SysML Reliability Modeling of Ground Based Systems with Virtualized Architectures

Myron Hecht and Daniel Winton
The Aerospace Corporation

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Organization

- Overview
- A Very Quick Introduction to SysML
- Model Description and Modeling Approach
- Example Result
- Conclusions

Overview

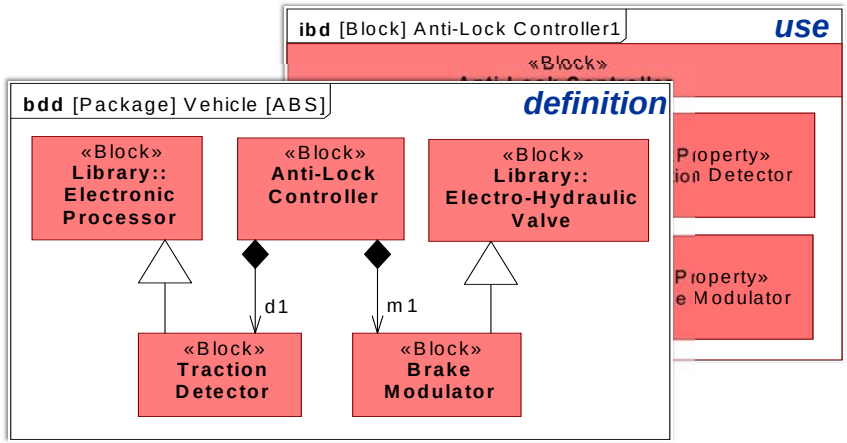
- Question
  - *How can Reliability Modeling and Prediction be Incorporated into SysML models of Virtualized Ground Systems?*
- Motivation
  - *Growing use of SysML*
  - *Significant Potential Benefits for Tightly Integrating Dependability Analysis into System Engineering*
- Method
  - *Package Structure*
  - *Abstract Classes*
  - *Structural and Parametric Models*
  - *Model Transformation and Results*

Reliability and Dependability are Important

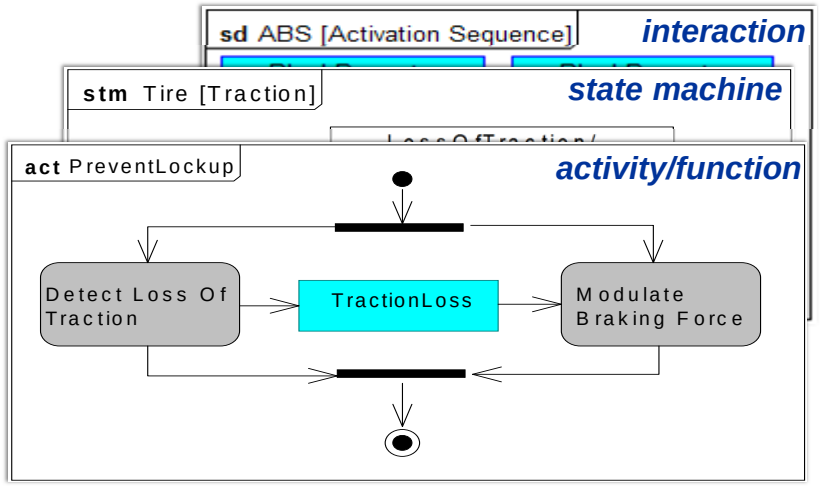
- Required by Law
  - *Public Law 111-123 "Weapons System Acquisition Reform Act of 2009," Section 102 (codified as 10 USC 4 Section 139d)*
- DoD Policies
  - *CJCSI 3170.01, "Operation Of The Joint Capabilities Integration And Development System," May, 2007: " Materiel Availability and Operational Availability as Key Performance Parameters (KPPs) Reliability and Ownership Costs as Key System Attributes"*
  - *DTM 11-03 "Reliability Analysis, Planning, Tracking, and Reporting", OUSD AT&L, March 21, 2011*
- Investment in RMA Pays Off
  - *See GAO 2003 and DLA reports: Predator, Global Hawk cited as showing Return on Investment of Reliability Improvement of 5:1 to 128:1*

