

ModelCenter MBSE

The next generation MBSE to
Analysis integration tool

GLOBAL PRODUCT DATA
INTEROPERABILITY
S U M M I T
2019



- [illegible]

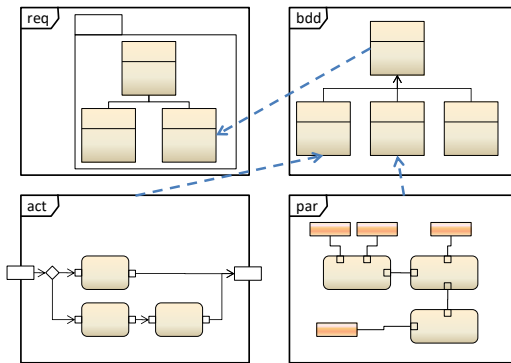


https://en.wikipedia.org/wiki/Paper_clip#/media/File:Wanzijia.jpg

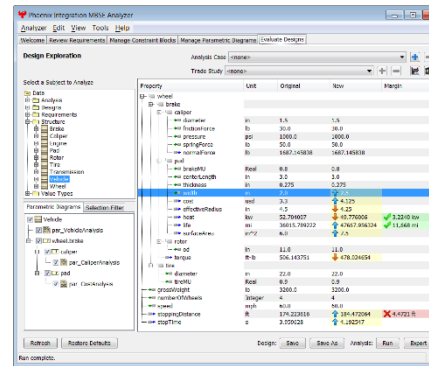


Phoenix Integration MBSE Pak

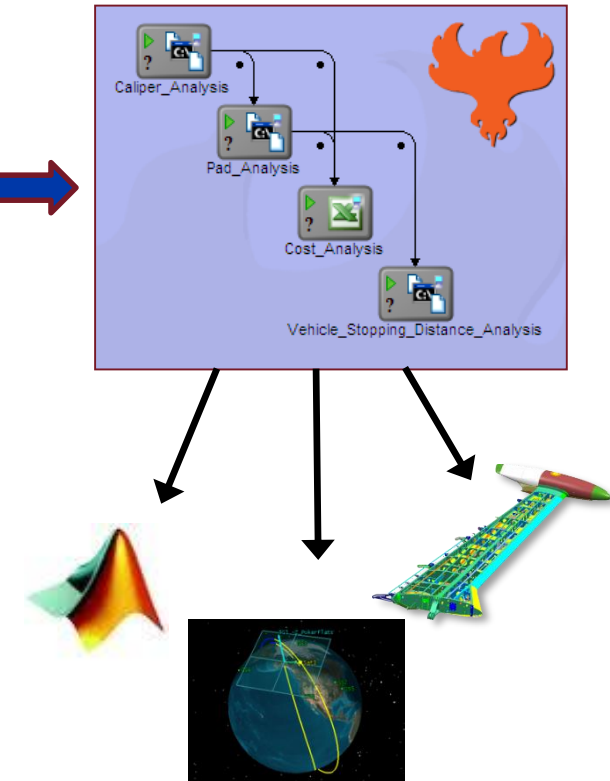
Systems Engineering: Architectural Model



MBSE Pak



Domain/Discipline Engineering: Executable Analysis Model



Connect systems architecture models with engineering analyses to calculate system performance, check requirements, and perform design trade-offs

Capabilities

Execute SysML parametric diagrams to evaluate designs

Perform requirements compliance analysis using modeling and simulation

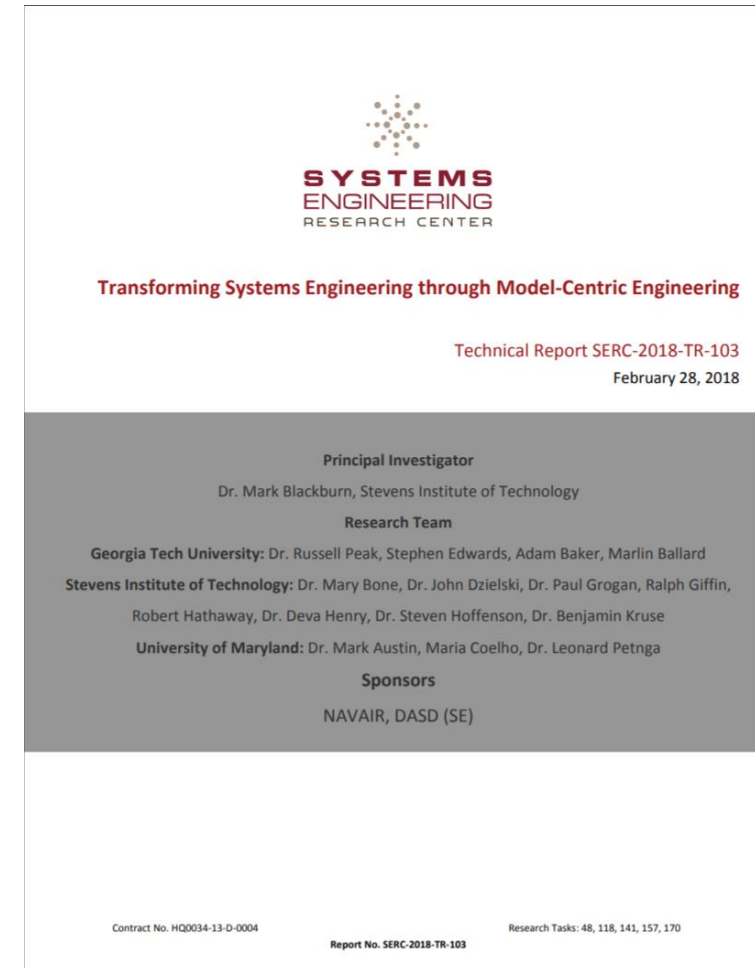
Perform design trade-off studies

Update SysML models with analysis results

Import engineering analyses into a SysML model

Engineering Analysis

- **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.**



Blackburn, Mark, et al. SERC, RT-170: <https://archive.sercuarc.org/publications-papers/technical-report-transforming-systems-engineering-through-model-centric-engineering-4/>

Stevens Institute Phoenix Integration Webinar

Dr. Mark Blackburn, Ph.D.

Research Professor

Stevens Institute of Technology



Why did you choose ModelCenter?

"The key reason was:

- We interacted with over 30 organizations ... they all used ModelCenter
- Most advanced tools ... Some of the tools don't do that
- So you spend a lot more time working on the tools rather than looking at the research"

Dr. Mark Blackburn, PhD.

