Integrated Model Framework for Concept Development

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NORTHROP GRUMMAN

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Christopher Hoffman
NGES Systems Engineer

Christopher.Hoffman@ngc.com

Today's Outline

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- Today, I will discuss Model Based Engineering
- Using a developed "Integrated Model Framework"
- How a Descriptive to Analytical Model approach
- Using existing disparate models
- Can validate architectural choices quickly, efficiently, and optimally

How can Model Based Engineering (MBE) be implemented on a program?

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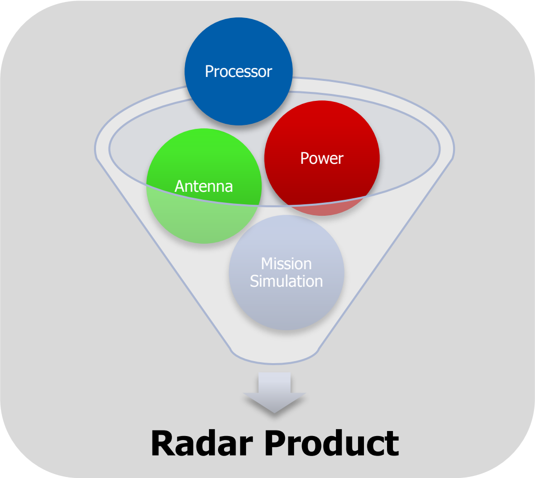
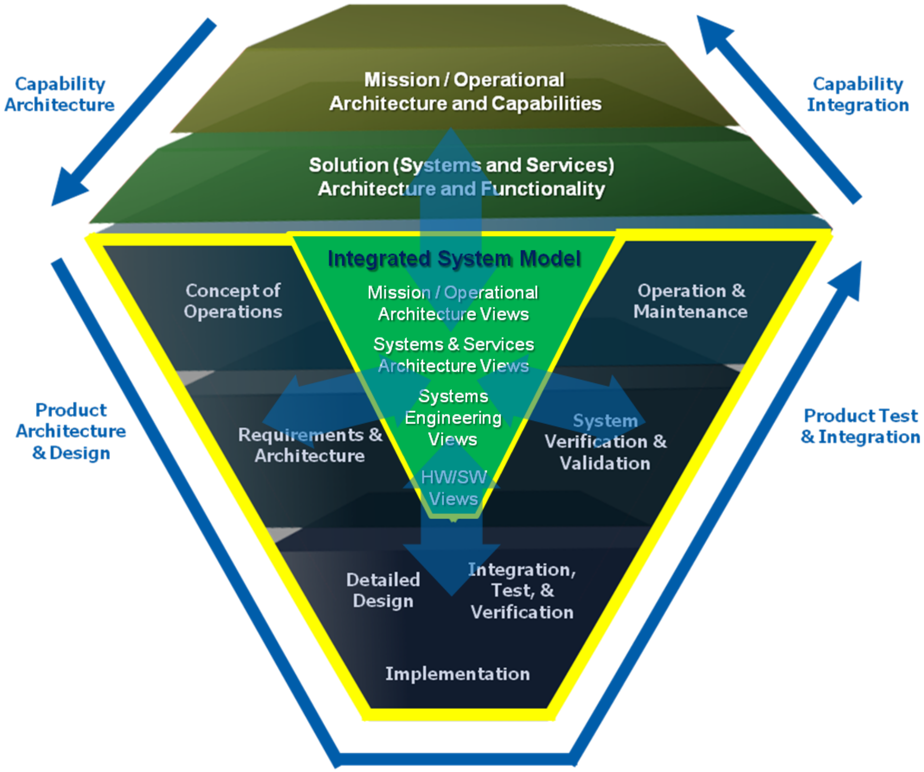
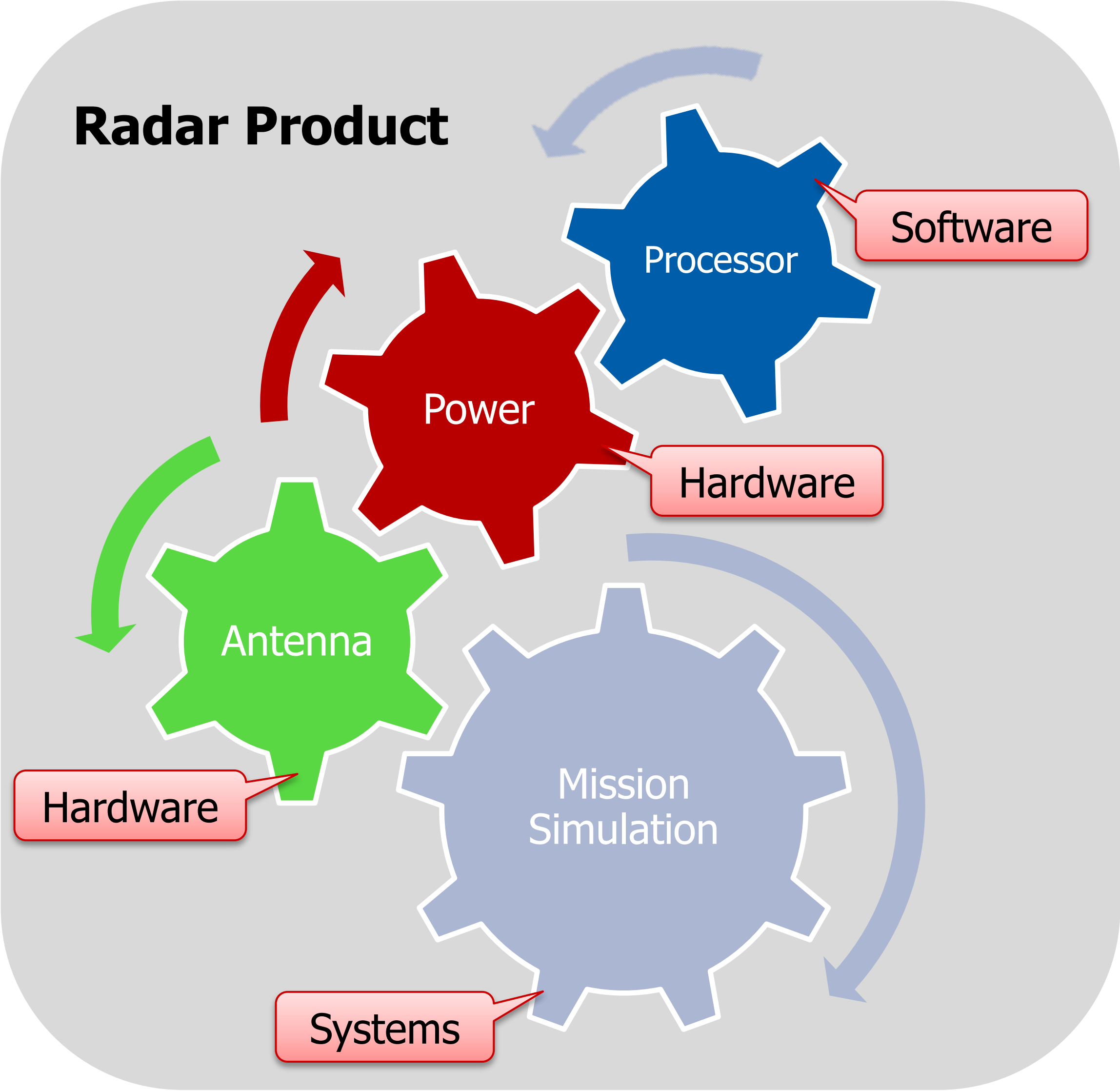
- Many use MBE successfully today…
  - Solving hard problems
  - Finding new novel solutions
- Unfortunately, most have been stovepiped…
  - Models are typically limited to a discipline, limiting the trade space



Primary MBE scope to date

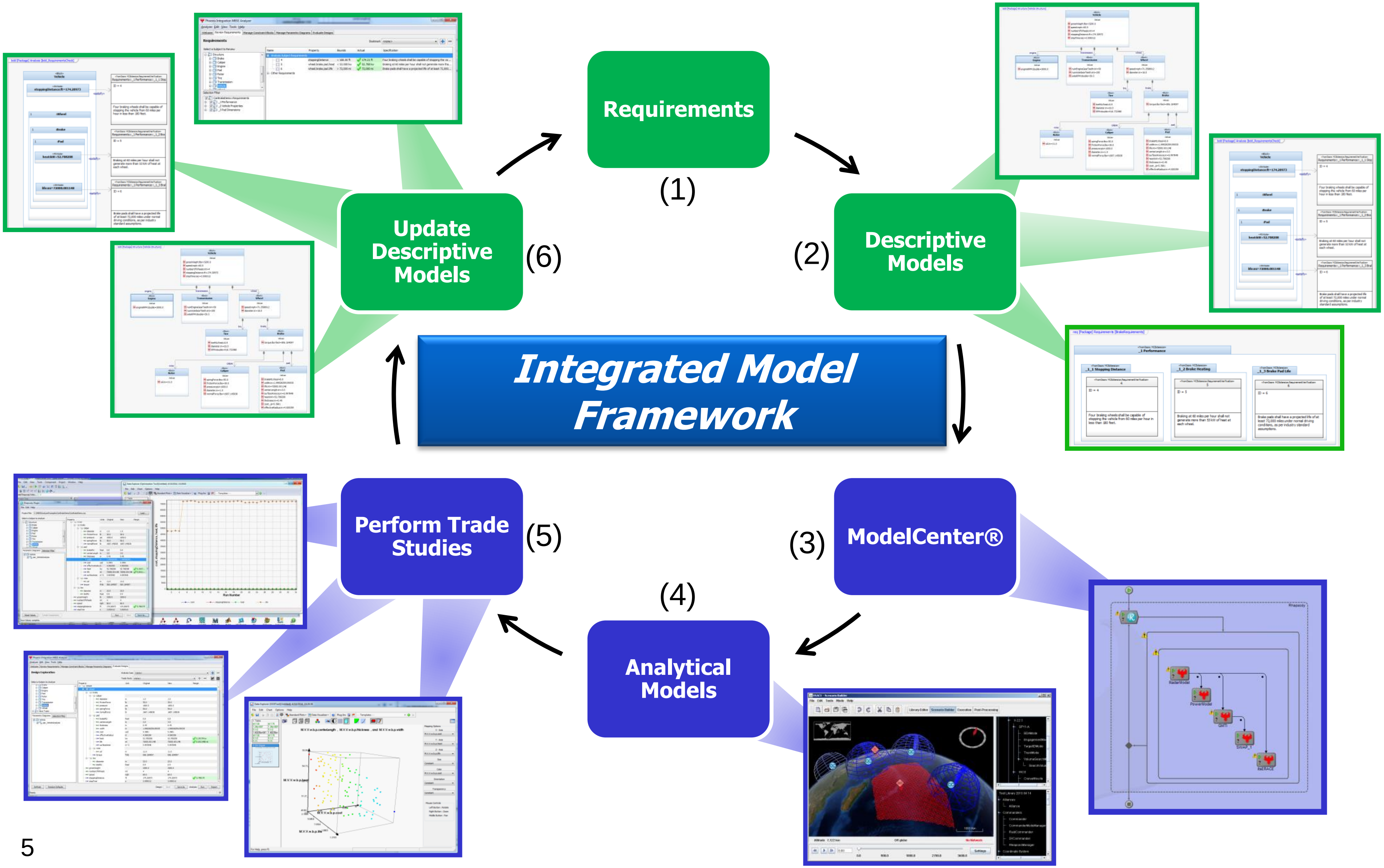


A Cohesive Process Using Integrated Modeling



- The Mission Systems Engineering group at Northrop Grumman decided to take the next step
- 6-Step process for integrating models
  - "Integrated Model Framework"
  - Phoenix Integration's MBSEPak®
- Will integrated models enable better/quicker system level decisions?

