Tradespace Exploration of MBSE and MBE Integrated Workflows

Tony Davenport
Josh Edwards
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GLOBAL PRODUCT DATA INTEROPERABILITY
SUMMIT
2018

ELYSIUM Parker Aerospace NORTHROP GRUMMAN BOEING

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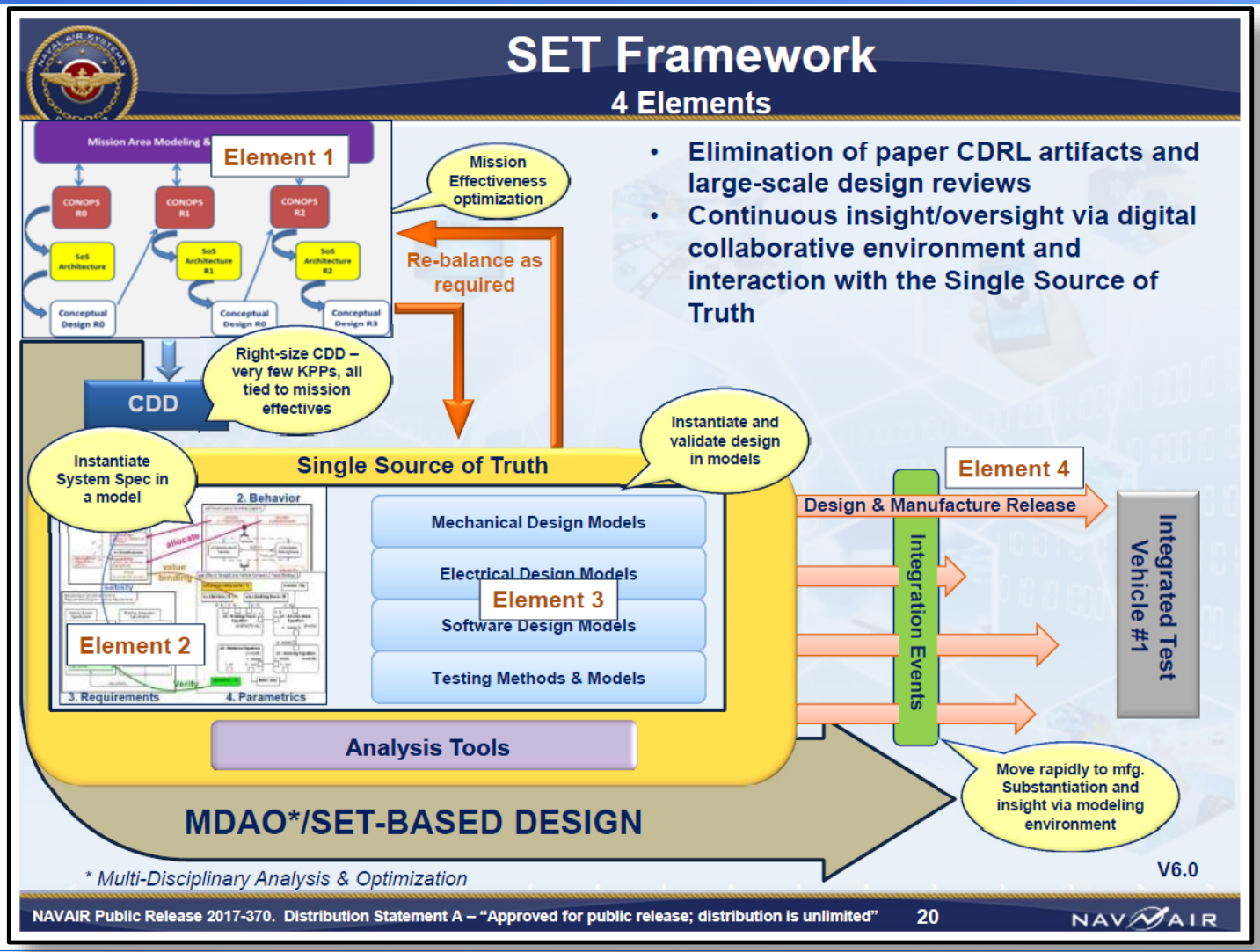
Systems Engineering Transformation

Global Product Data Interoperability Summit | **2018**



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MBSE Integration Example

Components, Sub-System & System Analytical Models- Integrated and Linked to the Mission

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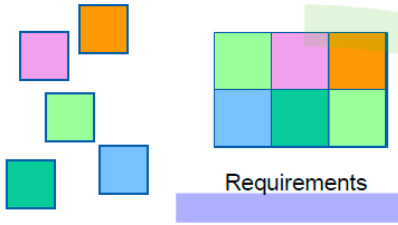
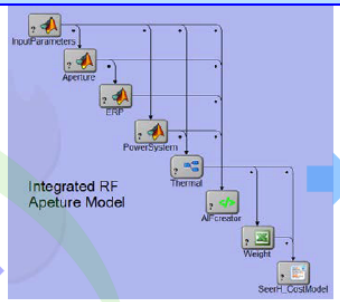
Multi Disciplinary Models Leveraged & Connected

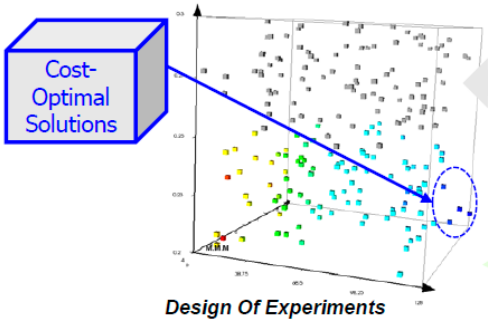


Integrated Cost-Performance Model



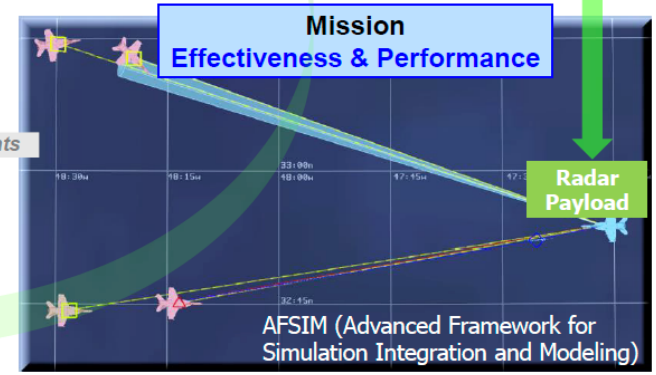
Link To Radar

Visualization & Optimization



Constraints

Mission Effectiveness & Performance



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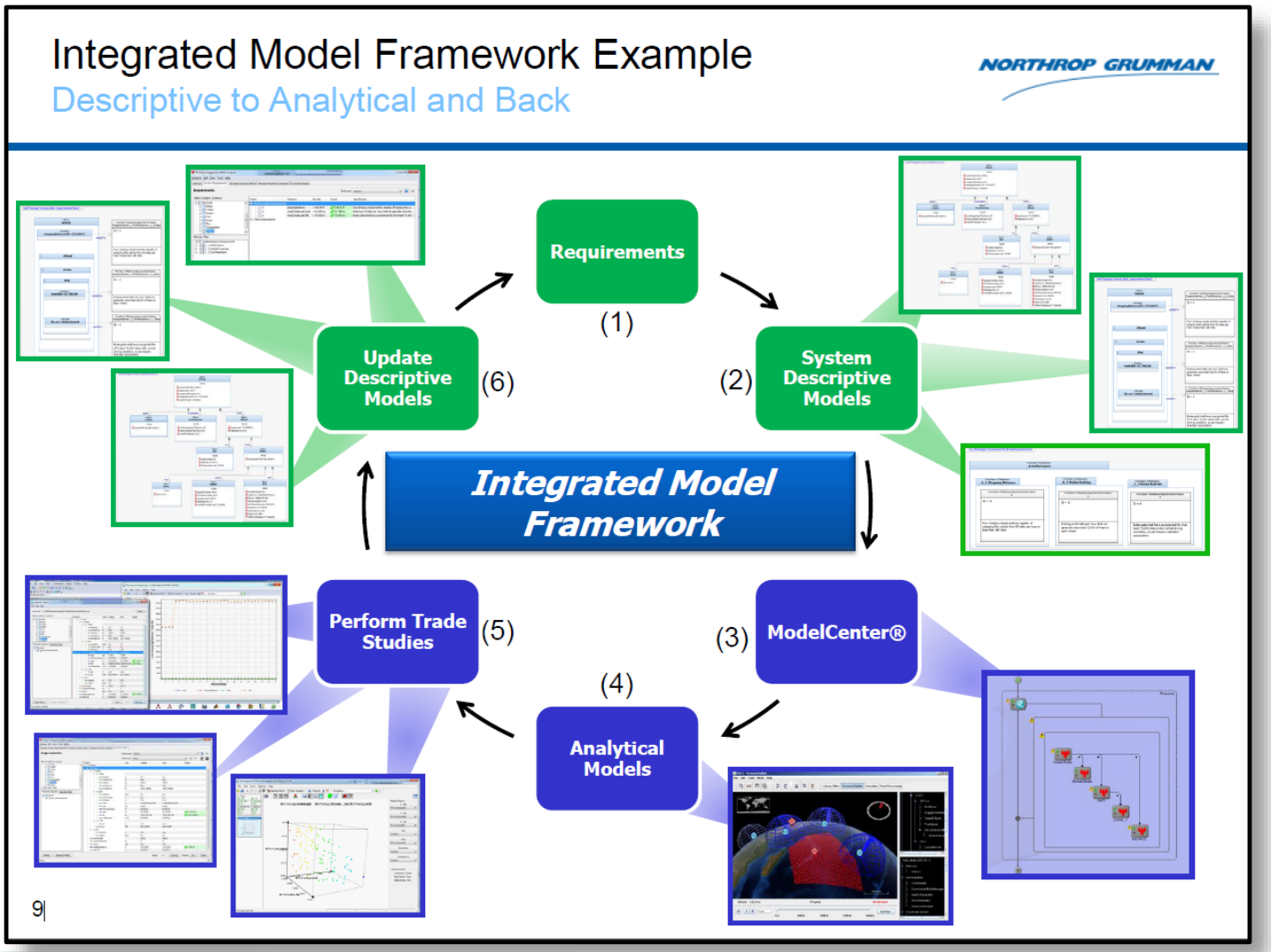
MBSE Integrated Model Framework Example



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Phoenix Integration Brings A Team with 20+ Years Of MBE & MBSE Experience To Customers

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ModelCenter is an Integration Conductor for both MBE and MBSE

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ModelCenter's 3 Major Components

- **ModelCenter Integrate**
  - **Automate**
  - **Integrate**
  - **To Create a Workflow**

- **ModelCenter Explore**
  - **Iterate The Workflow**
  - **Design Studies**
  - **Optimizations**
  - **Risk/Reliability**

- **ModelCenter MBSEPak**
  - **Integrate Systems Engineering Models with Domain Expert Models.**

