

Integrating Mission Analysis with SysMLv2 and Requirements Assessment

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Peter Douglas

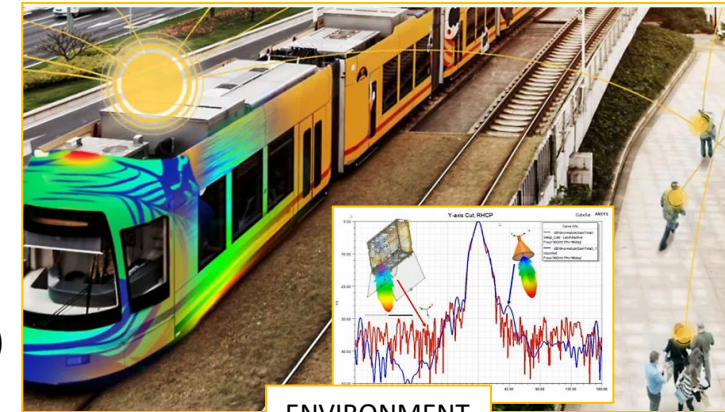
Section Header

DIGITAL MISSION ENGINEERING AND SYSTEMS V DIAGRAM

Framing of the problem...

- **How do I...**
 - Use my requirements to drive the system development
 - Produce high quality digital engineering products (frameworks, models, etc.)
 - Integrate multiple tools across the MBSE, MBE, and MS&A stack
- **What if...**
 - We use a different algorithm, architecture, component, or antenna
 - We place the hardware in a different location, or change the configuration
 - The operational environment changes... ambient temperature, landscape, etc.

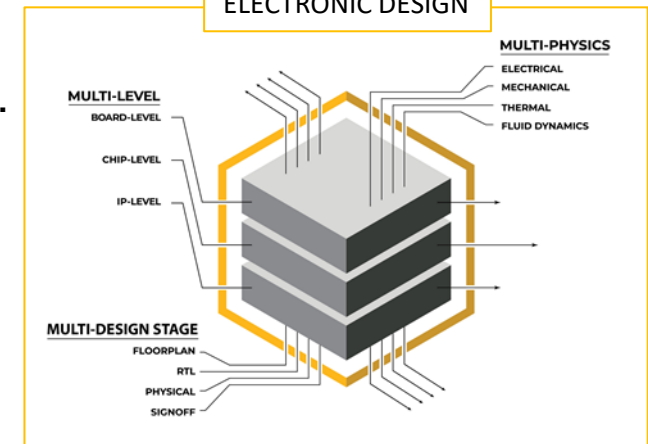
Using a digital engineering framework results in system knowledge capture, insight in system interoperability, system ability to meet mission objectives – ultimately leading to a better engineered solution throughout the lifecycle.



ENVIRONMENT

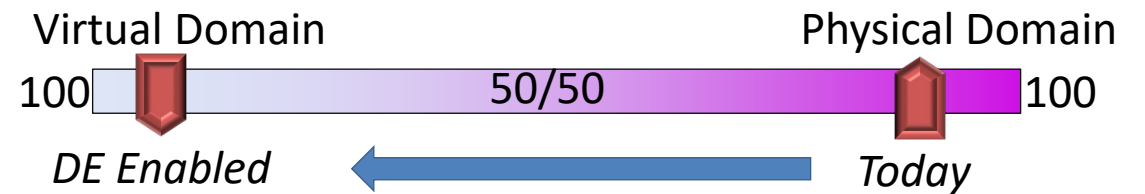
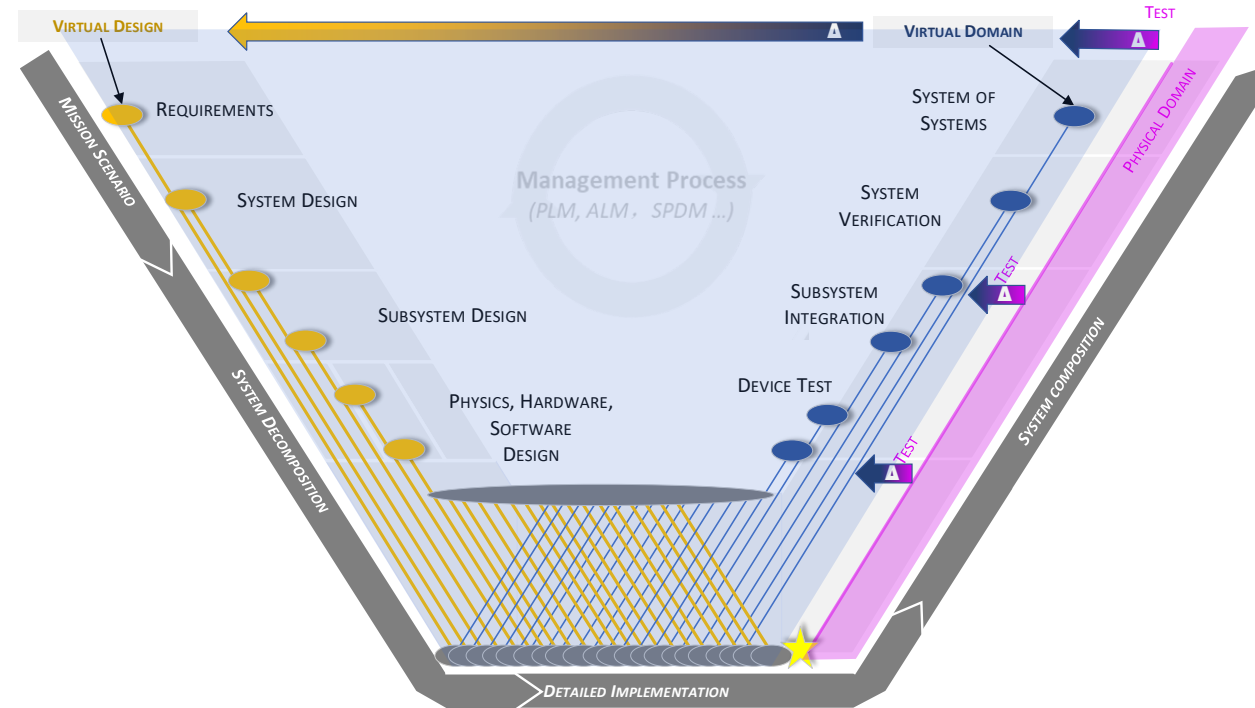
DIGITAL ENGINEERING

ELECTRONIC DESIGN



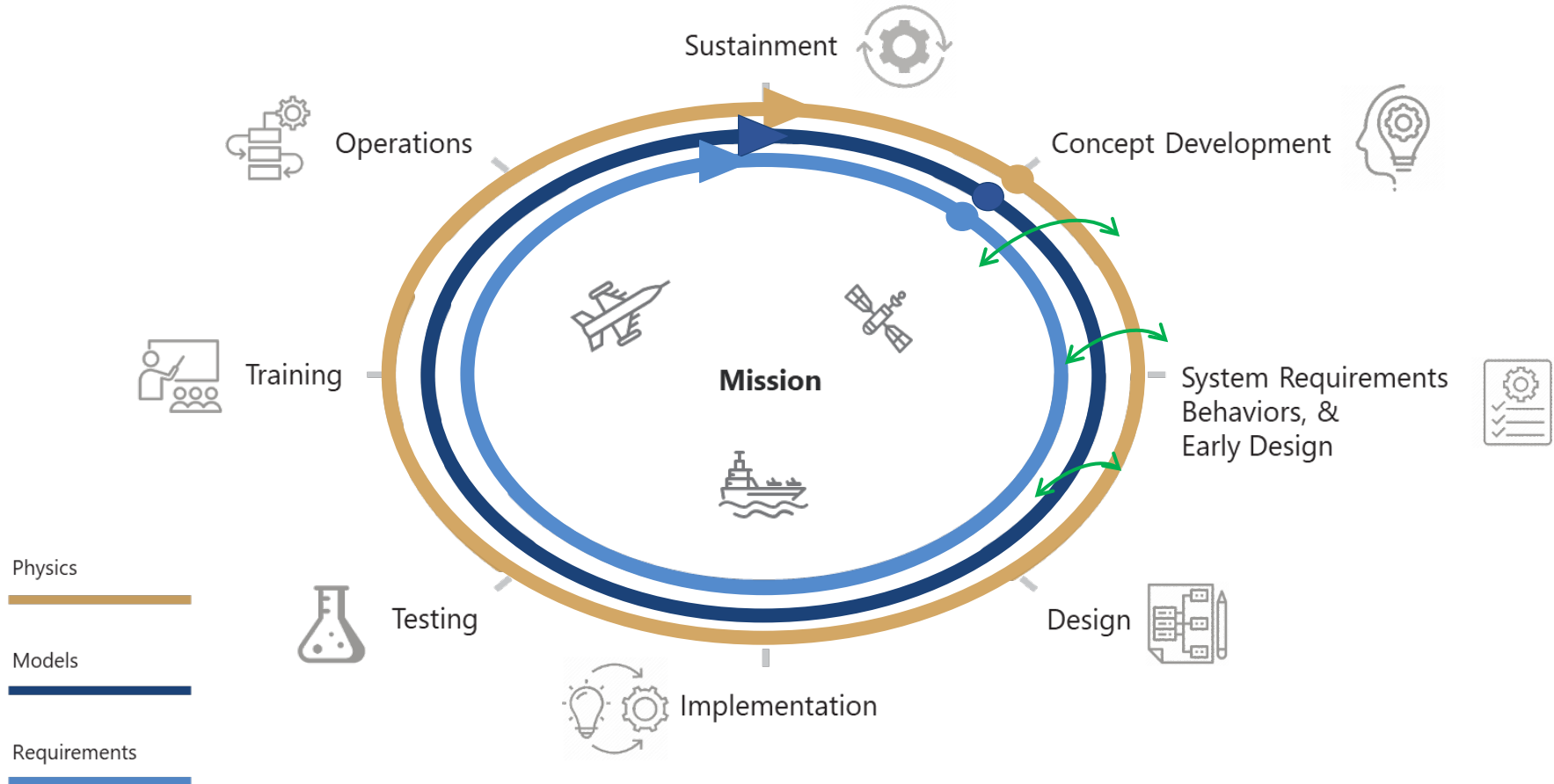
Digital Engineering enabled System-V Diagram

- A connected and collaborative Model Based Systems Engineering and Modeling, Simulation and Analysis ecosystem
- 2-Domain System-V Diagram
 - Virtual Design and Integration
 - Physical Domain and Test
- Value occurs through the combined use of the Virtual and Physical domain to solve complex engineering challenges



Result: Increased use of modeling and simulation accelerates integration, deployment, and sustainment.