Integrated Model Framework:
Descriptive to Analytical and Back



Investigating Radar Performance vs. Cost Over a Variety of Generic Platforms

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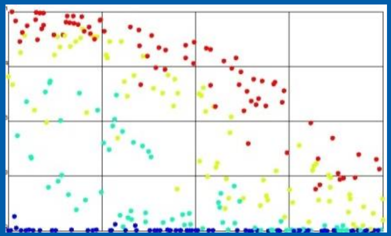
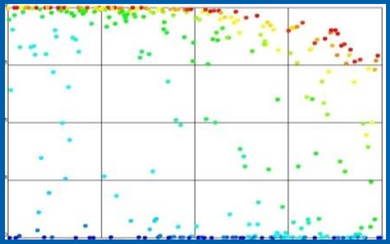
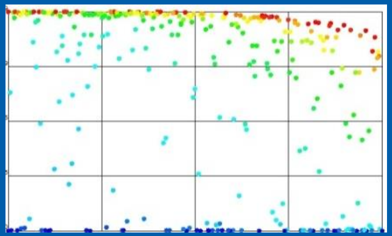
Helicopter
- Altitude
- Weight
- Speed



Large Aircraft
- Altitude
- Weight
- Speed



Fighter Jet
- Altitude
- Weight
- Speed



Utilizing Disparately Designed Models to Perform Trade Analysis

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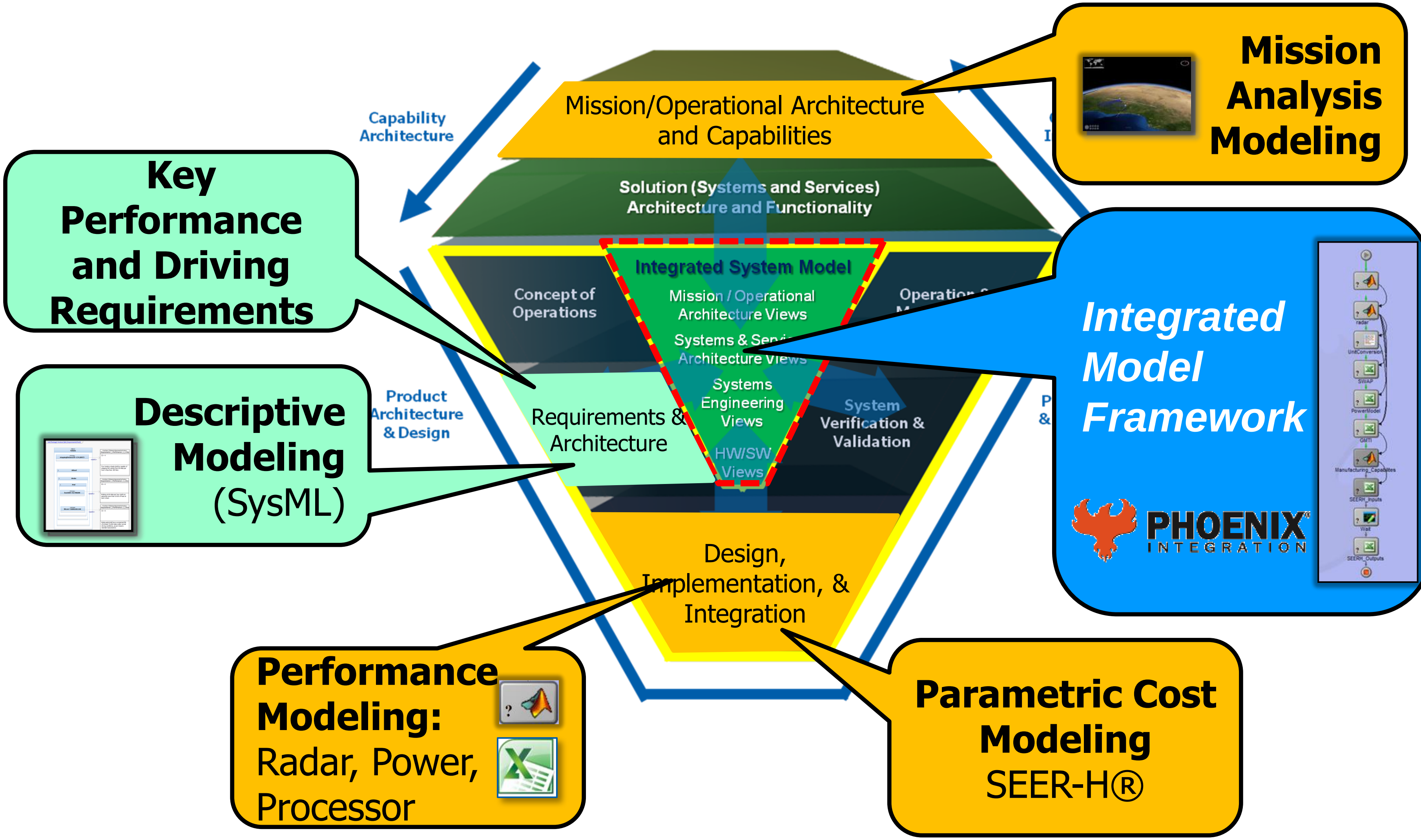


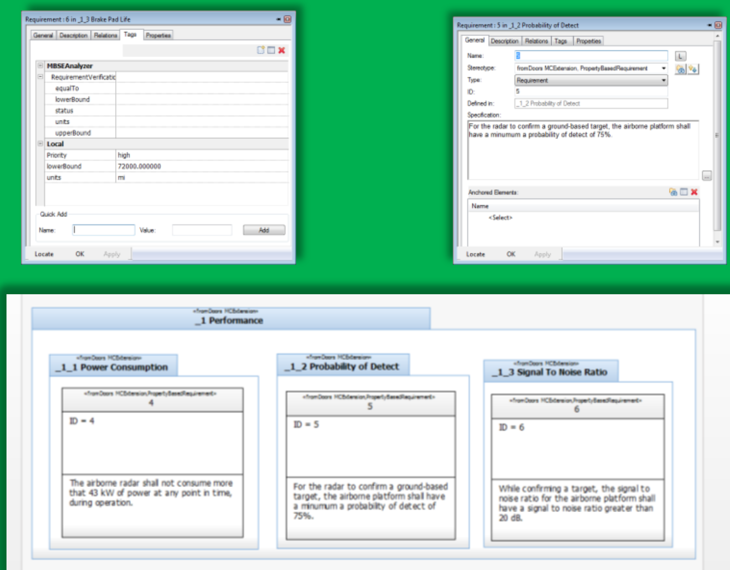
System level models from different departments inherently share information

Step 1: Generate a Requirements Diagram

DOORS or Excel Requirements

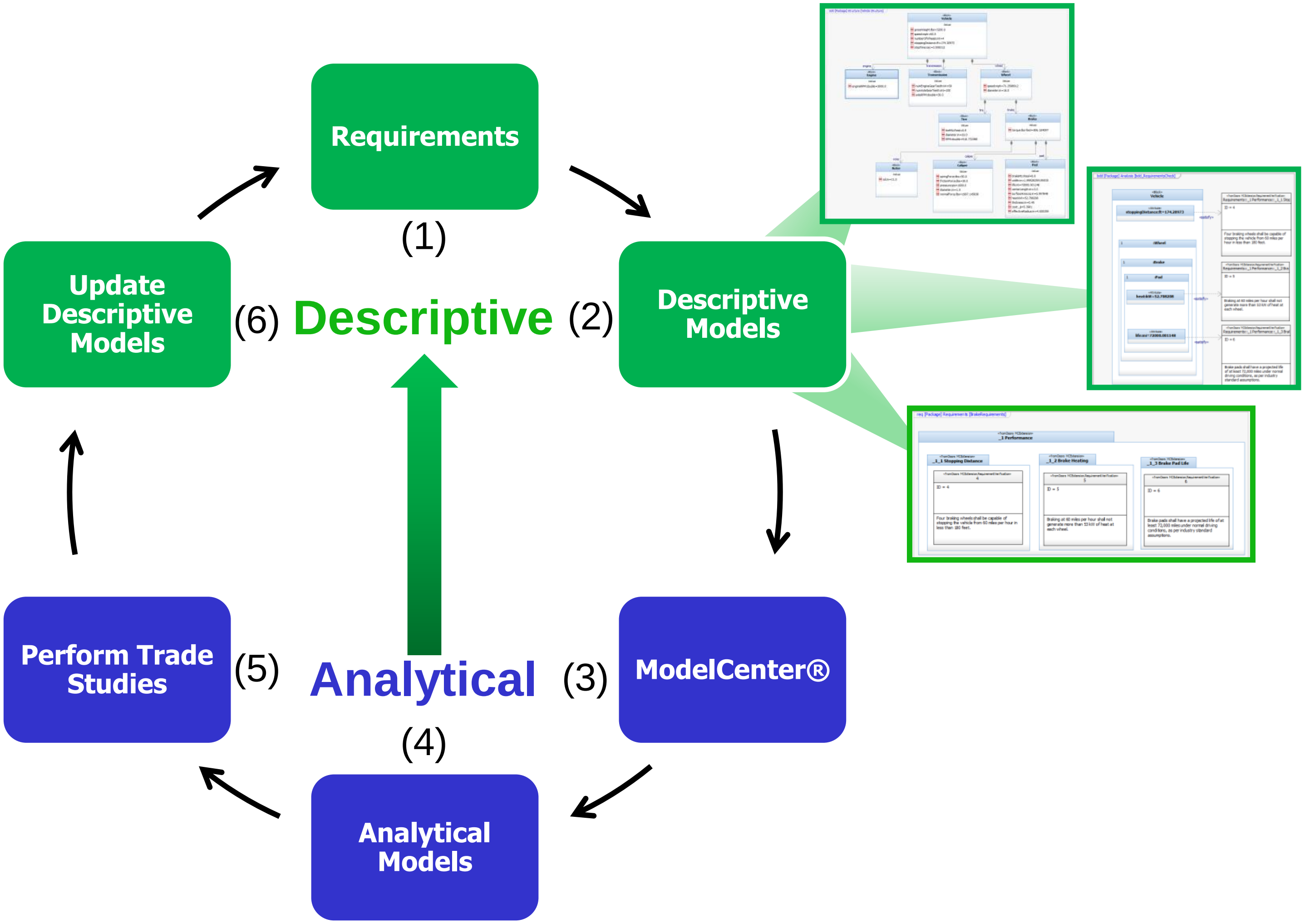
- *Power Consumption*
- *Radar System Weight*
- *Probability of Detection*
- *Signal to Noise Ratio*

