Integrating Mission Analysis with SysMLv2 and Requirements Assessment

Cameron Krivitsky

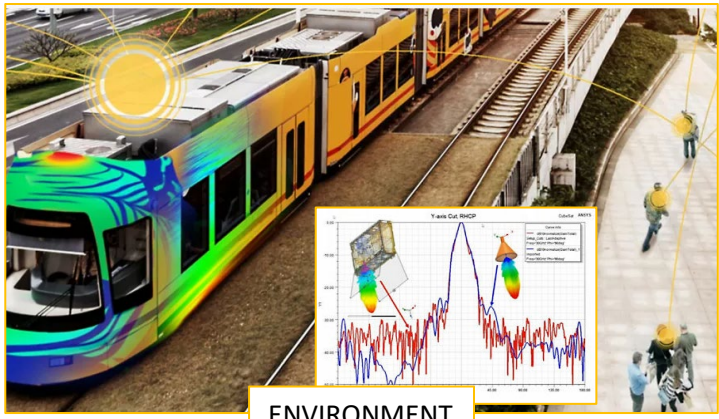
Peter Douglas

Section Header

DIGITAL MISSION ENGINEERING AND SYSTEMS V DIAGRAM

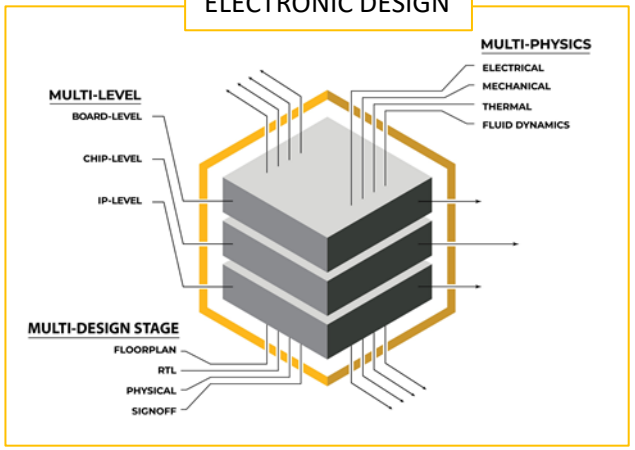
Framing of the problem…

- **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.