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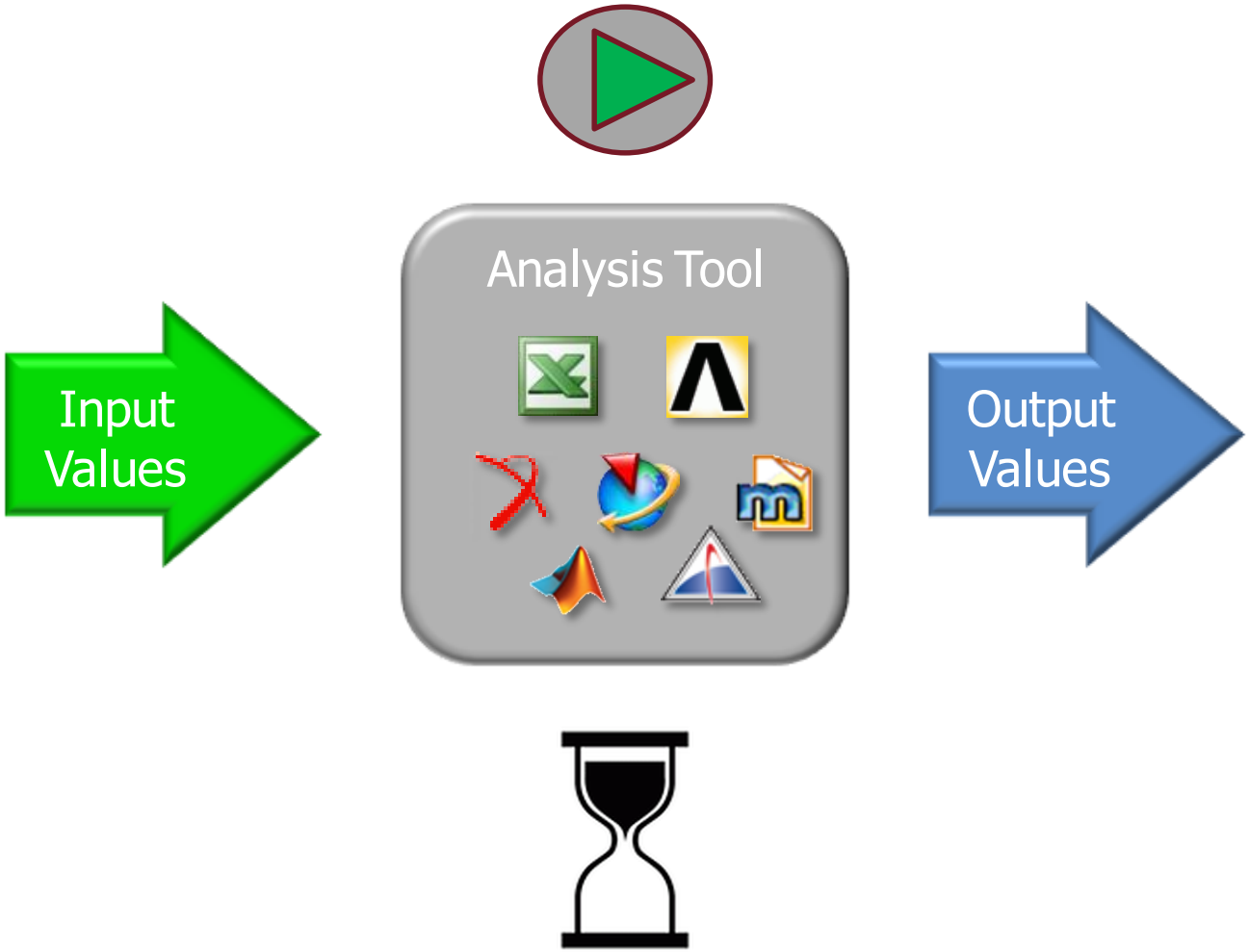
ModelCenter Integrate
Integrate Any Simulation via an easy to use GUI



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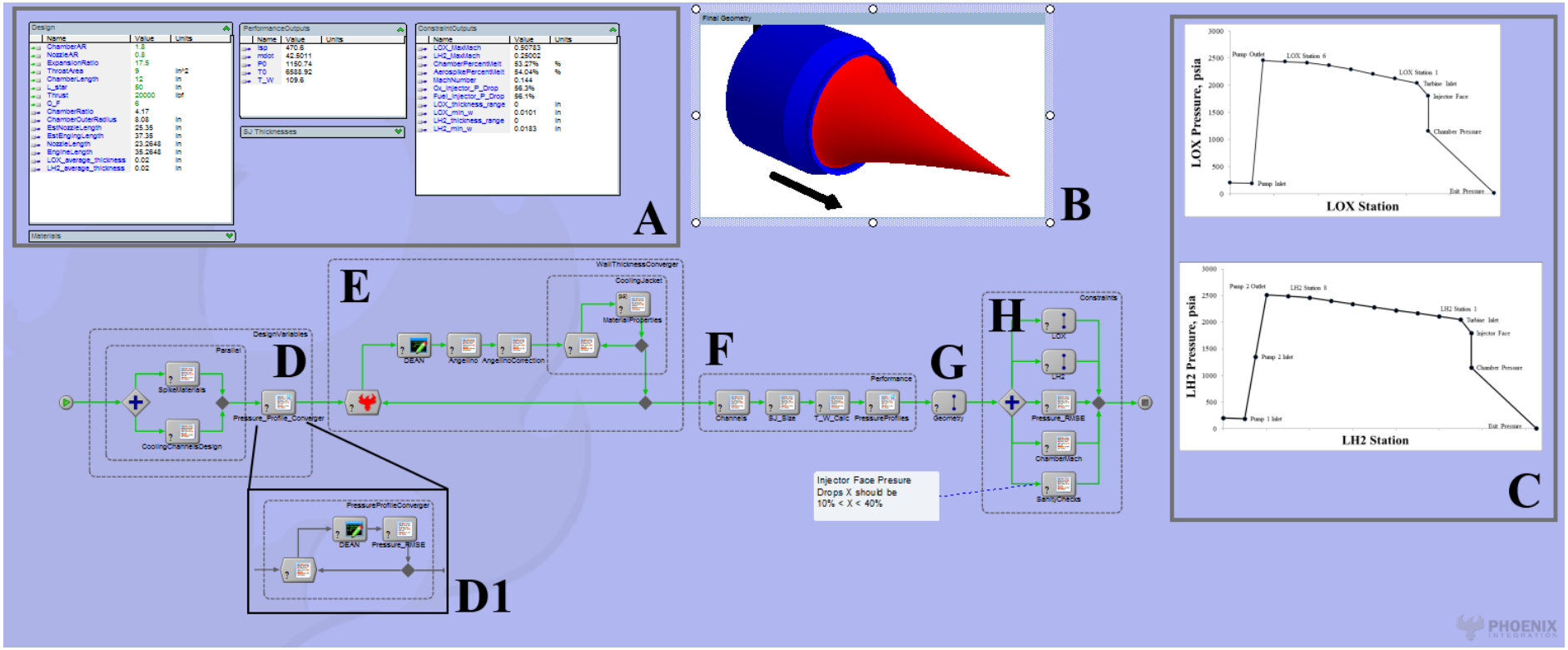
Sample Multi-Disciplinary Workflow



- **A ModelCenter User Can…**
  - **Integrate just about any software solution – COTS or Home Grown software,**
  - **Integrate and update CAD and SysML solutions as part of a workflow,**
  - **Perform DoE, Probabilistic, Optimization, and Sensitivity Studies on the workflow,**
  - **Allows nesting of existing workflows,**

…So your organization can create a more robust, high fidelity analysis and design.

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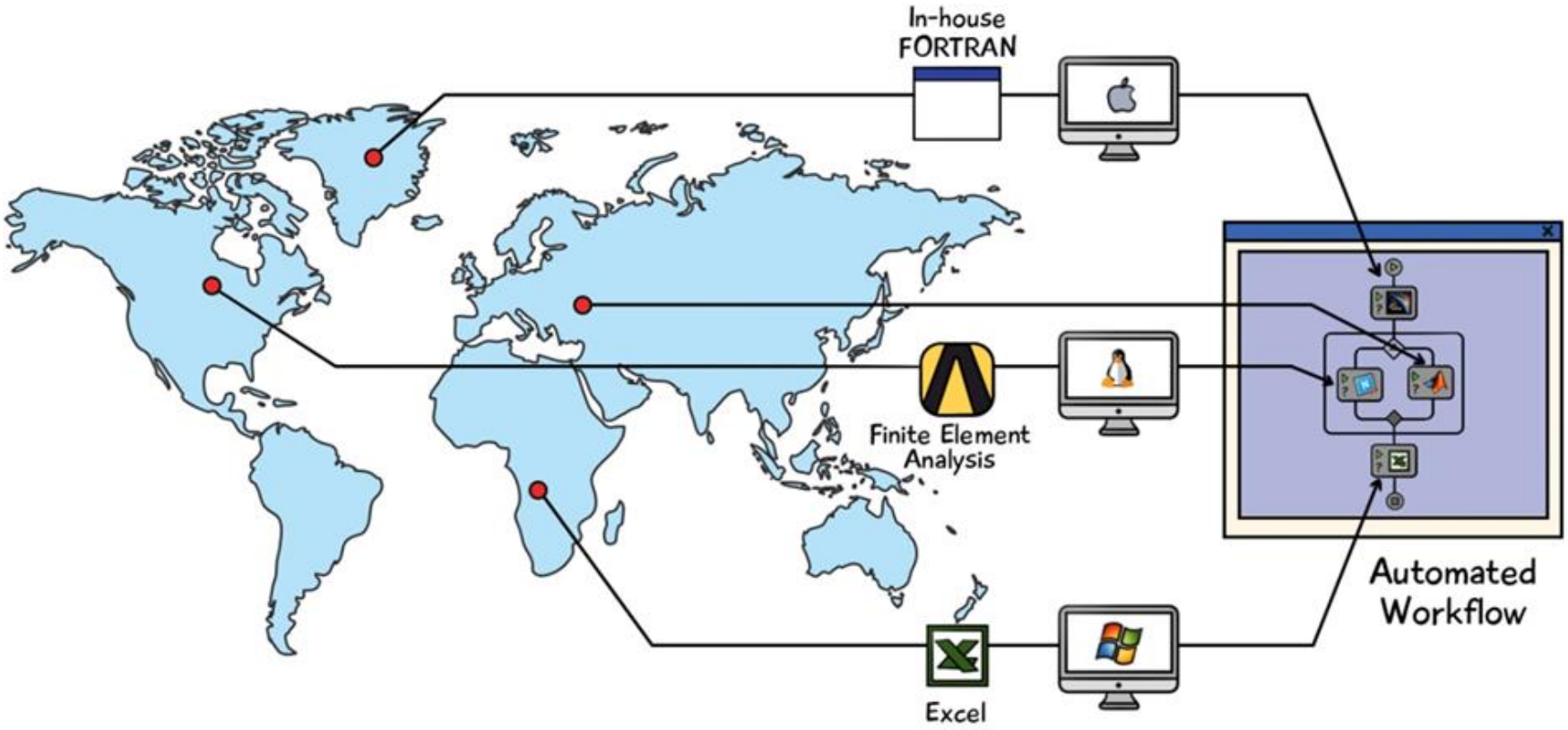
Model as a Service (MaaS) OEM & Supply Chain Benefits



Utilize MaaS to *Share the Execution* of Models but *NOT the IP* (Intellectual Property) Across *Your Organization & Supply Chain*
IP is kept *LOCAL*, as only Key Parameters and Results are passed.