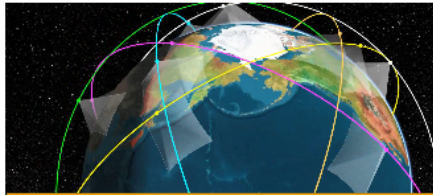
Why?



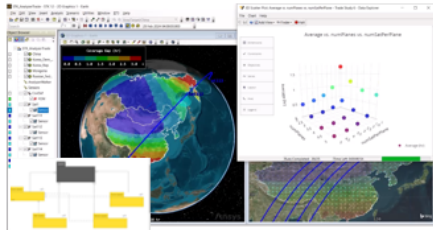
DME Accelerates Space Systems Design and Verification



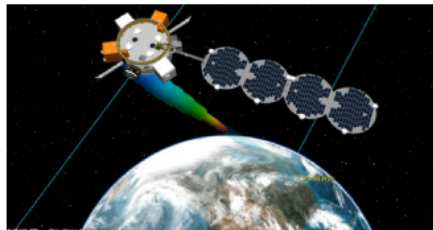
Systems Engineering



Design Reference Missions (Ansys STK)

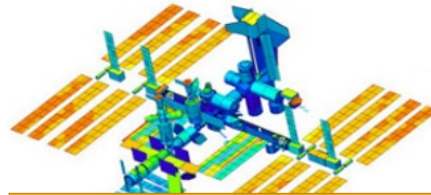


MBSE Analytic Integration (Ansys ModelCenter/SAM)

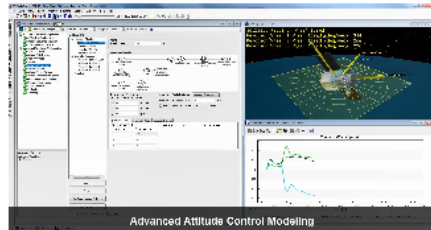


Subsystems Assessment (Ansys STK)

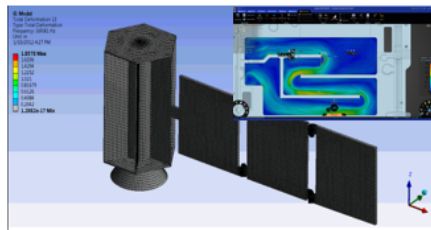
Vehicle Engineering



Thermal Analysis (Ansys Thermal Desktop)

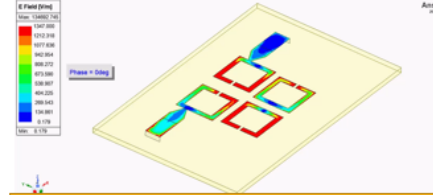


ADCS and Propulsion (Ansys STK SOLIS)

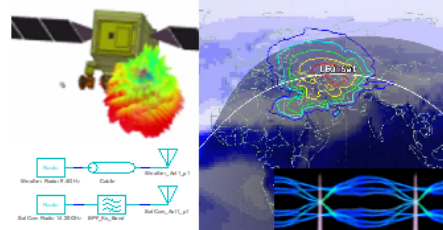


Structures / Deployment (Ansys Mechanical LS-Dyna)

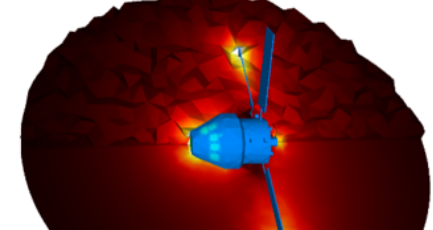
Electronics Engineering



RF Chips/Filters/Amps (Ansys Electronics)



RF Antennas and Cosite (Ansys Electronics)

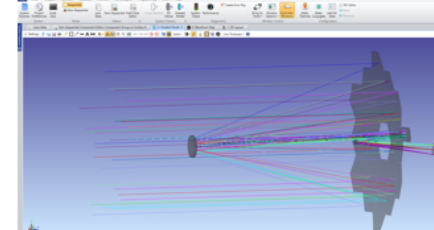


Radiation EMC (Ansys STK / Charge Plus)

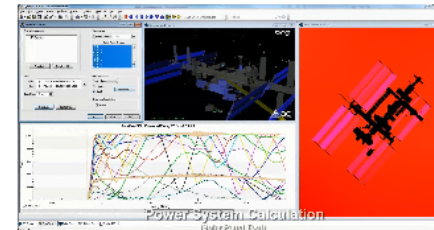
Payloads / Software



Flight Software (STK SOLIS / SCADE)

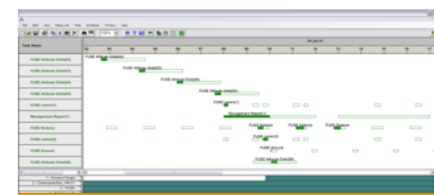


Optics / IR Evaluation (STK / Zemax Optics)

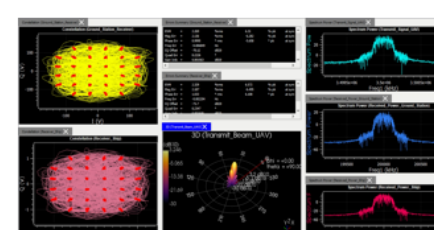


Power and Batteries (Ansys STK / Twin Builder)

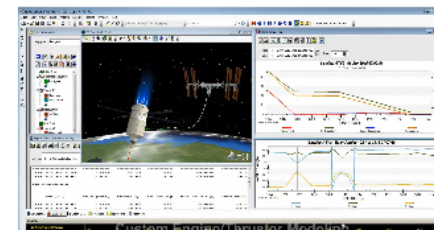
System Test / Ops



TTC Ground Integration (Ansys STK / Scheduler)

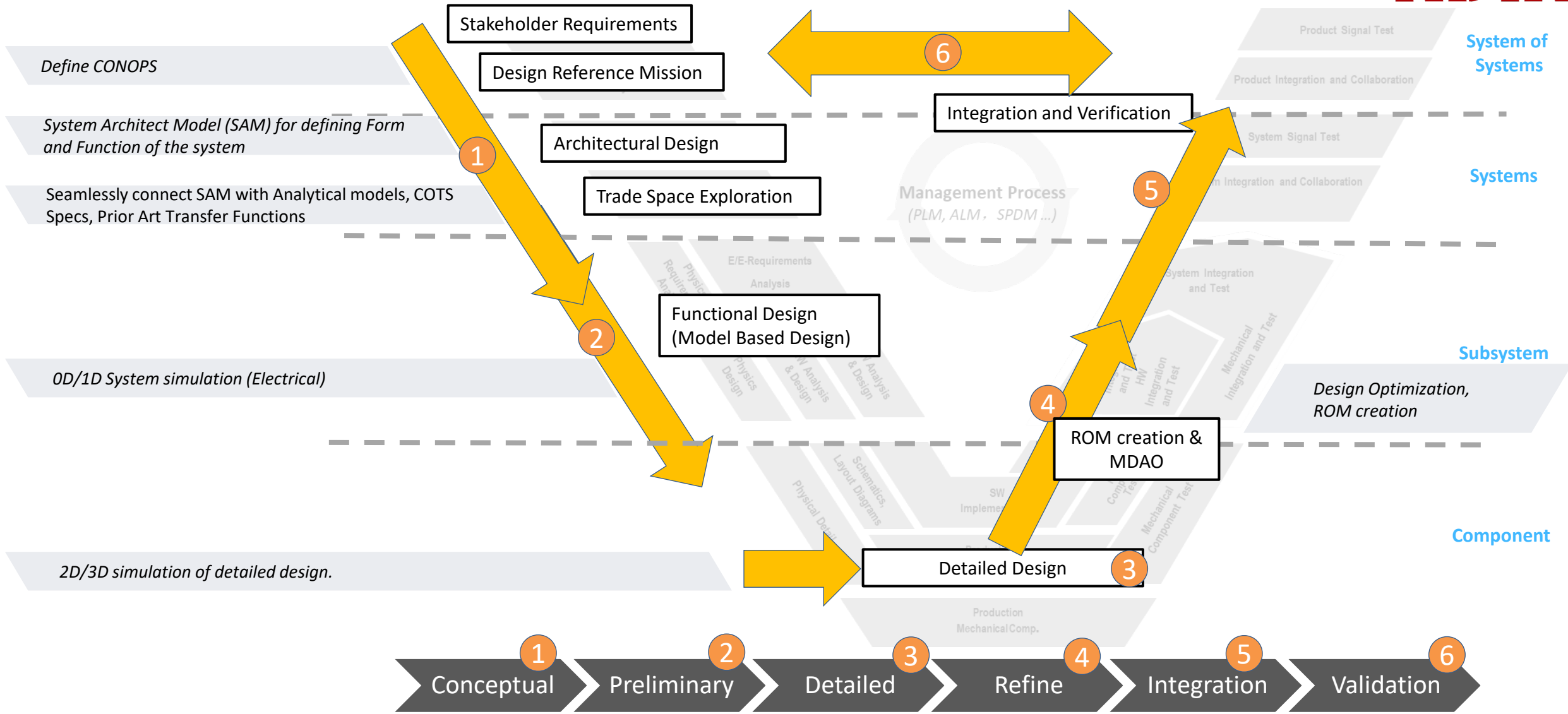


HIL/SIL Integration (Ansys STK/Keysight)