DIGITAL ENGINEERING

ELECTRONIC DESIGN



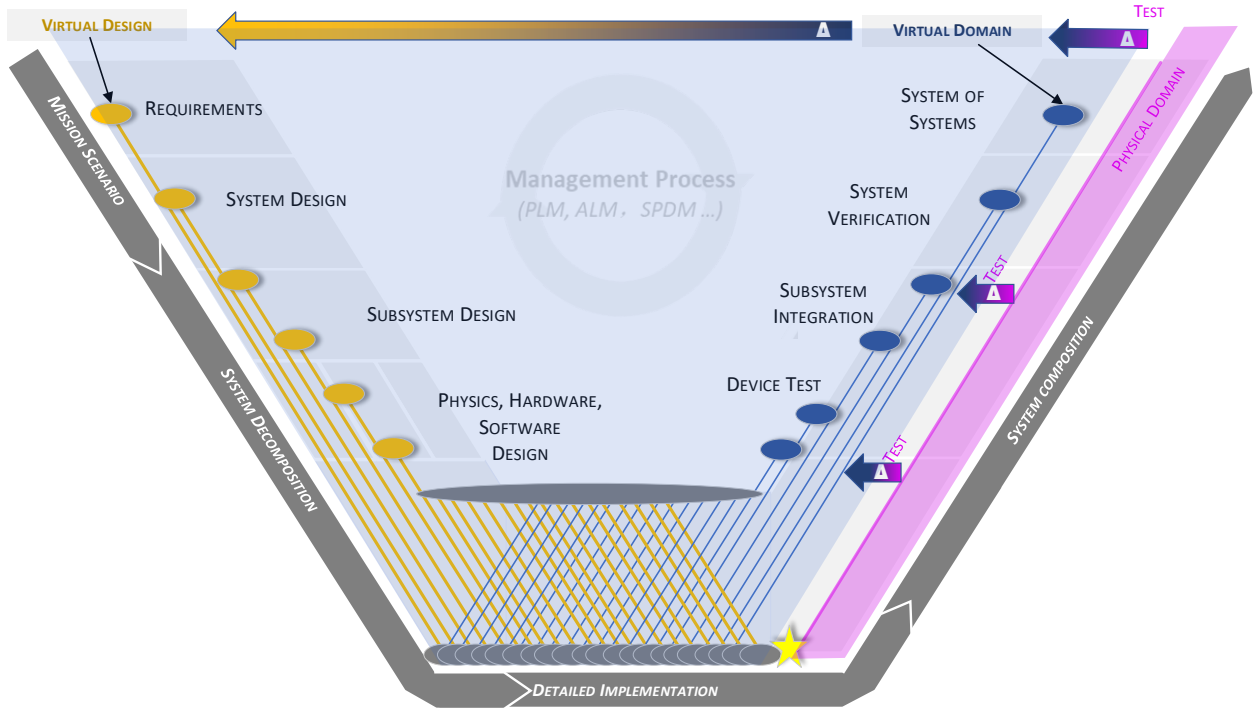
Using a digital engineering framework results in system knowledge capture, insight in system interoperability, system ability to meet mission objectives – ultimately leading to a better engineered solution throughout the lifecycle.