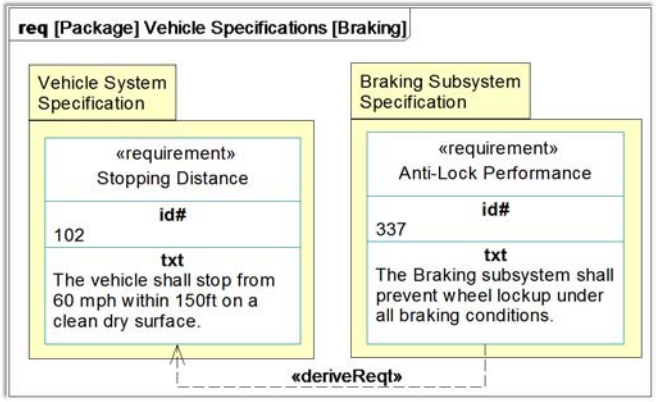
A Very Quick Introduction to SysML

1. Structure

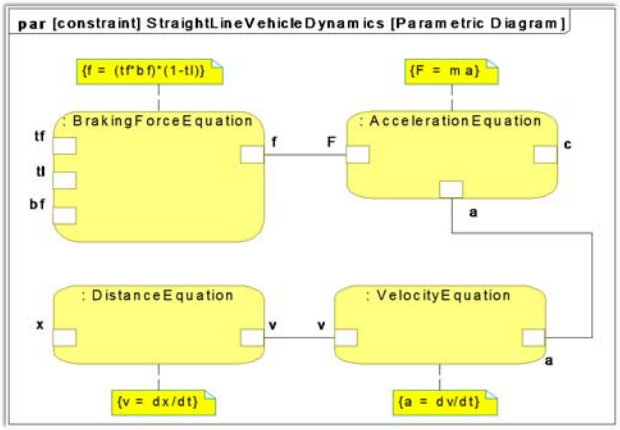


2. Behavior





