Integrated Modeling and Analysis to Support Model Based Systems Engineering (MBSE)

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10/24/12

PHOENIX INTEGRATION

DESIGNPROCESSOPTIMIZATION

Phoenix Integration

- Provide engineering software and services to customers in aerospace, defense, and related industries
- 16 year history
- US based; Evolved out of a research program at Virginia Tech
- Office locations
  - Philadelphia, PA (Corporate)
  - Blacksburg, VA (R&D)
  - California (Sales)
  - Northeast (Sales)
  - Toulouse, France
- World-wide sales in North America, Europe, and Asia

PHOENIX INTEGRATION

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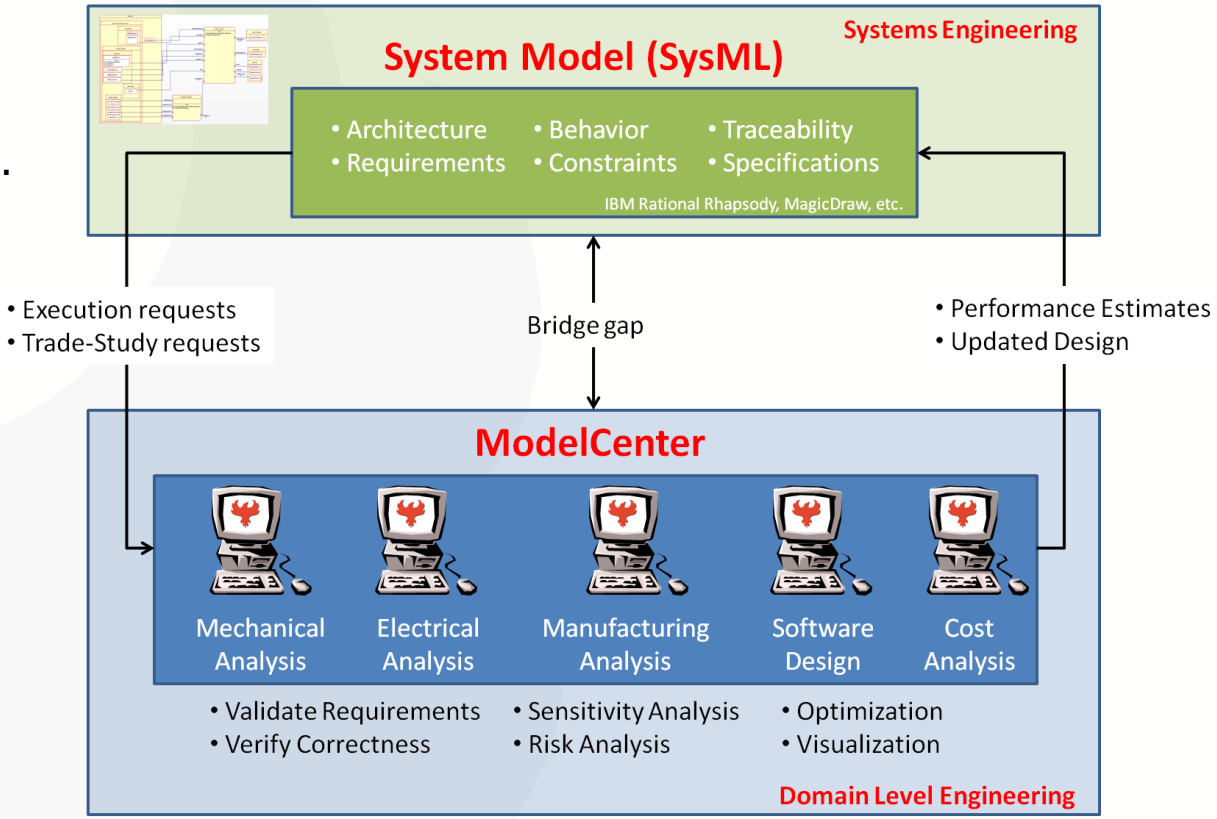
Company Mission

Help customers in the aerospace, defense, and related industries fully realize the value of modeling and simulation tools

- Explore more design alternatives
- Make better design decisions
- Reduce time to market

Summary: DARPA SBIR Phase II

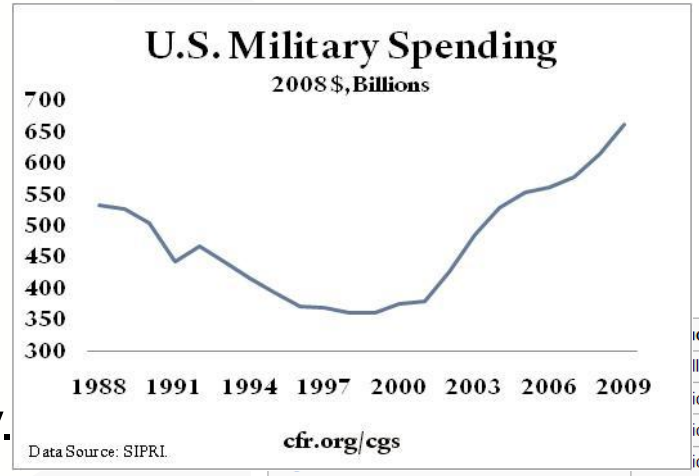
- Lower program costs by connecting SysML and engineering analysis tools.
- Result: MBSE Pak
  - Jan. 2013 release
- Lead: Hongman Kim
  - David Fried
  - Ingrid Liu
  - Andy Gardner
  - Sandy Friedenthal
- $750 K
- 2 yrs: 1/12 – 3/14 w/ 2 yr option



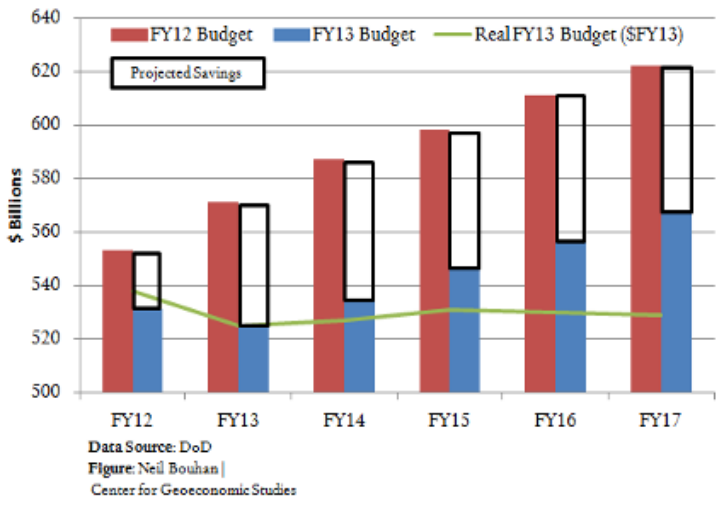
"An Integrated Model Based System Development Capability for Integrating Architecture Design, Analysis, and Verification of Large Scale Complex Systems"
DARPA Contract # W31P4Q-12-C-0049

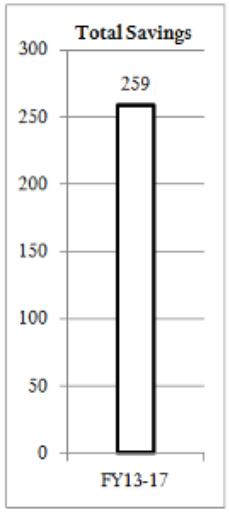
Current Defense Procurement Issues

- DoD procurement is expensive and has been rising rapidly.
- Cost control on MDAP (major defense acquisition programs) has become mandatory.
- Programs are still high risk, high collaboration, and high tech
- Requirements changes are particularly onerous
- How do we manage this?
- How does engineering help?