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MaaS Maturity Through Time (X) & Supply Chain Connectivity (Y)

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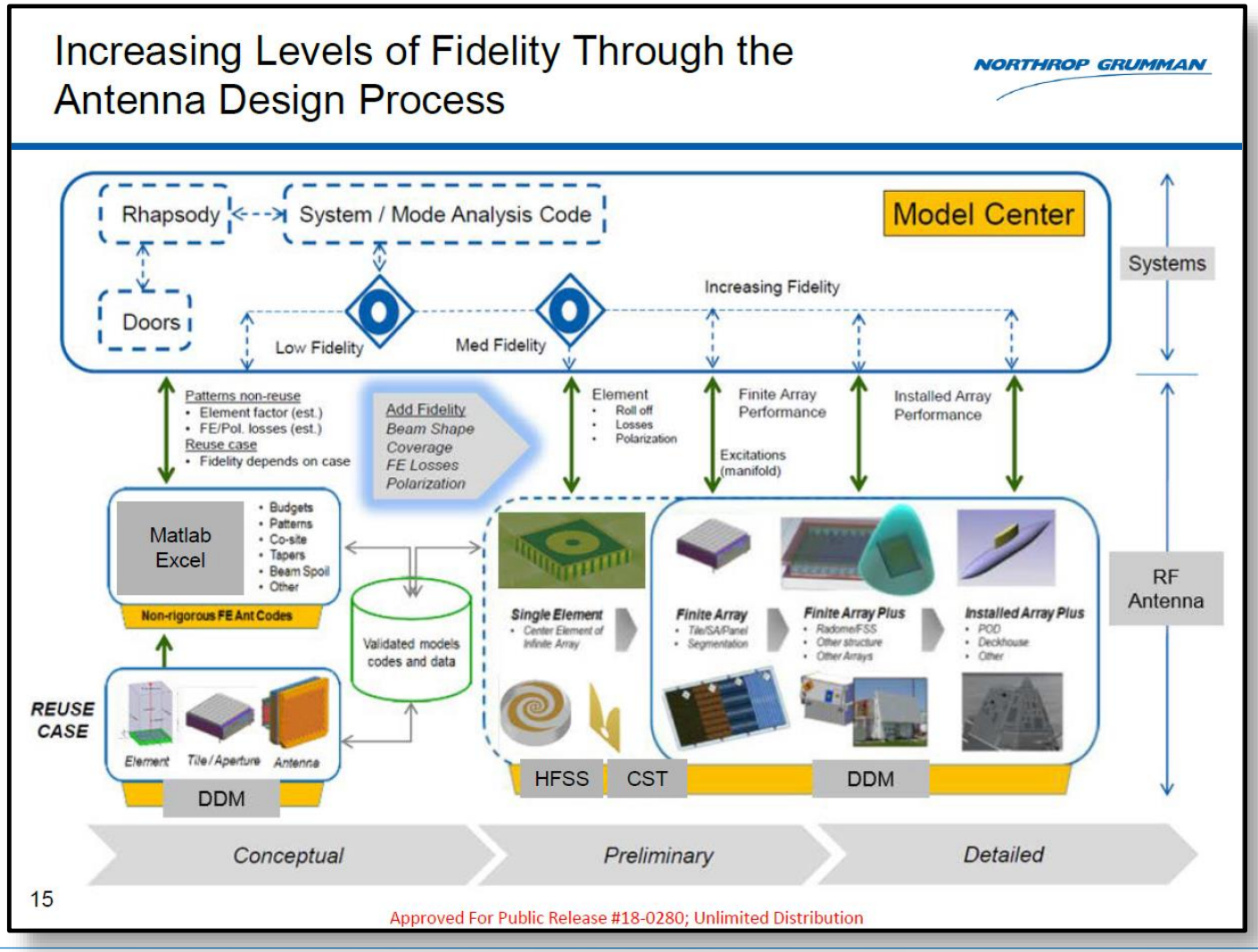

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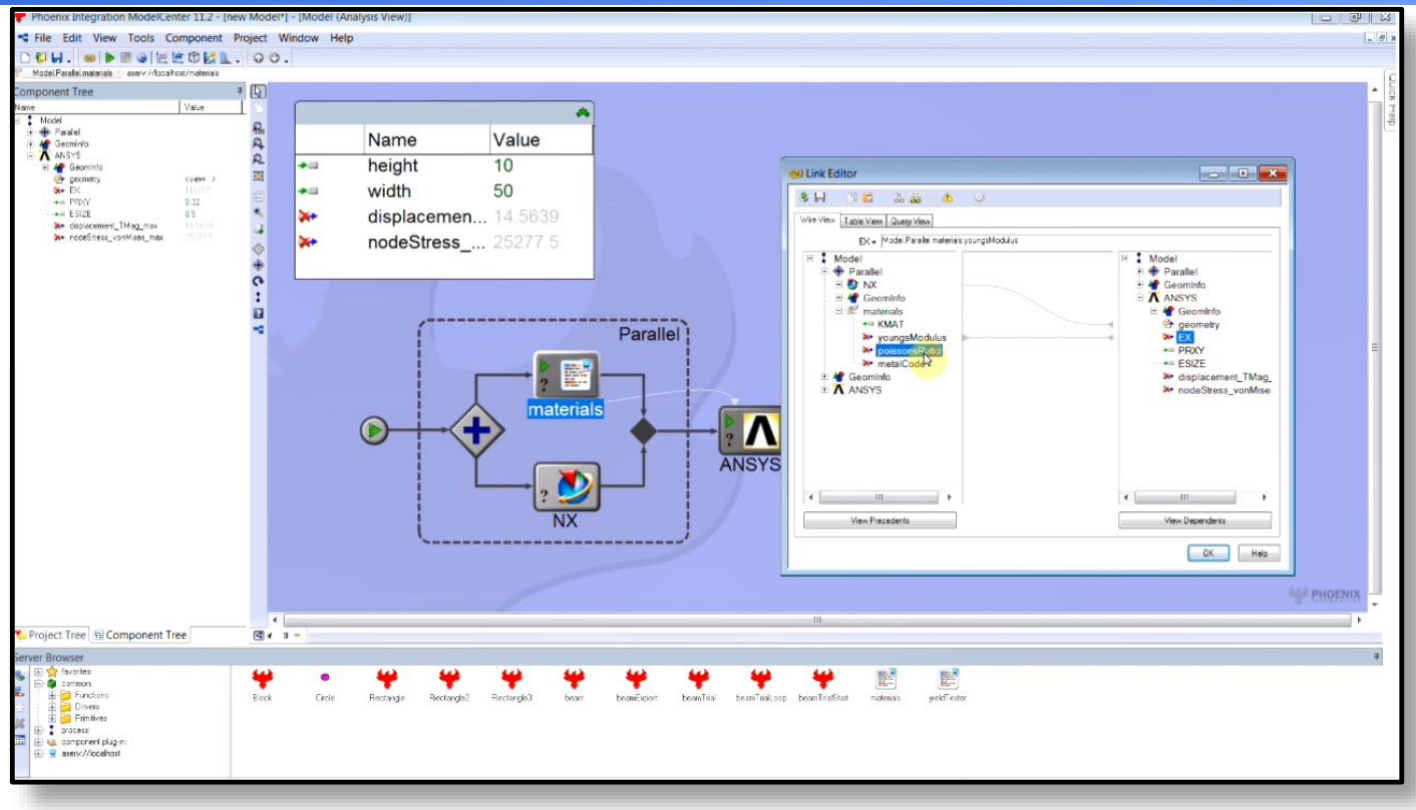
How Does MBE/MBSE Integration Work?



- **Integrated Workflows are created through the ModelCenter graphical environment.**
- **Models and Workflows can be integrated from any location world-wide.**
- **Inputs and Outputs of a Software Solution are easily stitched together.**
- **Workflows can then be "Played" with new inputs through the click of a button.**

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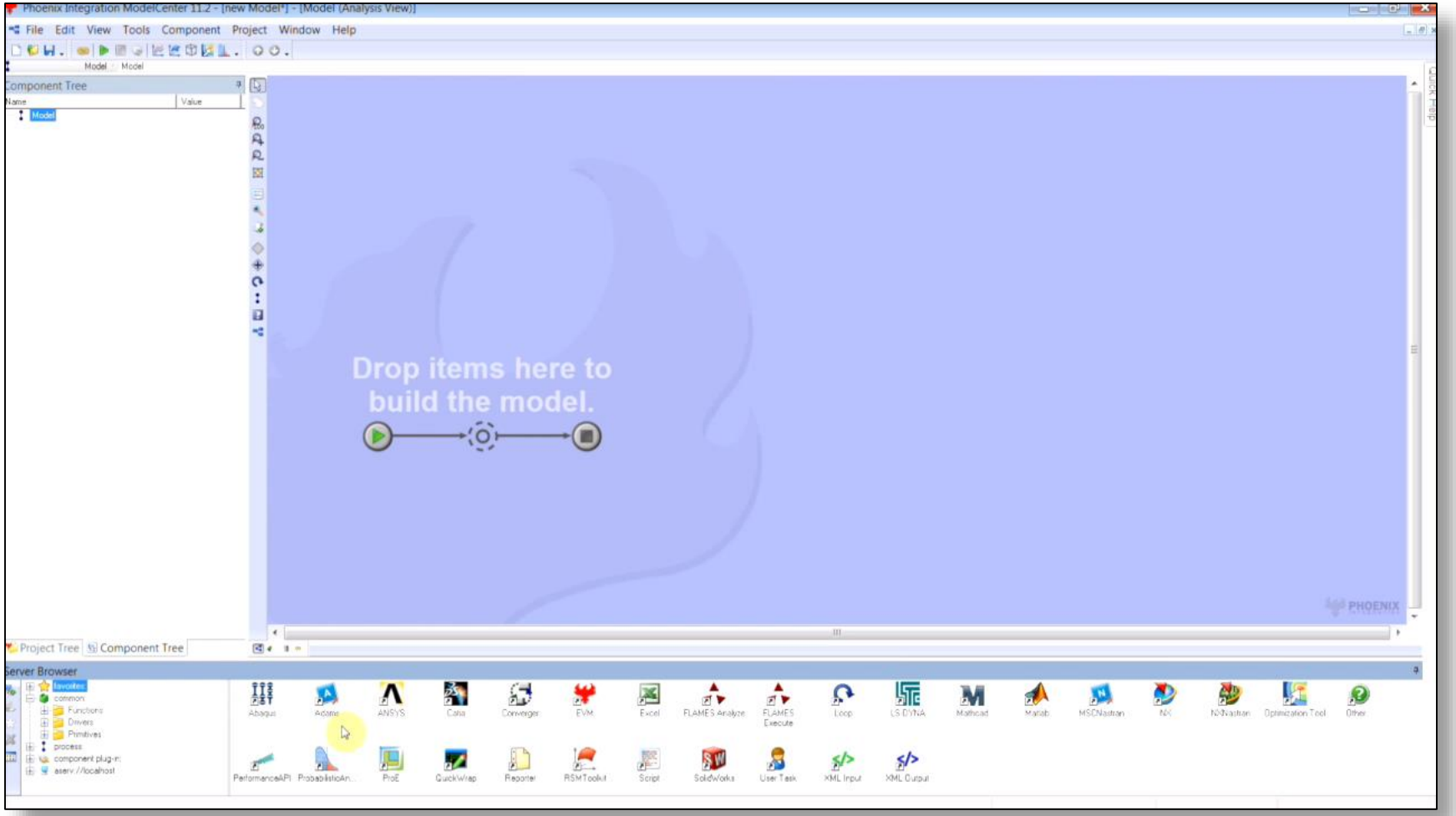
Create and Automate Workflows



Video Demonstration of ModelCenter
Contact Phoenix Integration for more details.