IBM Rational Rhapsody



- Requirement Specifications brought into Rhapsody
- Lower and Upper Bounds can be established in Rhapsody
  - Requirement goals are established

Setting up the System Architecture



Step 2: Decompose Visio/Initial Block Diagrams to Rhapsody Block Definition Diagrams

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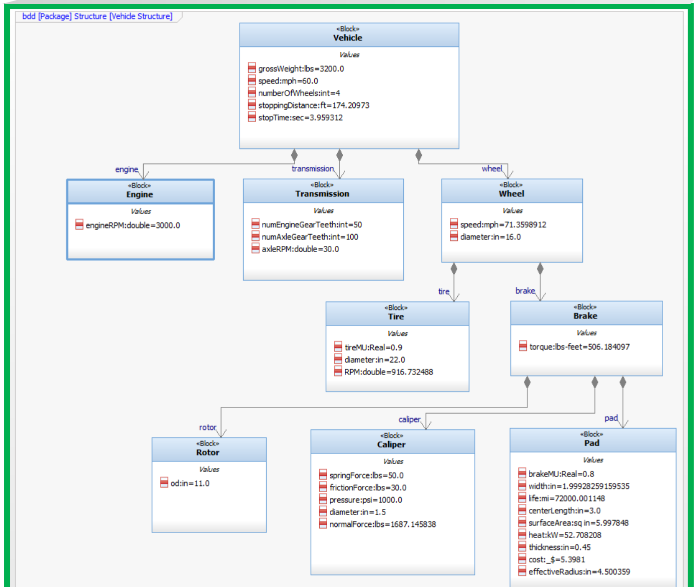
- Generate an Architecture based on requirements
- Typically designs are created in Visio
  - Visio does not offer the traceability needed in this process
- Manually decompose Visio diagrams into SysML Block Definition Diagrams

Microsoft Office Visio Block Diagrams → Rhapsody Block Definition Diagrams



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Step 2: System Architecture Connects to Requirements

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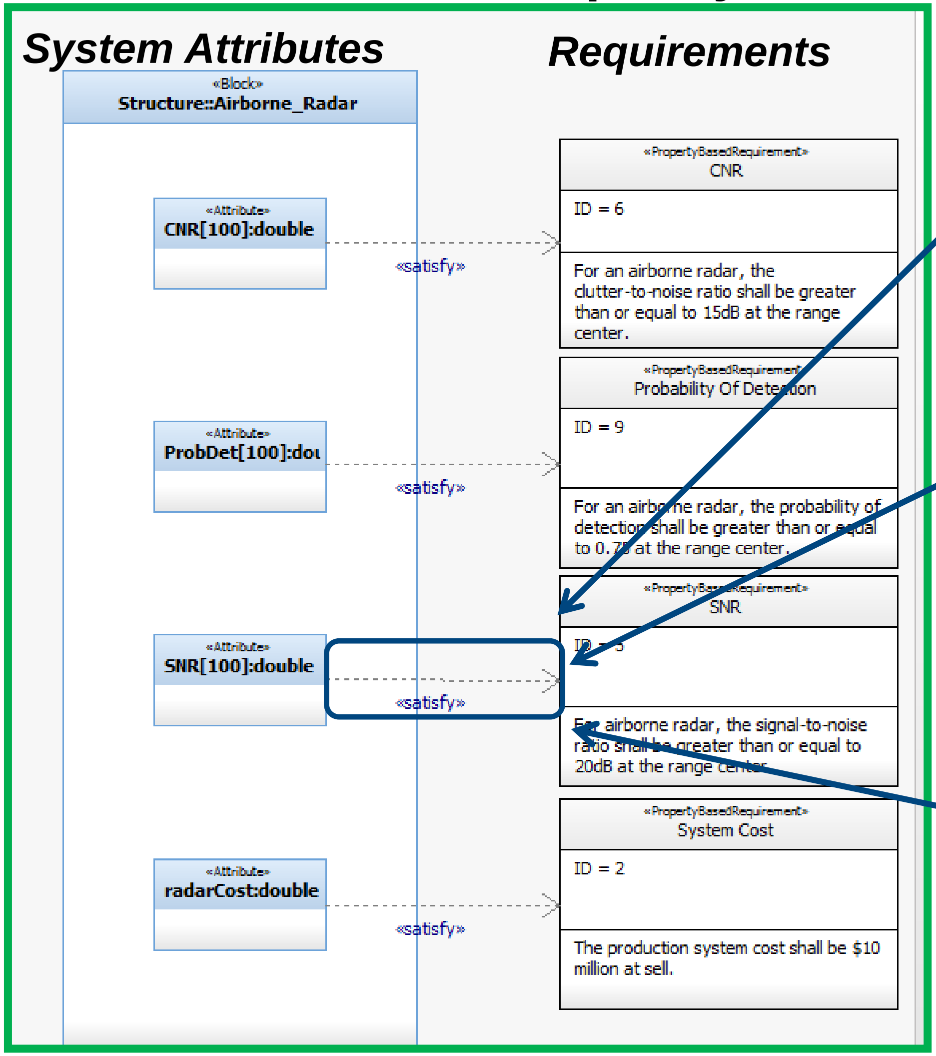
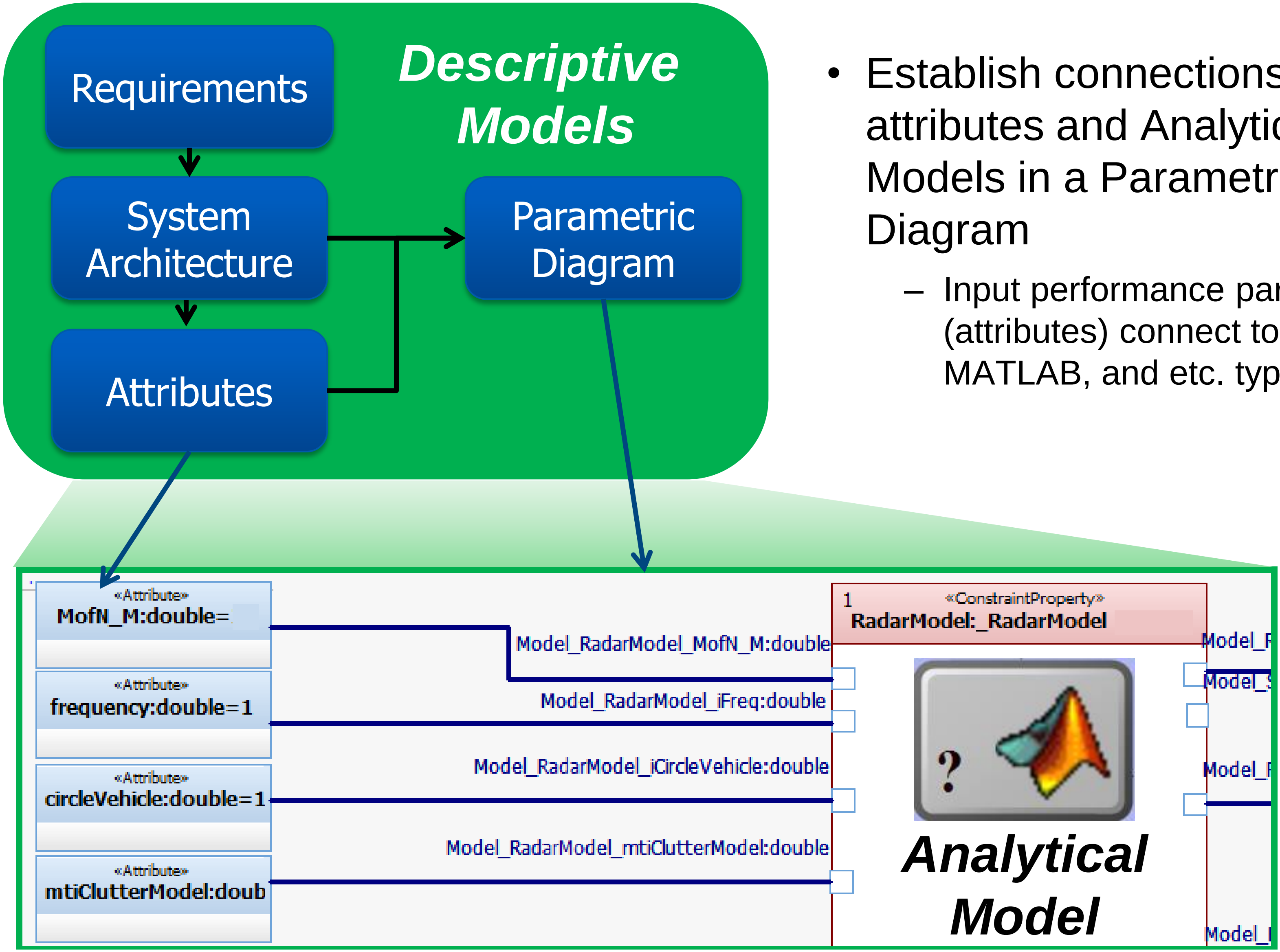
IBM Rational Rhapsody