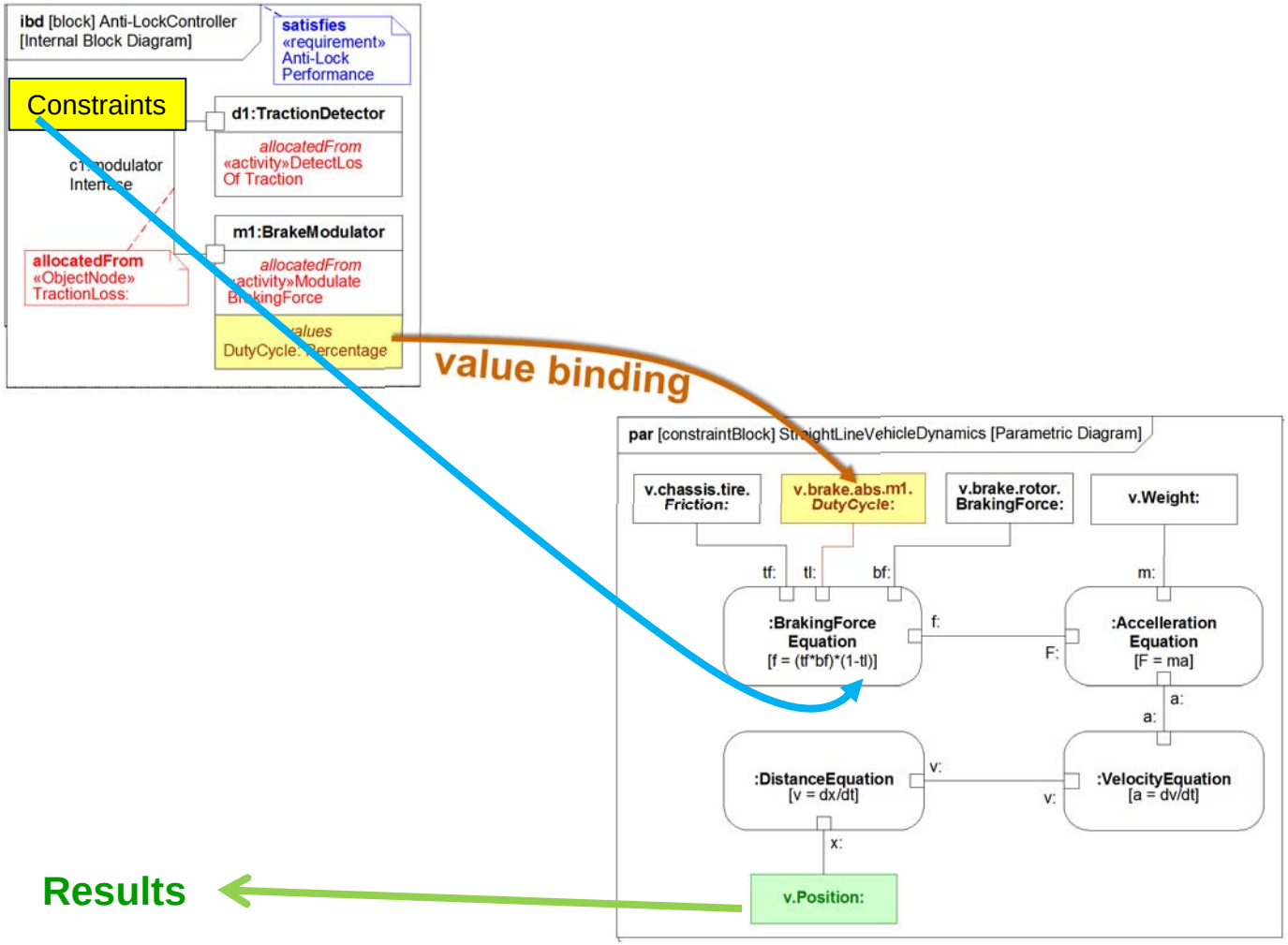
3. Requirements



4. Parametrics

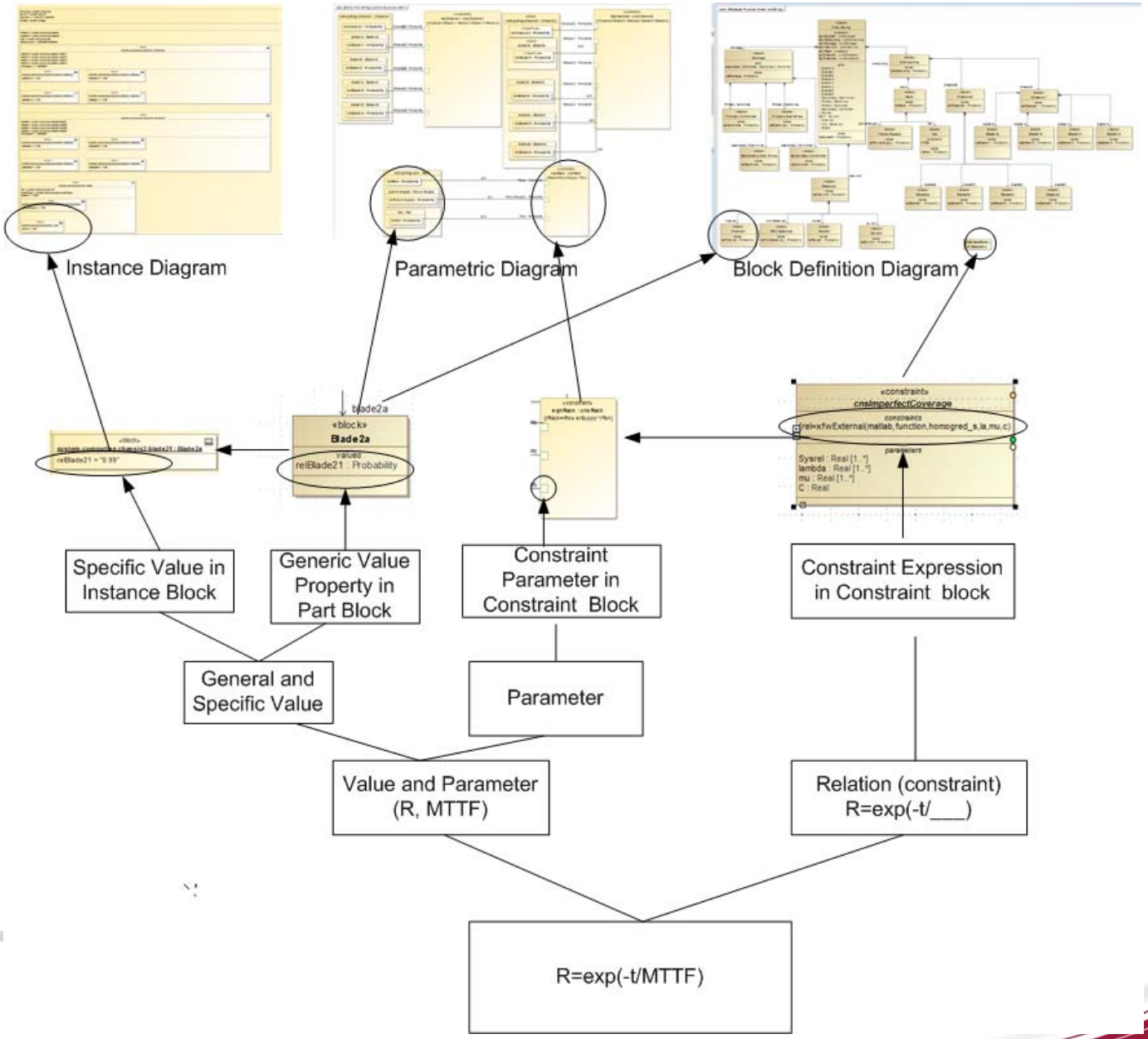
Parametric Analysis with SysML (top level)