Cleaner, easier interface

Simple to use with repeatable integration patterns

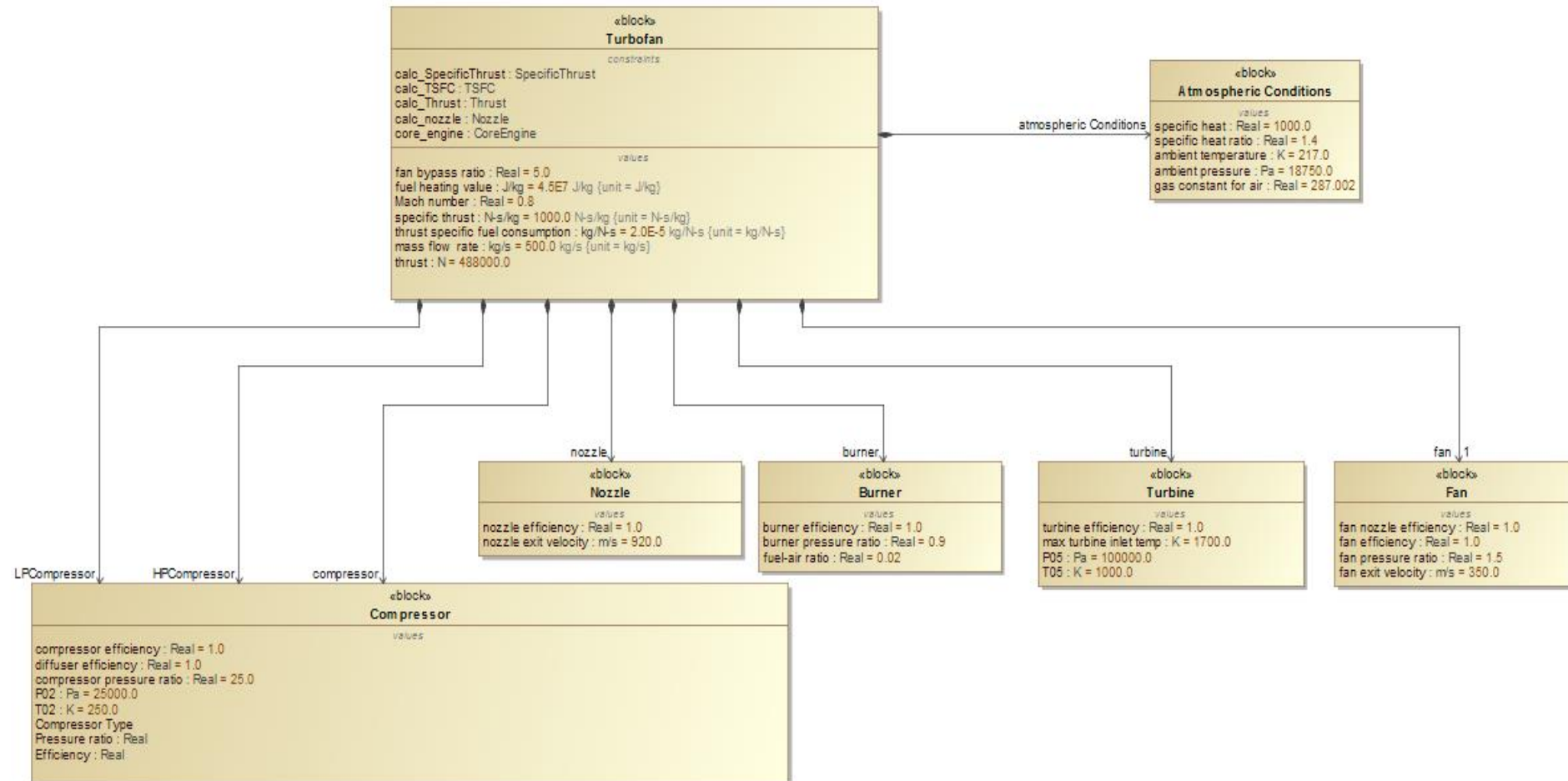
Flexible enough with ANY systems language

Flexible enough to integrate with ANY modeling tool

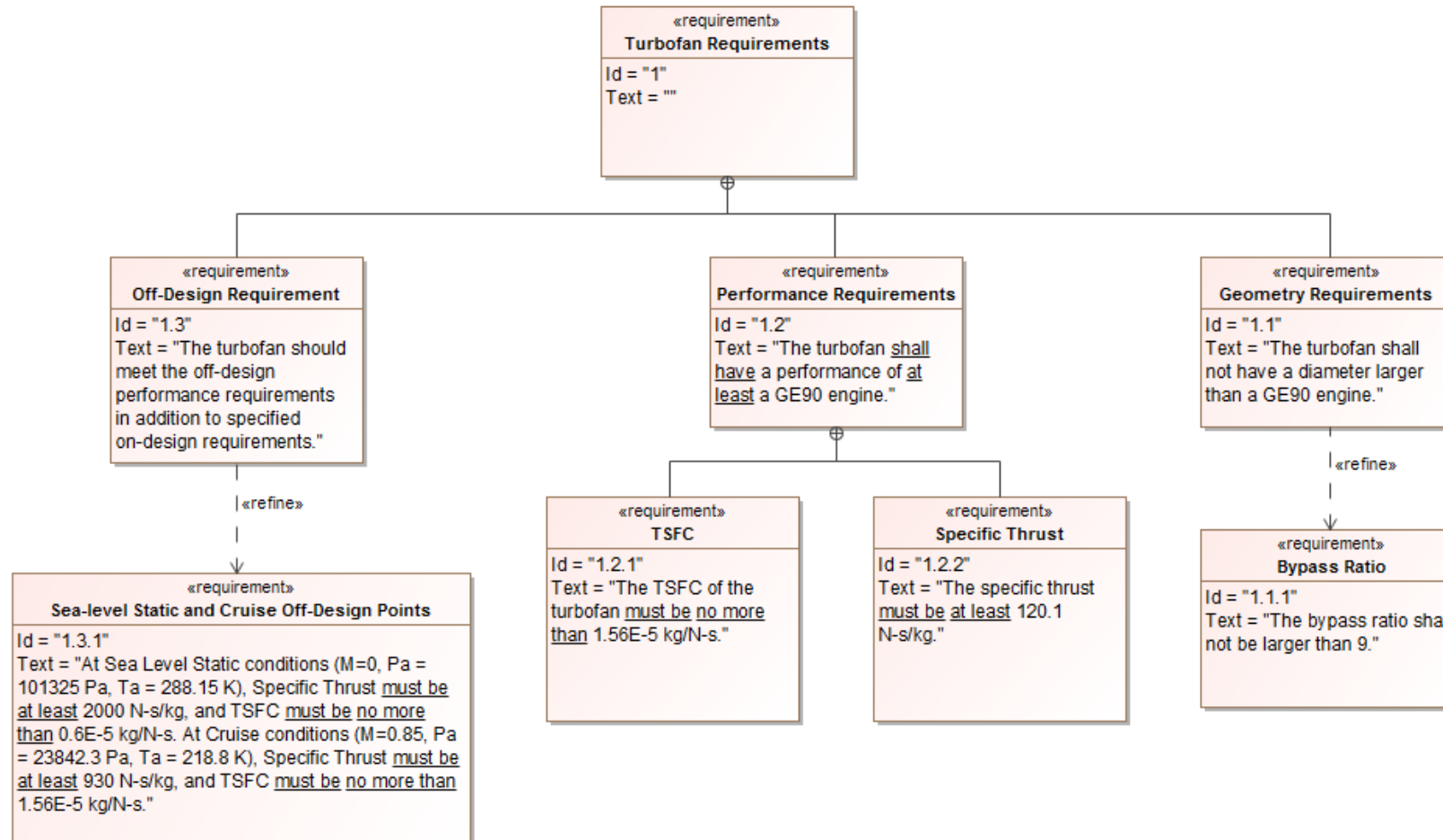
Versatile to take us into the future

Turbofan structure

bdd [Package] 03 - Structure [Turbine Structure]



req [Package] 01 - Requirements [Turbofan Requirements]

