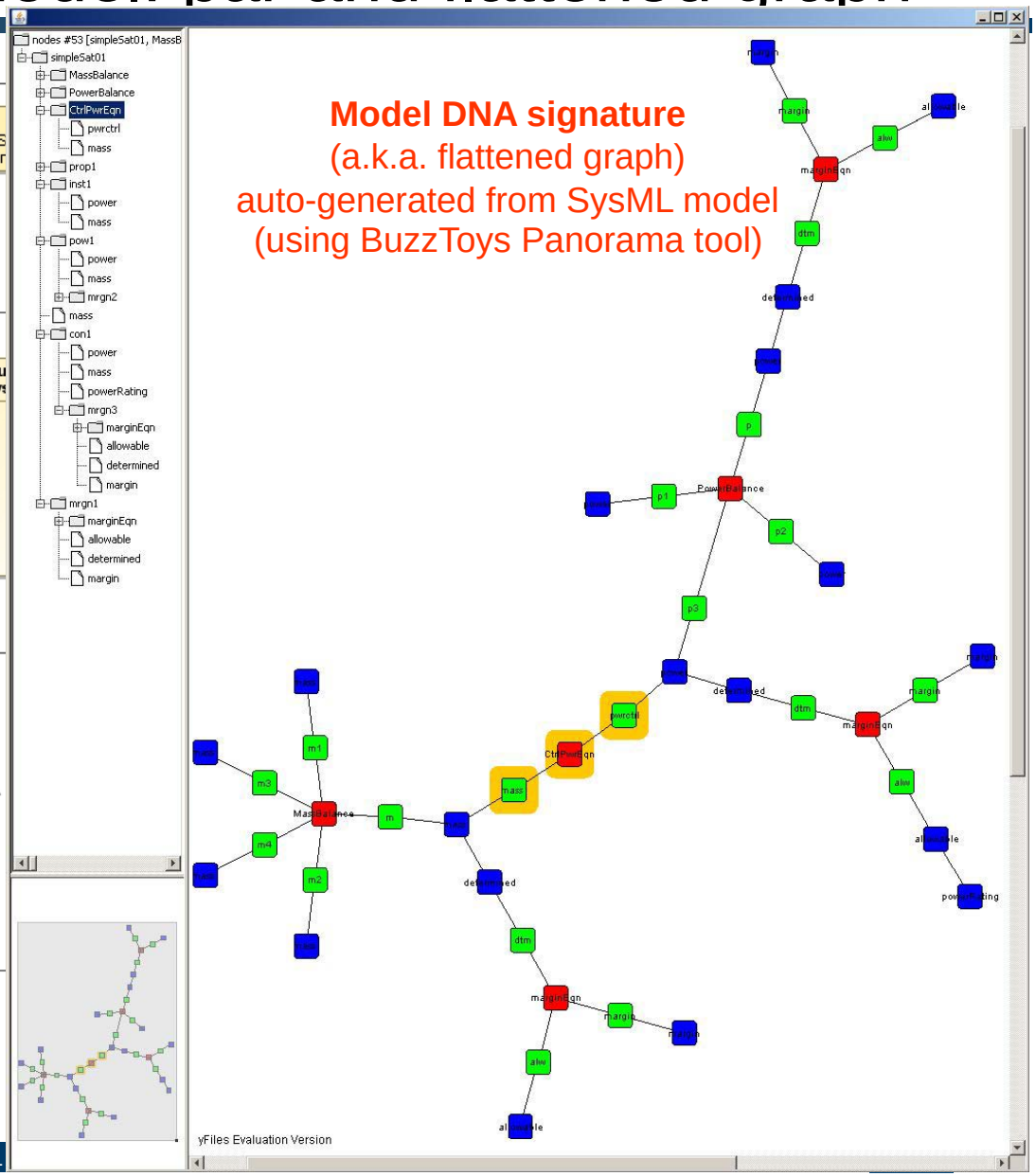


"Object-Oriented Spreadsheet++"

Satellite Tutorial Highlights: SimpleSat

Two views of same model: par and flattened graph





Modeling Interoperability Method (MIM)
Example System Design & Simulation Applications

Applications / Projects - Completed

- Excavator systems – design & mfg
- Airframes - structures
- Electronics - circuit boards
- Electronics - chip package design & analysis
- Mechanical assemblies - part design & analysis (benchmark tutorial)