1. Structure



4. Parametrics

Ingredients of a SysML Parametric Analysis



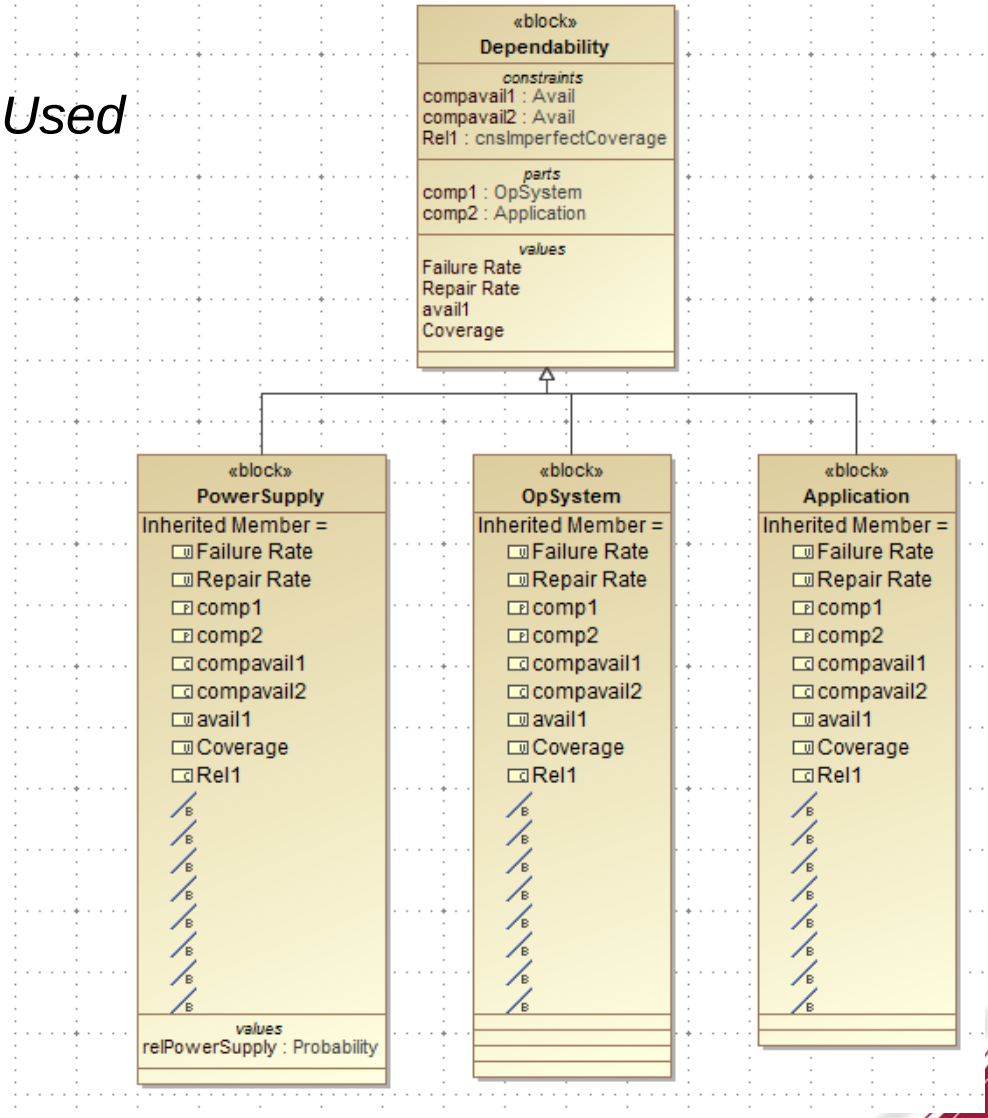
Model Packages

- Documentation
  - *Both source documents and documentation of the model*
- Abstract Classes
  - *Classes contain properties and behaviors that component blocks inherit*
- System
  - *Component Blocks*
  - *Block Definition Diagrams for composition of system, subsystem, and components*
  - *Internal Block Diagrams for connectivity*
- Constraints-Parameters
  - *Constraint blocks for equations*
  - *Parametric diagrams for relations*
- ValueTypes
  - *Units in the model*
- Instances
  - *Separate package for each instance: Blocks and relations*

Abstract Classes Package

SysML Block Definition Diagram Used as a Class Diagram

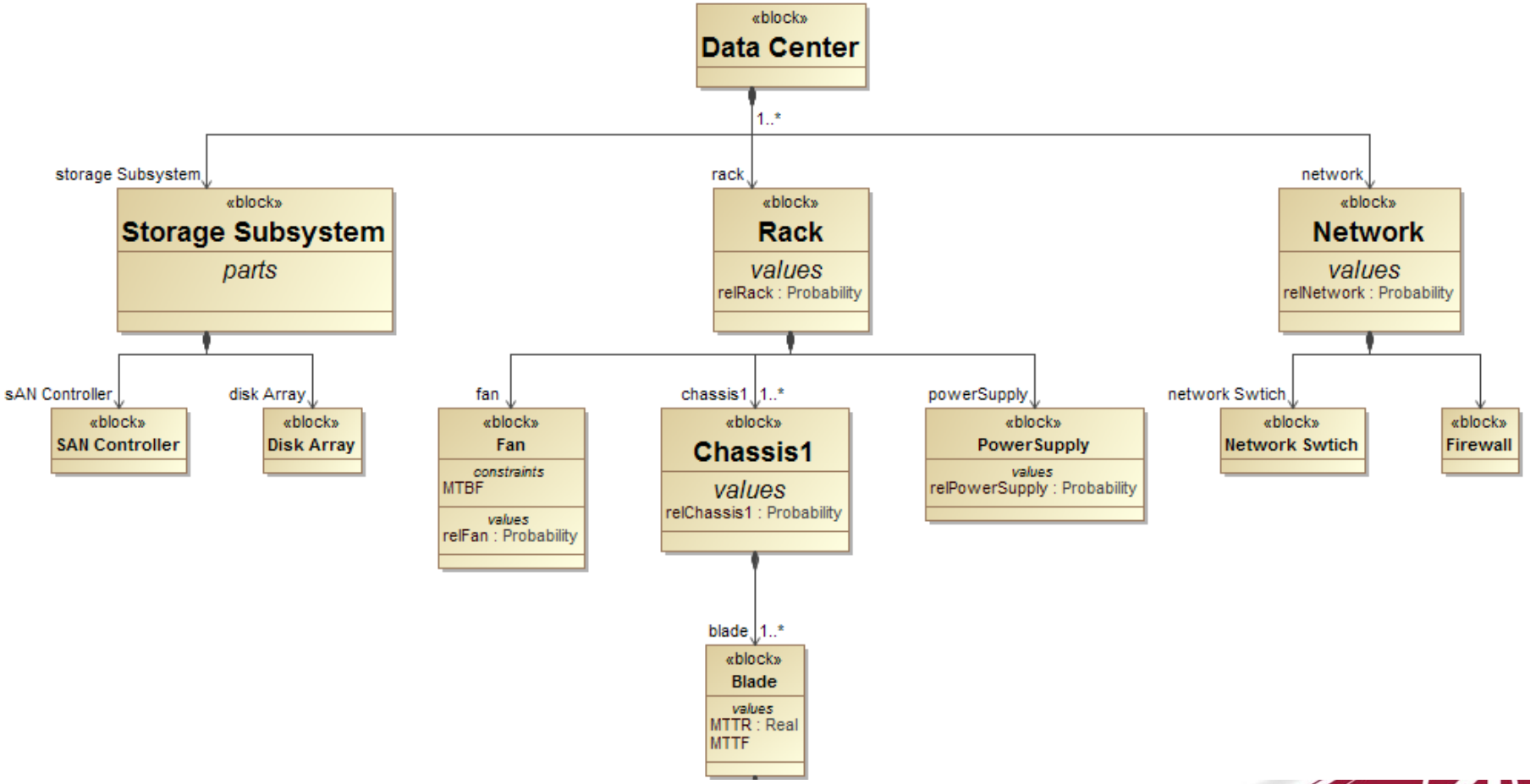
- Properties propagated to all child components
- Transverses composition hierarchies
- Examples
  - Reliability/Availability
  - IT Security
  - Failure Behavior
  - Capacity and response time
  - Facility requirements