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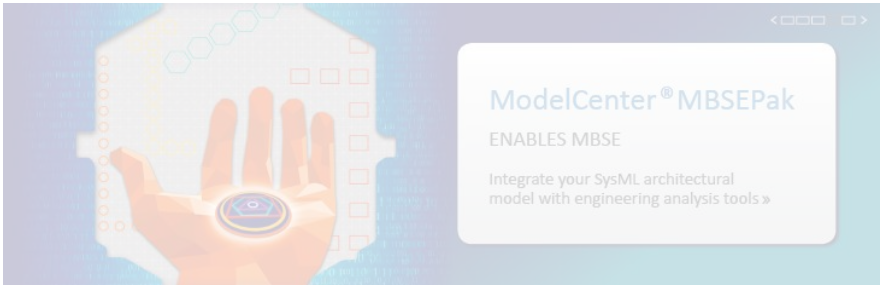

- ModelCenter Integrate
  - Automate
  - Integrate
  - To Create a Workflow
- **ModelCenter Explore**
  - **Iterate The Workflow**
  - **Design Studies**
  - **Optimizations**
  - **Risk/Reliability**
- ModelCenter MBSEPak
  - Integrate Systems Engineering Models with Domain Expert Models.

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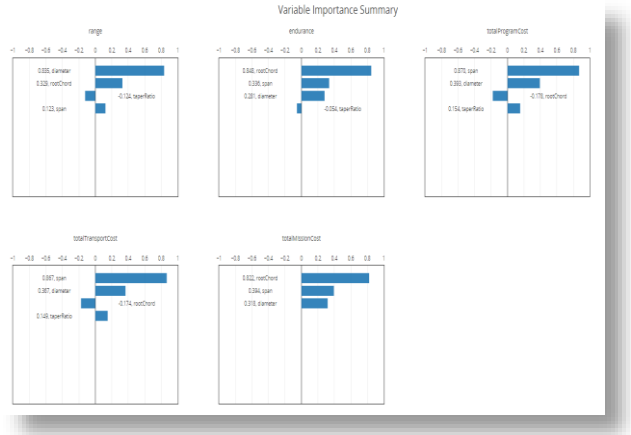
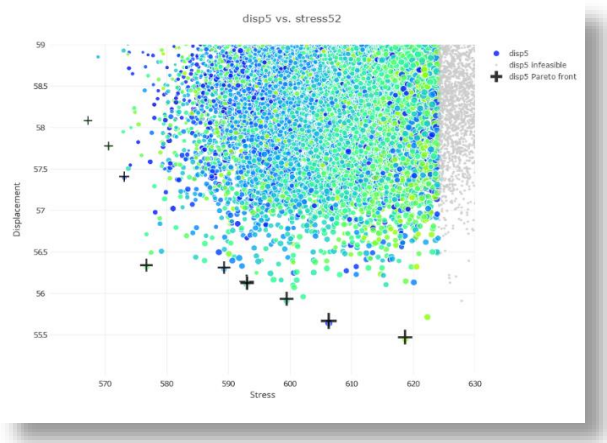
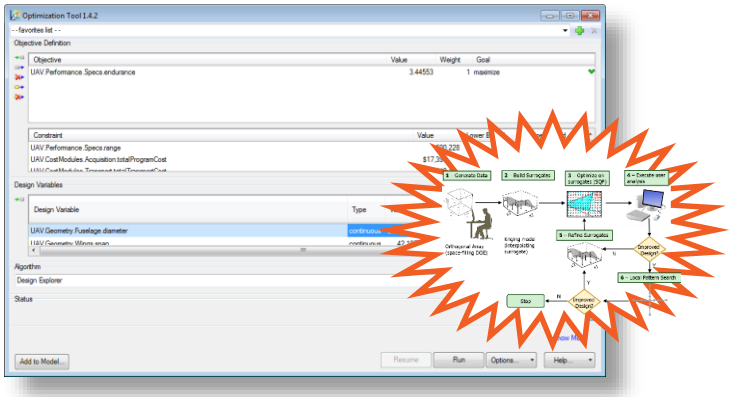
MDAO In Decision Making



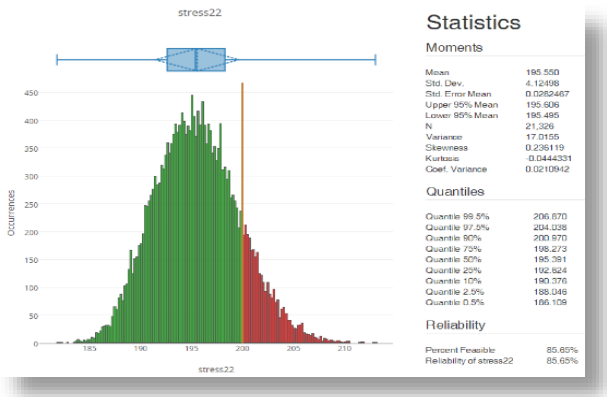
Sensitivity Analysis



Trade Space Visualization



Optimization



Probabilistic Analysis

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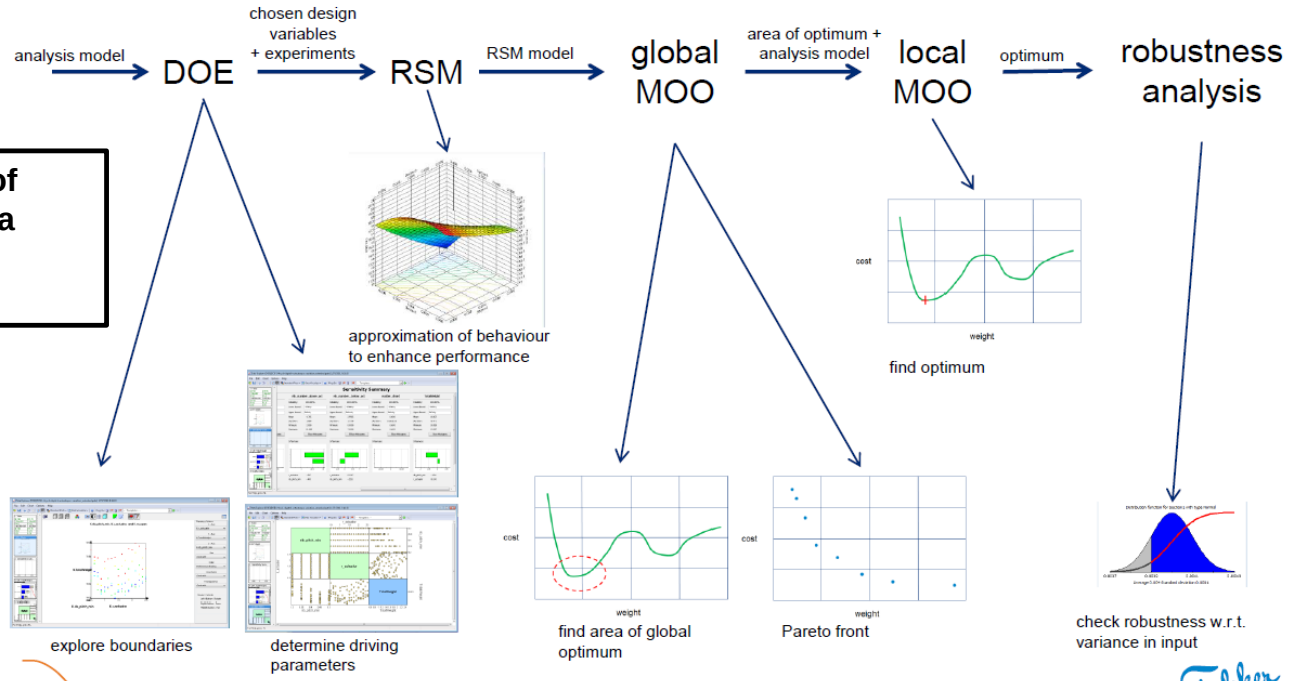
Reducing the Variables via Design Sensitivity Analysis

PHOENIX INTEGRATION

Increase design maturity
The principle

Reduction of Variables via Sensitivity Analysis



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ModelCenter Data Explore (Tradespace Visualizer)

Evaluate Program-Specific Tradeoffs and View Structure of Data Using Visualization Tools

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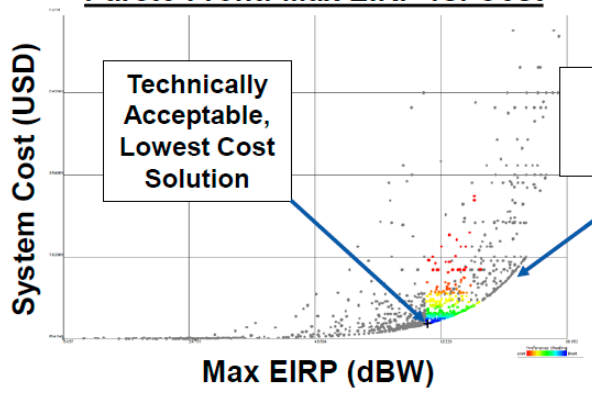
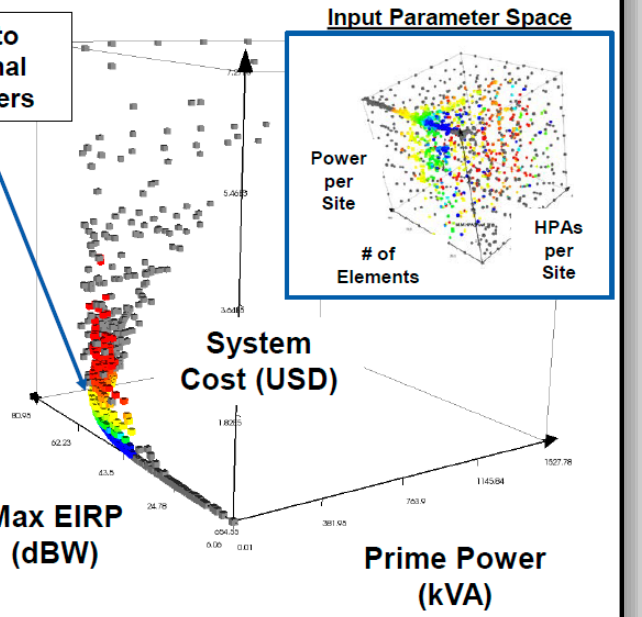
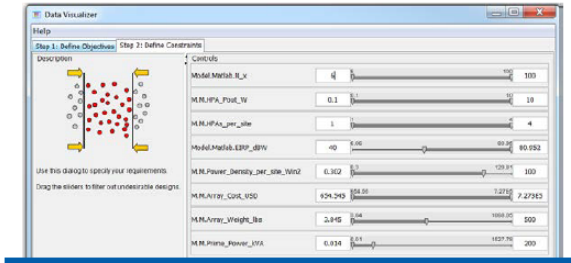
Pareto Front: Max EIRP vs. Cost