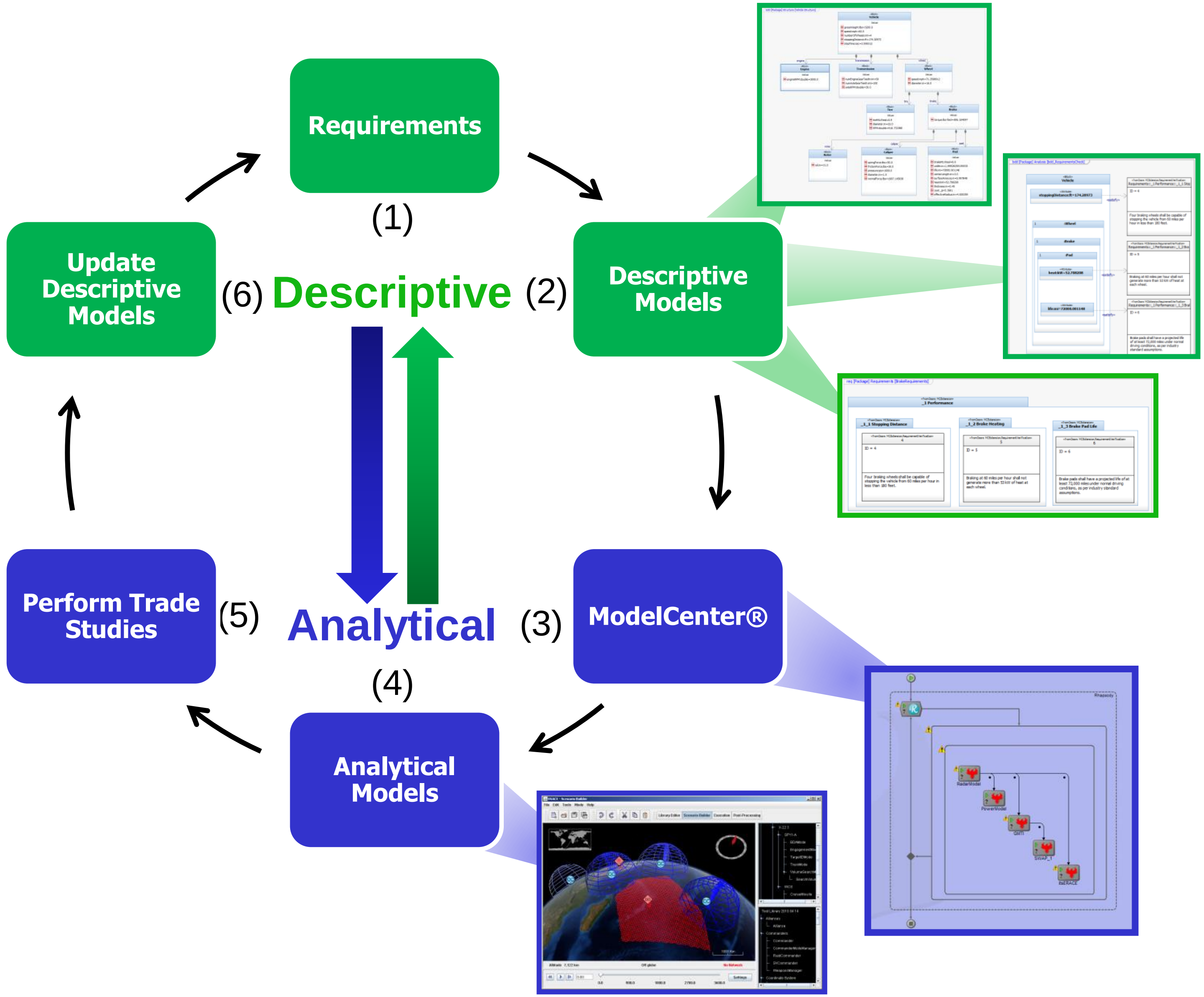
- Establish a connection between Requirements and System Architecture
  - Traceability
- Link attributes of system performance to Requirements
  - Clutter-Noise-Ratio
  - Probability of Detect
  - Signal-To-Noise Ratio
  - Radar Cost
- Satisfy Relationships are set up in Rhapsody

Step 2: Connecting Descriptive and Analytical Models

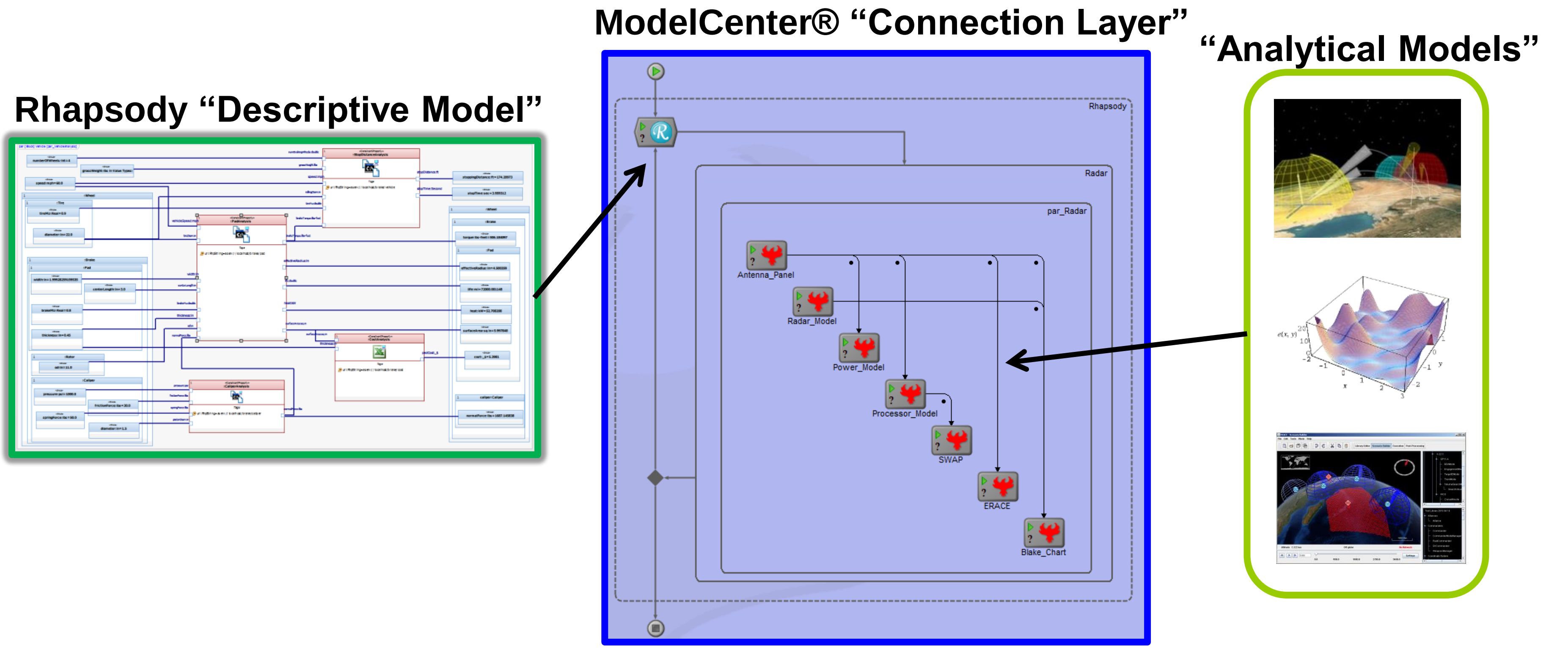


- Establish connections between attributes and Analytical Models in a Parametric Diagram
  - Input performance parameters (attributes) connect to C++, Java, MATLAB, and etc. type models

Moving Between Descriptive and Analytical House



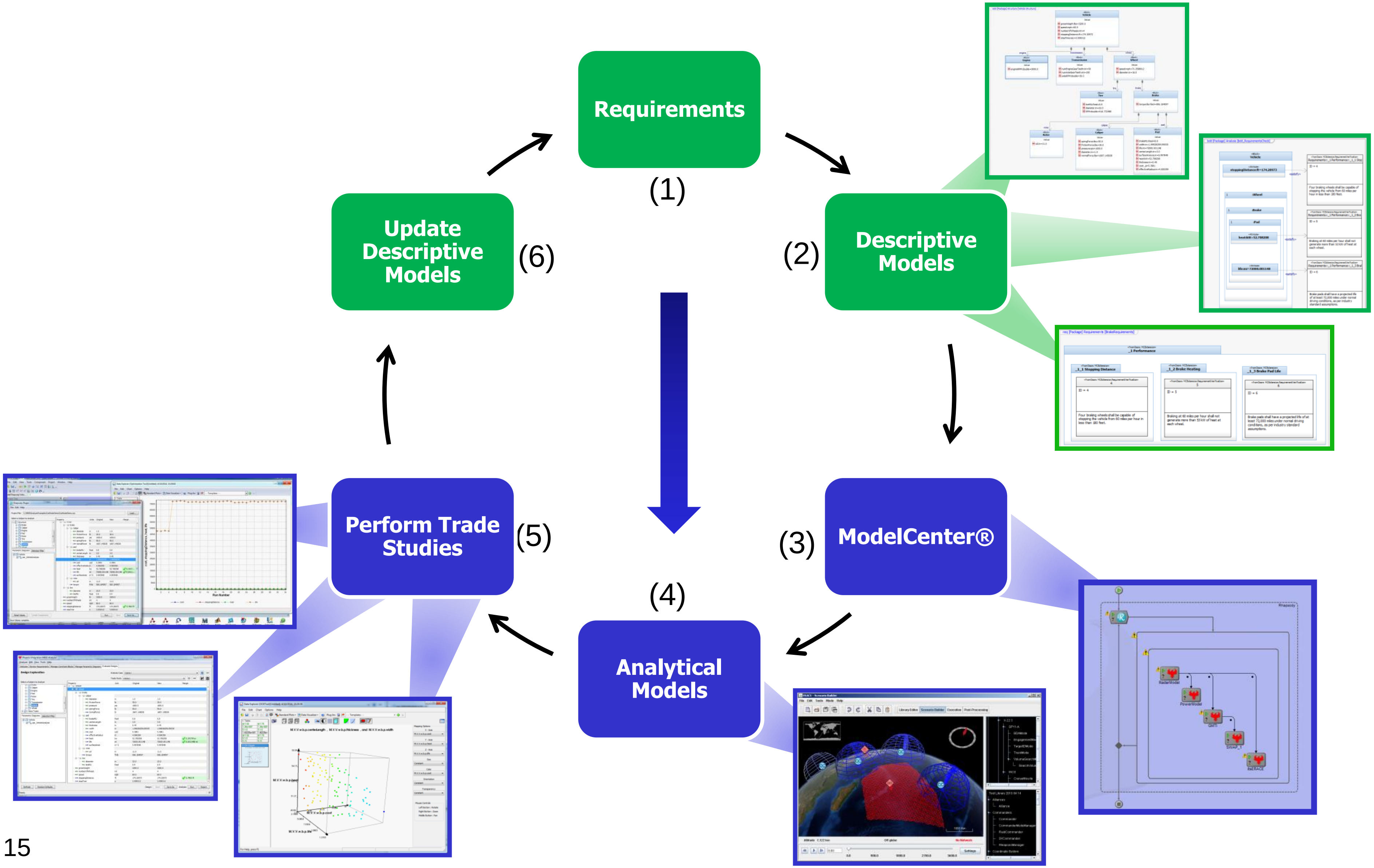
Step 3 & 4: Establish Connection Layer



- Phoenix Integration's MBSEPak® will establish physical connections between Descriptive and Analytical Models
- After analysis is performed, ModelCenter® will flow data back to Descriptive Model