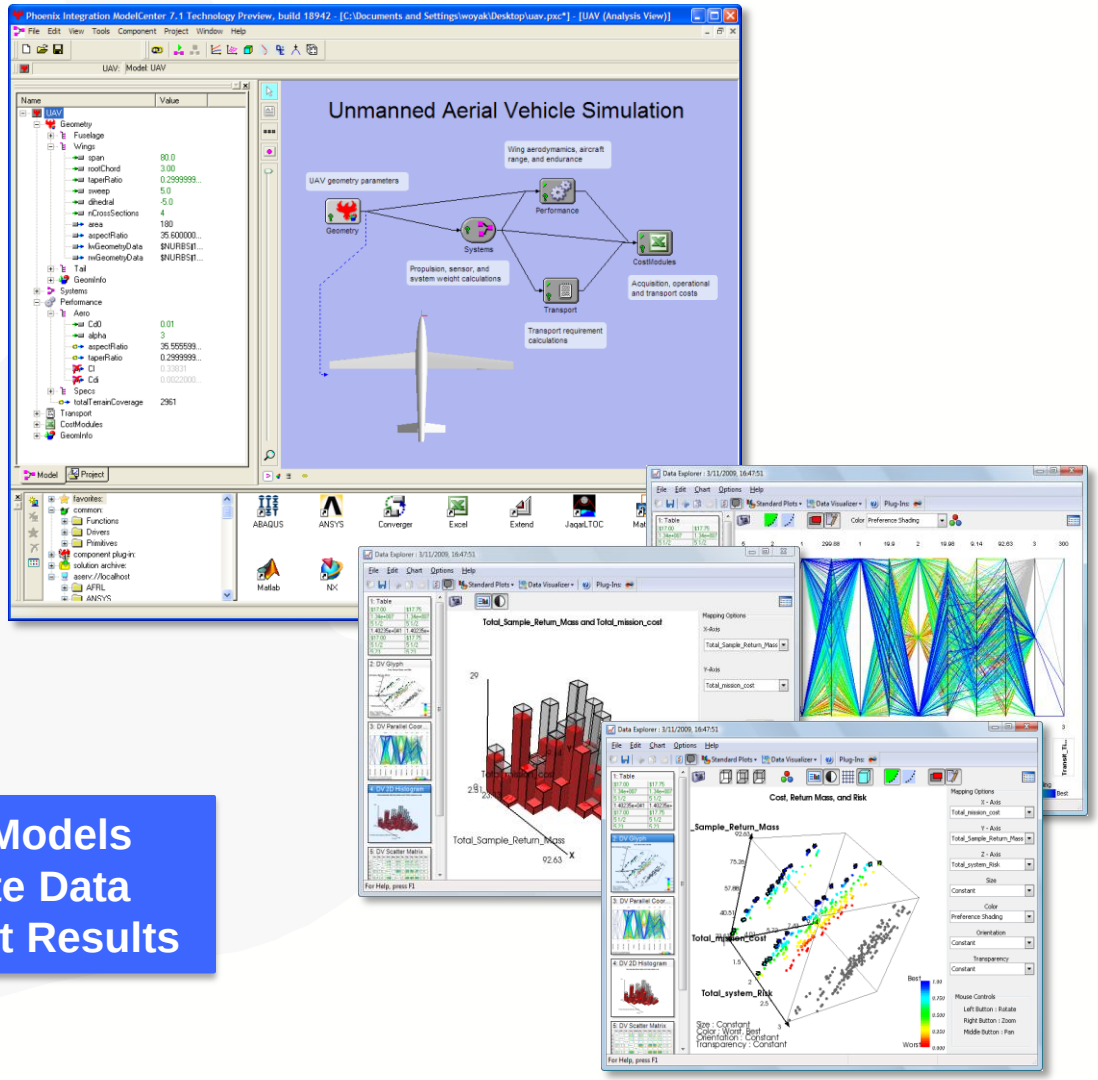
		dget request[11]	Change, 2010 to 2011
		llion	+2.1%
		ion	+7.3%
		ion	+28.0%
		ion	+21.8%
DDG 51 Burke-class Aegis Destroyer	$3.0 billion		+19.6%
P–8A Poseidon	$2.9 billion		−1.6%
V-22 Osprey	$2.8 billion		−6.5%
Carrier Replacement Program	$2.7 billion		+95.8%
F/A-18E/F Hornet	$2.0 billion		+17.4%





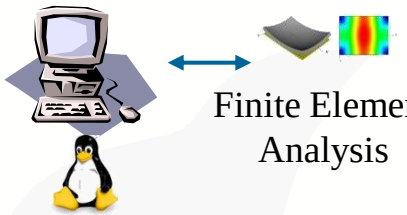
ModelCenter

- Visual environment for process integration
- Graphically link analyses together
- Automatically transfer data from analysis to analysis
- Reduce data transfer errors
- Save time
- Perform trade studies to find better designs



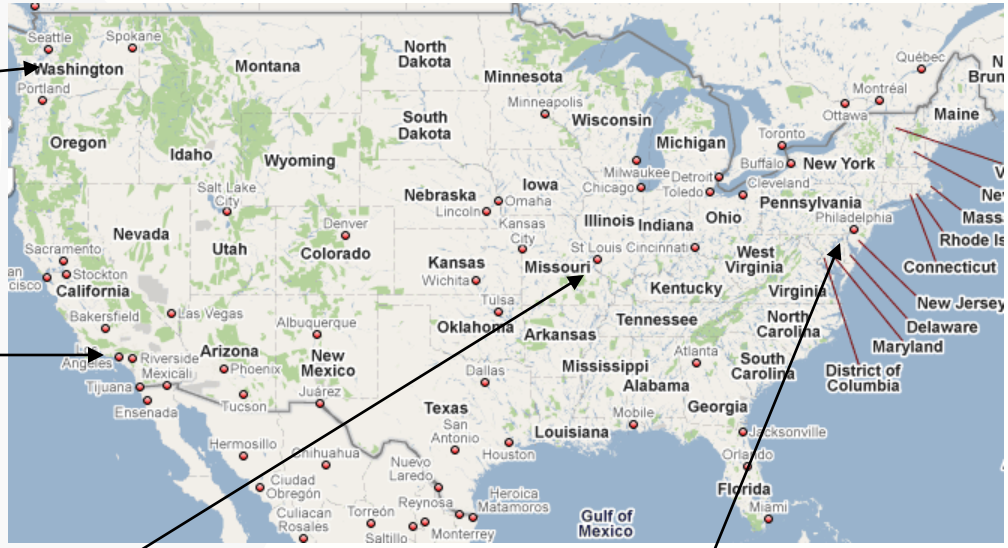
1. **Create Models**
2. **Generate Data**
3. **Interpret Results**

Analysis Server



Finite Element Analysis

Analysis Server



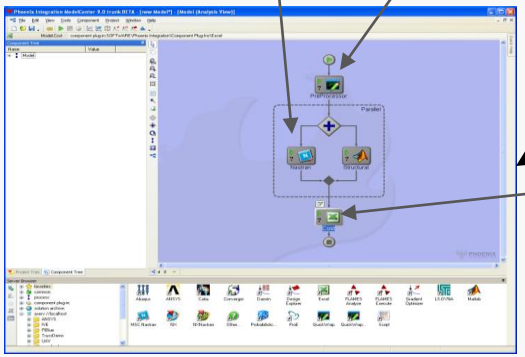
In-house FORTRAN

Analysis Server

Network (LAN or WLAN)

Excel

Analysis Server



ModelCenter

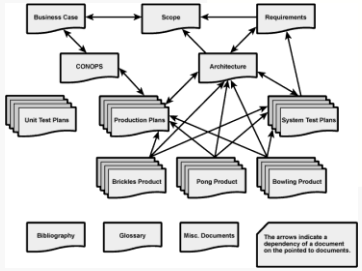
So what's the problem?