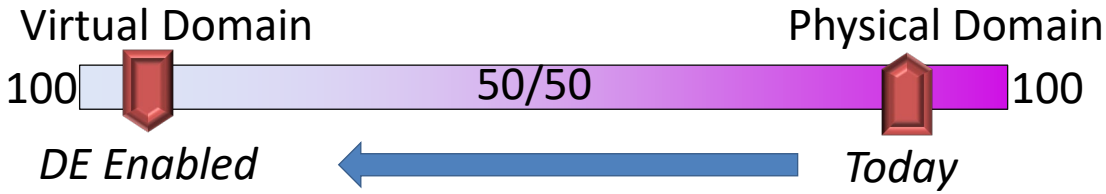
Digital Engineering enabled System-V Diagram

- 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

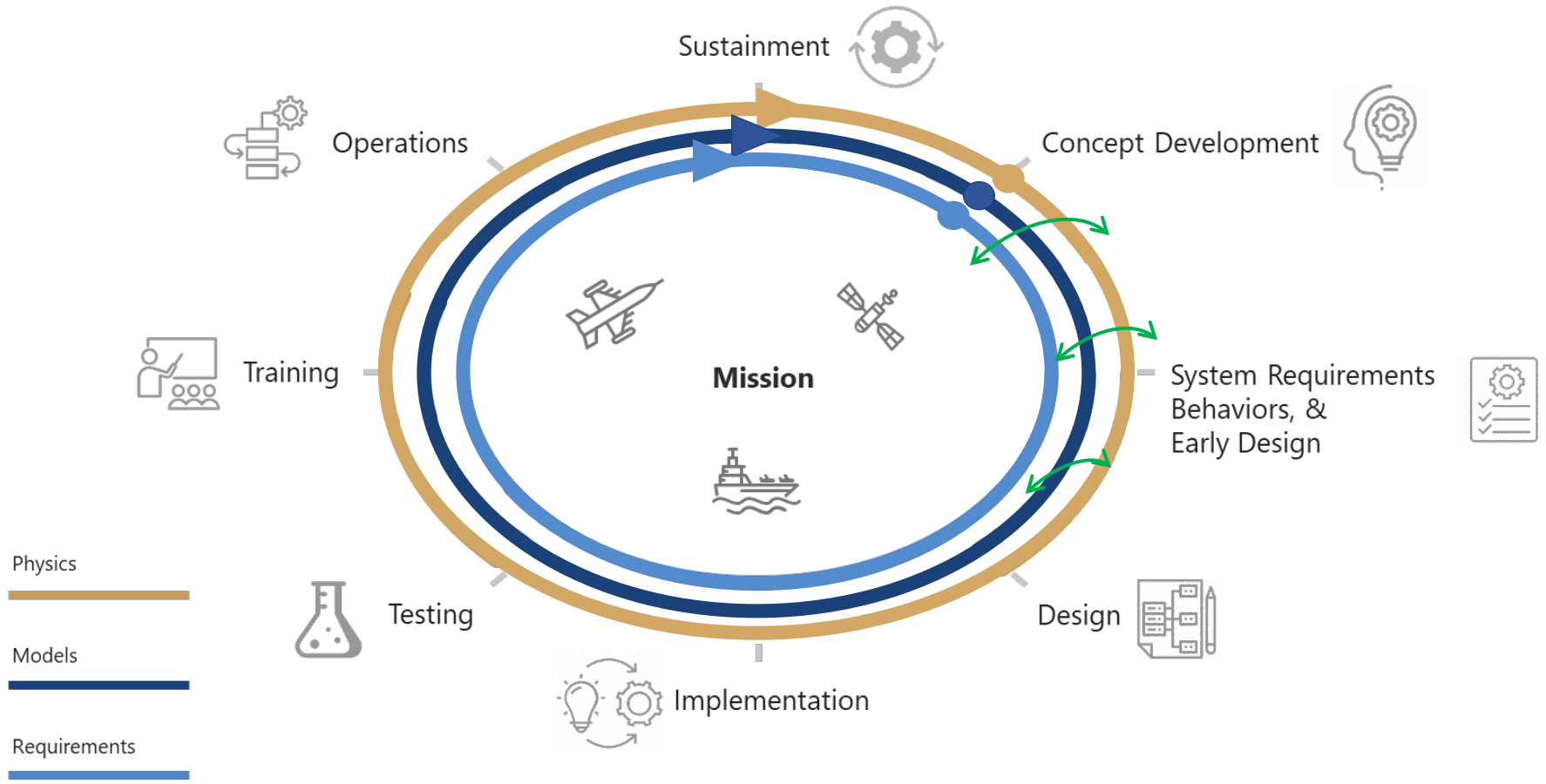
- Value occurs through the combined use of the Virtual and Physical domain to solve complex engineering challenges