Integrated Model Framework:

Perform Trade Studies



Step 5: Perform Trade Studies in ModelCenter

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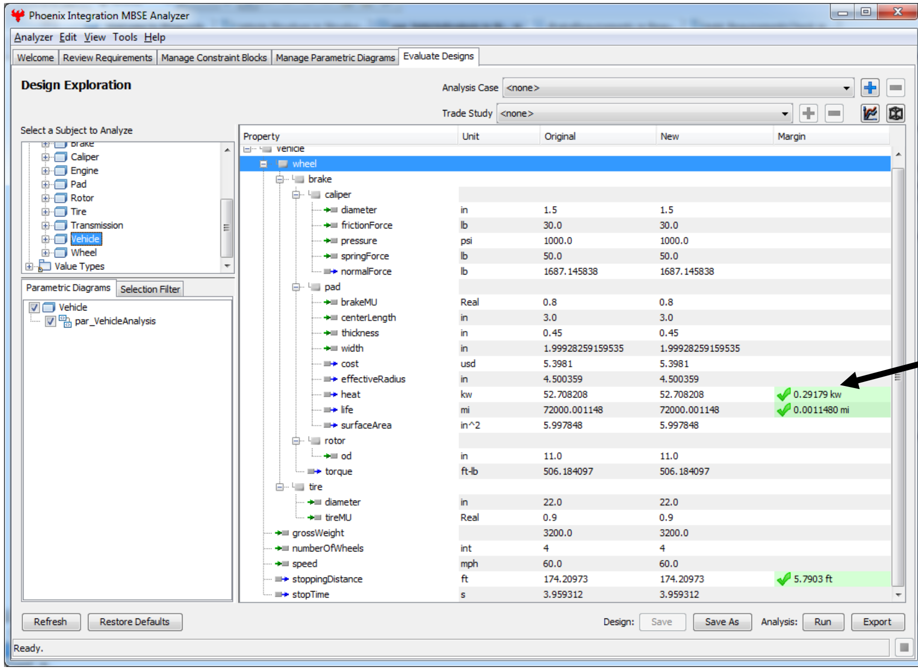
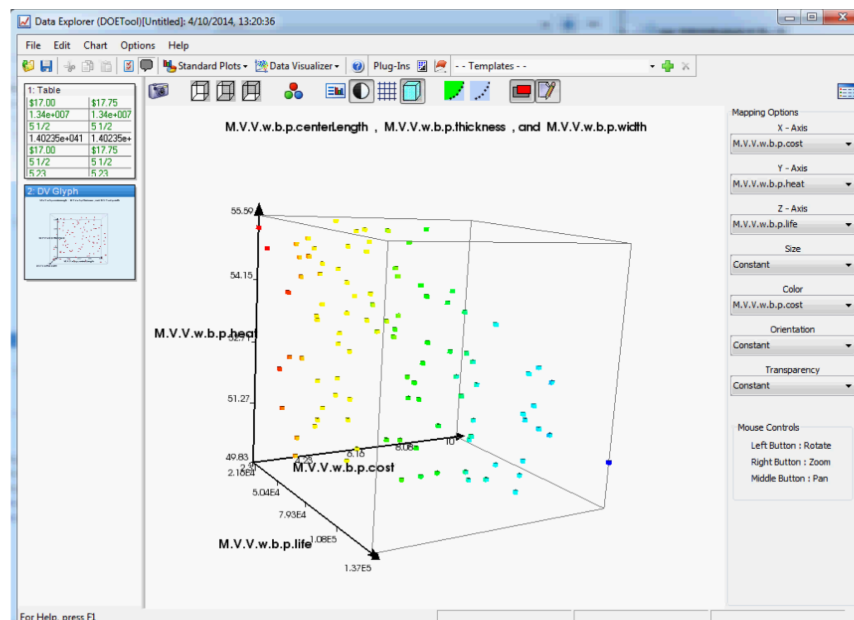


- Design of Experiments and Optimization Analysis
- Dashboards are created automatically for feedback of requirement verification

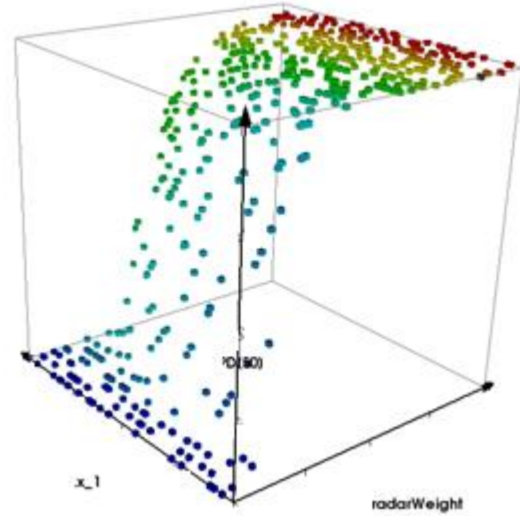


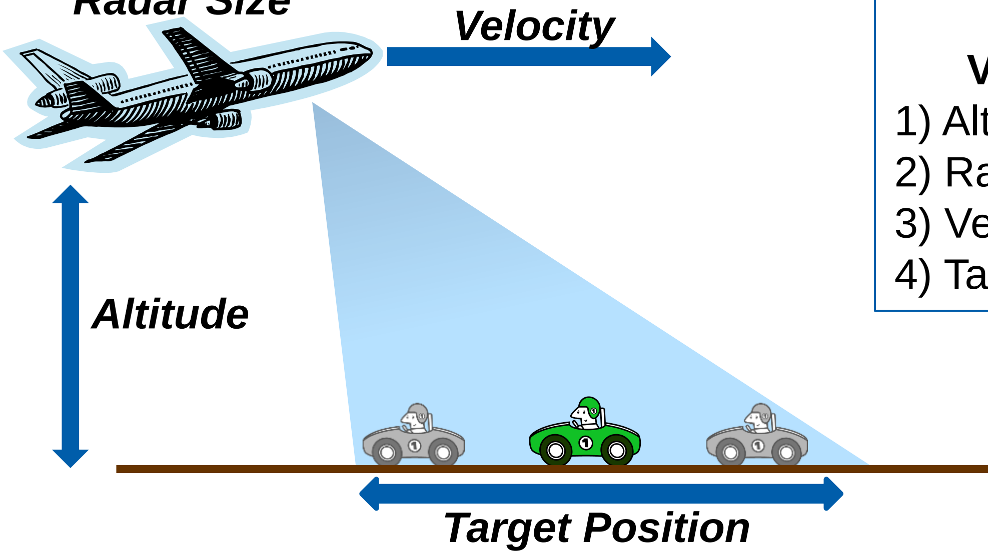
- Visual analysis of the data can be created

PHOENIX INTEGRATION

Cost and Performance Scaling of Varying Size Radar Options

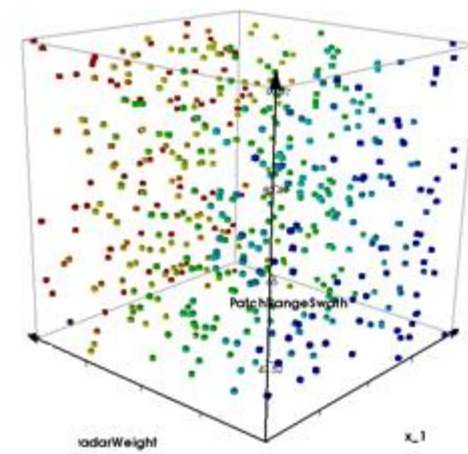
- This simple experiment confirms logical expectation:
  - Bigger Radar yields Higher Probability of Detect at a Higher Cost
- Detailed analysis enables discussion of:
  - Can we achieve target performance within specific platform limitations?
  - What performance requirements drive solution cost and size?
  - How much is more performance worth?
- Able to evaluate more experiments along more dimensions using models integrated through ModelCenter® than ever possible manually





Design Variables

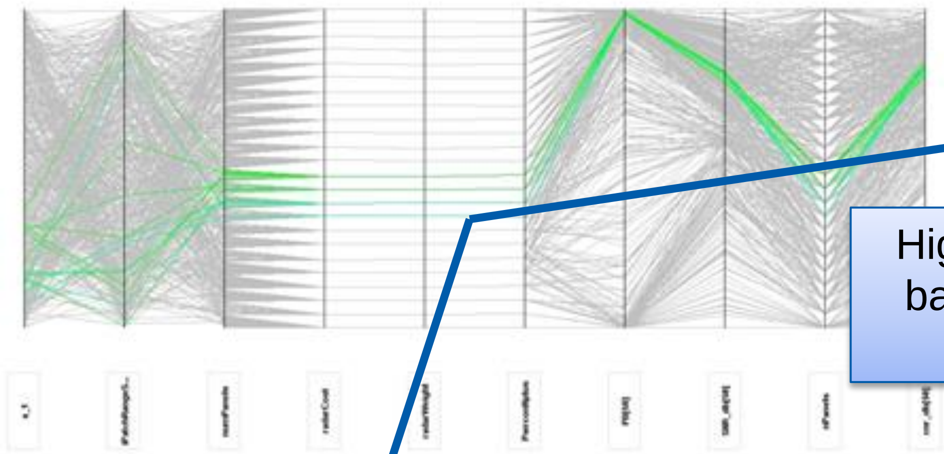
1) Altitude
2) Radar Size
3) Velocity
4) Target Position



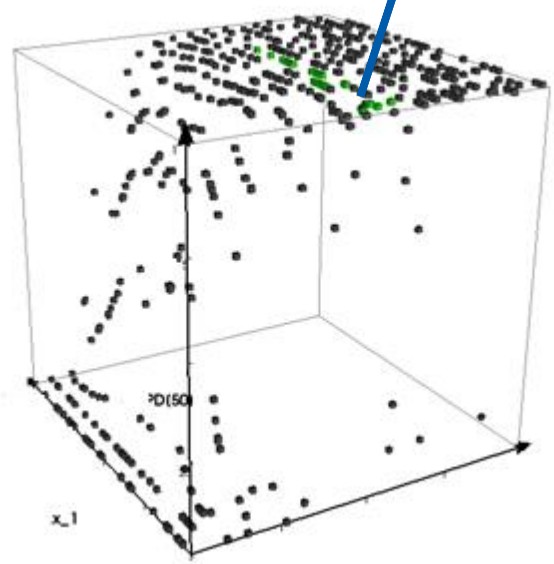
Color : Cost
- Red Higher Cost
- Blue Lower Cost