System Model

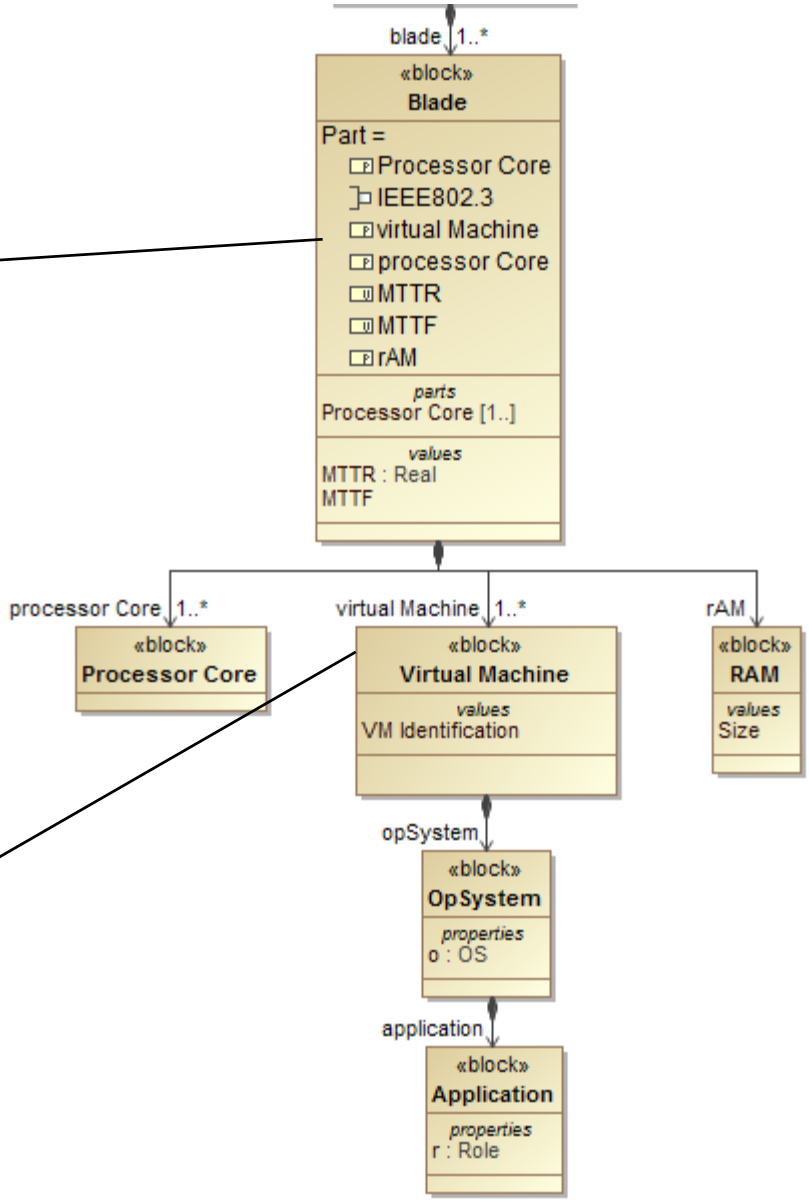
Block Definition Diagram

- The SysML Block Definition shows the blocks bound with directed composition arrows



Virtual Machines

Part Properties

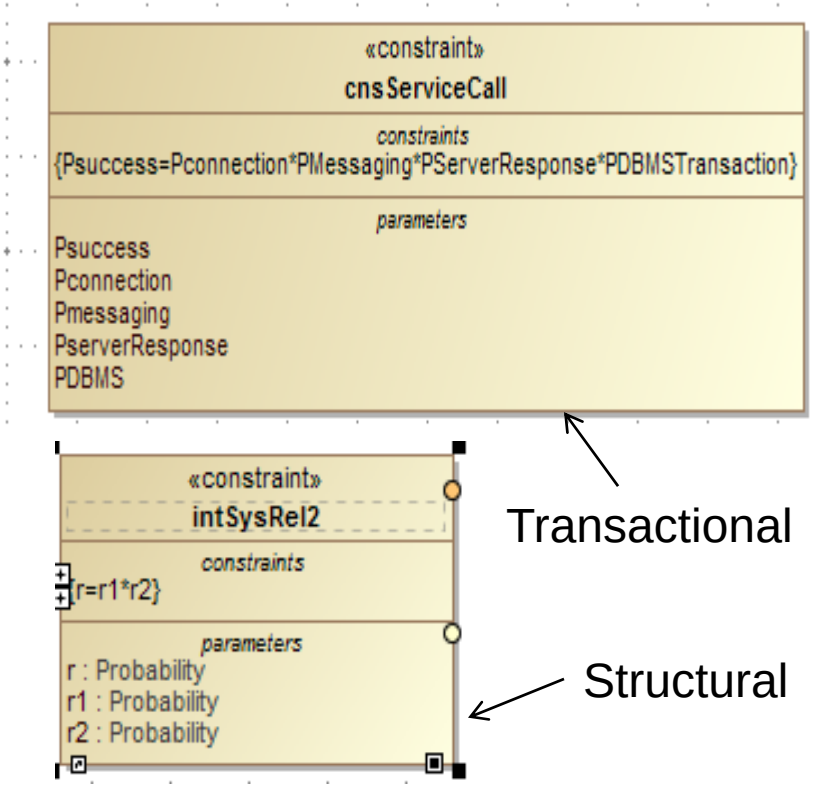


Assumes Static Allocation of Virtual Machines to Processors (if not, virtual machines become part of Data Center Block)