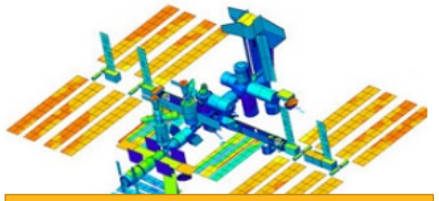
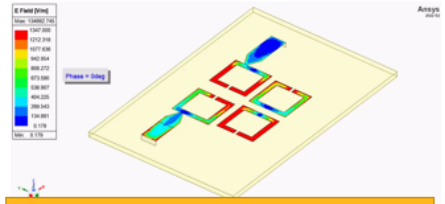
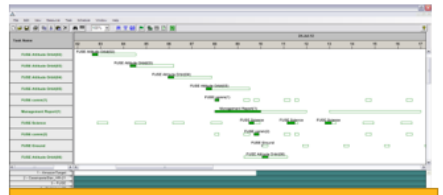
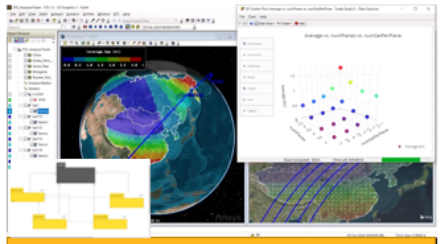
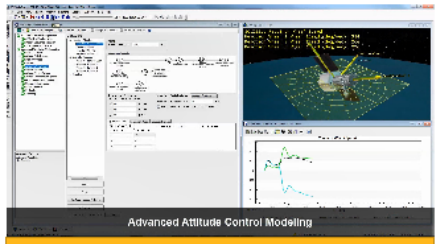
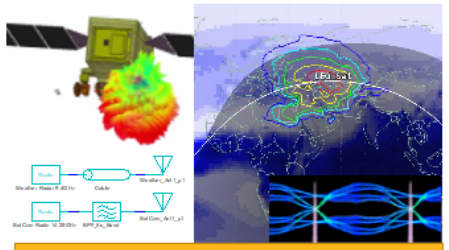
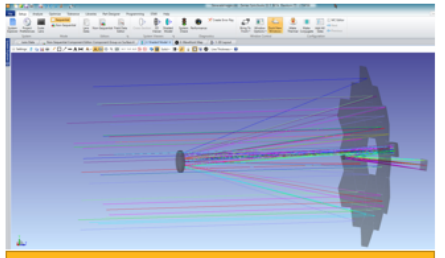
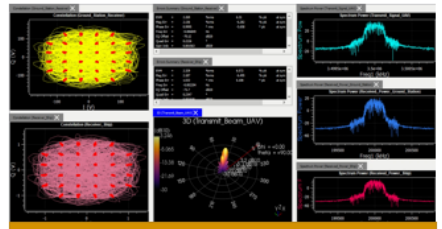
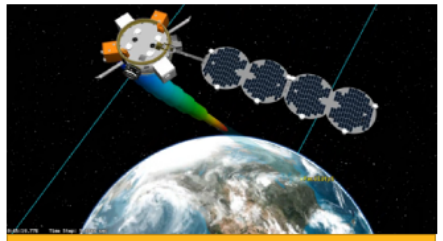
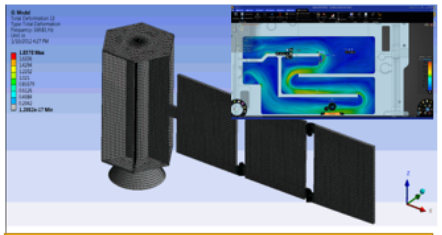
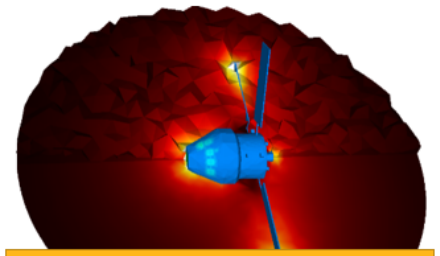
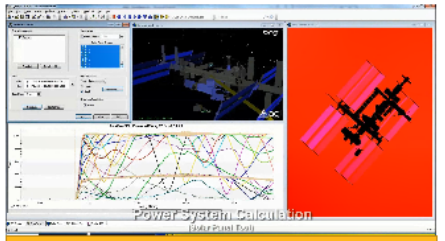
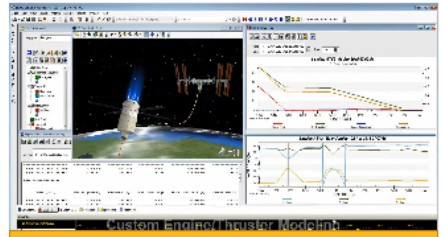


Result: Increased use of modeling and simulation accelerates integration, deployment, and sustainment.