3-D Data Manifold of KPP Output Space: Max EIRP vs. Cost vs. Prime Power



Define Component & SWaP Constraints



Color Shading Design Cases Based on Best (Blue) to Worst (Red); Able to Gray Out Design Cases That Do Not Meet Specified SWaP Constraints

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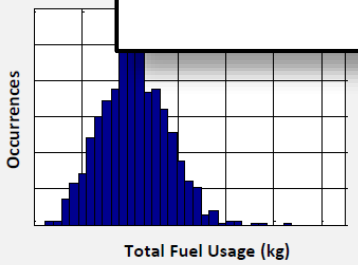
ModelCenter Risk/Reliability Analysis Benefits

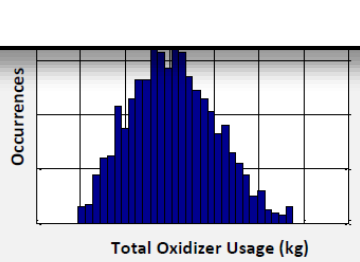
Statistical Validation of Propellant Load

Orbital ATK

- Propellant load validated from CRS Performance Integrated Monte Carlo analysis
- Analysis calculated total mission +3σ propellant, fuel, and oxidizer consumption
  - Total mission +3σ propellant results in 7-9% reduction vs. sum of budget +3σ line items
- Prope…te

"results in 7-9% reduction [in propellant mass]"





Descent Attitude Keeping			
Descent Slews			
Descent Consumption			
Residuals			
Total Mission +3σ Consumption			
Sum of +3σ Consumption			

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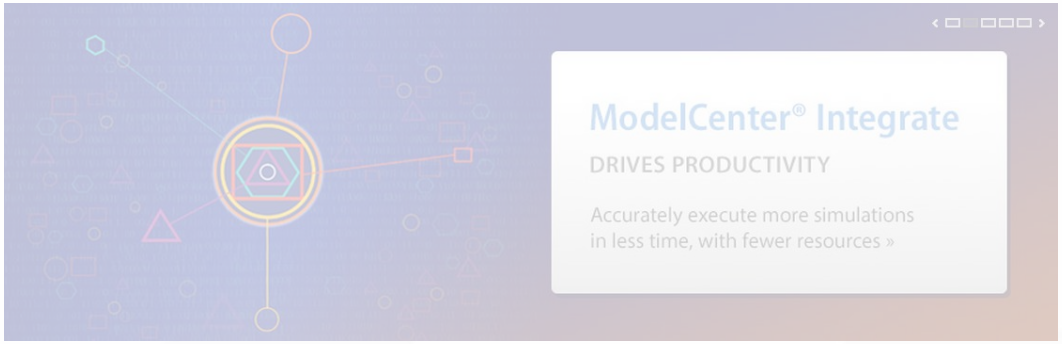

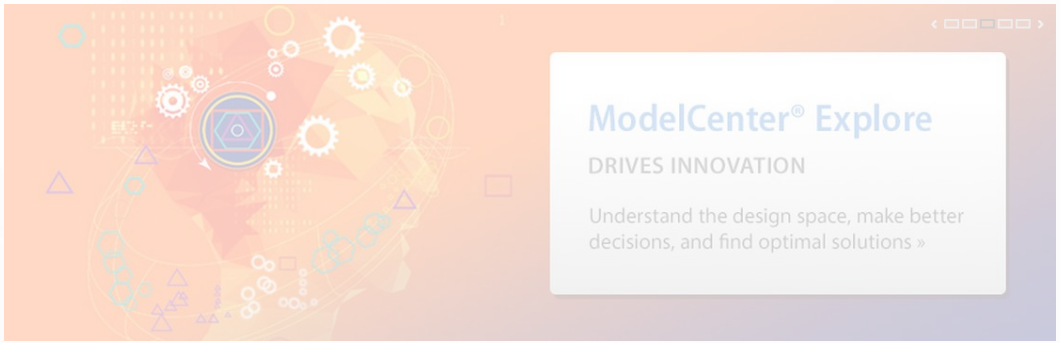

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  - Risk/Reliability
- ModelCenter MBSEPak
  - Integrate **Systems Engineering** Models with **Domain Expert** Models.

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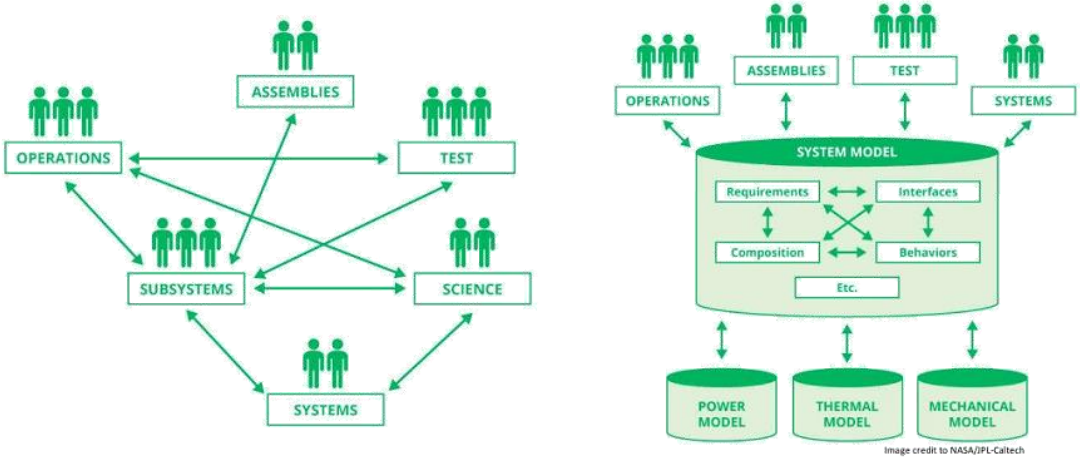
MBSE – Moving System Engineering from Document to Authoritative Source of Truth

MBSE in a Nutshell



Traditional Systems Engineering | *Model Based Systems Engineering*

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MBSE - SysML

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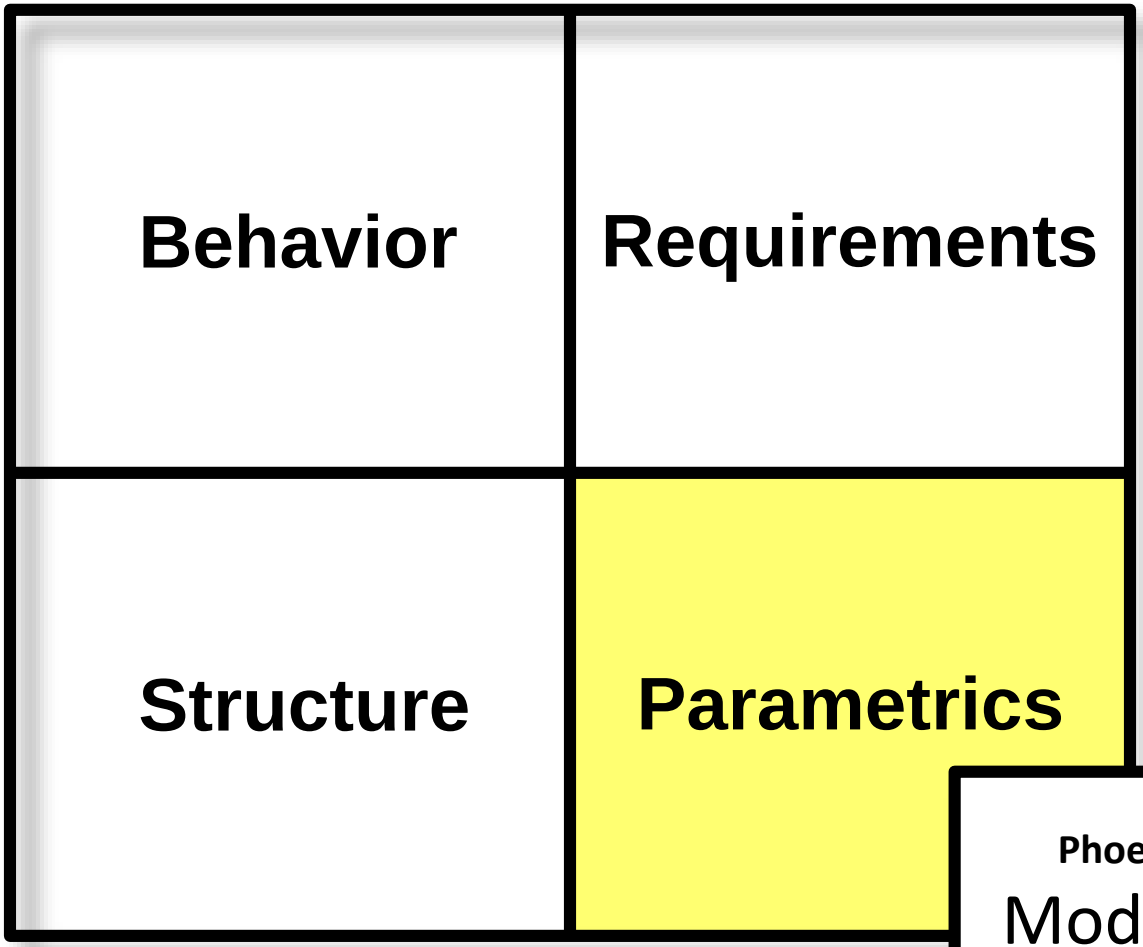
The Four Pillars of SysML