Flight Dynamics (FDS) (Ansys STK / ODTK)

Generalized Process for Establishing Digital Engineering

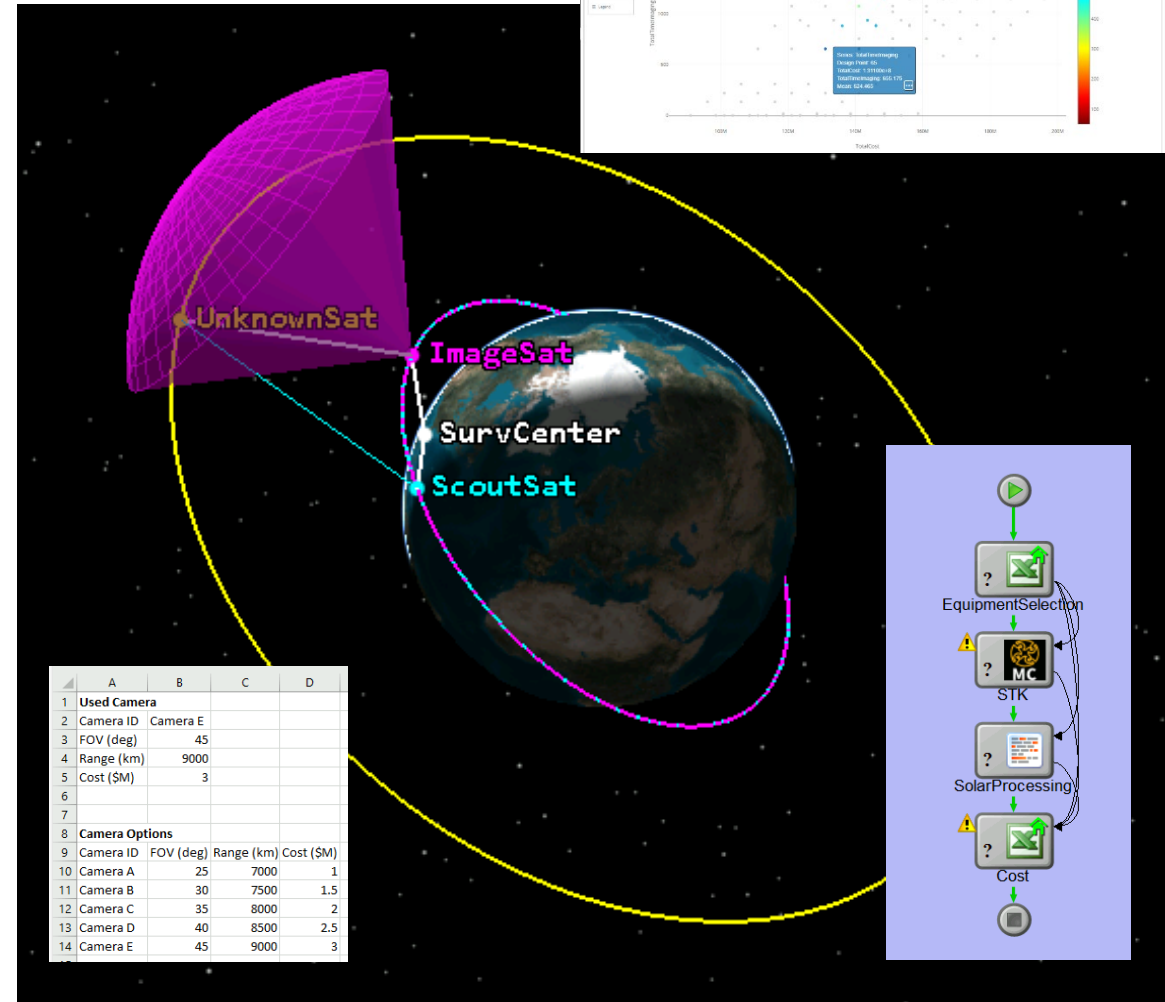


Section Header

NOTIONAL USE CASE

Example Demo – Notional RFP

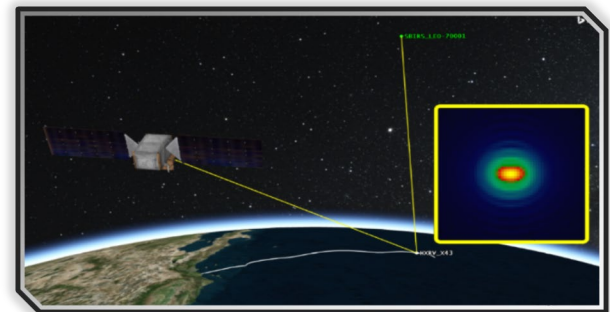
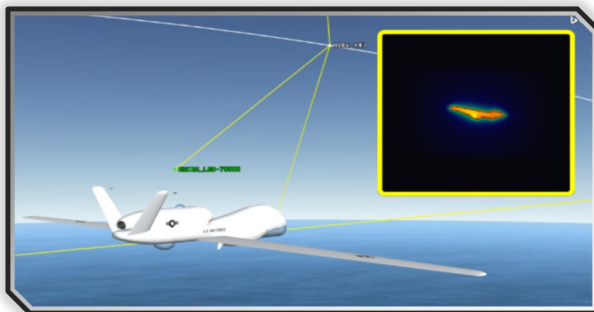
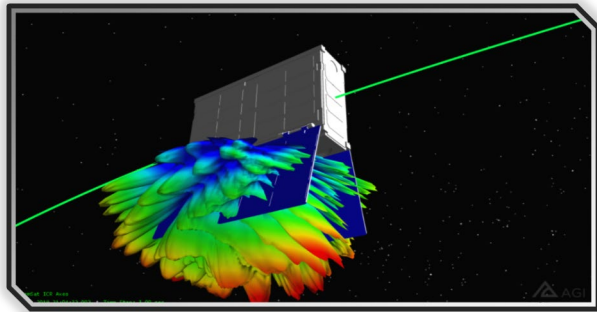
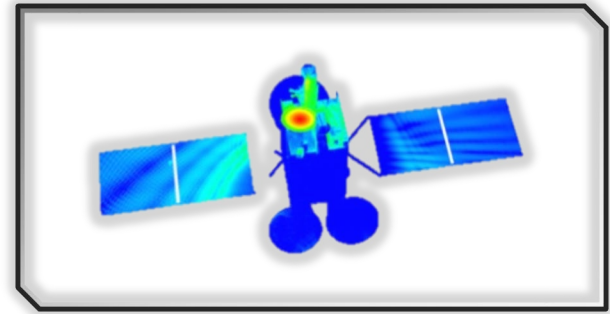
- **RFP Overview:**
 - Design two satellites in LEO that image unknown satellites
 - ScoutSat must first identify an unknown satellite before notifying ImageSat via ground relay to begin taking images
- **RFP Requirements:**
 1. Total cost of mission shall be less than **\$150M**
 2. Total imaging time of the unknown satellite shall be above **5 minutes**
 3. The ImageSat’s solar panels shall generate an average of **300 W of power**
 4. The ImageSat’s sensor shall have a mean **SNR greater than 200**
- **Design Variables:**
 - ScoutSat & ImageSat’s Semimajor Axis, Inclination, and Spacing (True Anomaly)
 - ImageSat’s Camera Selection
 - ImageSat’s Solar Panel Selection