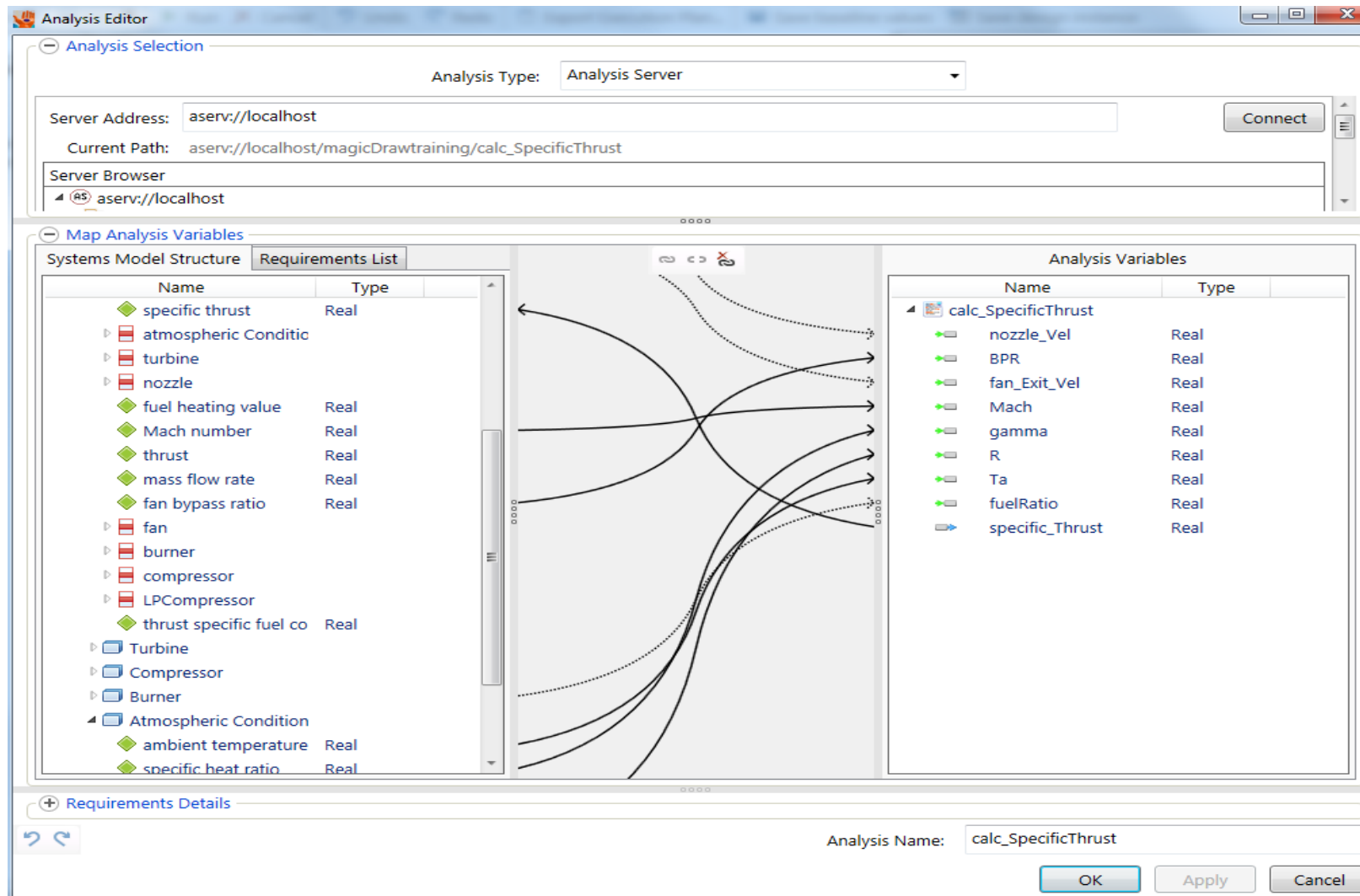


The screenshot displays the ModelCenter MBSE software interface. The top menu bar includes options like 'Systems model', 'New', 'Save', 'Run', 'Cancel', 'Undo', 'Redo', 'Export Execution Plan...', 'Save baseline values', and 'Save design instance'. The main workspace is divided into several panels:

- Workspace Explorer:** Shows a tree view with 'Specific Thrust Analysis' (containing 'Execution Result 1' and 'Execution Result 2') and 'Turbofan Analysis' (containing 'Execution Requirement Failed' and 'Execution Requirement Satisfie').
- Structure Elements:** A table showing the hierarchical structure of the Turbofan model.

Name	Value
Turbofan	
03 - Structure	
Turbofan	
compressor	
diffuser effci	1.0000
P02	25000
T02	250.00
compressor	25.000
compressor	1.0000
turbine	
T05	1000.0
max turbine	1700.0
turbine effci	1.0000
- Analyses:** A list of analyses with checkboxes: TSFC_Verification, SpecificThrust_Verification, BypassRatio_Verification, and Turbofan.
- Requirements:** A list of requirements: 1 Turbofan Requirements, 1.1 Geometry Requirements, 1.1.1 Bypass Ratio, 1.2 Performance Requirements, 1.2.1 TSFC, and 1.2.2 Specific Thrust.
- Systems Model Structure:** A tree view showing the model's hierarchy: Turbofan, 06 - Turbofan Designs, 01 - Requirements, 02 - Behavior, 04 - Parametrics, 03 - Structure, and 05 - Support Data.
- Analyses List:** A list of analyses: BypassRatio_Verification, SpecificThrust_Verification, TSFC_Verification, calc_SpecificThrust, and Turbofan.
- Requirements List:** A list of requirements: 1 Turbofan Requirements, 1.1 Geometry Requirements, 1.3 Off-Design Requirement, and 1.2 Performance Requirements.

Link system model elements to analytical models



Create execution plan and execute

The screenshot shows a software interface with four main panels:

- Structure Elements:** A table with columns 'Name' and 'Value'. It lists various components and their values.
- Systems Model Structure:** A tree view showing the hierarchy of the system model.
- Analyses (2 of 2 selected):** A list of analyses with checkboxes.
- Analyses List:** A list of analyses with checkboxes.