- Still have engineering disciplines working in silos
- ModelCenter / Analysis Server are engineering-centric, not program/project-centric
- Need to put engineering analysis in the context of system design
- Tools / methods for systems engineering are already established

The Solution – MBSE

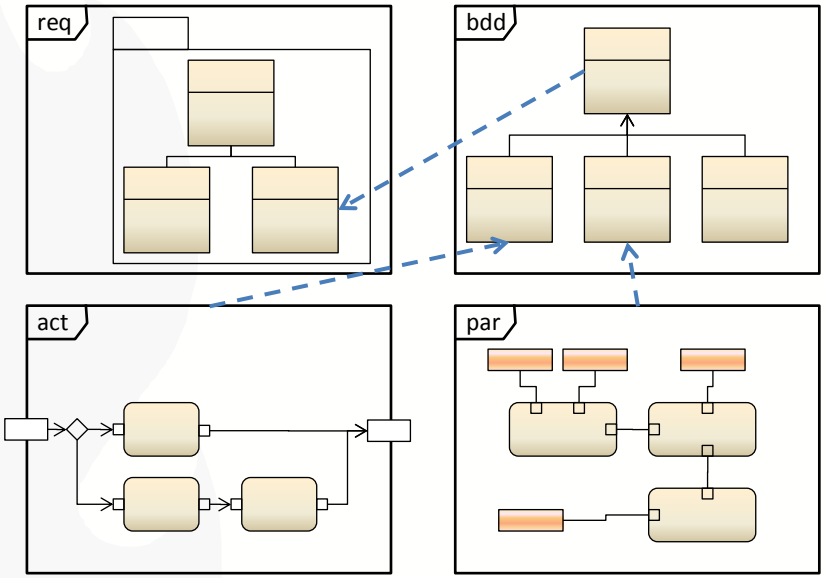
Model Based Systems Engineering

Requirements



Design

Tests



Document-based approach (traditional)

The trend toward MBSE is like the trend toward CAD of previous years

Model-Based Systems Engineering

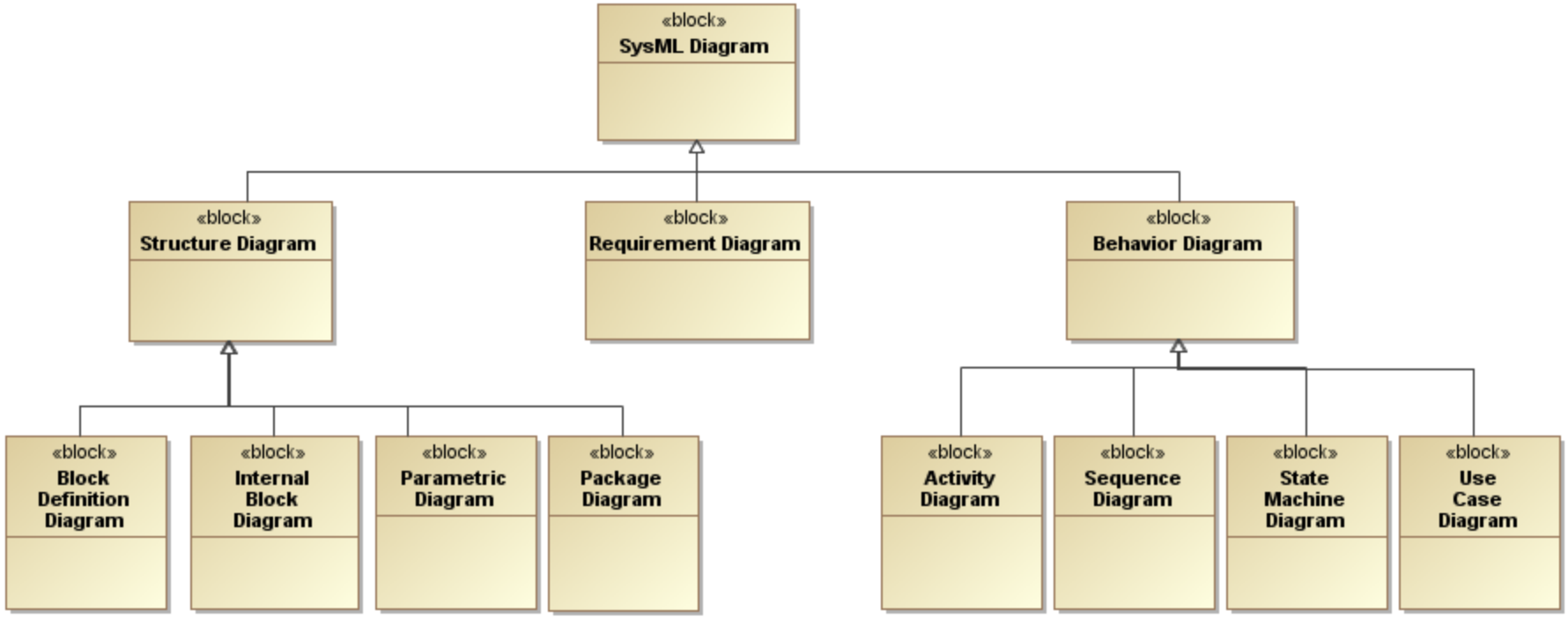
- **Improve understanding**
- **Improve communication**
- **Reduce inconsistency and error**

Benefits of MBSE with ModelCenter

- Ties together systems engineering & management documents
  - Improved communication across functional layers and between engineering levels
  - Everything is documented in the master model
- Ties systems engineering to executable engineering models
  - Full traceability from requirements to analytical models to test results
  - Trade studies can be performed very early in the process
- Ties requirements to analysis parameters in the design process
  - Rapidly respond to inevitable changes in requirements
- Ties disciplines together at the systems level rather than at the domain level
  - No more implicit interaction between engineering groups

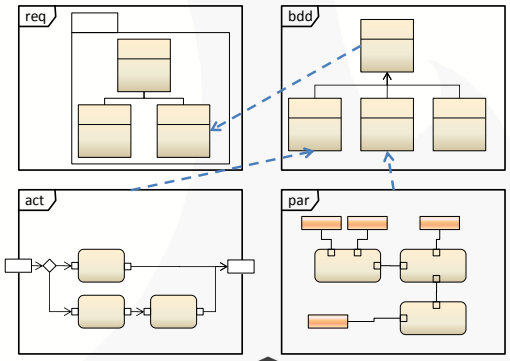
SysML (System Modeling Language)

- SysML is a modeling language for systems engineering
  - Extension of UML
  - OMG standard since 2007
  - Combine various diagrams to define requirements, structure, and behavior of the system
  - Parametric diagram is used to define parametric relationships among system attributes that may require engineering analysis