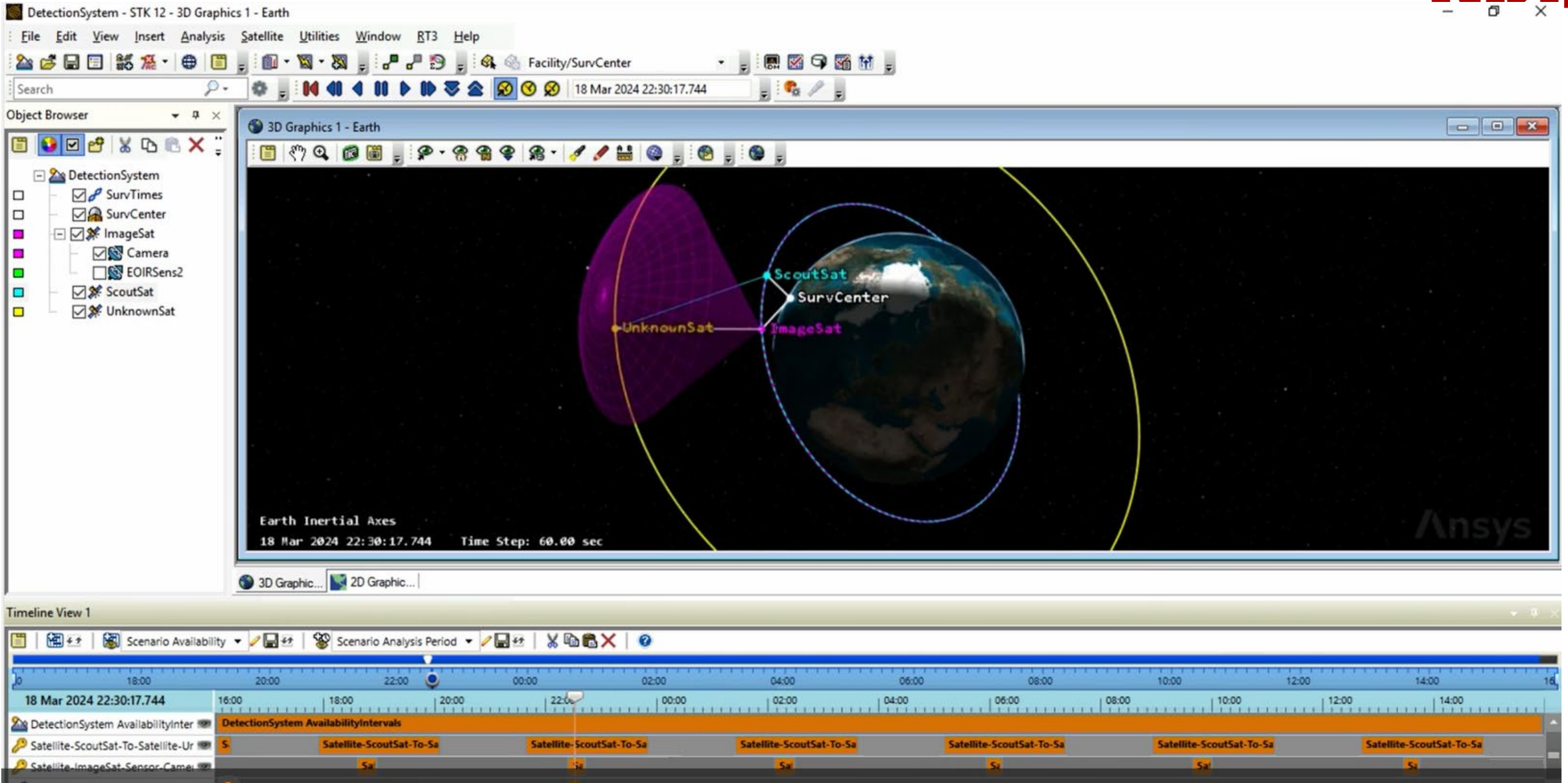
Design Reference Mission (DRM)

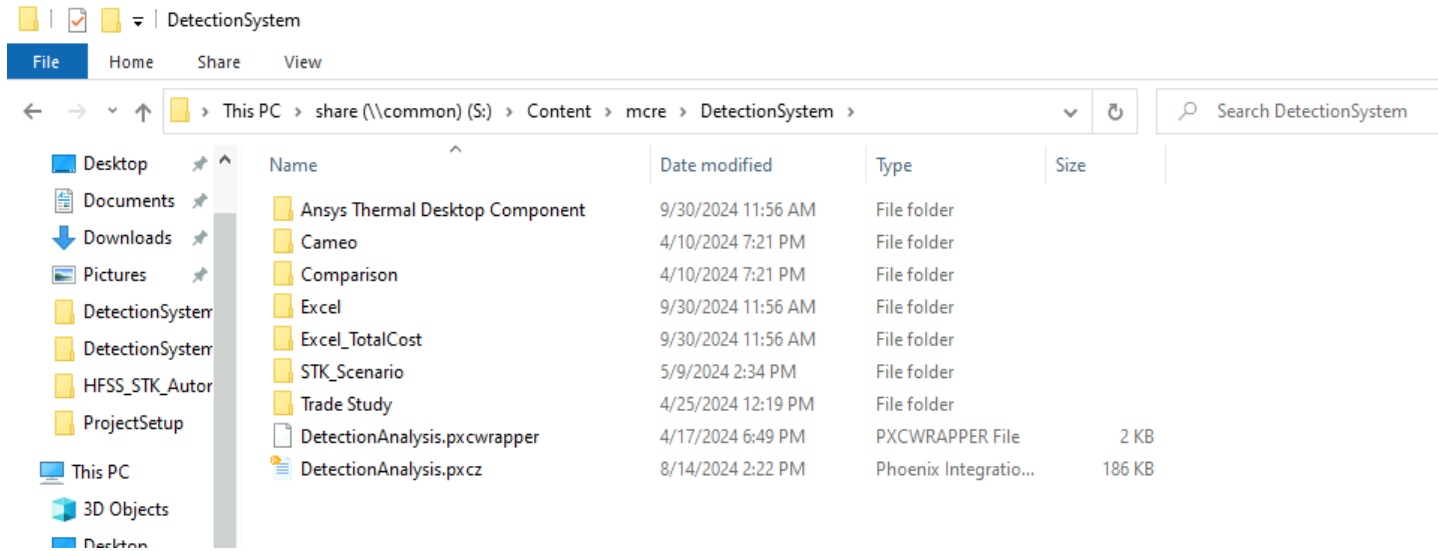
A series of **representative mission profiles** that **sufficiently describe the intended system use** across its nominal and most stressful operating conditions.

The DRM is used to **evaluate system performance** and **guide development efforts**.



Mission Scenario

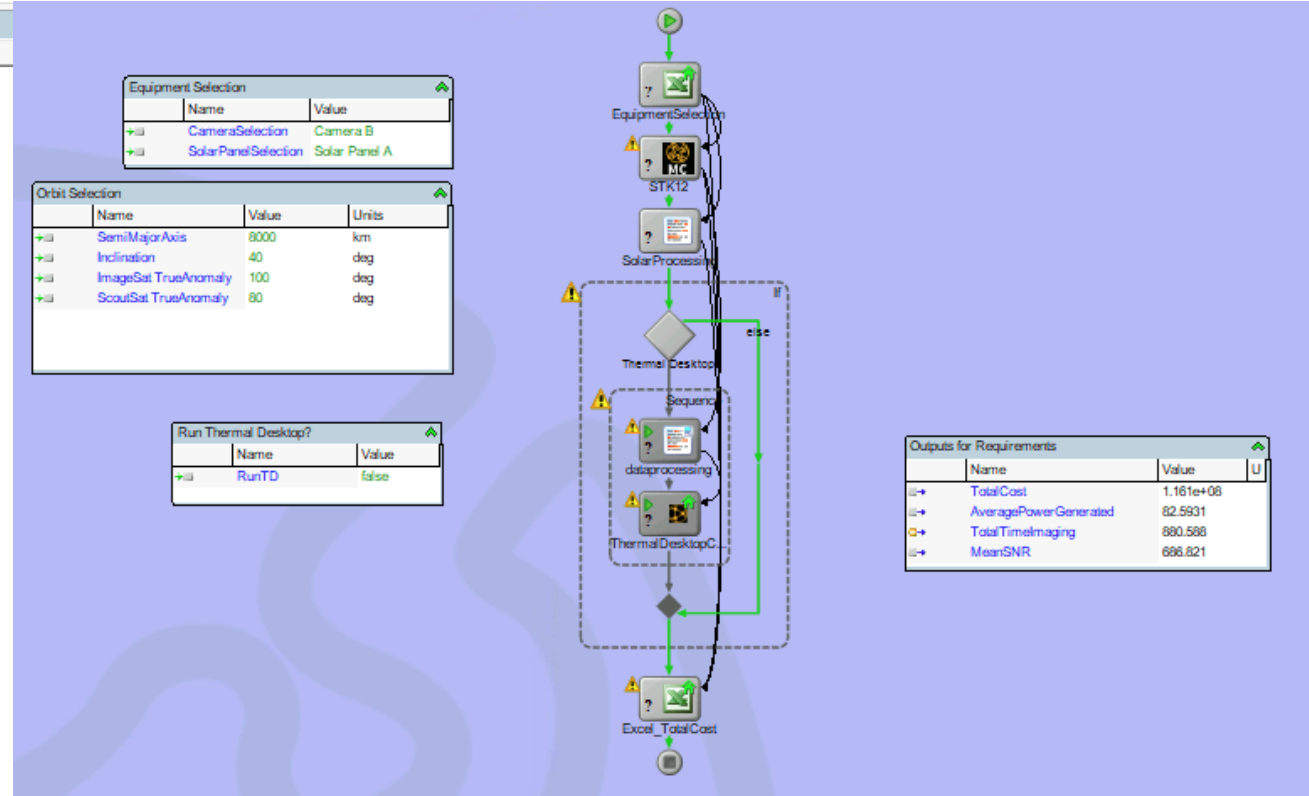
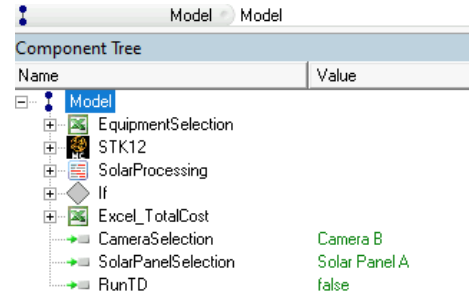




- Logging into the Ansys Digital Engineering Lab Machines which are VMs hosted using AWS or Azure resources.
- The files needed for my workflow are shown below.