Structure Elements Table:

Name	Value
Turbofan	
03 - Structure	
Burner	
fuel-air ratio	2.0000E-2
Atmospheric Co	
gas constant fi	287.00
specific heat r	1.4000
ambient temp	217.00
Fan	
fan exit velocit	350.00
Nozzle	
nozzle exit vel	920.00
Turbofan	
Mach number	0.80000
specific thrust	1000.0
fan bypass rati	5.0000

Systems Model Structure:

- Turbofan
 - 06 - Turbofan Designs
 - 01 - Requirements
 - 02 - Behavior
 - 04 - Parametrics
 - 03 - Structure
 - Nozzle
 - Fan
 - Turbofan
 - Turbine
 - Compressor
 - Burner
 - Atmospheric Conditions
 - 05 - Support Data

Analyses (2 of 2 selected):

- ☒ SpecificThrust_Verification
- ☒ calc_SpecificThrust

Analyses List:

- BypassRatio_Verification
- SpecificThrust_Verification
- TSFC_Verification
- calc_SpecificThrust
- ☒ Turbofan

Execution results and requirement verification

The screenshot displays a software interface with three main panels. The top panel, titled 'Results', shows a table of execution data for a Turbofan model, completed on 6/27/2019 at 1:37:28 PM. The table includes columns for Name, Initial Value, Value, Change, Delta, and Delta %. The data is organized into a tree structure under 'Turbofan', with sub-entries for '03 - Structure', 'Burner', 'Atmospheric Condition', 'Fan', 'Nozzle', and 'Turbofan' (repeated). The 'specific thrust' value is 1271.0, which is 27.105% higher than the initial value of 1000.0. The bottom panel, titled 'Requirements', shows a table of requirement verification. It includes columns for Name, Satisfied, and Margin. The requirements are organized into a tree structure under '1 Turbofan Requirements', with sub-entries for '1.1 Geometry Requirements', '1.2 Performance Requirements', and '1.2.2 Specific Thrust'. The '1.2.2 Specific Thrust' requirement is marked as 'Satisfied' with a green checkmark and has a margin of 1150.9. The right panel, titled 'Systems Model Structure', shows a tree view of the model structure, including 'Turbofan', '06 - Turbofan Designs', '01 - Requirements', '02 - Behavior', '04 - Parametrics', '03 - Structure', 'Nozzle', 'Fan', 'Turbofan', 'Turbine', 'Compressor', 'Burner', 'Atmospheric Conditions', and '05 - Support Data'. The 'Analyses List' panel shows a list of analyses: 'BypassRatio_Verification', 'SpecificThrust_Verification', 'TSFC_Verification', 'calc_SpecificThrust', and 'Turbofan'. The 'Requirements List' panel shows a list of requirements: '1 Turbofan Requirements', '1.1 Geometry Requirements', '1.2 Performance Requirements', and '1.2.2 Specific Thrust'.

Results Completed: 6/27/2019 1:37:28 PM

Name	Initial Value	Value	Change	Delta	Delta %
Turbofan					
03 - Structure					
Burner					
fuel-air ratio	2.0000E-2	2.0000E-2	=	0.0	0.0
Atmospheric Condition					
gas constant for a	287.00	287.00	=	0.0	0.0
specific heat ratio	1.4000	1.4000	=	0.0	0.0
ambient temperat	217.00	217.00	=	0.0	0.0
Fan					
fan exit velocity	350.00	350.00	=	0.0	0.0
Nozzle					
nozzle exit velocit	920.00	920.00	=	0.0	0.0
Turbofan					
Mach number	0.80000	0.80000	=	0.0	0.0
specific thrust	1000.0	1271.0	↑	271.05	27.105
fan bypass ratio	5.0000	5.0000	=	0.0	0.0

Requirements

Name	Satisfied	Margin
1 Turbofan Requirements		
1.2 Performance Requiren		
1.2.2 Specific Thrust	✓	1150.9

Systems Model Structure

- Turbofan
 - 06 - Turbofan Designs
 - 01 - Requirements
 - 02 - Behavior
 - 04 - Parametrics
 - 03 - Structure
 - Nozzle
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 - Turbine
 - Compressor
 - Burner
 - Atmospheric Conditions
 - 05 - Support Data