Investigating Designs:

Tradeoffs & Model Exercising



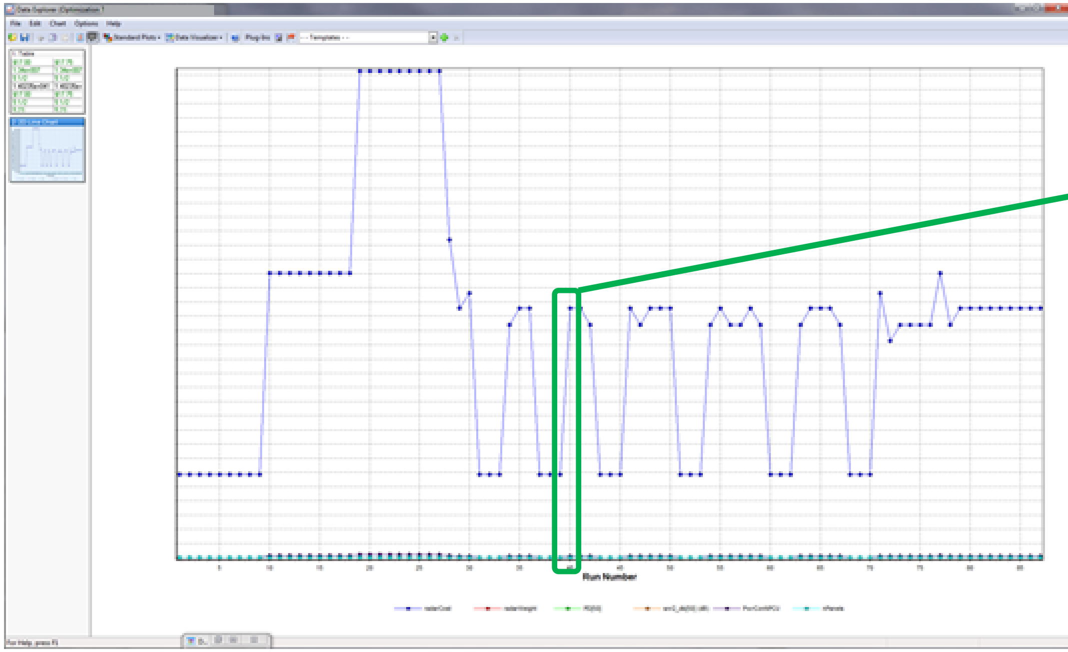
Highest ranked trade based on objectives and constraints

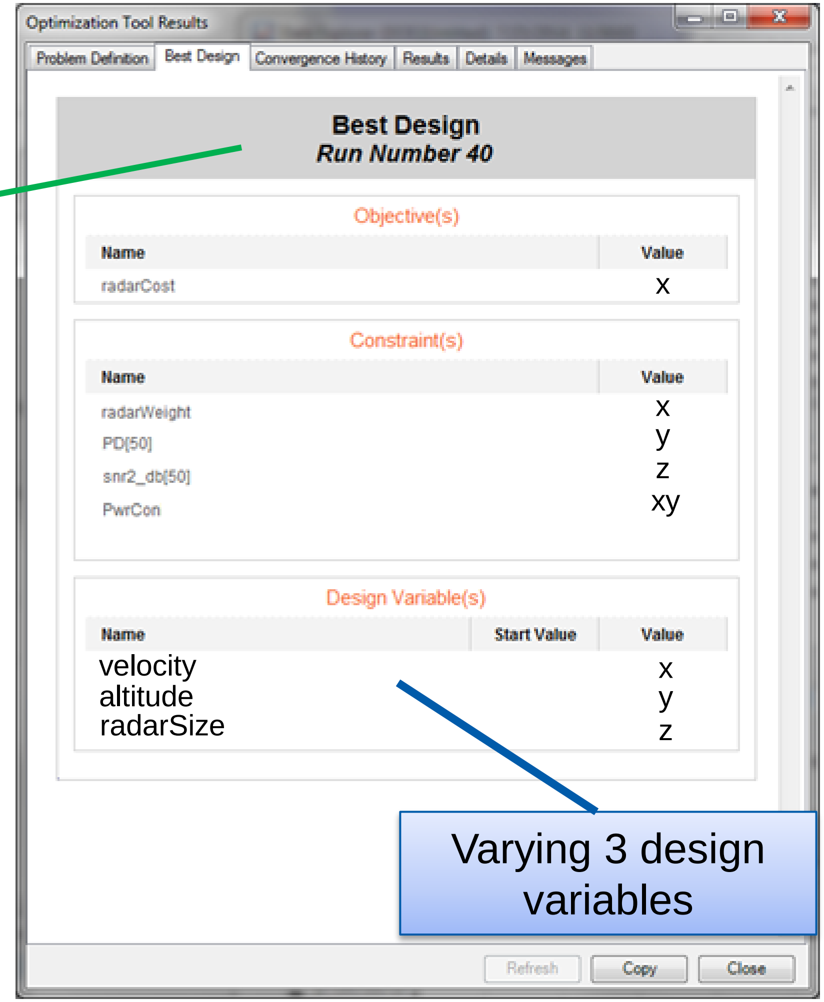


- Utilize requirements to drive analysis
- ModelCenter® will help identify best solutions:
  - Identify solutions that do not satisfy performance requirements
  - Identify the top solutions that optimize solution characteristics
  - Identify common characteristics of good solutions
- Outputs number of cases that meet the driving requirement and ranks them in terms of selected criteria, in this case cost

Data Visualizer				
	Category	Design 250	Design 16	Design 424
	Rank	1	2	10
Variables				
	size	x	y	z
	position	x	y	z
	swath	x	y	z
	radarCost	x	y	z
	radarWeight	x	y	z
	PwrCons	x	y	z
	PD	x	y	z
	SNR	x	y	z
	CNR	x	y	z
Objectives				
	x_1 maximize: 100%	x	y	z
	radarCost minimize: 100%	x	y	z
	PD maximize: 100%	x	y	z
	SNR maximize: 100%	x	y	z
Constraints				
	position	Margin: 72.48%	Margin: 60.35%	Margin: 25.64%
	PD	Margin: 15.78%	Margin: 15.73%	Margin: 15.94%
	radarCost	Margin: 6.85%	Margin: 12.25%	Margin: 18.19%
	SNR	Margin: 0.2%	Margin: 1.8%	Margin: 4.89%
	CNR	Margin: 11.68%	Margin: 10.12%	Margin: 2.53%

Trade Space Optimization to Investigate Optimal Designs

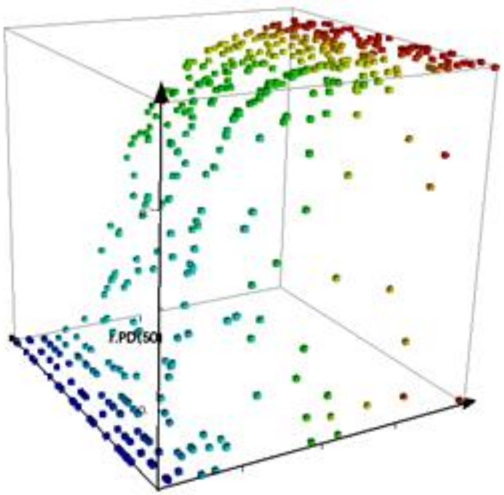




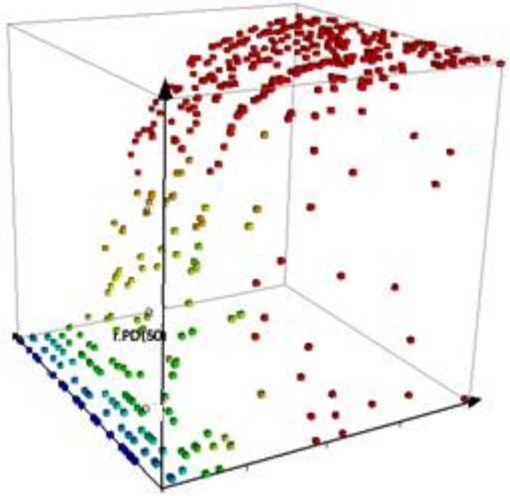
- ModelCenter® tries to leverage certain design variables by getting as close as possible to the constraints
- ModelCenter® suggests a best design (run 40 out of 86)
- Goal: Minimize Radar Cost
- Constraints are based on requirements

Running the Optimizer provides feedback about the models and flexibility of designs based on requirements