Automated Toolchain for DME

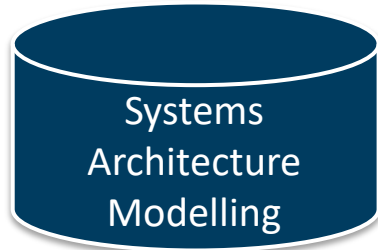
- This is my automated workflow showing various tools.
- Once tools are chained, can be used to execute and run design of experiments.
- This is what I will use to tie to the systems model.



Model-Based Systems Engineering Approach



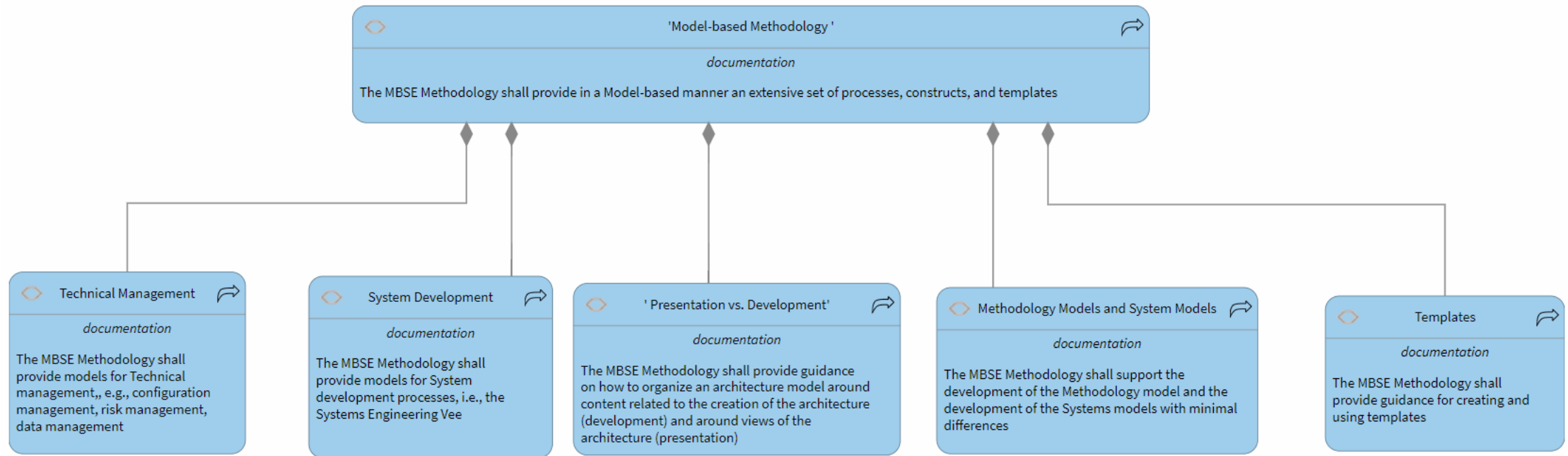
Model-Based Systems Engineering (MBSE) it is not a tool! It is a methodology!



...

Ansys System Architecture Modeler (SAM)

- The Ansys SAM is a general-purpose system architecture modeling tool based on SysML v2



Why SysML v2?

- **We chose SysML v2 for our modeler because we believe that it will be significantly easier to learn, easier to use, and more powerful than SysML v1.**
- **Compared to SysML v1, SysML v2 was designed to be:**
 - **More Precise**
 - **More Expressive**
 - **More intuitive and Regular**
 - **More Consistent**
 - **Have better Interoperability with other engineering models and tools**
- **SysML v2 is grounded in formal semantics and includes a very powerful API.**
- **Expect v2 to be the new industry standard**

Key Characteristics of the Ansys SAM

- **Cloud Native.** The Ansys SAM can be installed on a public cloud (*e.g.* AWS, Azure, etc.) or installed on an on-premise server. It will be accessible to any user from a standard web browser. This means that our modeler is scalable to large numbers of users.
- **Real-time Collaboration.** A key feature of the Ansys SAM is real-time collaboration. Multiple users will be able to work on model development at the same time, and each user can see in real-time what other users are doing.
- **Open Infrastructure.** The SAM is built using an open infrastructure philosophy – open in terms of data, models, and APIs so that it fits into our customer’s MBSE ecosystem. Close integrations with Ansys tools (*e.g.* ModelCenter, Medini, Scade, solvers) and third-party tools (*e.g.* PLM, external simulations, etc.)

Ansys System Architecture Modeler



https://sysml2.architect-factory.com/api/login

My Apps Home FAD Team Huddle... MBE_NA_Resource... Cameron_Account... MC-MBSE-Account... Valerio_AgiPhysics... Ansys SAM and Sys... Ansys Resources Other favorites

Ansys / MBSE PLATFORM

Sign in

or

Email or username

At least 6 alphanumeric, dashes and periods tokens

Password

[Forgot password?](#)

I accept the [License agreement](#).

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Welcome to MBSE Platform

Sign in to discover how Ansys pushes the boundaries of Digital Engineering.

Ansys SAM Dashboard



Ansys DEMO Home Projects DSM AnsysOrga User Profile Help cameron.krivitsky AnsysOrga

Projects

Manage your projects and create new ones

AnsysOrga / Projects

[+ New Project](#) [Advanced Search](#)

Search: All types All visibility

1 project found

Name	Visibility	Library	Last modification date
DetectionSystem SysMLv2	Private	No	11 days ago

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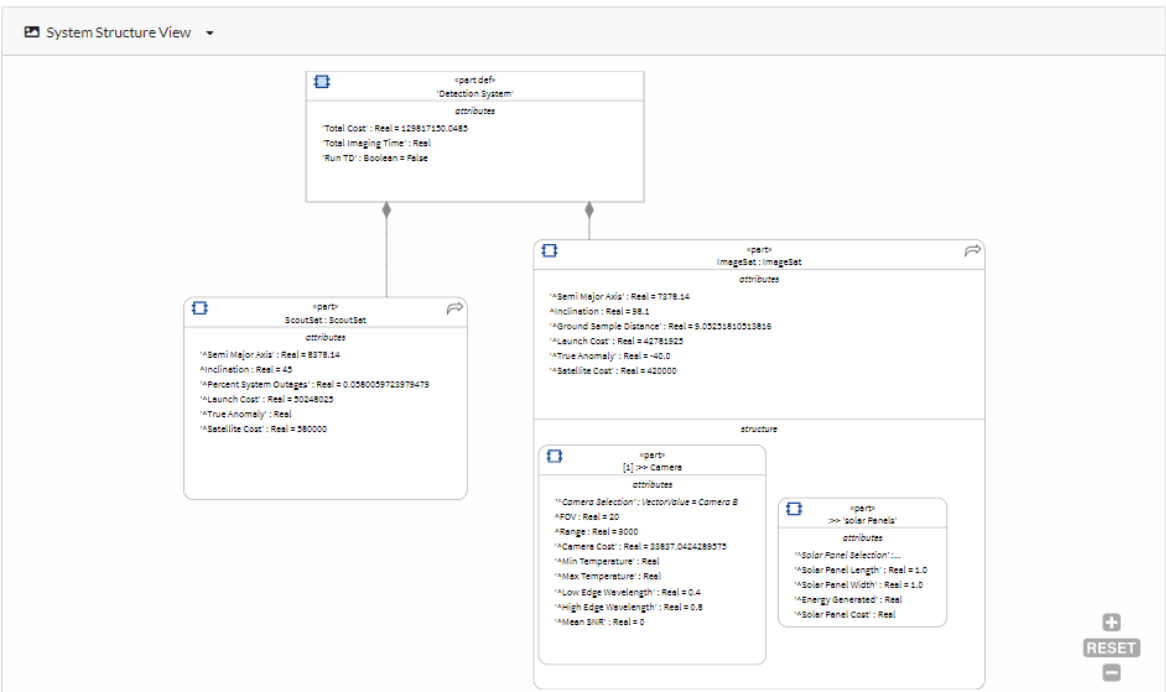
[Summary](#) [Collaboration](#) [Versions](#) [Settings](#)