Applications / Projects - WIP

- Space systems - satellites, etc. (FireSat, etc)
- Automotive - steering wheel systems

Pro Forma Applications

- Airport management - security/emergency response
- Building management - security/emergency response
- Naval/marine ships [including operation]
- UAVs - ~C4ISR [including mfg]
- Firefighting - communication systems - ~C4ISR

“Wiring Together” Diverse Models via SysML

Level 2: Inter-Template Diversity (per MIM patterns)

Naval Systems-of-Systems (SoS) Panorama—An Envisioned Complex Model Interoperability Problem Enabled by SysML/MIM/COBs

Based on HMX 0.1
2008-02-20

c2. Optimization Templates

c0. Context-Specific Models

Legend
- Parametric associativity
- Tool & native model associativity
- Composition relationship (re-usage)

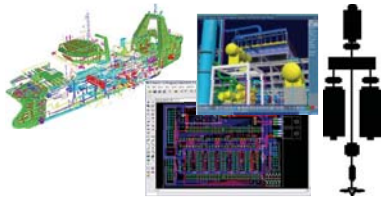
a0. Descriptive Resources

d0. Simulation Building Blocks

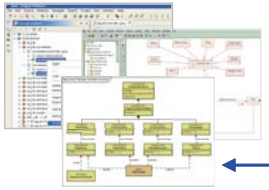
c1. Simulation Templates
(of diverse behavior & *fidelity*)

e0. Solver Resources

ECAD & MCAD Tools
Tribon, CATIA, NX, Cadence, ...

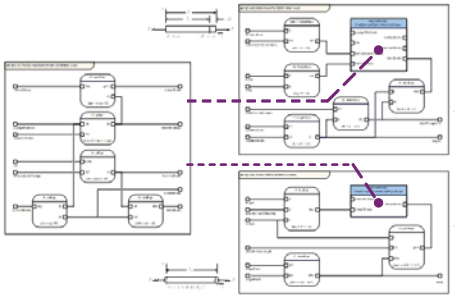


Systems & Software Tools
DOORS, E+ MagicDraw, Studio, Eclipse, ...

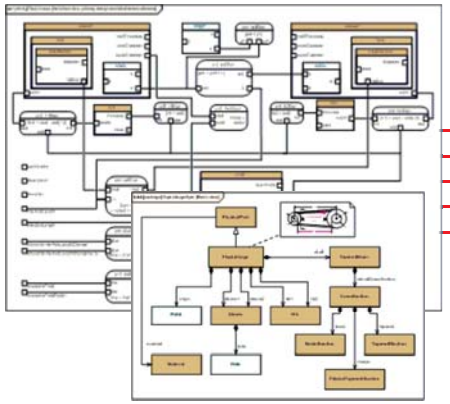


Operation Mgt. Systems

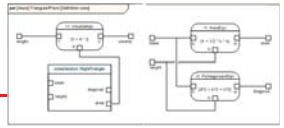
Libraries & Databases
Classification Codes, Materials, Personnel, Procedures, …



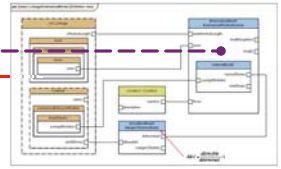
b0. Federated Descriptive Models



Evacuation Mgt.

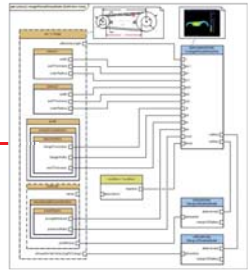


2D

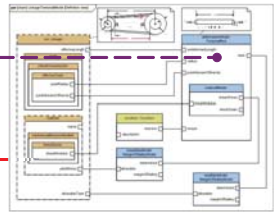


Propeller Hydro-dynamics

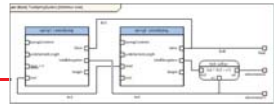
3D



Damaged Stability



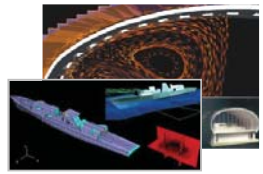
Navigation Accuracy



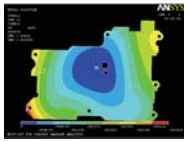
Evacuation Codes
Egress, Exodus, ...

General Math
Mathematica, Maple, Matlab...

CFD
Flotherm, Fluent, ...



FEA
Abaqus, Ansys, Patran, Nastran, ...



Discrete Event
Arena, Quest, ...