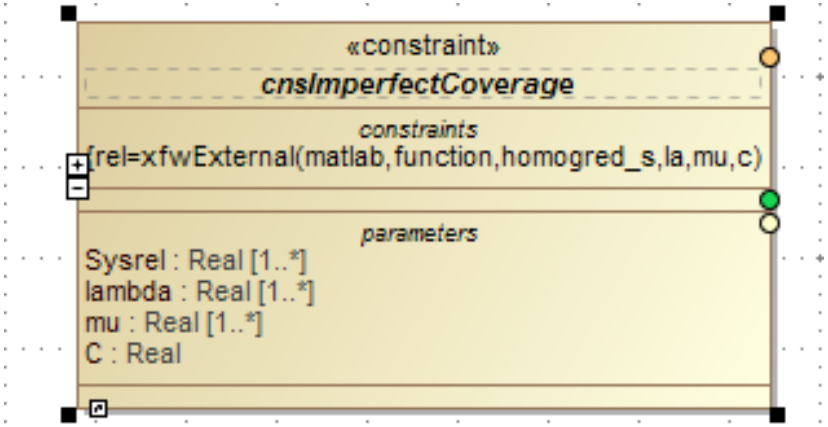
Constraints and Parameters Package

Constraint Blocks

- Internal Constraint Blocks
  - *Use restricted syntax of SysML constraint language*



- External Constraint Blocks
  - *Allows for more complex functionality*

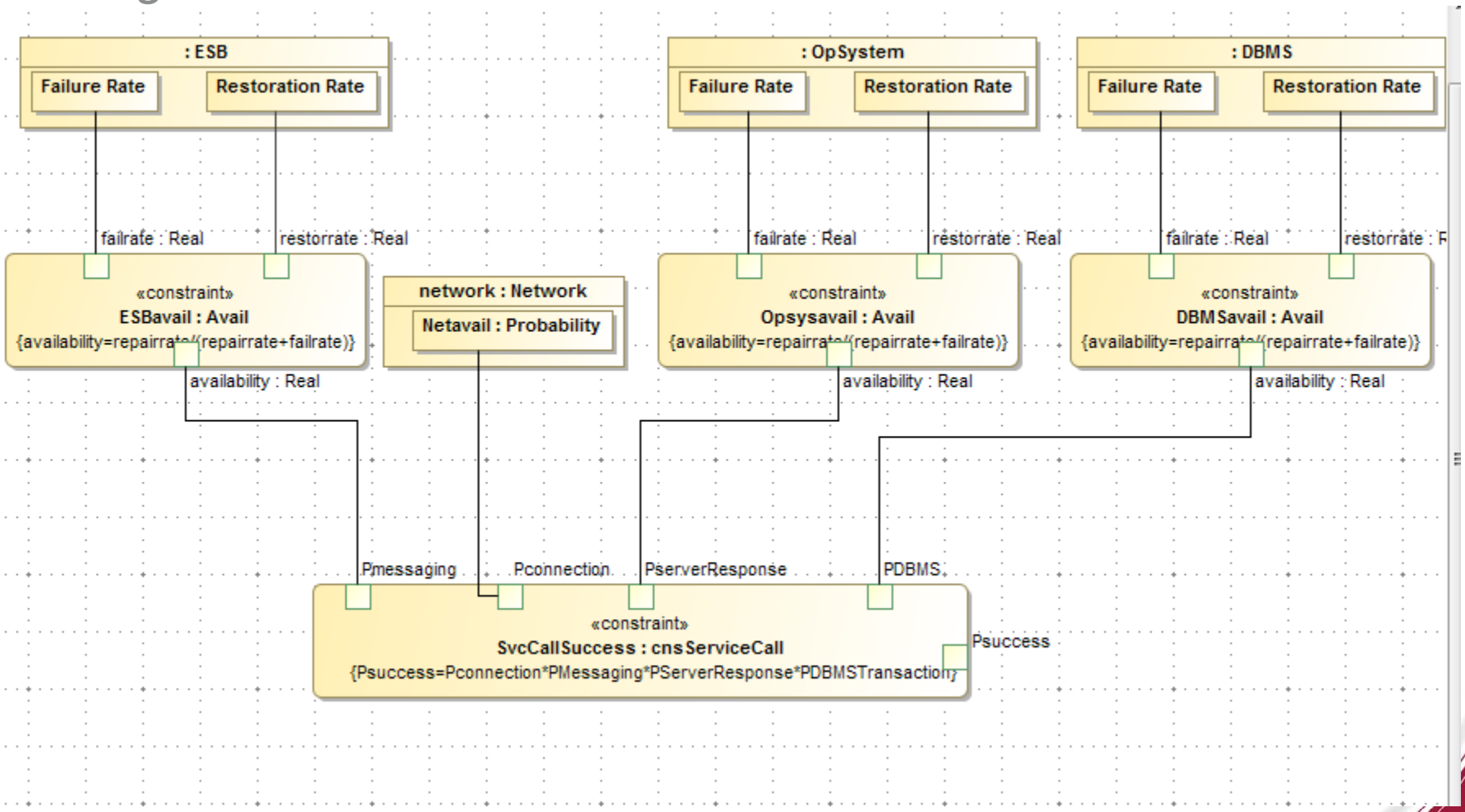


$$\begin{pmatrix} P_0 \\ P_1 \\ P_2 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & 1 & 1 \\ (1+c) & \lambda-(\mu+\lambda) & 0 \\ (1-c) & \lambda & -\mu \end{pmatrix}^{-1}$$