DetectionSystem

SysMLv2 private 2.0

Created on Mar 28, 2024 - Last Modified on Sep 17, 2024

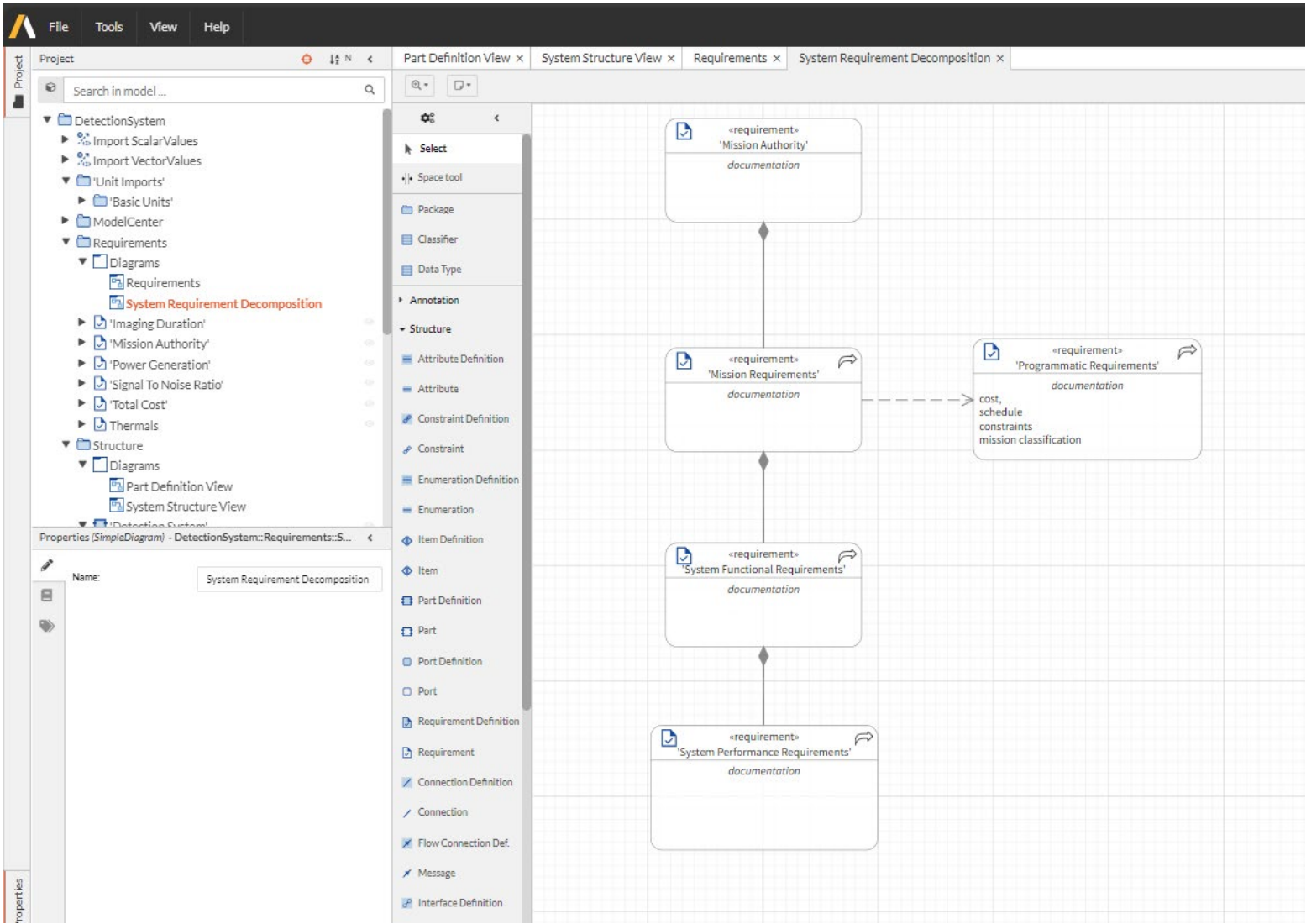
[Live view](#) [Open in Editor](#)



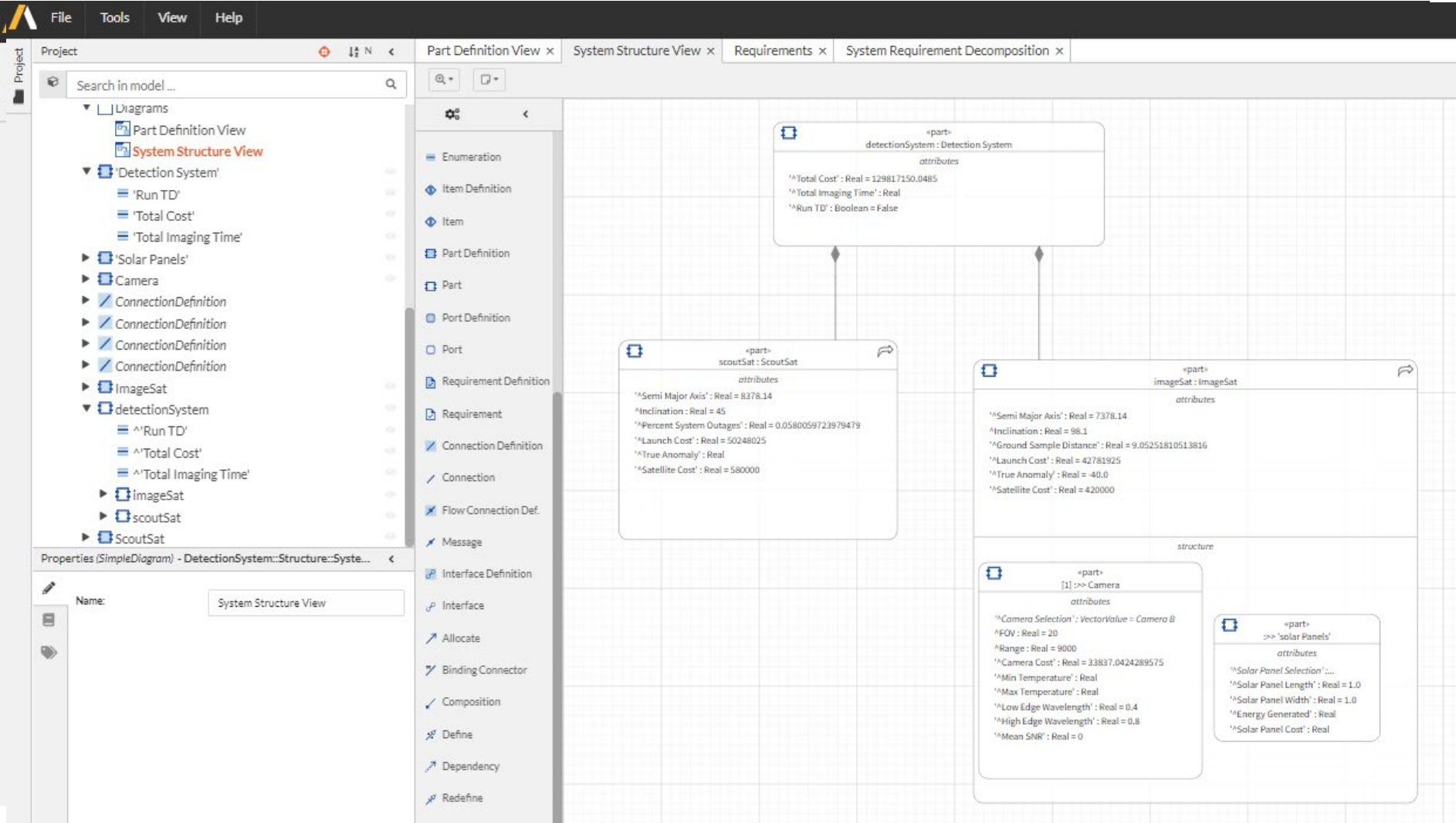
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Approved for Public Release