Phoenix Integration

ModelCenter©

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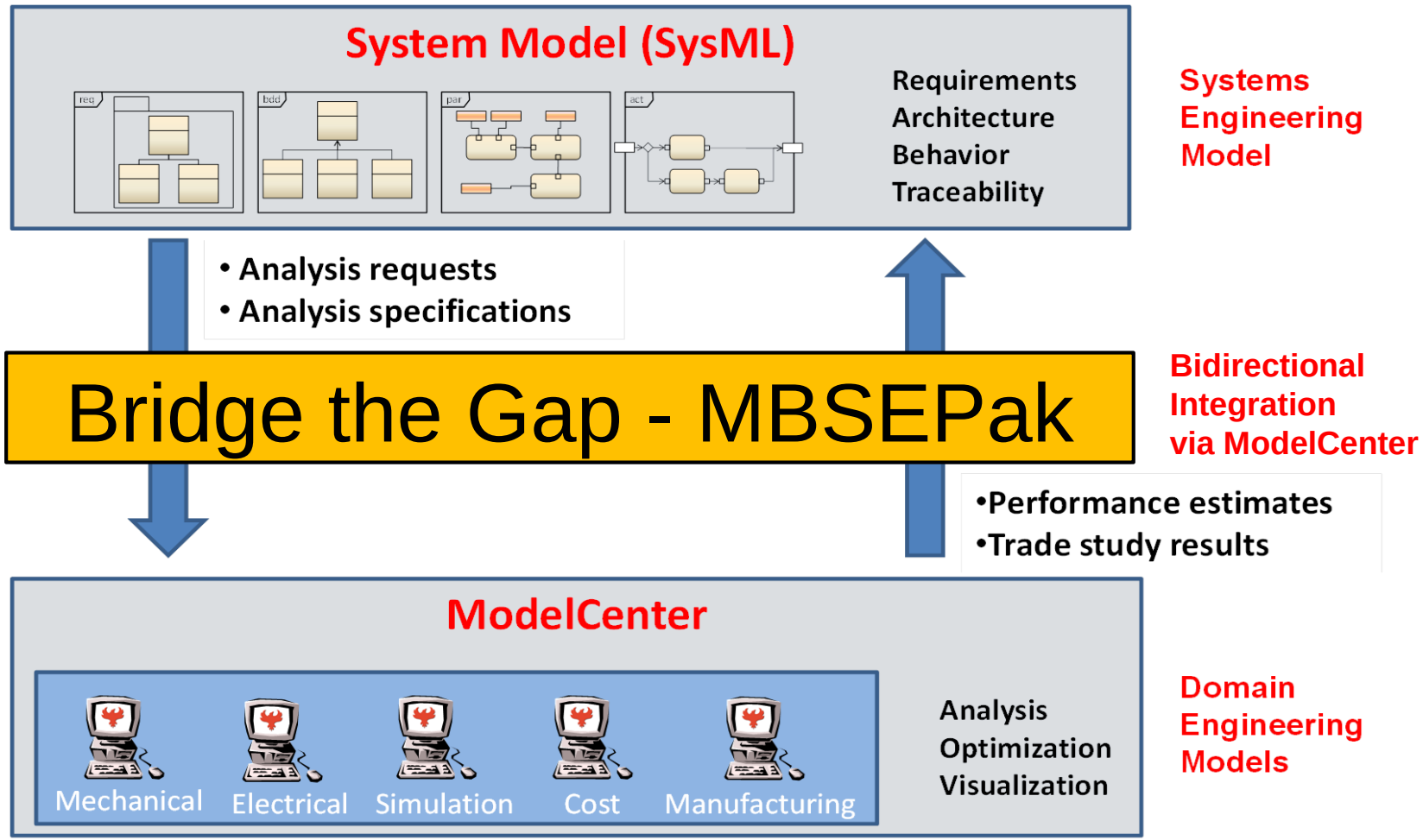
Today: Connect SysML with Engineering Analysis



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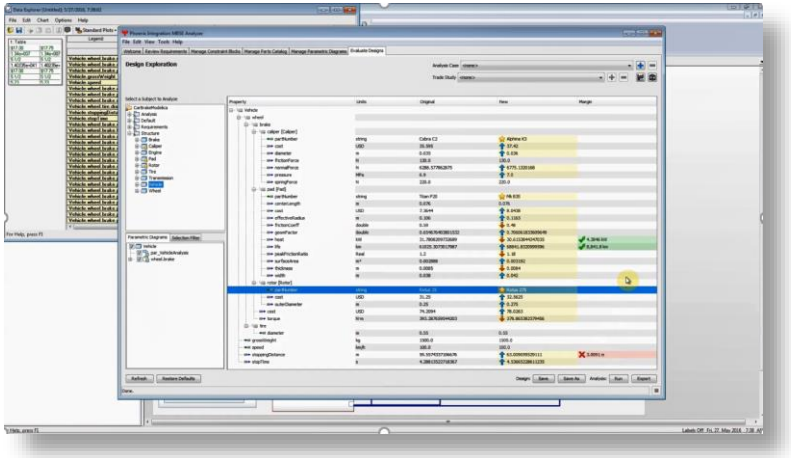
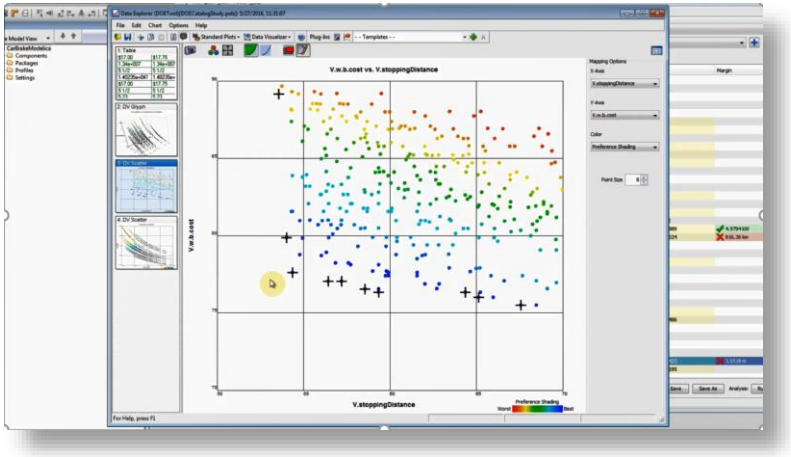
Design Exploration with MBSE integration

SysML Model to ModelCenter

- Automatic requirement verification via domain expert simulation results.



- Access ModelCenter Explore (MDAO) capabilities without leaving the SysML tool.



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Design Exploration with MBSE integration SysML to ModelCenter

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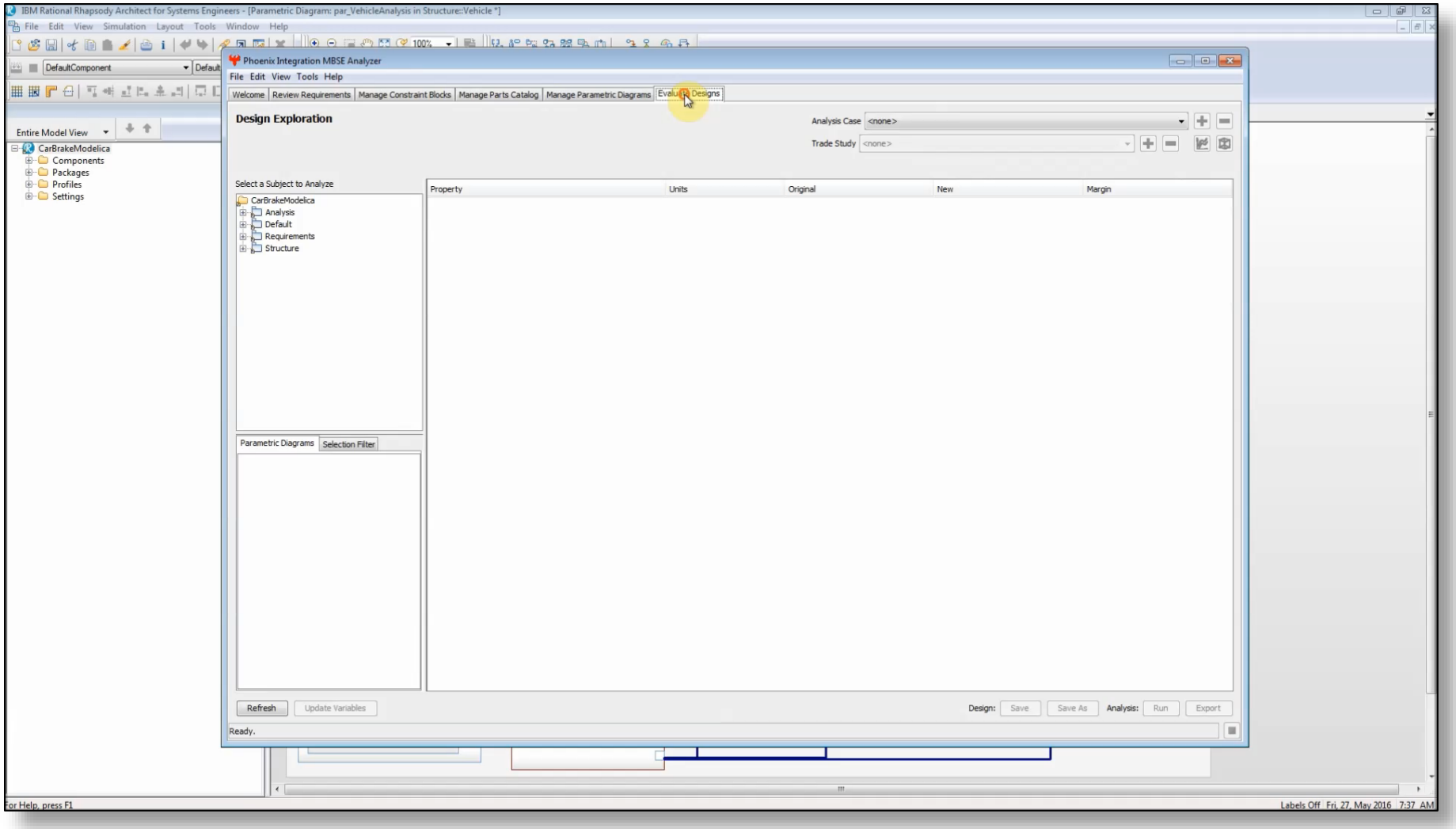

Video Demonstration of ModelCenter
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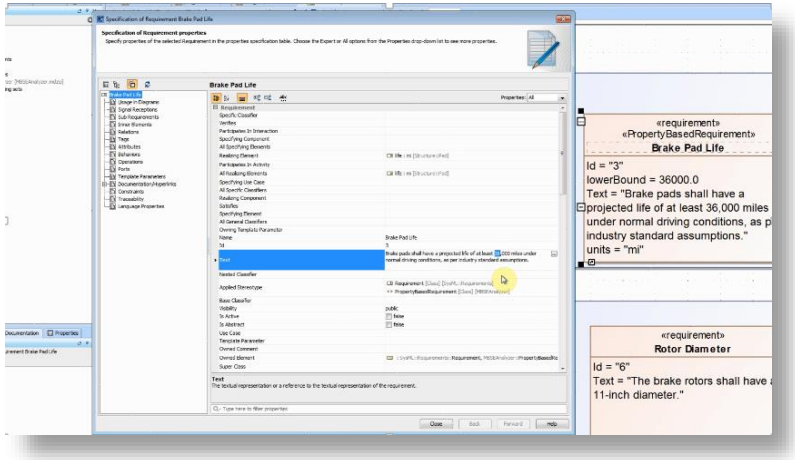
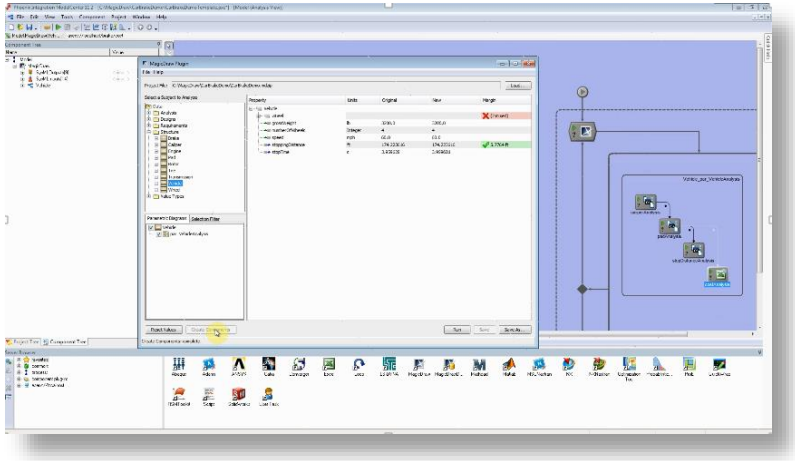
Responding to a Change Request with MBSE integration

ModelCenter to SysML Model

- Share performance requirements from SysML models with domain experts through SysML integration.