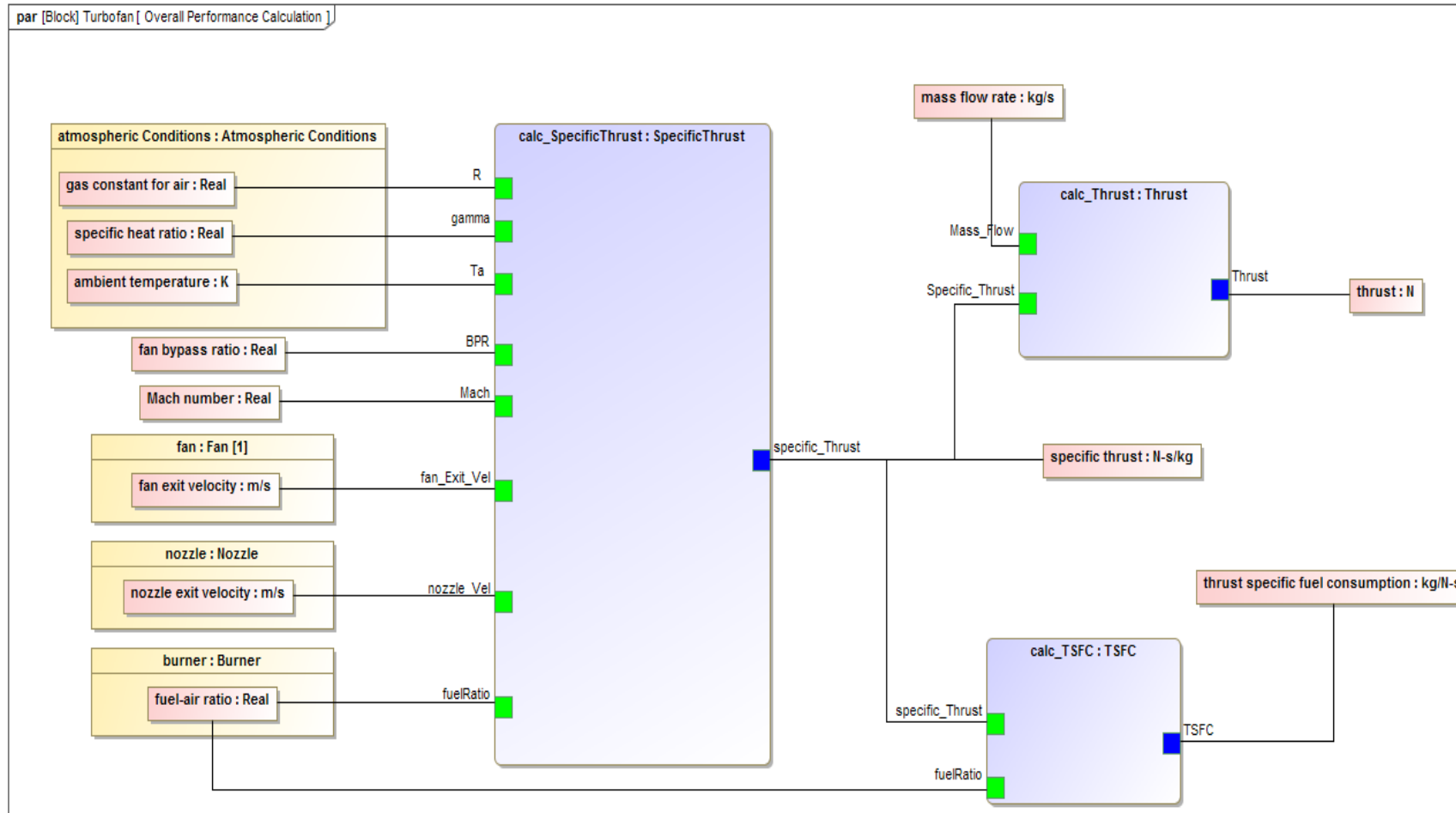
Analyses List

- BypassRatio_Verification
- SpecificThrust_Verification
- TSFC_Verification
- calc_SpecificThrust
- Turbofan

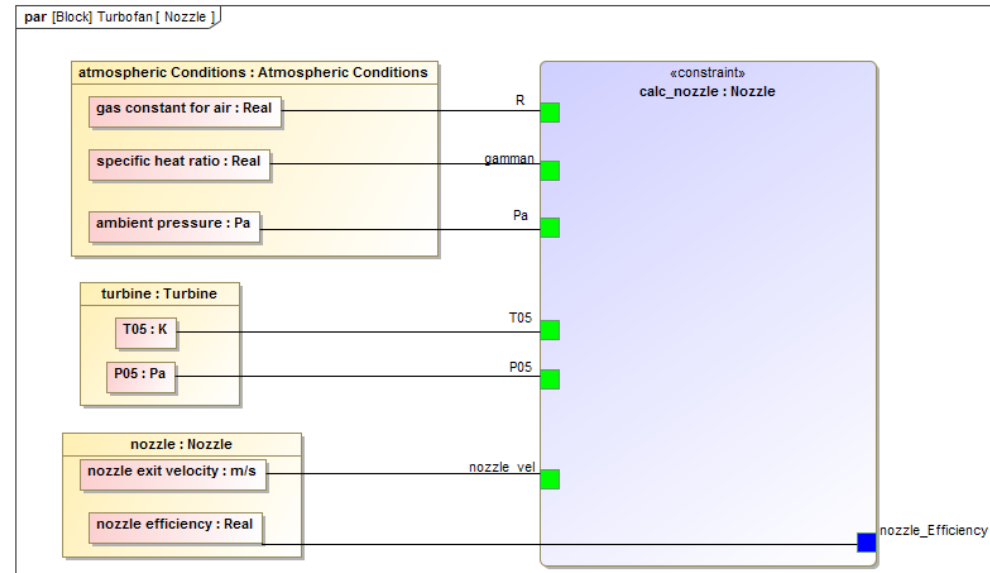
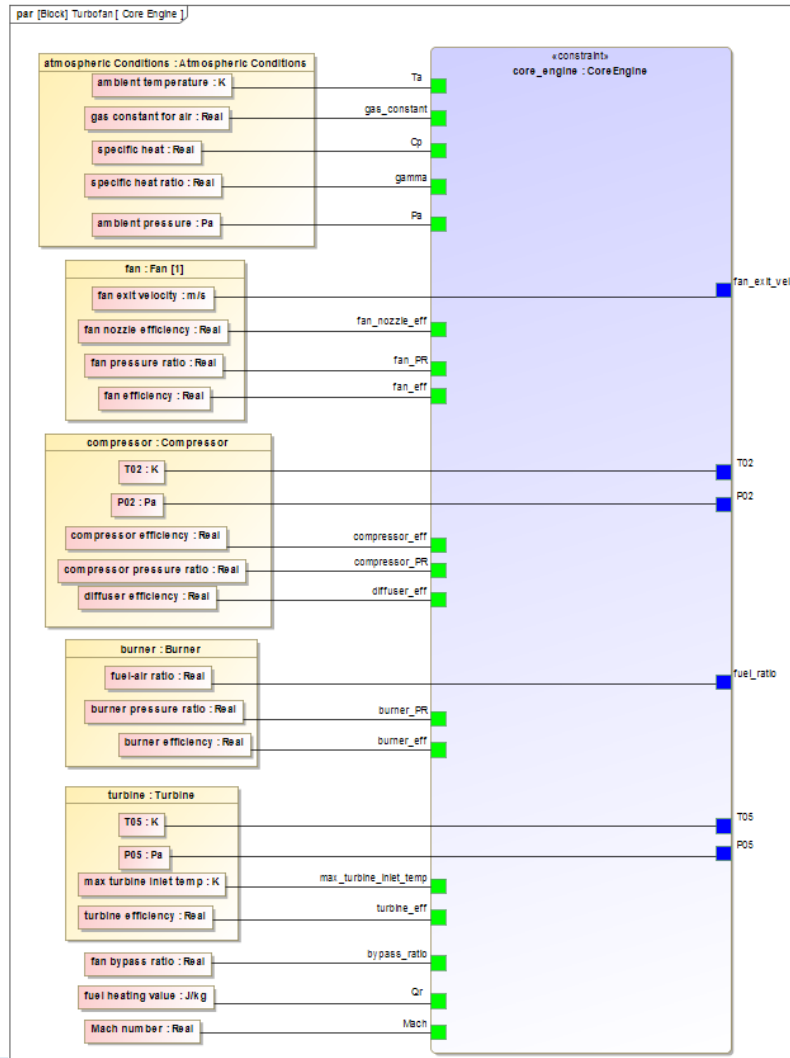
Requirements List

- 1 Turbofan Requirements
 - 1.1 Geometry Requirements
 - 1.2 Performance Requirements
 - 1.2.2 Specific Thrust