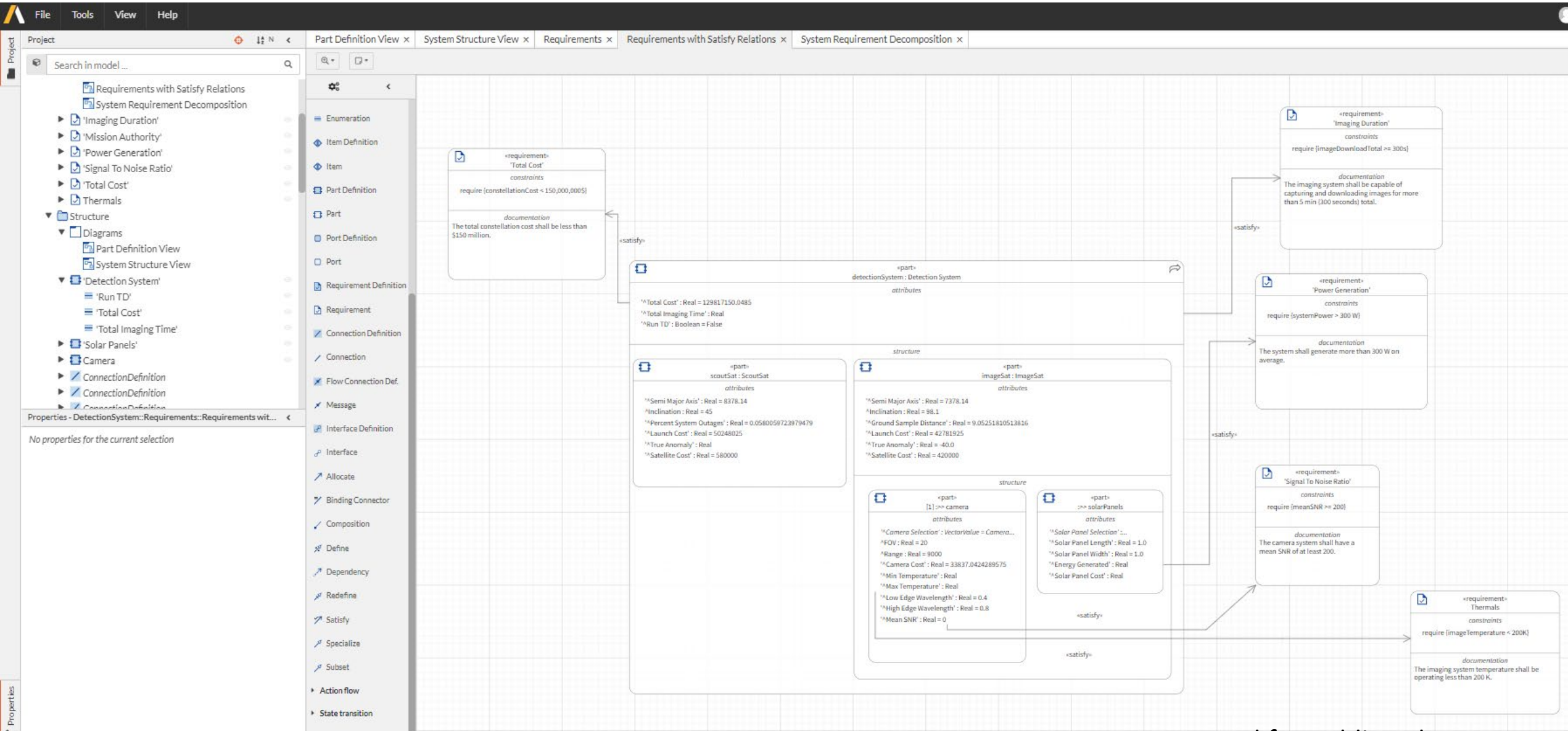
System Requirement Decomposition



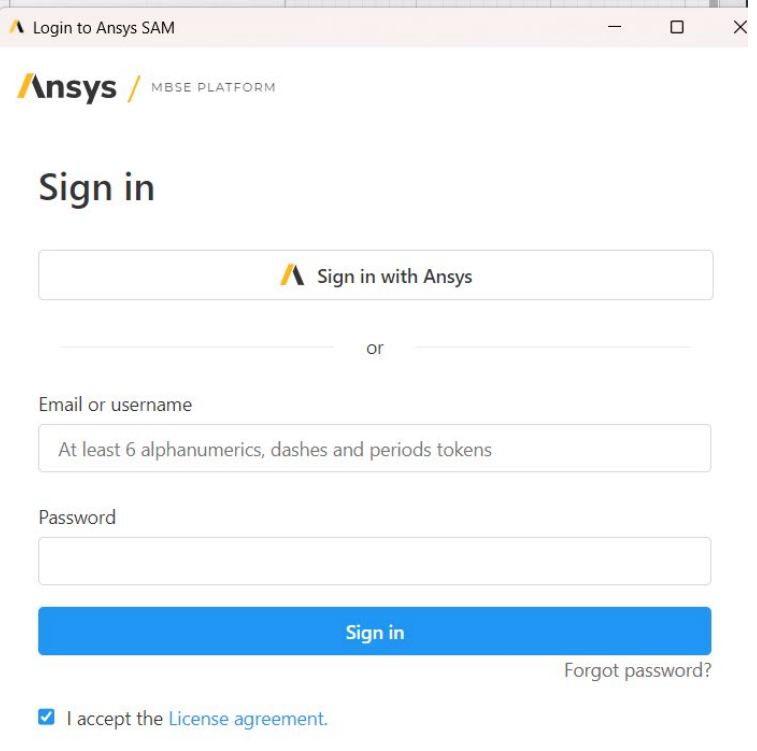
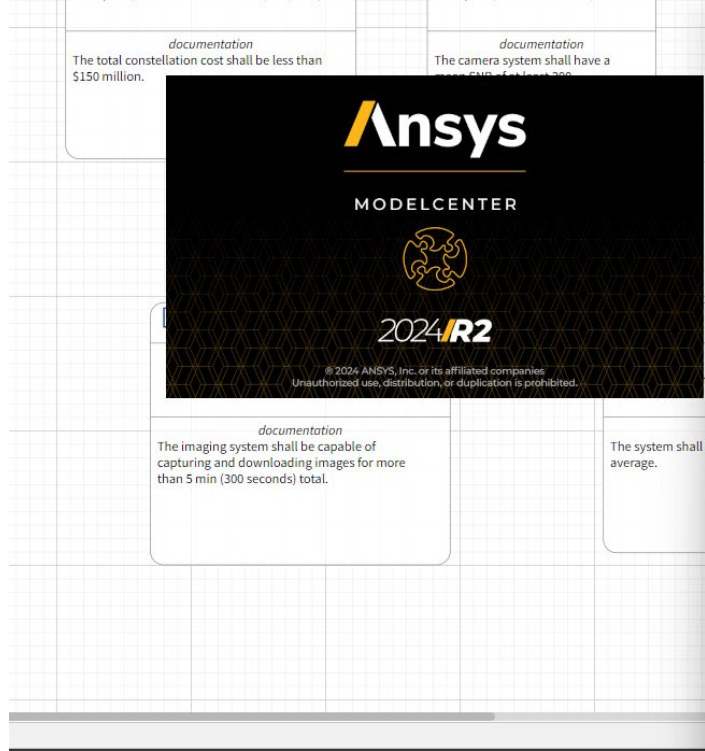
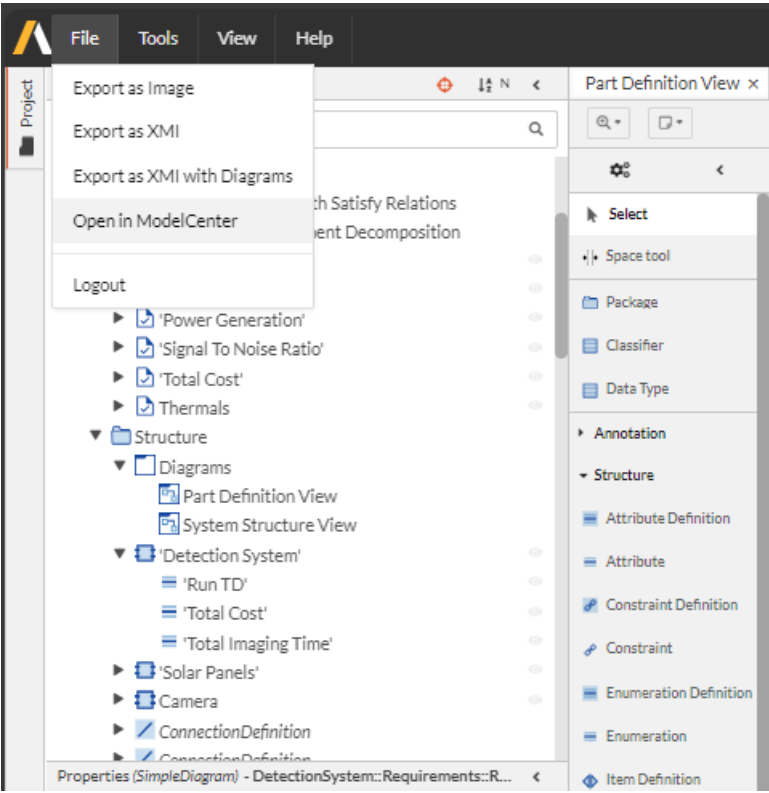
System Structure with Definition and Usages



Requirements Depicted and Structure Allocated



MBSE within the Ansys SAM



MBSE Execution Plan

ModelCenter MBSE - sysml2 [DetectionSystem @ https://sysml2.architect-factory.com/api/spaces/1485632895474126574525orgaid/sysml2]

File Edit Execution Plan Trade Study Help

Workspace Explorer

- DetectionSystemTest*
 - All_Requirements_Satisfied
 - Requirements_Half_Pass_Fail

DetectionSysteme... x All_Requiremen... x Requirements... x

Structure Elements

Name	Value	Type	Units	Associated Analyses
Structure				
Detection Syster				
Run TD	False	Boolean		DetectionAnalysis
Total Cost	1.2982E+8	Real		DetectionAnalysis, Total
Total Imaging	0.0	Real		ImageDuration, Detectic
detectionSystem				
imageSat				
Inclination	98.100	Real	deg	DetectionAnalysis
Semi Major /	7378.1	Real	km	DetectionAnalysis
True Anomal	0.0	Real	deg	DetectionAnalysis
camera				
Camera Se	Camera A	String		DetectionAnalysis
FOV	Camera A	Real		DetectionAnalysis
High Edge	Camera B	Real	um	DetectionAnalysis
Low Edge \	Camera C	Real	um	DetectionAnalysis
Mean SNR	Camera D	Real		DetectionAnalysis, Mear
Range	Camera E	Real		DetectionAnalysis
solarPanels				
Energy Ger	0.0	Real		DetectionAnalysis, Powe

Analyses (5 of 5 selected)

- DetectionAnalysis
- ImageDuration
- Mean SNR
- PowerGenerated
- TotalCost

Requirements

Name	Associated Analyses
2 Signal To Noise Ratio	Mean SNR
5 Power Generation	PowerGenerated
1 Total Cost	TotalCost

Systems Model Structure

- DetectionSystem

Analyses List

- DetectionAnalysis
- ImageDuration
- Mean SNR
- PowerGenerated
- TotalCost

Requirements List

- 3 Thermals
- 4 Imaging Duration
- 1 Total Cost
- 5 Power Generation
- 2 Signal To Noise Ratio
- req-id Mission Authority

Search Requirements...

Log

Execution Plan with Design of Experiments



ModelCenter MBSE - sysml2 [DetectionSystem @ https://sysml2.architect-factory.com/api/spaces/1485632895474126574525orgaid/sysml2]

File Edit Execution Plan Trade Study Help

Workspace Explorer

- DetectionSystemTest*
 - All_Requirements_Satisfied
 - Requirements_Half_Pass_Fail

Structure Elements

Name	Value	Type	Unit
Total Imaging	0.0	Real	
detectionSystem			
imageSat			
Inclination	98.100	Real	deg
Semi Major Axis	7378.1	Real	km
True Anomaly	0.0	Real	deg
camera			
Camera Selection	Camera A	String	
FOV	20.000	Real	
High Edge	0.80000	Real	um
Low Edge	0.40000	Real	um
Mean SNR	0.0	Real	
Range	9000.0	Real	

Analyses (5 of 5 selected)

- DetectionAnalysis
- ImageDuration
- Mean SNR

Requirements

Name	Associated Analysis
2 Signal To Noise Ratio	Mean SNR
5 Power Generation	PowerGenerated

DOE Tool 24.2.0

favorites list

Design Variables

Name	Values
Model.Inputs.DetectionSystem.Structure.detectionSystem.imageSat.Inclination	Low: 0 High: 100
Model.Inputs.DetectionSystem.Structure.detectionSystem.imageSat.Semi_Major_Axis	Low: 7200 High: 7500

Response Variables

- Model.Outputs.DetectionSystem.Structure.Detection_System.Total_Imaging_Time

Design

Full Factorial (selected)

Number of Levels: 25 runs

Resume... Run... Options... Help...