- Automatically generate workflows from SysML models to rapidly respond to requirements changes.



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Responding to a Change Request with MBSE integration ModelCenter with SysML model

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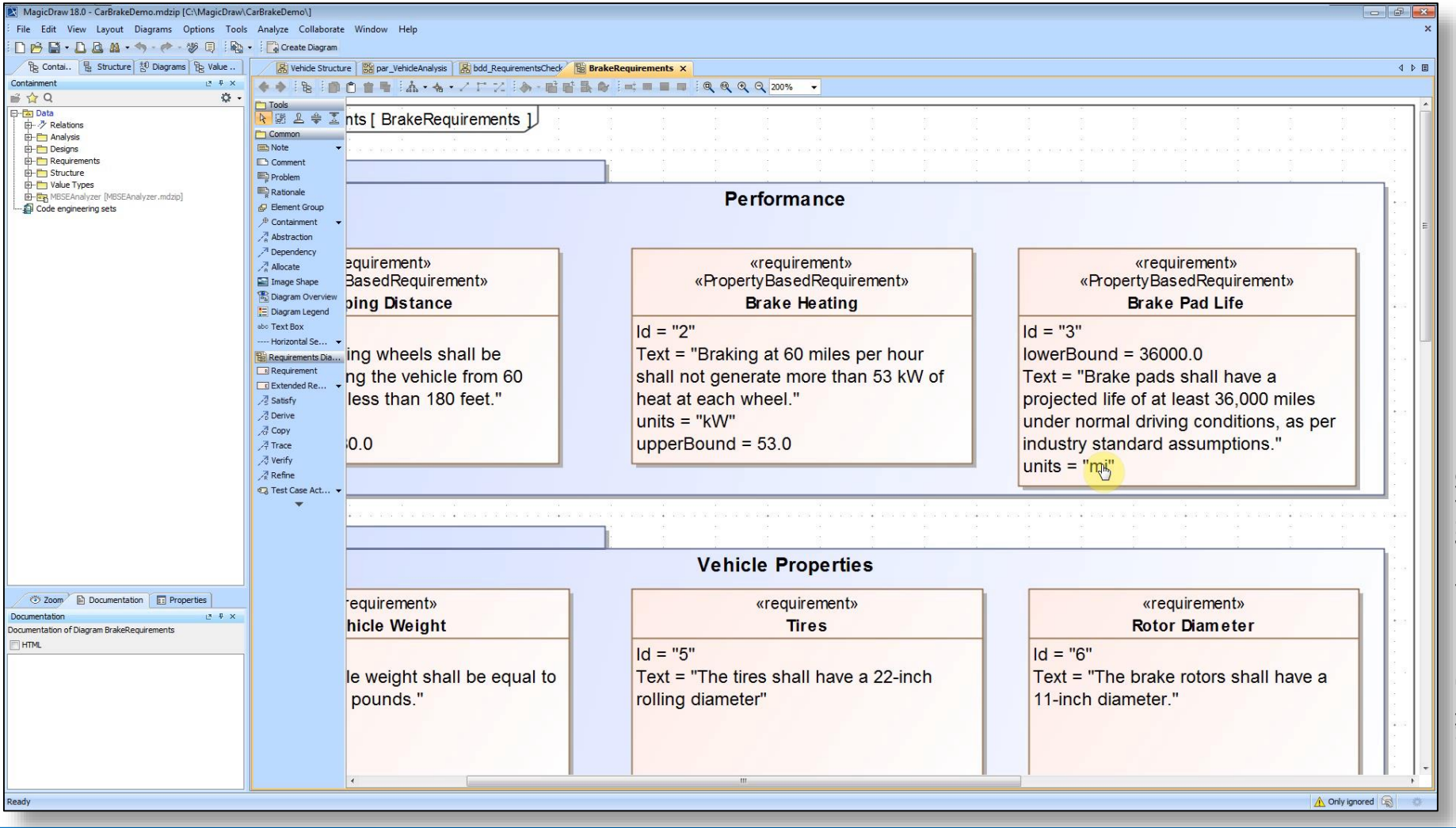

Video Demonstration of ModelCenter Integration for more details.
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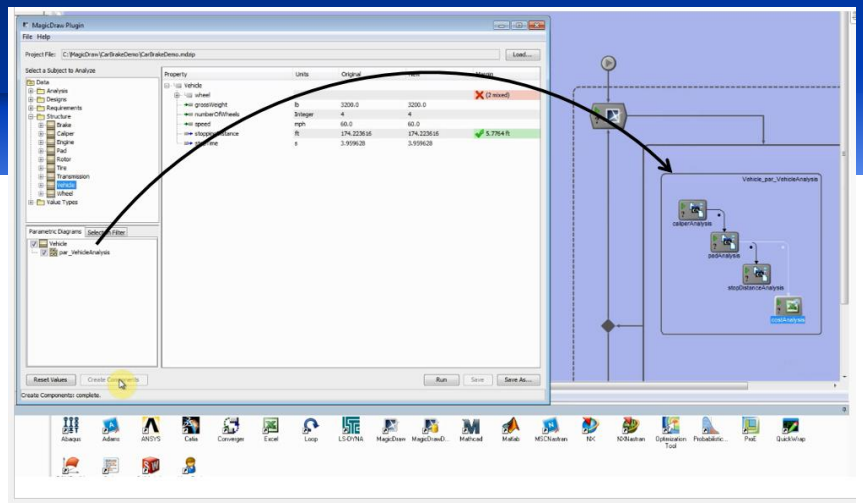
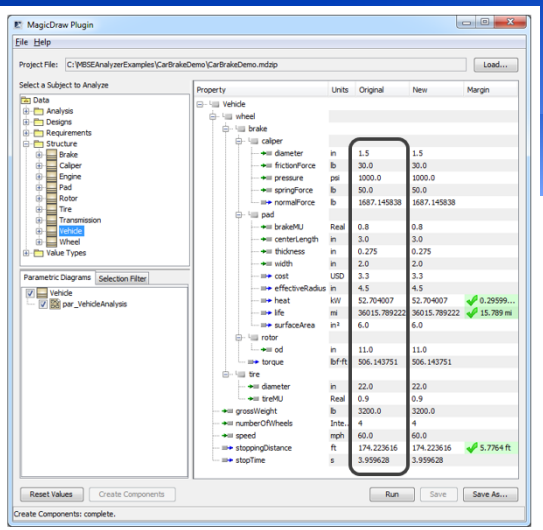
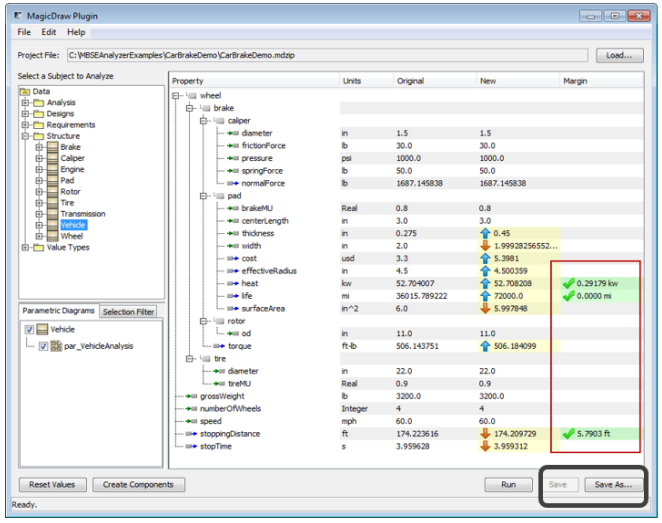