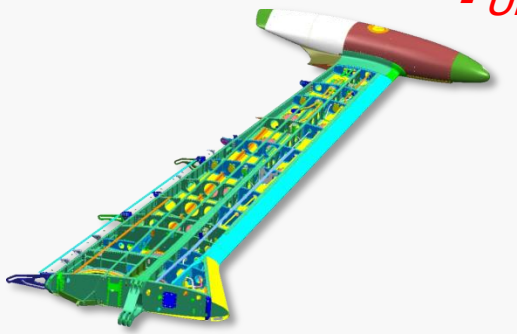
Gap Between Systems Engineering and Engineering Analysis

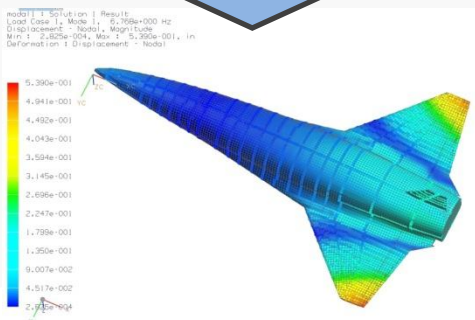
- Tools, models, and terminology are different
- SysML models are descriptive in nature
- The gap causes inefficiencies and errors



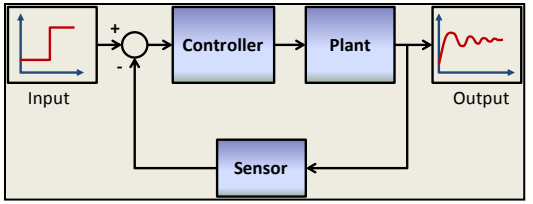
Systems engineering model

- Error Prone
- Slow
- Expensive
- Unresponsive to Changes



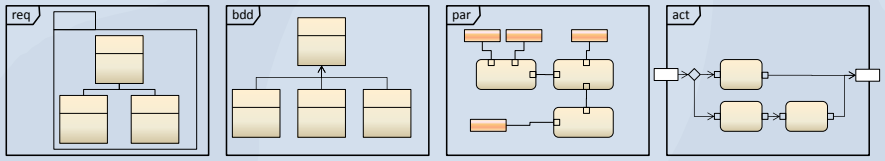


Domain engineering models



Connect SysML with Engineering Analysis

System Model (SysML)



Requirements
Architecture
Behavior
Traceability

Systems Engineering Model

- Analysis requests
- Analysis specifications

Bridge the Gap

- Performance estimates
- Trade study results

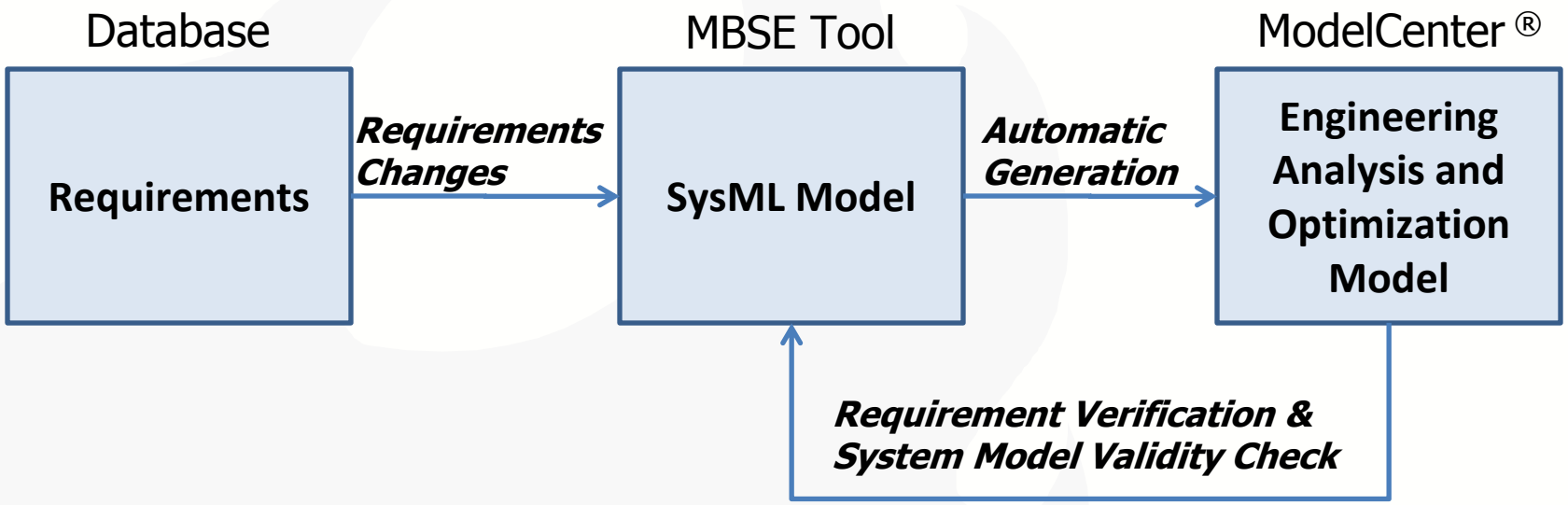
ModelCenter

Mechanical | Electrical | Simulation | Cost | Manufacturing

Analysis
Optimization
Visualization

Domain Engineering Models

Overall Solution Approach



- Integrate requirements database, SysML tools, and ModelCenter
- Requirements changes automatically propagate through SysML models and analysis models
- Assess impacts of requirements changes
  - Are the requirements satisfied?
  - What parts of the system need to be analyzed again?
  - Which parts of the system need to be redesigned?
- Perform parameter study and optimization to find a design that meets the new requirements
- Update the system model using the new design

Example: Brake Pad Design

Jupiter Motor Company — Vehicle Engineering Department

Brake Pad Design Requirements

Brake pads must be similar in design to StopIt Model No. GZ-3876, but sized to meet the following requirements:

Performance

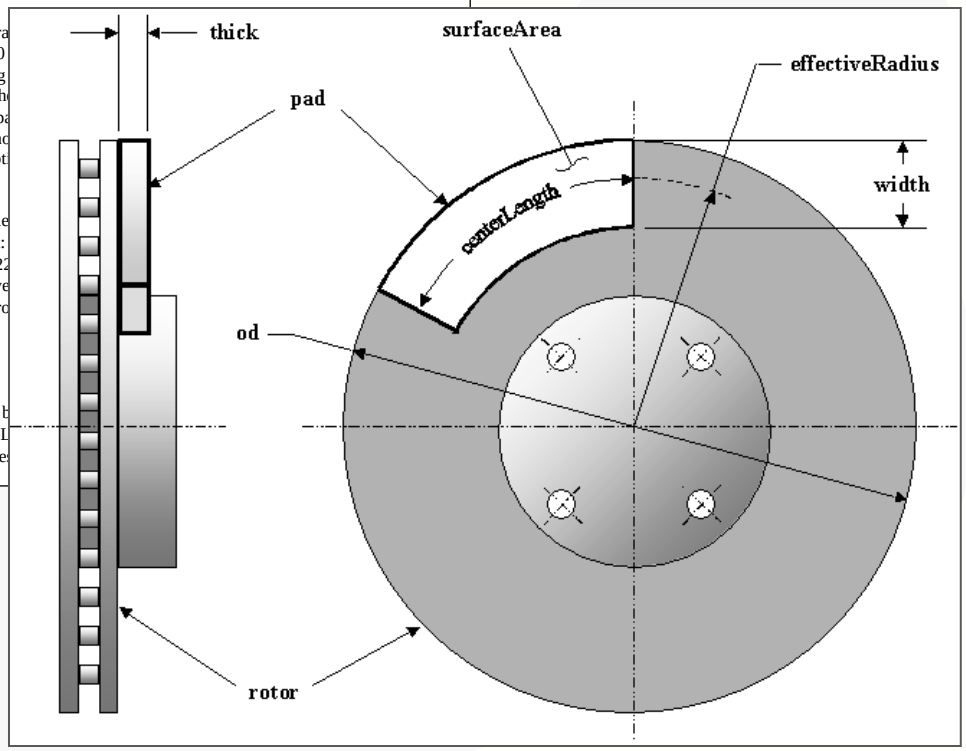
- Four bra
  from 60
- Braking
  kW of h
- Brake pa
  under nc
  assumpt