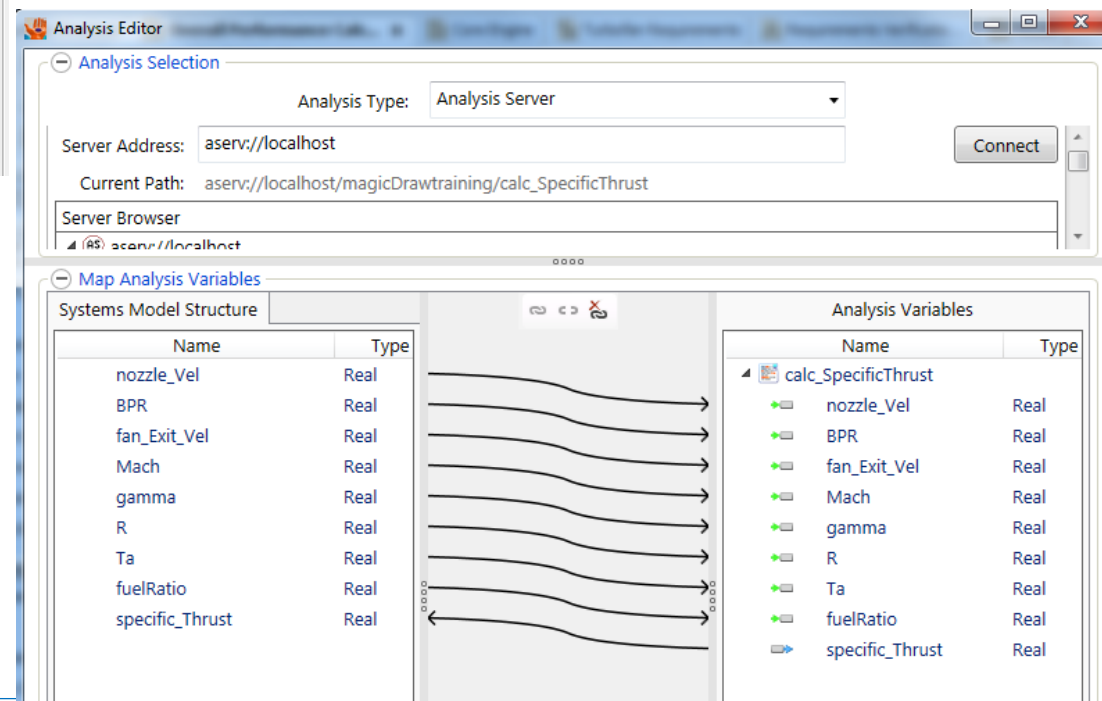
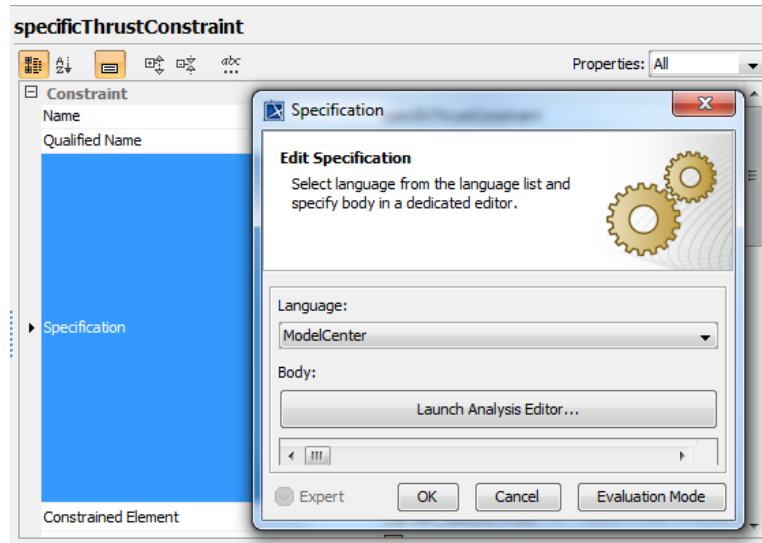
Performance calculation parametric diagram



Core Engine and Nozzle parametric diagram



Connect constraint to ModelCenter



Execution results parametric diagram

Systems model ▾ New ▾ Save ▾ Run Cancel Undo Redo Export Execution Plan... Save baseline values Save design instance

Workspace Explorer

- Specific Thrust Analysis
 - Execution Result 1
 - Execution Result 2
- Turbofan Analysis
 - Execution Requirement Failed
 - Execution Requirement Satisfied

Turbofan Analy... x Execution Requ... x Execution Requ... x

Results Completed: 6/27/2019 2:07:44 PM

Name	Initial Value	Value	Change	Delta	Delta %
03 - Structure					
Turbofan					
compressor					
diffuser efficienc	1.0000	1.0000	=	0.0	0.0
P02	25000	28581	↑	3581.4	14.326
T02	250.00	244.78	↓	5.2240	2.0896
compressor pre:	25.000	25.000	=	0.0	0.0
compressor effi	1.0000	1.0000	=	0.0	0.0
turbine					
T05	1000.0	698.95	↓	301.05	30.105
max turbine inle	1700.0	1700.0	=	0.0	0.0
turbine efficienc	1.0000	1.0000	=	0.0	0.0
P05	100000	28659	↓	71341	71.341
thrust	488000	964679	↑	476679	97.680
thrust specific fue	2.0000E-5	1.2999E-5	↓	7.0006E-6	35.003
fan bypass ratio	7.0000	7.0000	=	0.0	0.0
specific thrust	1000.0	1929.4	↑	929.36	92.936
burner					
burner efficiency	1.0000	1.0000	=	0.0	0.0
fuel-air ratio	2.0000E-2	2.5080E-2	↑	5.0804E-3	25.402
burner pressure	0.90000	0.90000	=	0.0	0.0
nozzle					
nozzle efficienc	1.0000	1.0000	=	0.0	0.0

Systems Model Structure

- Turbofan
 - 06 - Turbofan Designs
 - 01 - Requirements
 - 02 - Behavior
 - 04 - Parametrics
 - 03 - Structure
 - Nozzle
 - Fan
 - Turbofan
 - Turbine
 - Compressor
 - Burner
 - Atmospheric Conditions
 - 05 - Support Data

Analyses List

- BypassRatio_Verification
- SpecificThrust_Verification
- TSFC_Verification
- calc_SpecificThrust
- Turbofan