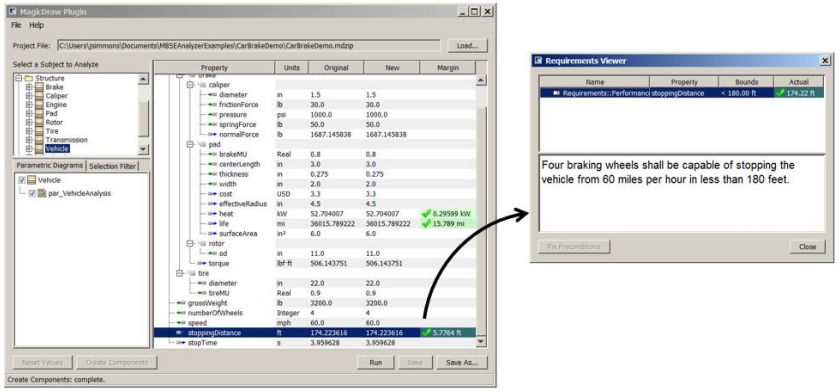
Generate Workflow from SysML…



Import Current Design Values
From SysML Into Domain Expert Models…



Push back to SysML with Single Click…



And Review/Verify Requirements
Stored in SysML Model

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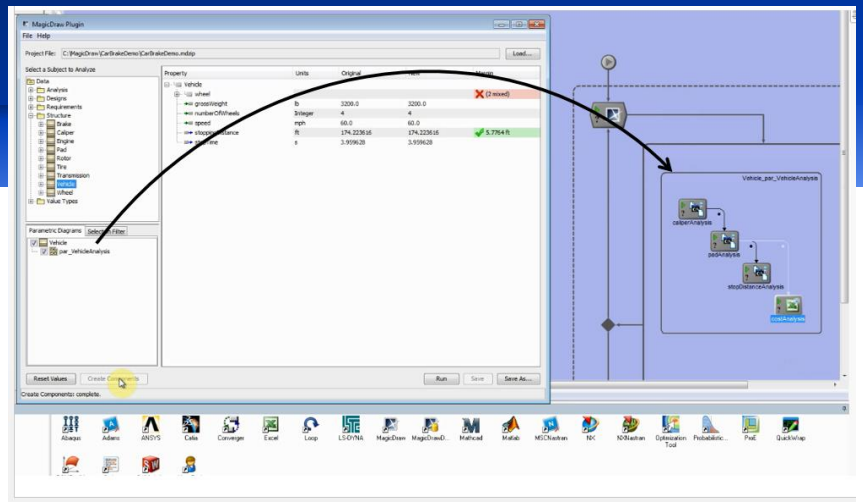
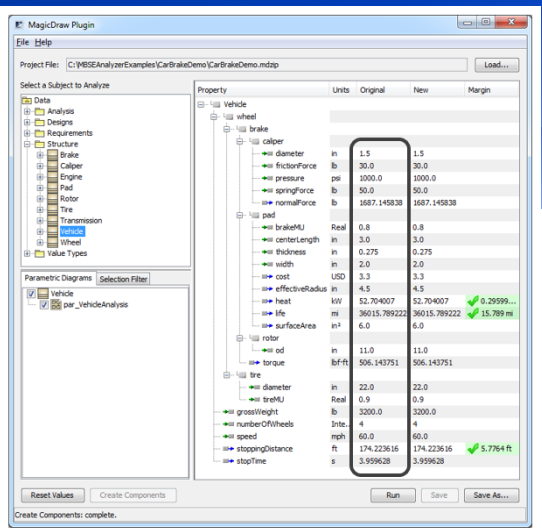
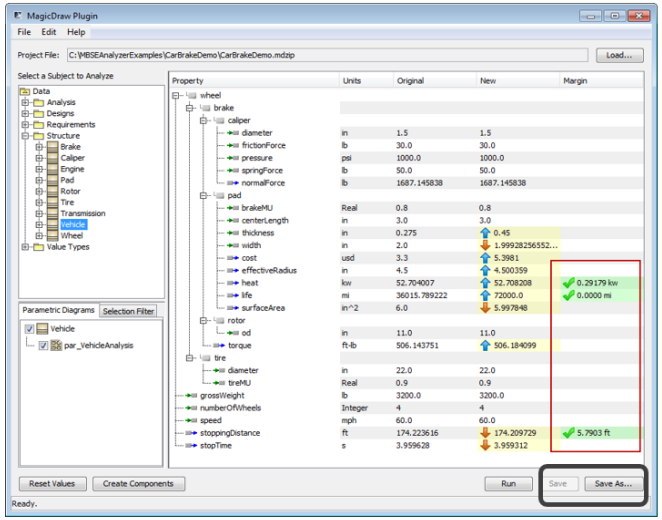


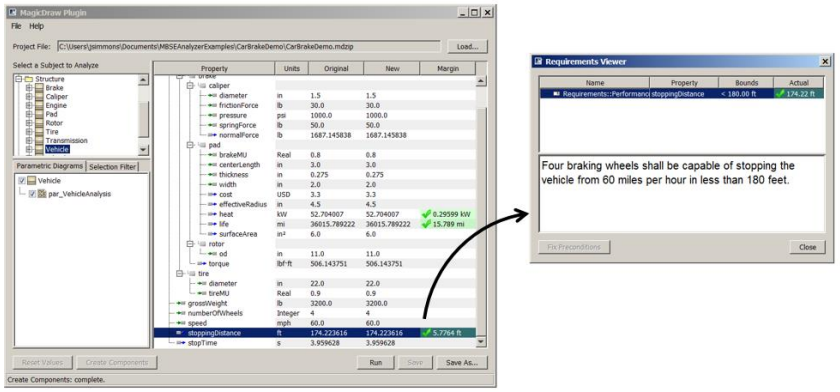
Domain Experts are using the same Analysis
As the Systems Engineer…



With the Same Values…



And Storing the Results in the
Authoritative Source of Truth…



With the same context as other
Domain Experts and Systems Engineers!

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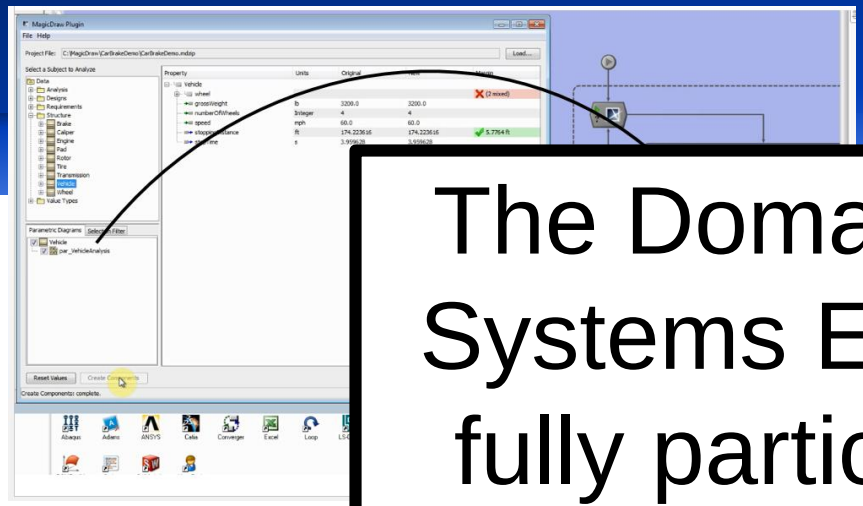
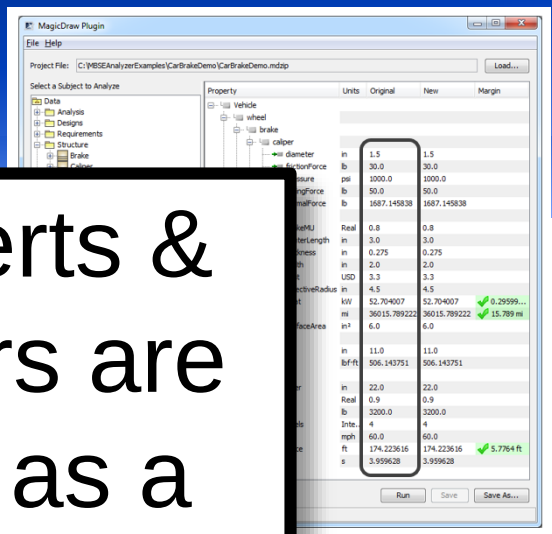


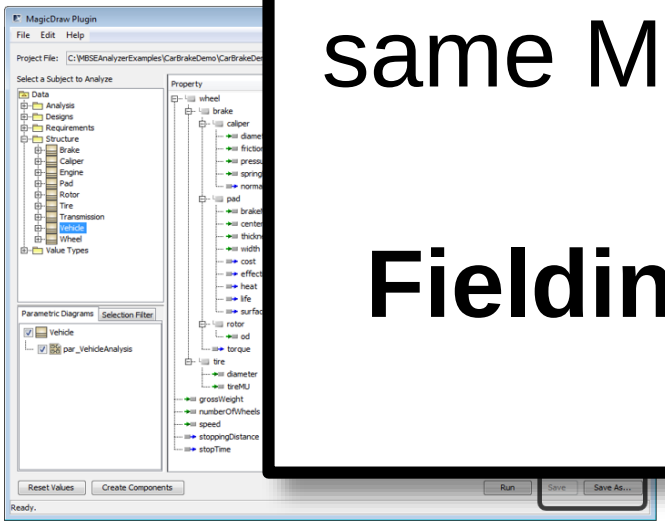
Domain Experts
As the S



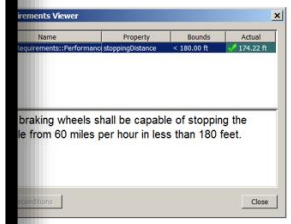
me Values…

The Domain Experts & Systems Engineers are fully participating as a team, both utilizing the same Models and Data.

Fielding Technology Faster!



And Storing the Results in the Single Source of Truth…



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Tradespace Exploration of MBSE and MBE Integrated Workflows

Tony Davenport
Josh Edwards
Dave Mastrorocco

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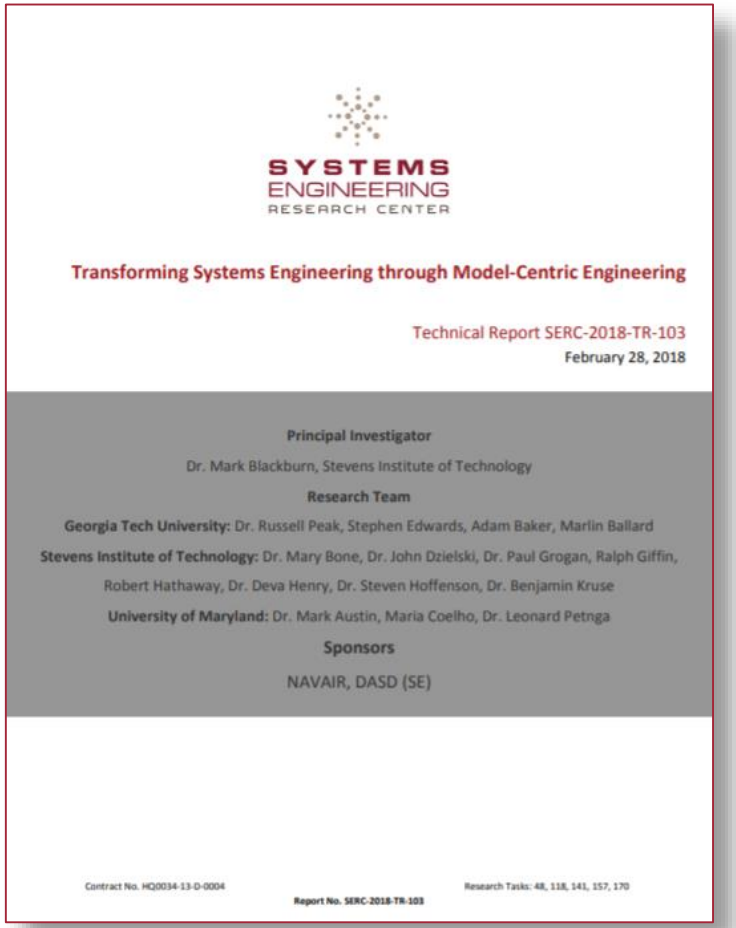
Stevens Institute / NAVAIR Study

- **Modeling Framework Requirements**
  - **HPC enabled**
  - **Single Source of Truth**
  - **Integration of Multi-domain/physics models**
  - **Method for Model Integrity**
- **Systems Engineering (SE) activities… in the context of a Digital Thread.**



SYSTEMS ENGINEERING RESEARCH CENTER

Transforming Systems Engineering through Model-Centric Engineering

Technical Report SERC-2018-TR-103
February 28, 2018

Principal Investigator
Dr. Mark Blackburn, Stevens Institute of Technology

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University of Maryland: Dr. Mark Austin, Maria Coelho, Dr. Leonard Petnga

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Contract No. HQ0034-13-D-0004 Research Tasks: 48, 118, 141, 157, 170
Report No. SERC-2018-TR-103

Blackburn, Mark, et al. SERC, 2018-TR-103: http://www.dtic.mil/dtic/tr/fulltext/u2/1048002.pdf

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