Vehicle Propertie

- Weight:
- Tires: 22
  dry pave
- Brake ro

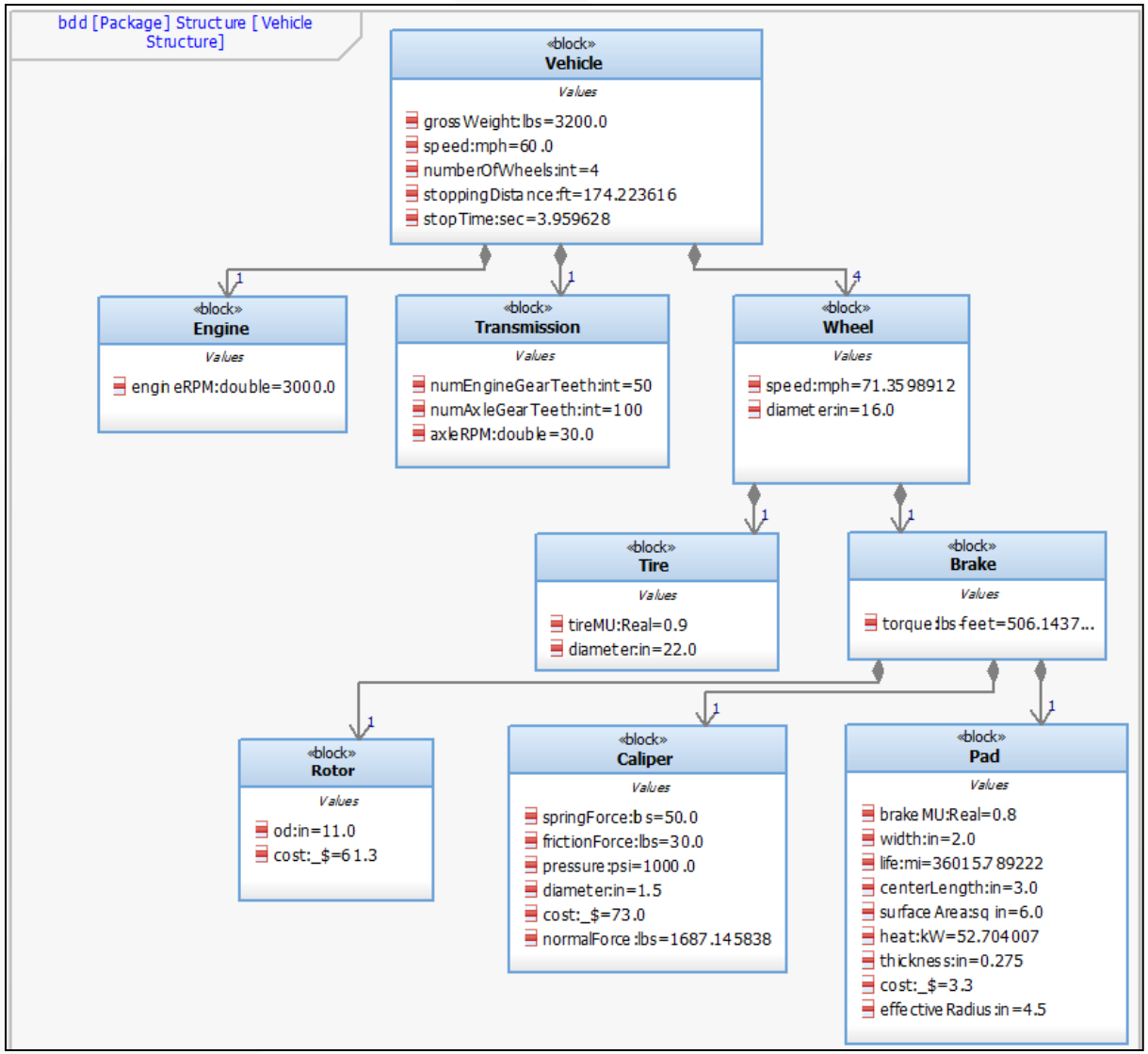
Pad Dimensions

- Width: b
- Center L
- Thickne

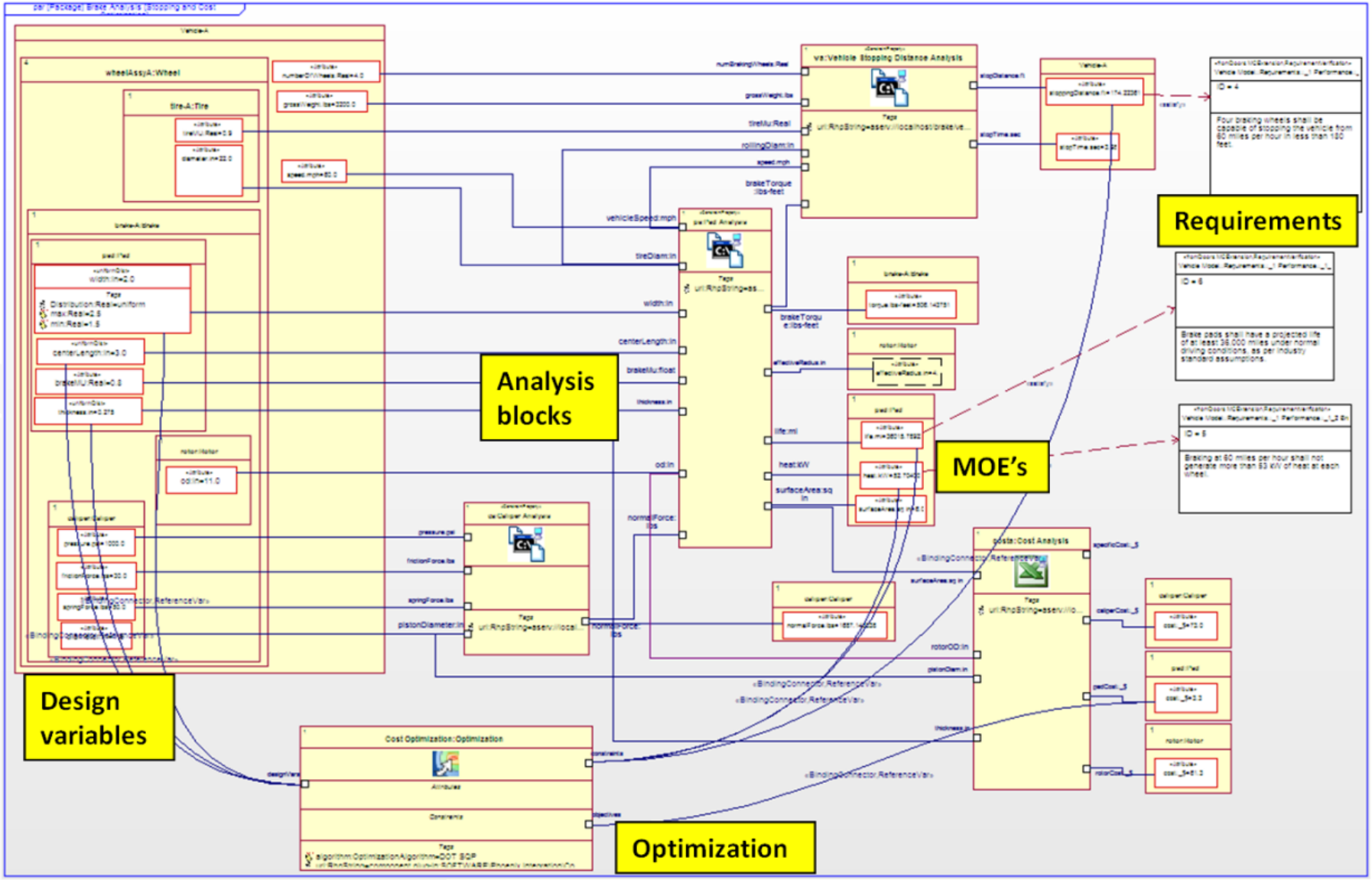


- Minimize cost
- Requirements
  - Stopping distance
  - Heat generated
  - Pad life
- Design parameters
  - Thickness