Internal Constraint Blocks can be mixed with Externals

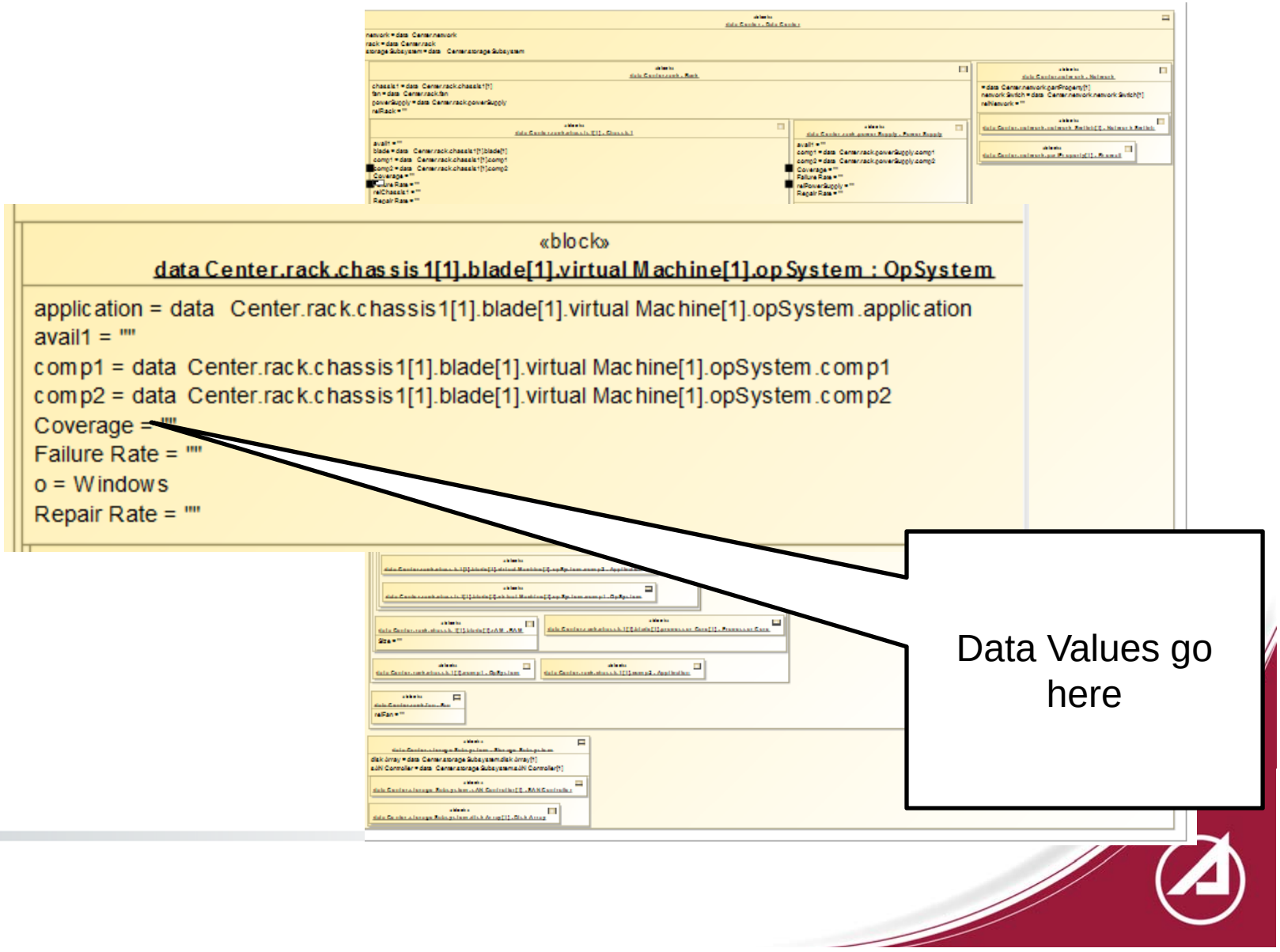
Parametrics Diagrams

Linking Constraints with Parameters



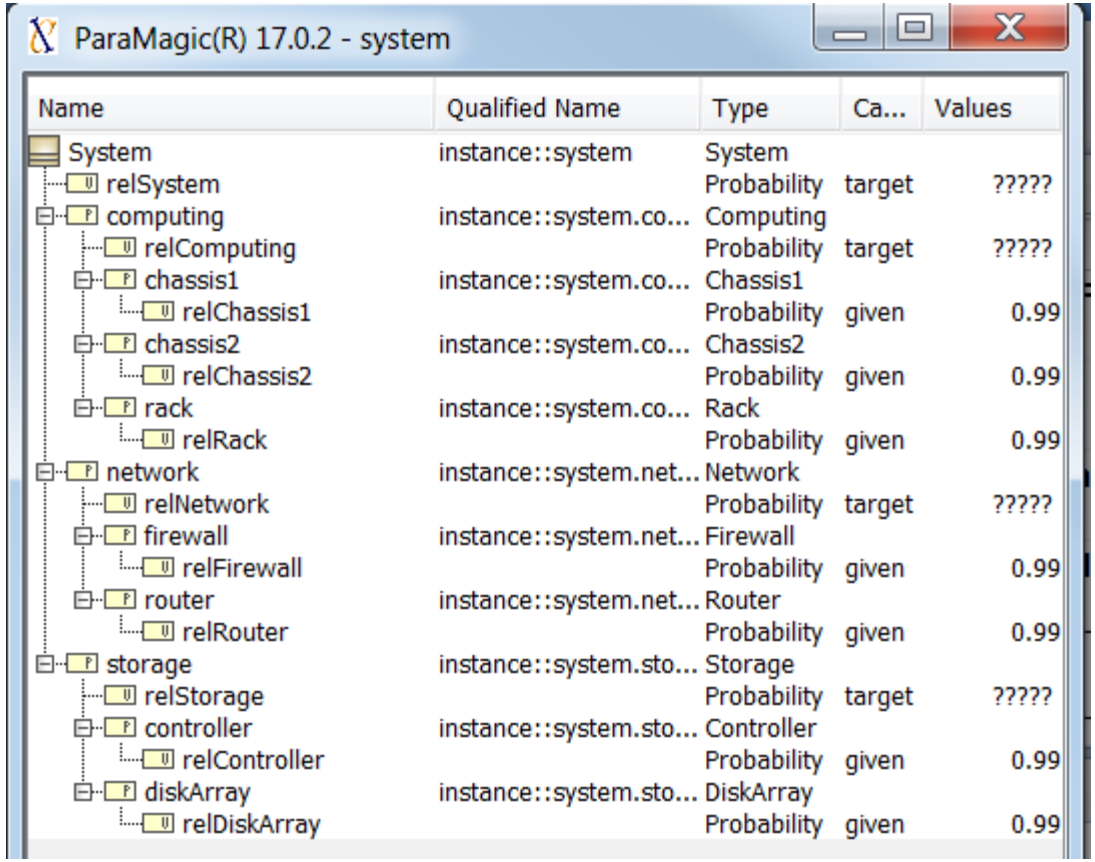
Instantiation of the Ground System Model