Data Explorer and 2D Scatter Plot

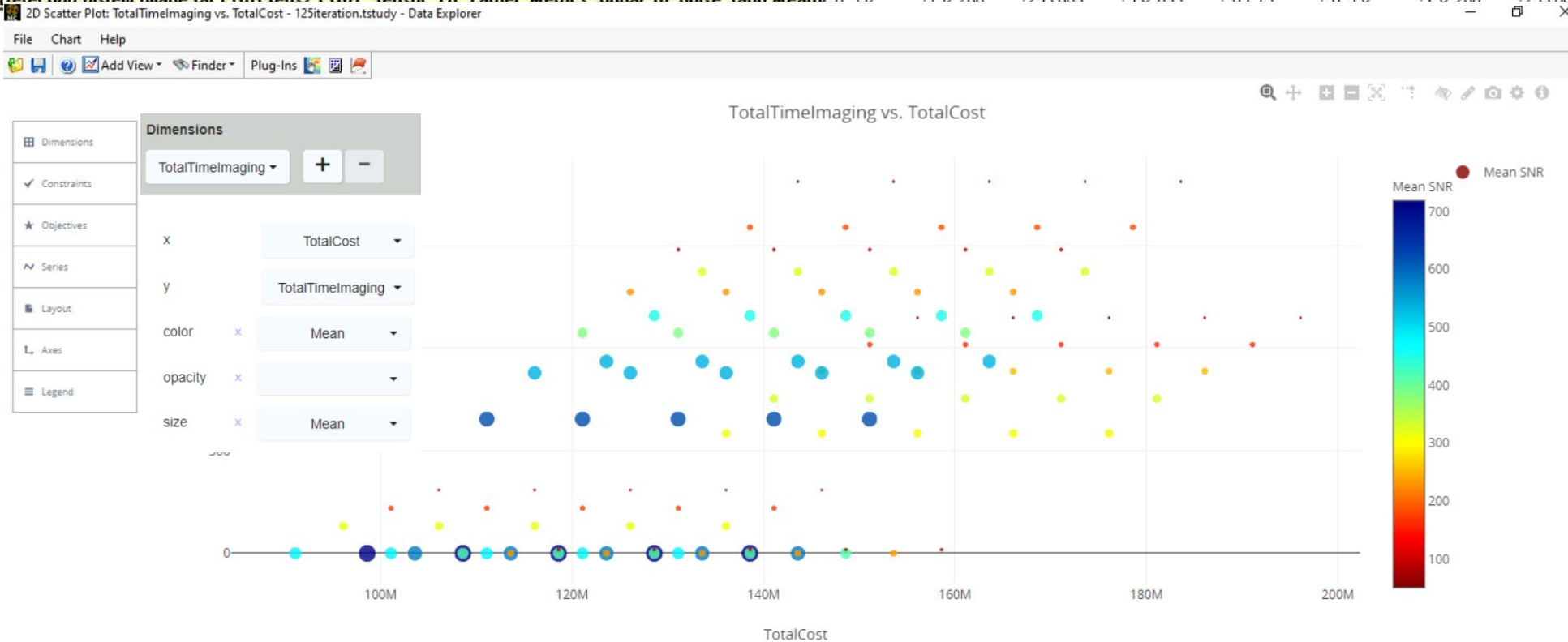
Table - 125iteration.tstudy - Data Explorer

File Chart Help

Legend: input valid output invalid output modified value

AUTO SCROLL

	1	2	3	4	5	6	7	8	9	10	11
design variable(Model.CameraSelection)	Camera E	Camera D	Camera C	Camera B	Camera A	Camera E	Camera D	Camera C	Camera B	Camera A	Camera
design variable(Model.SolarPanelSelection)	Solar Panel E	Solar Panel E	Solar Panel E	Solar Panel E	Solar Panel E	Solar Panel D	Solar Panel D	Solar Panel D	Solar Panel D	Solar Panel D	Solar Pa
design variable(Model.STK12.DetectionSystem.ImageSat.Propagator.SemiMajorAxis)	8500	8500	8500	8500	8500	8500	8500	8500	8500	8500	8500
response(Model.Excel.TotalCost.TotalCost)	1.961e+08	1.911e+08	1.861e+08	1.811e+08	1.761e+08	1.861e+08	1.811e+08	1.761e+08	1.711e+08	1.661e+08	1.761e+
response(Model.Excel.TotalCost.AveragePower)	677.385	677.385	677.385	677.385	677.385	677.385	677.385	677.385	677.385	677.385	456.762
response(Model.Excel.TotalCost.TotalImaging)	1148.94	1018.8	889.019	754.526	585.644	1148.94	1018.8	889.019	754.526	585.644	1148.94
response(Model.STK12.DetectionSystem.ImageSat.FNIRSens2.FNIR_Sensor_To_Target_Metrics.Signal_to_noise_ratio_Mean)	51.557	157.288	253.009	332.695	311.15	51.557	157.288	253.009	332.695	311.15	51.557



MBSE Results with Two Failed Requirements

ModelCenter MBSE - sysml2 [DetectionSystem @ https://sysml2.architect-factory.com/api/spaces/1485632895474126574525orgaid/sysml2]

File Edit Execution Plan Trade Study Help

Workspace Explorer

- DetectionSystemTest*
 - All_Requirements_Satisfied
 - Requirements_Half_Pass_Fail

DetectionSysteme... x All_Requiremen... x Requirements... x

Results Completed: 10/2/2024 8:58:50 PM

Name	Baseline	Value	Units	Change	Delta	Delta %
DetectionSystem						
Structure						
Detection System						
Run TD	False	False		=		
Total Cost	1.2982E+8	1.2001E+8		↓	9.81%	7.5584
Total Imaging Time	0.0	0.0		=		0.0
detectionSystem						
imageSat						
Inclination	98.100	98.100		=	0.0	0.0
Semi Major Axis	7378.1	7378.1		↓	4.00%	5.4214E
True Anomaly	-40.000	0.0		↑	40.0%	-100.00
camera						
Camera Selection	Camera B	Camera A		≠		
FOV	20.000	30.000		↑	10.0%	50.000
High Edge Wavelength	0.80000	1.2000		↑	0.40%	50.000
Low Edge Wavelength	0.40000	0.30000		↓	0.10%	25.000
Mean SNR	0.0	53.719		↑		53.71
Range	9000.0	7500.0		↓	1500	16.667
solarPanels						
Energy Generated	0.0	675.98		↑	675.98	

Requirements

Name	Satisfied	Margin
5 Power Generation	✓	375.98
1 Total Cost	✓	2.9995E+7
4 Imaging Duration	✗	-300.00
2 Signal To Noise Ratio	✗	-146.28

Systems Model Structure

- DetectionSystem

Analyses List

- DetectionAnalysis
- ImageDuration
- Mean SNR
- PowerGenerated
- TotalCost

Requirements List

- 3 Thermals
- 4 Imaging Duration
- 1 Total Cost
- 5 Power Generation
- 2 Signal To Noise Ratio
- req-id Mission Authority

Search Requirements...

Log

MBSE Results with All Requirements Satisfied

ModelCenter MBSE - sysml2 [DetectionSystem @ https://sysml2.architect-factory.com/api/spaces/1485632895474126574525orgaid/sysml2]

File Edit Execution Plan Trade Study Help

Workspace Explorer

- DetectionSystemTest*
 - All_Requirements_Satisfied
 - Requirements_Half_Pass_Fail

DetectionSystem... x All_Requiremen... x Requirements_... x

Results Completed: 10/2/2024 8:18:37 PM

Name	Baseline	Value	Units	Change	Delta	Delta %
DetectionSystem						
Structure						
Detection System						
Run TD	False	False		=		
Total Cost	1.2982E+8	1.3110E+8		↑	1.28%	0.9882%
Total Imaging Time	0.0	686.51		↑	686.51	
detectionSystem						
imageSat						
Inclination	98.100	40.000		↓	58.1%	59.225%
Semi Major Axis	7378.1	8000.0		↑	621.8	8.4284%
True Anomaly	-40.000	100.00		↑	140.0	-350.00%
camera						
Camera Selection	Camera B	Camera A		≠		
FOV	20.000	30.000		↑	10.0%	50.000%
High Edge Wavelength	0.80000	1.2000		↑	0.40%	50.000%
Low Edge Wavelength	0.40000	0.30000		↓	0.10%	25.000%
Mean SNR	0.0	733.33		↑	733.33	
Range	9000.0	7500.0		↓	1500	16.667%
solarPanels						
Energy Generated	0.0	457.09		↑	457.09	

Requirements

Name	Satisfied	Margin
2 Signal To Noise Ratio	✓	533.33
1 Total Cost	✓	1.8900E+7
5 Power Generation	✓	157.09
4 Imaging Duration	✓	386.51

Systems Model Structure

- DetectionSystem

Analyses List

- DetectionAnalysis
- ImageDuration
- Mean SNR
- PowerGenerated
- TotalCost

Requirements List

- 3 Thermals
- 4 Imaging Duration
- 1 Total Cost
- 5 Power Generation
- 2 Signal To Noise Ratio
- req-id Mission Authority

Search Requirements...

Thank You!