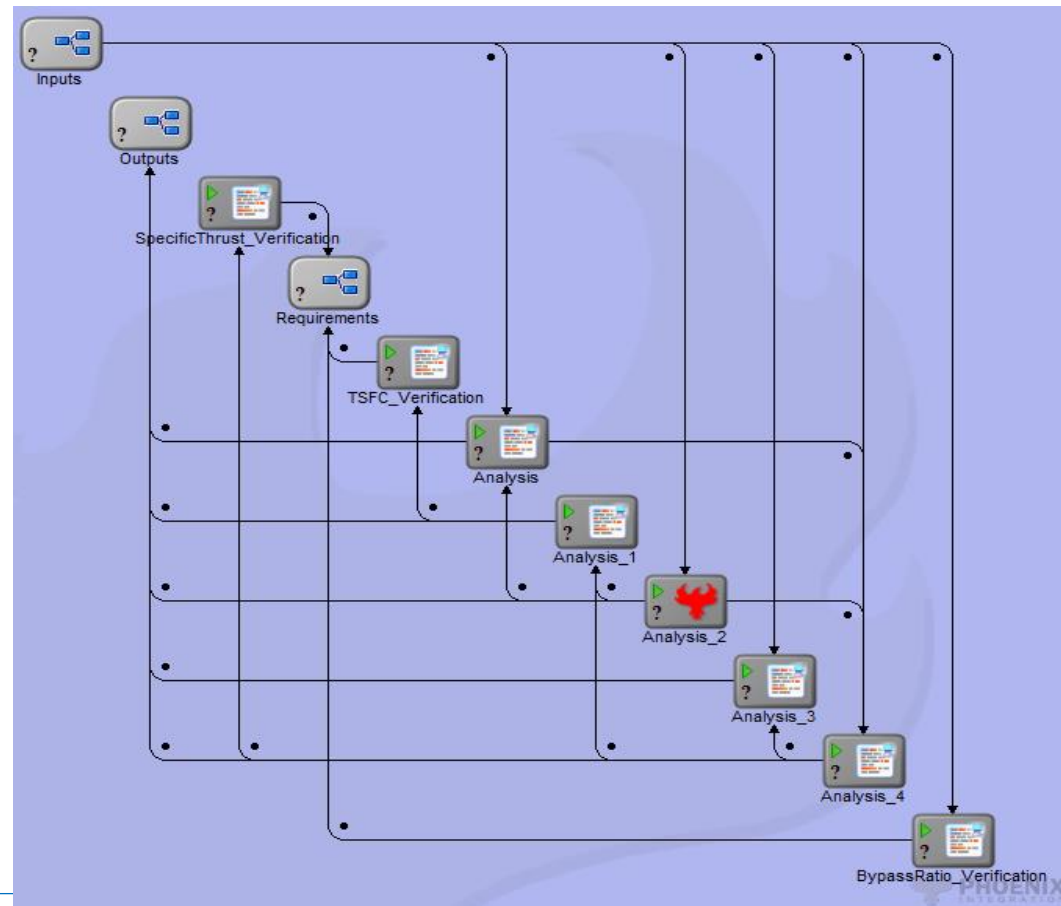
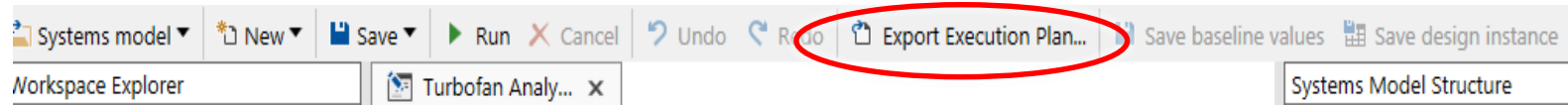
Requirements

Name	Satisfied	Margin
1 Turbofan Requirements		
1.1 Geometry Requiremer		
1.1.1 Bypass Ratio	✓	2.0000
1.2 Performance Requiremen		
1.2.1 TSFC	✓	2.6006E-6
1.2.2 Specific Thrust	✓	1809.3

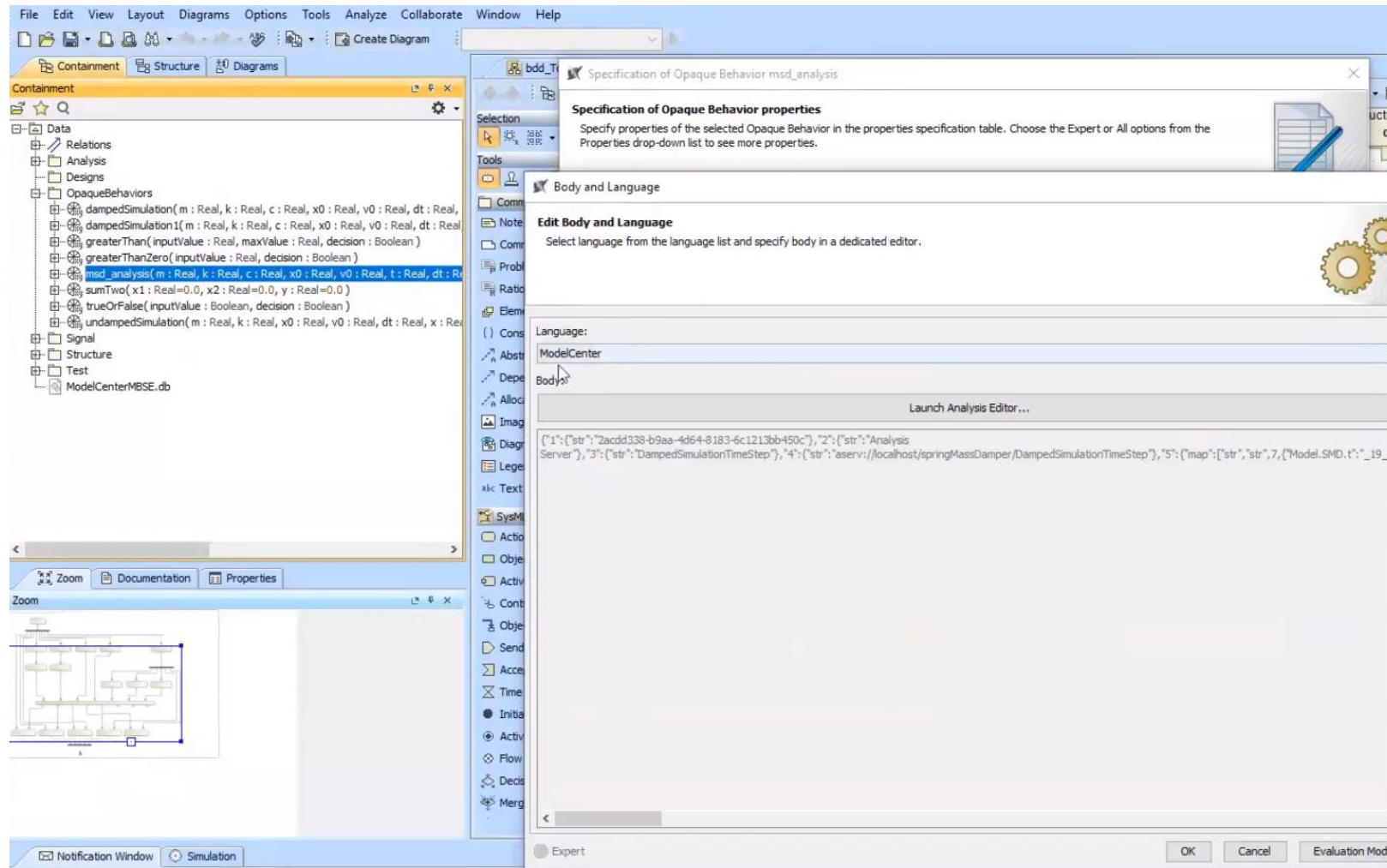
Requirements List

- 1 Turbofan Requirements
 - 1.1 Geometry Requirements
 - 1.3 Off-Design Requirement
 - 1.2 Performance Requirements