Block Definition Diagram in Instance Package



Part V Solve the Instance

Parameter Assignment for Paramagic Solution

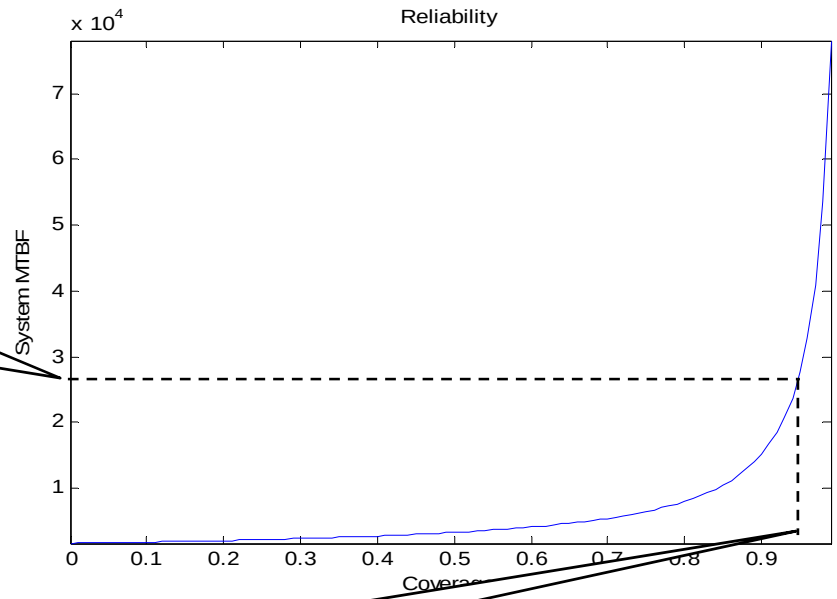


Name	Qualified Name	Type	Ca...	Values
System	instance::system	System		
relSystem		Probability	target	?????
computing	instance::system.co...	Computing		
relComputing		Probability	target	?????
chassis1	instance::system.co...	Chassis1		
relChassis1		Probability	given	0.99
chassis2	instance::system.co...	Chassis2		
relChassis2		Probability	given	0.99
rack	instance::system.co...	Rack		
relRack		Probability	given	0.99
network	instance::system.net...	Network		
relNetwork		Probability	target	?????
firewall	instance::system.net...	Firewall		
relFirewall		Probability	given	0.99
router	instance::system.net...	Router		
relRouter		Probability	given	0.99
storage	instance::system.sto...	Storage		
relStorage		Probability	target	?????
controller	instance::system.sto...	Controller		
relController		Probability	given	0.99
diskArray	instance::system.sto...	DiskArray		
relDiskArray		Probability	given	0.99

Results of Quantitative Model: Derived recovery probability requirement

Coverage, failure rate, and restoration rate from SysML model were transformed by Paramagic and analyzed using a Matlab Function

MTBF requirement of 2500 hours



Derived Replicated virtual server recovery probability requirement of 0.95

Conclusions

- SysML can support quantitative analysis of ground systems with virtualized architectures
  - *Methodology, Approach, and Results Demonstrated*
- Benefits
  - *Integration with system baseline*
    - Models can be immediately evaluated for conformance with dependability, safety, and other related requirements
    - Traceability of conformance to requirements up through the TRD and into the CDD KPPs and KSAs
  - *Reduce cost and schedule impacts of*
    - Evaluation of change proposals
    - Demonstrating compliance with RMA requirements and
    - Architecture and design rework in the event of non-compliance

References

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- MATLAB version R2013a: http://www.mathworks.com
- Paramagic User's Guide, InterCAX, http://www.intercax.com, © 2013
- SA Friedenthal, A. Moore, R. Steiner, *A Practical Guide to SysML,* The MK/OMG Press, www.mkp.com, © 2012 http://www.elsevierdirect.com/product.jsp?isbn=9780123786074
- RS Peak, RM Burkhart, SA Friedenthal, MW Wilson, M Bajaj, I Kim (2007) Simulation-Based Design Using SysML—Part 1: A Parametrics Primer. INCOSE Intl. Symposium, San Diego.