  - Center length
  - width, etc

SysML Block Definition Diagram

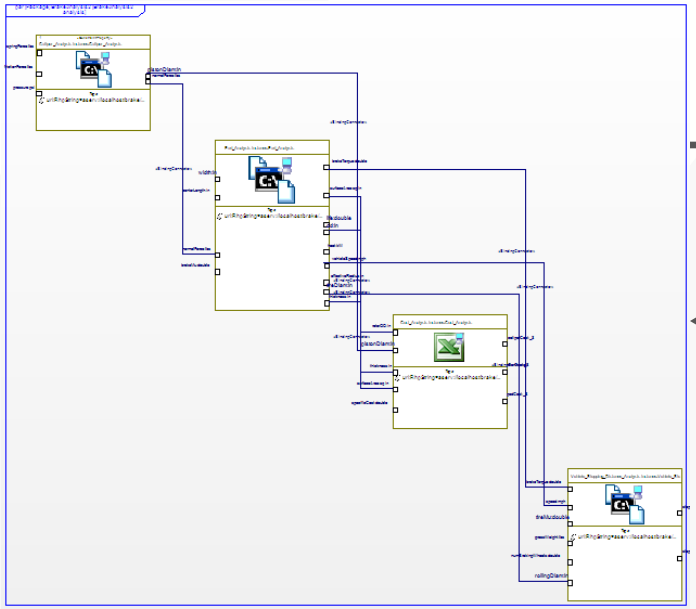


SysML Parametric Diagram



Automatic Generation of Analysis Model from SysML Model

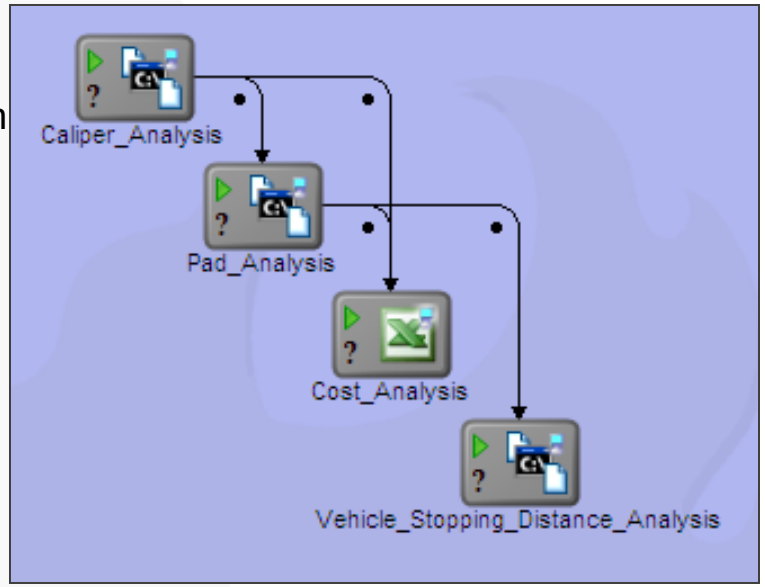
SysML parametric diagram in Rhapsody (Blueprint of engineering analysis)