Export ModelCenter workflow



Connect opaque behaviors to ModelCenter



Initially release in October 2018

Initial feature set

API for vendor integration

Integration with PTC Integrity Modeler shortly after

Integration with MagicDraw

Integration with Vitech GENESYS



Cleaner, easier interface

Simple to use with repeatable integration patterns

Flexible enough with ANY systems language

Connect to system model elements

More flexible and powerful requirements verification

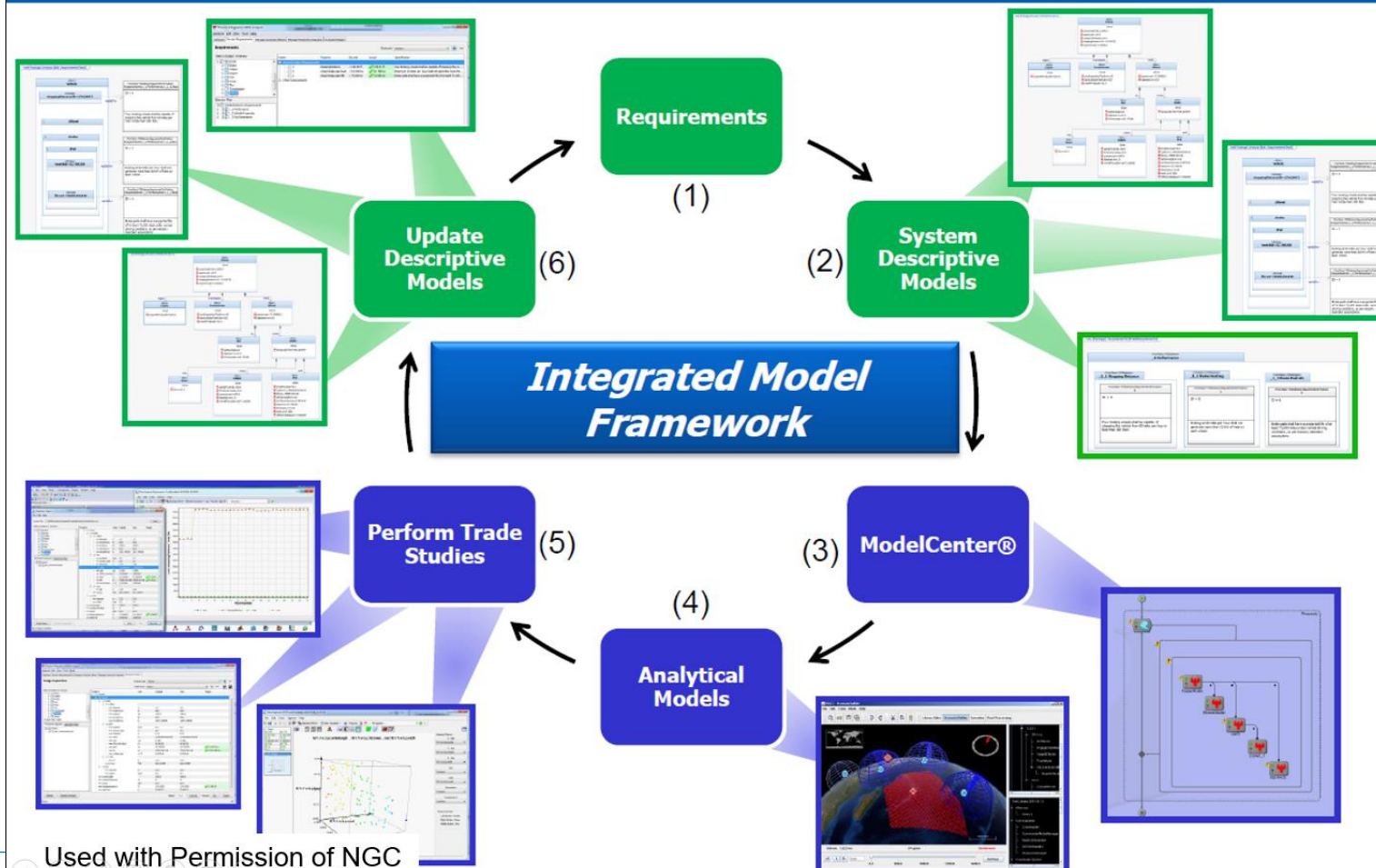
Update MBSE model with design

More native powerful integration with Behavioral diagrams

Integrated Model Framework Example

Descriptive to Analytical and Back

NORTHROP GRUMMAN



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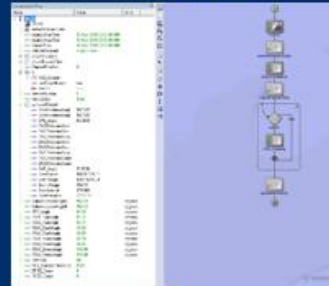
- Proven results at NGES with MBE with demonstrated
 - Reduction in cost
 - Reduction in schedule
 - Improvement in delivered quality
 - Higher customer engagement in the engineering process and satisfaction with the results

Presented at Phoenix Integration International User's Conference - April 14, 2015
- Guy Babineau, Chief Engineer

Overview
Challenges
Objectives
Approach
Modeling
Simulating
Results
Reflections
Future Work

SIMULATION PROCESS OVERVIEW

6. Evaluate STK parameters;
return results to MBSE
Analyzer.

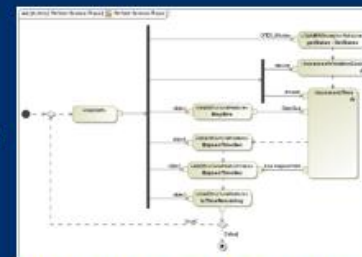
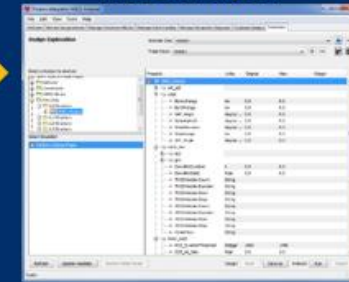


1. Enter simulation settings
and constraints.

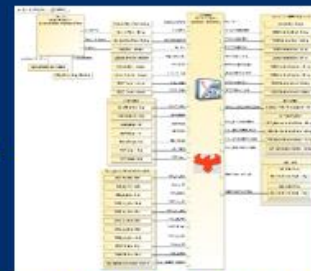
#	Name	Default Value
1	AnalysisStartTime	12 Nov 2018 00:00:00.000
2	AnalysisInterval	00:00:00.000
3	Interval	00:00:00.000
4	StepSize	00:00:00.000

7. Display simulation results for
each time step.

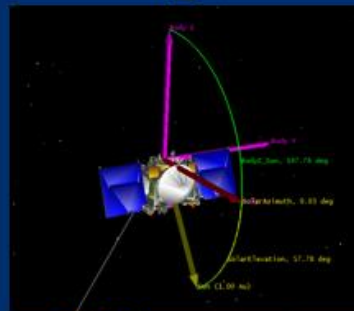
2. Initiate simulation from
MBSE Analyzer.



3. Step through the mission
simulation.



4. Point to external
analysis tools.



5. Retrieve parameter
values from STK.

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Questions?