Higher Fidelity Cost Model Added: SEER-H Integration

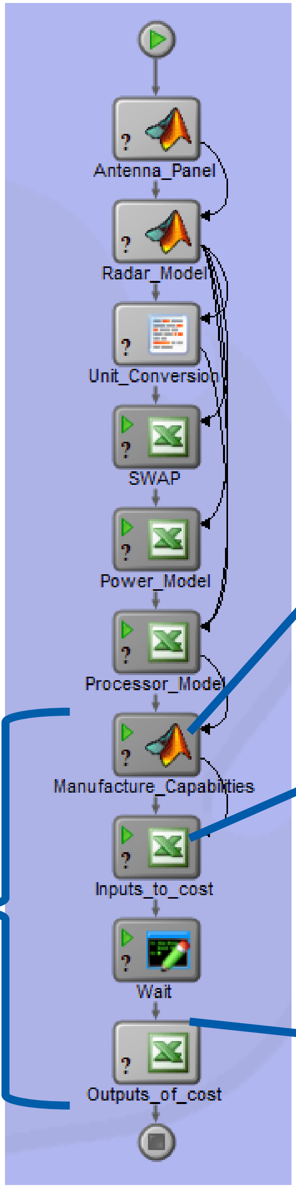


Color : Labor Prod Cost
- Red Higher Cost
- Blue Lower Cost



Color : Development Cost
- Red Higher Cost
- Blue Lower Cost

- Higher Fidelity Cost Model allows us to look beyond the material cost



SEER-H

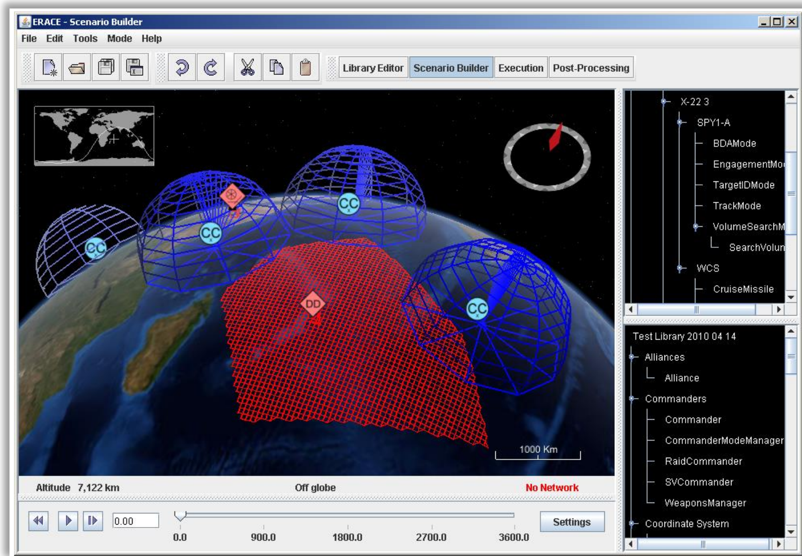
Logic for Manufacturing Capabilities

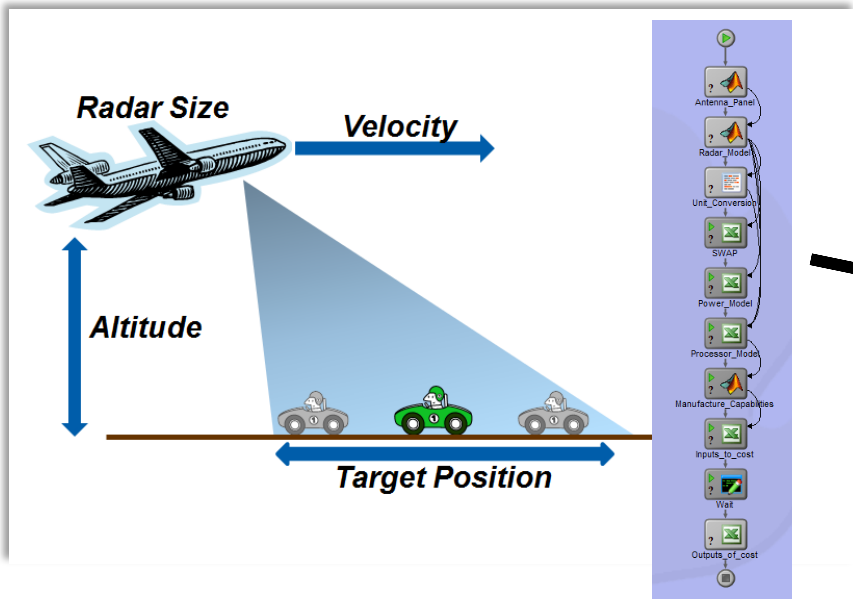
Quantity Produced

Production, Development, and Labor Costs

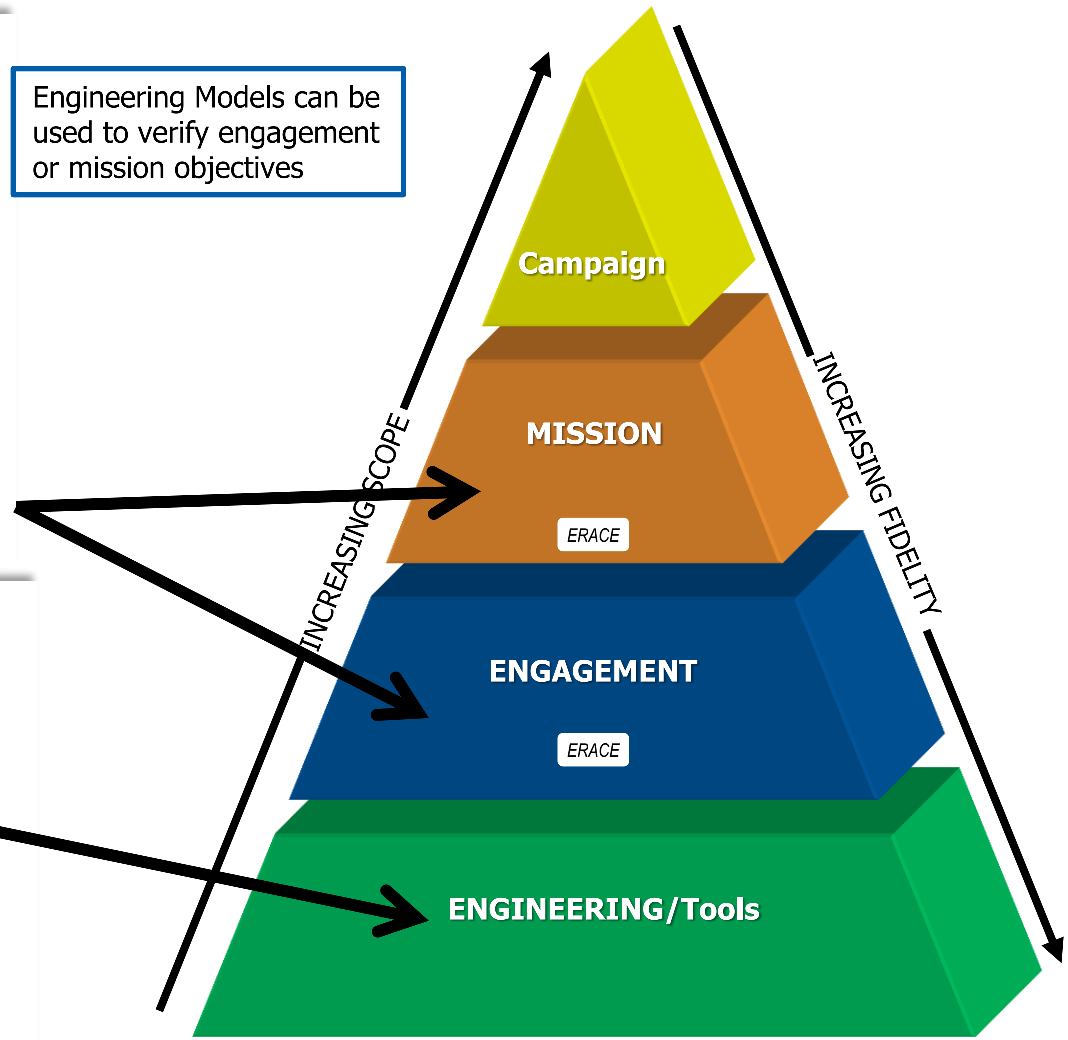
Mission/Engagement Simulation Validation:

Enhanced Radar Centric Engagement Model



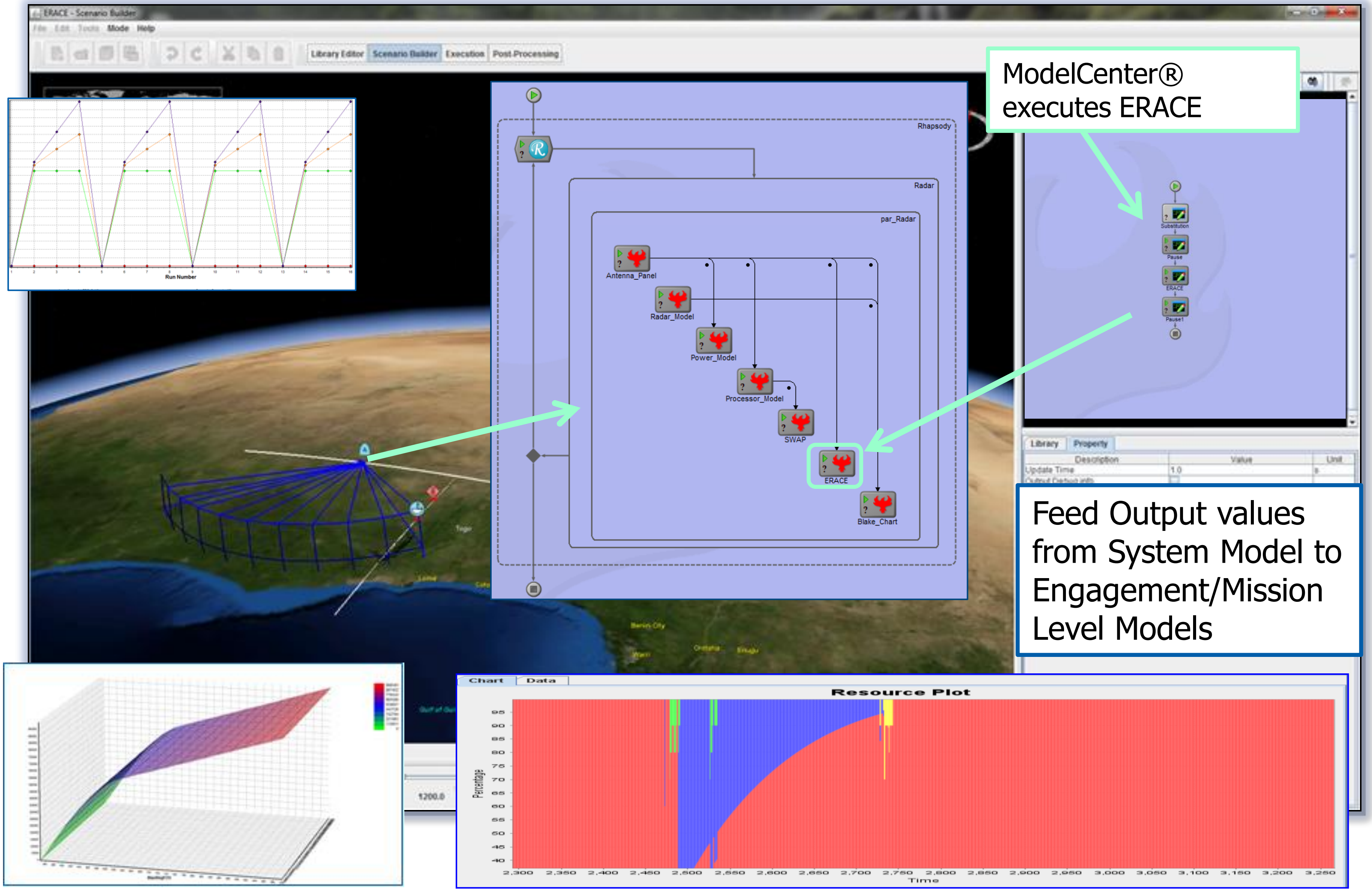


Engineering Models can be used to verify engagement or mission objectives



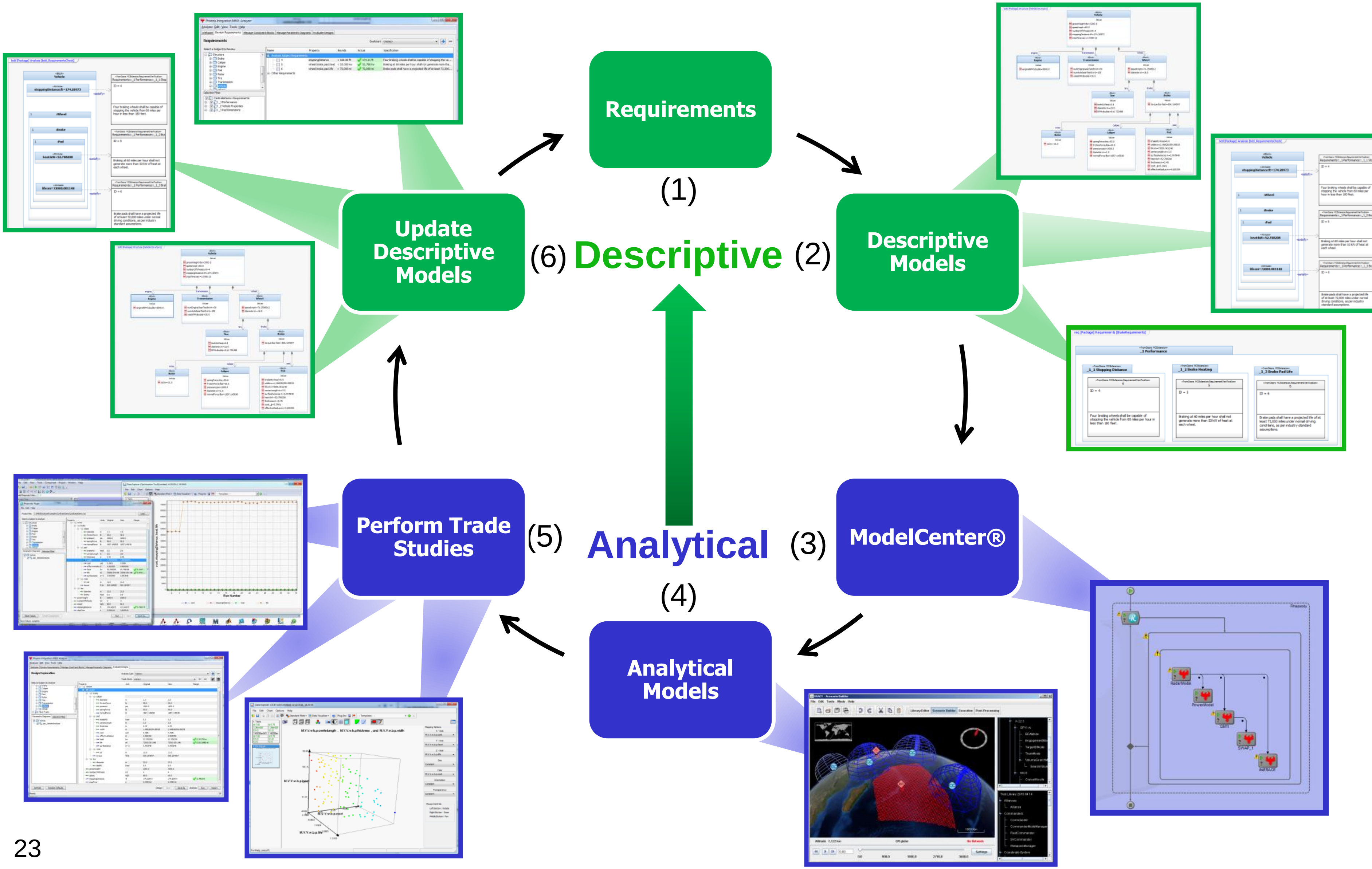
Validate system level parameters in an Engagement/Mission by increasing the scope

Integrate ERACE with Engineering Models



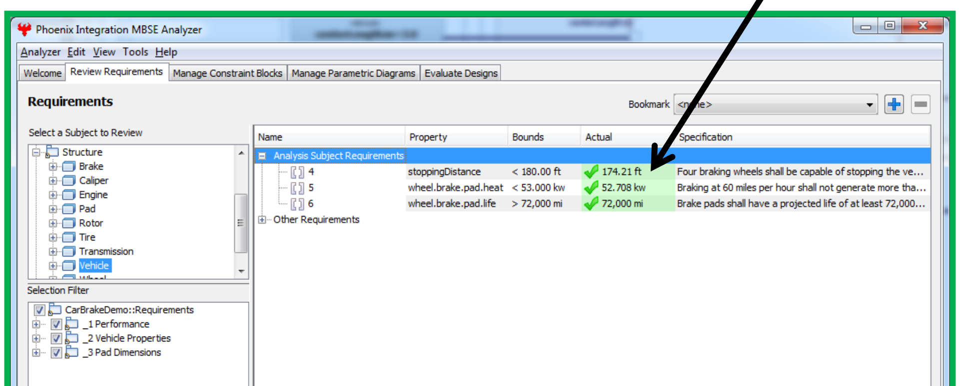
Analytical Back to Descriptive:

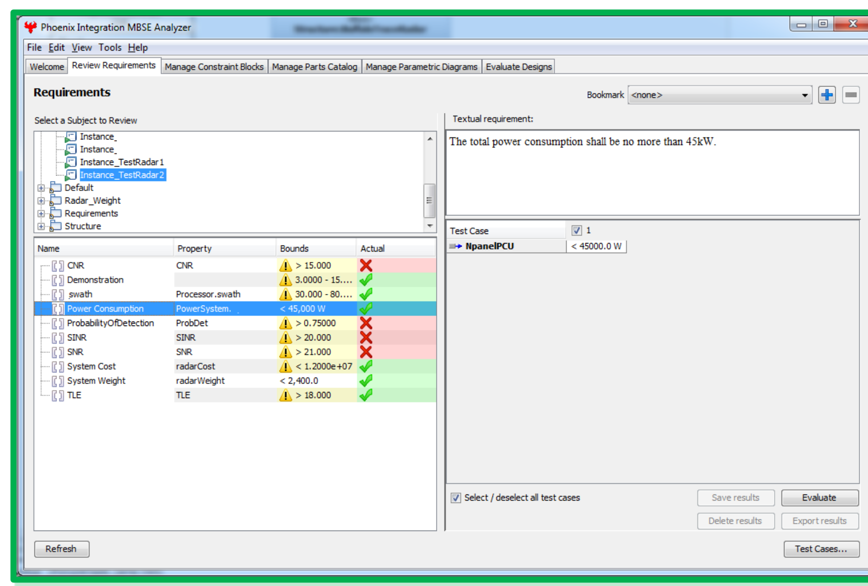
Update Architecture with New Attribute Values



Step 6: Update Descriptive Model with New Design Variable Values

- Design parameters (attributes) have changed due to trade studies performed
  - Rhapsody "Descriptive Model" is updated with new attribute values
  - New parameters show where current architecture fits with performance requirements





Getting Ever Closer to the End-to-End Model

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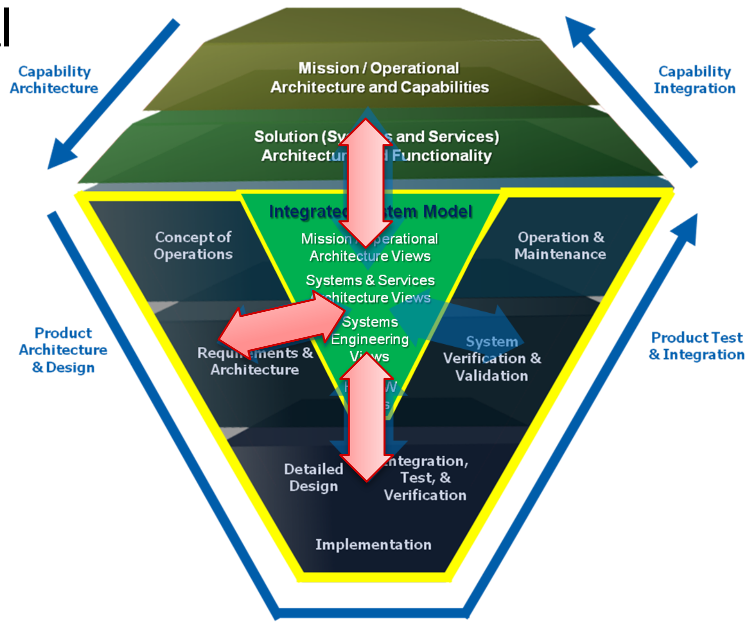
- ***Linked*** requirements and architecture (descriptive modeling), with engineering and engagement/mission models (analytical modeling)
- ***Generated*** vast quantities of trade studies to perform cost vs performance analysis
- ***Reduced*** manual communication between teams
- ***Paved*** the way for validating engineering design decisions with respect to the customer's mission



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Christopher Hoffman

Christopher Hoffman is currently in the Professional Development Program as a Systems Engineer for Northrop Grumman Electronic Systems (NGES) in Baltimore, MD where he has worked for the last year. Prior to working at NGES, he worked for an organization designing and building micro and nanosatellites for the Air Force Research Labs in Boston, MA. He received a Bachelor's of Science in Electrical Engineering at Boston University in 2013 and is currently finishing a Master of Science degree in Electrical Engineering at Johns Hopkins University. Since joining NGES he has worked in the Power Conversion Technology group designing and testing power supplies for future radar designs and is now part of the Mission Systems Engineering group tasked with implementing Model Based Engineering practices on internal programs.

Abstract

As systems become more complex, turning the many knobs on design choices becomes a complex n-dimensional problem. Not only is this difficult from an analysis point of view but it is further inhibited by the amount of communication needed between different system designers. Because of this, it is easy to optimize a portion of the system at first, say an antenna, but later find that the rest of the system components (power, physical structure, and software design) are now all constrained. Flexibility in both design and cost are now lost and the ability to change designs in the future are timely and expensive. Alleviating the stove piping effect of designing complex individual components for large systems throughout concept development is a must.

An integrated model framework was implemented for an internal customer, generating large amounts of trade studies by connecting architectural models with integrated software, antenna, power, and cost models for a radar design. What came out of this implementation was the ability to cut down on the labor and time required to combine data from independent models from many disciplines. This opened up the possibilities of turning new and more knobs of designs that would not have been considered due to the stove piping of information.

Acknowledgements

- Guy Babineau – Chief Engineer Model Based Engineering
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- Tamara Valinoto – Manager Model Based Systems Engineer
  - Subject Matter Expert
- Chris Urquhart – Systems Engineer
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- Phoenix Integration
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