Automatic Generation

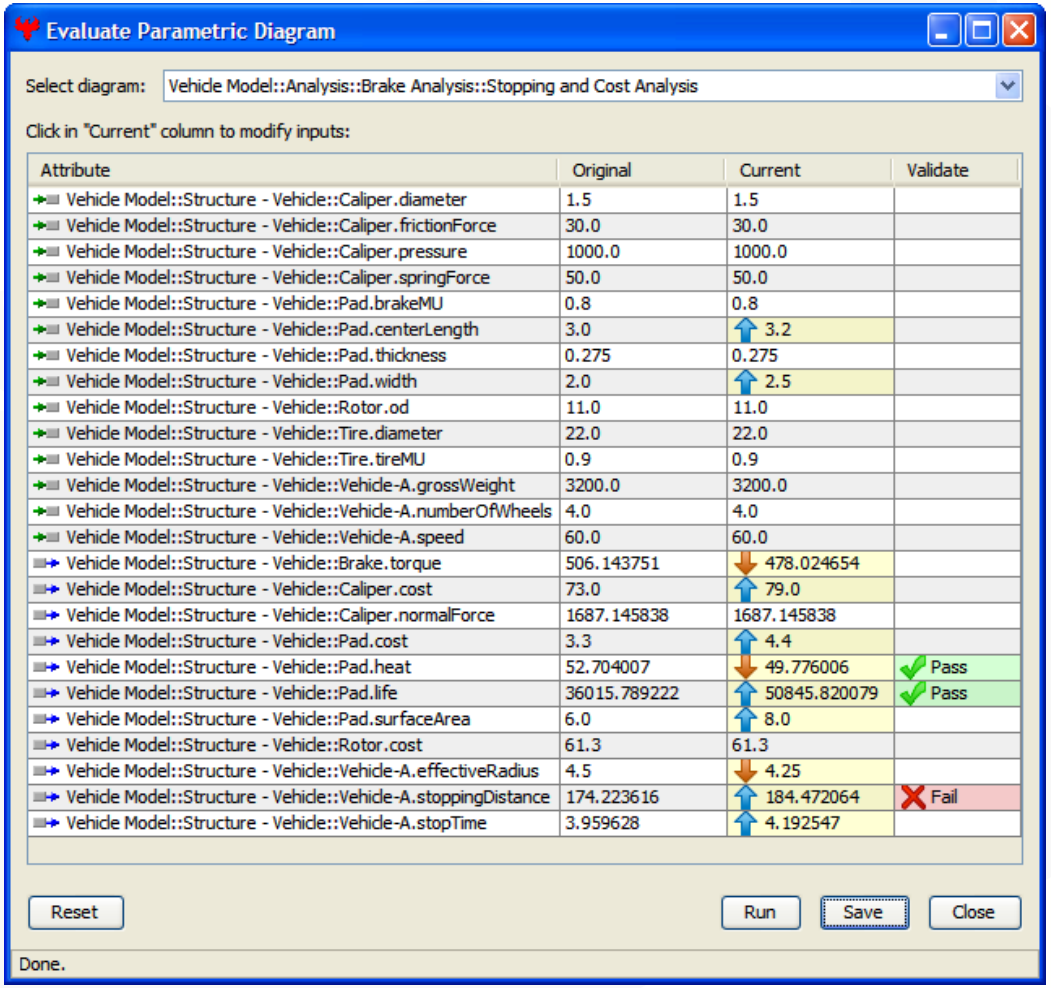
Analysis Results

Executable analysis model in ModelCenter



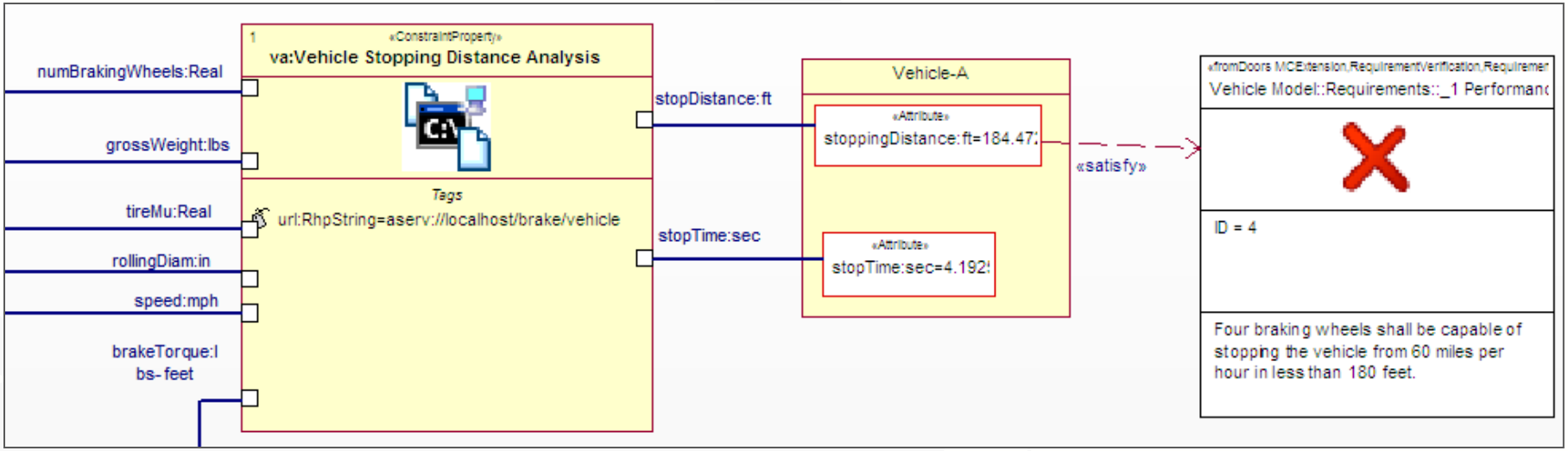
- SysML was extended to be able to define engineering analysis that will be executed through ModelCenter
- Define engineering analyses in SysML and automatically convert them to ModelCenter models
- Engineering analysis results can be automatically transferred to update SysML models

Evaluate System Configuration



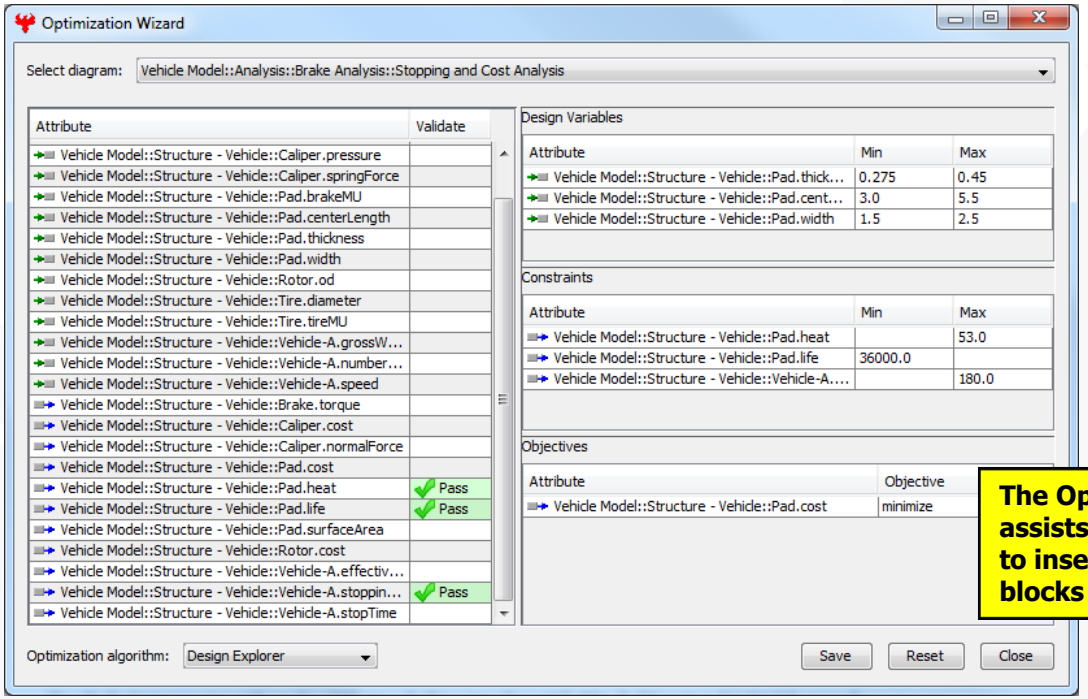
- A graphical tool was developed to execute SysML parametric diagrams through ModelCenter
- Evaluate system configurations defined in SysML by executing accurate engineering analysis
- Requirements satisfaction status is automatically updated
- SysML model can be updated automatically using the analysis results

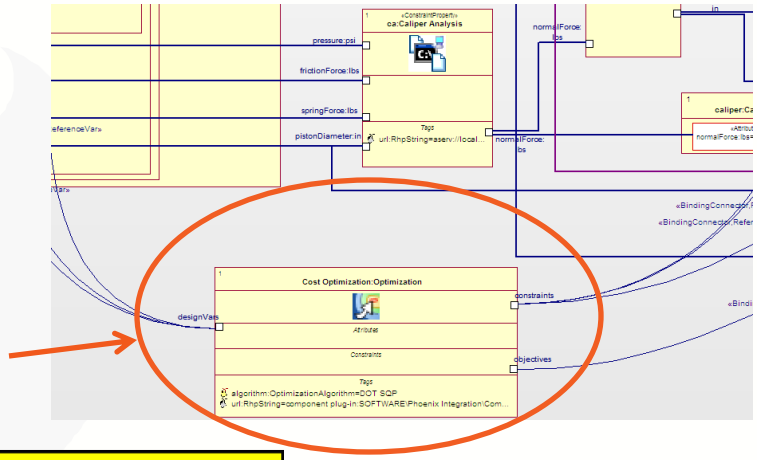
Requirements Conformance Analysis



- Requirements conformance analysis capability was added to Rhapsody.
- Lower/upper bounds information can be associated with each requirement.
- Requirements that are not satisfied will be automatically highlighted.
- This allows engineers to identify problems as soon as they are introduced and take necessary actions.

Optimization Definition Wizard for SysML

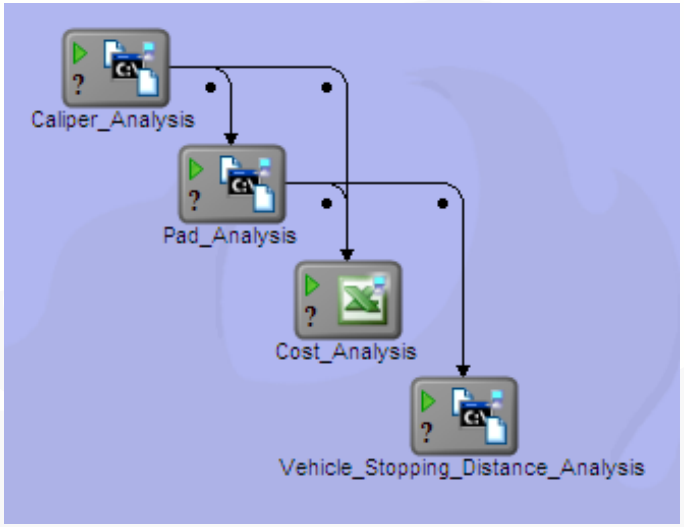




The Optimization Wizard assists SysML modelers to insert optimization blocks into SysML

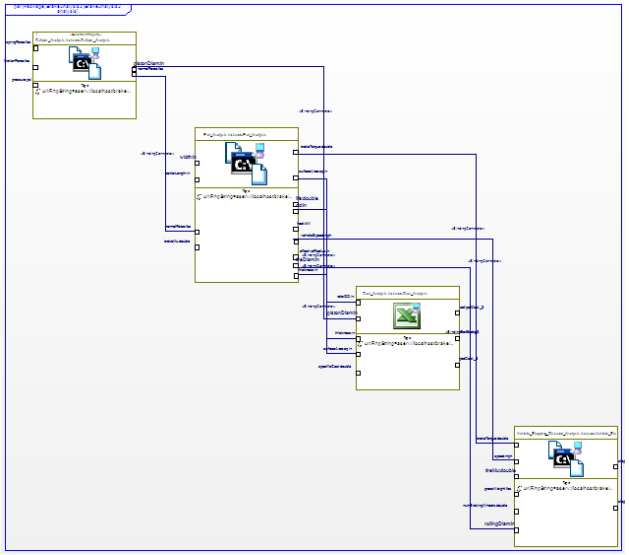
- An extension to IBM Rhapsody was developed to simplify steps to define optimization problems in SysML.
- Using the Optimization Wizard, users can graphically select design variables, constraints and objectives.
- The Wizard will automatically create an optimization block in SysML.
- If requirements are associated with design parameters, the requirement information is automatically picked up and used for the optimization problem.

Import Analysis Model into SysML



Analysis model in ModelCenter

Rhapsody was extended to convert a ModelCenter model to a SysML parametric diagram.



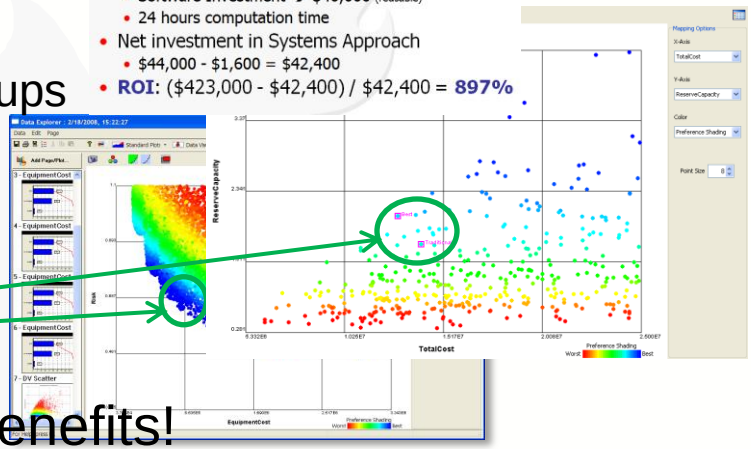
Descriptive model in Rhapsody

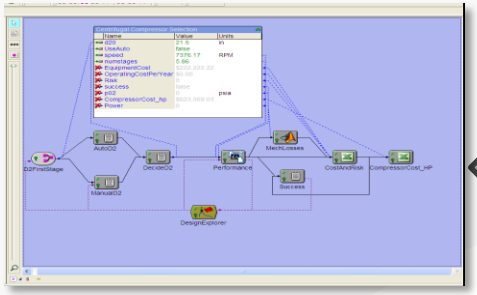
- So far the project has focused on converting SysML models to engineering analysis models. Oftentimes, conversion in the reverse direction is also desired. If engineering analysis models are already available, systems engineers may want to create SysML parametric diagrams off the analysis models.
- Rhapsody was extended to import a ModelCenter model to create a SysML parametric diagram.
- This bi-directional conversion allows users to start from either end of systems engineering and engineering analysis to close the gap between them.

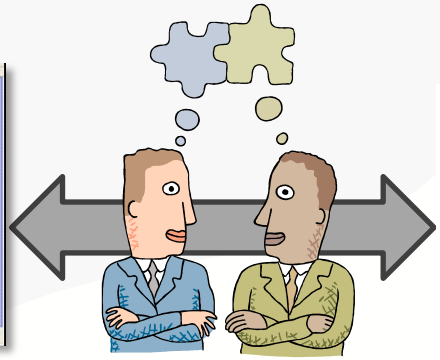
MBSE ROI – A Frequently Asked Question

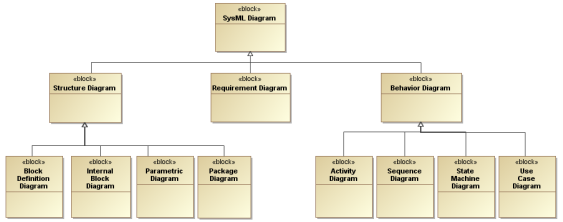
- MBSE Gives You:
  - More design alternatives
  - Better communication between siloed groups
  - Requirements traceability
  - Reduced time to market
  - Reduced project risk
  - Better decisions
- A relatively small investment for big benefits!
- DARPA SBIR project will collect ROI information from users and report to the community – too early for quantifiable results

- Savings Realized: $423,000
- Cost of Traditional Approach
  - 16 hours →$1,600
- Cost of Systems Approach:
  - 40 hours setup →$4,000 (depends on complexity)
  - Software Investment → $40,000 (reusable)
  - 24 hours computation time
- Net investment in Systems Approach
  - $44,000 - $1,600 = $42,400
- **ROI**: ($423,000 - $42,400) / $42,400 = **897%**

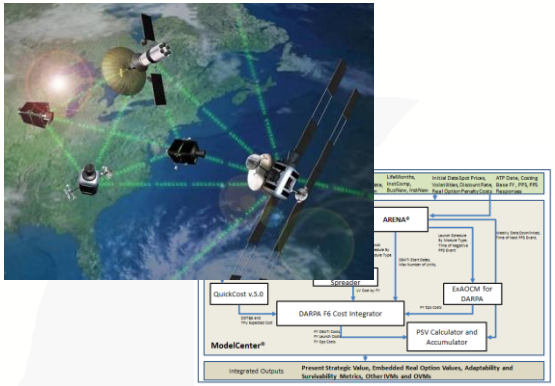








Other MBSE Related Efforts



- DARPA / JPL F6 Program
  - Economic analysis & design of fractionated satellite concepts
  - Autogeneration of ModelCenter engineering models from SysML
  - Supports wide architectural variations

- ARDEC Enhancement
  - Customization of MBSE technology for ARDEC systems engineering processes
  - Proposal approved

- USMC MARCORSYM FACT
  - Integration of ModelCenter with USMC FACT decision support environment.
  - Proposal in development

What's Next

- Tech preview is available now
  - Tech preview of Rhapsody or MagicDraw and ModelCenter integration is currently being used by industry pilot projects
- See our demo at the DARPA Booth
- Contact:

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QUESTIONS / DISCUSSION