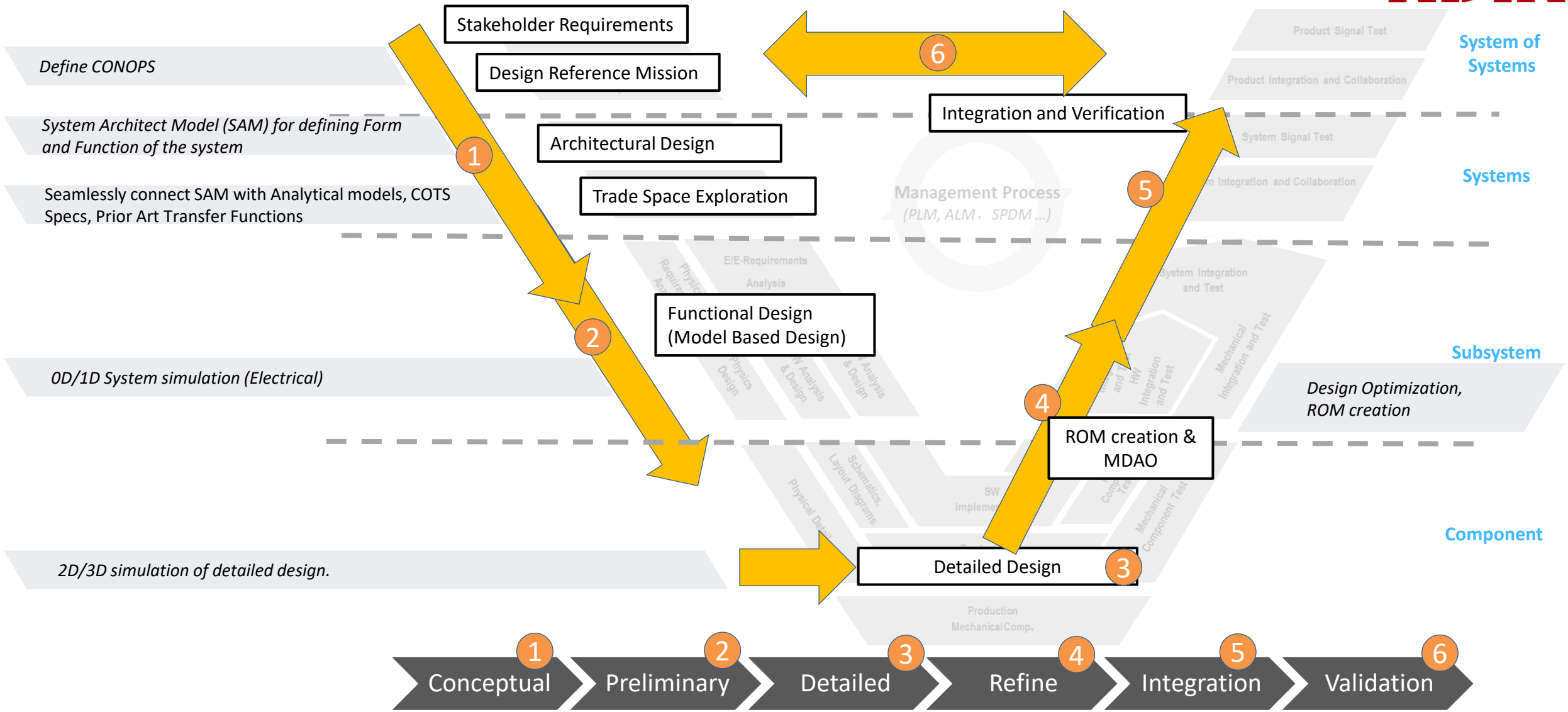
Why?



DME Accelerates Space Systems Design and Verification

Systems Engineering	Vehicle Engineering	Electronics Engineering	Payloads / Software	System Test / Ops
				
Design Reference Missions (Ansys STK)	Thermal Analysis (Ansys Thermal Desktop)	RF Chips/Filters/Amps (Ansys Electronics)	Flight Software (STK SOLIS / SCADE)	TTC Ground Integration (Ansys STK / Scheduler)
				
MBSE Analytic Integration (Ansys ModelCenter/SAM)	ADCS and Propulsion (Ansys STK SOLIS)	RF Antennas and Cosite (Ansys Electronics)	Optics / IR Evaluation (STK / Zemax Optics)	HIL/SIL Integration (Ansys STK/Keysight)
				
Subsystems Assessment (Ansys STK)	Structures / Deplyment (Ansys Mechanical LS-Dyna)	Radiation EMC (Ansys STK / Charge Plus)	Power and Batteries (Ansys STK / Twin Builder)	Flight Dynamics (FDS) (Ansys STK / ODTK)

Generalized Process for Establishing Digital Engineering

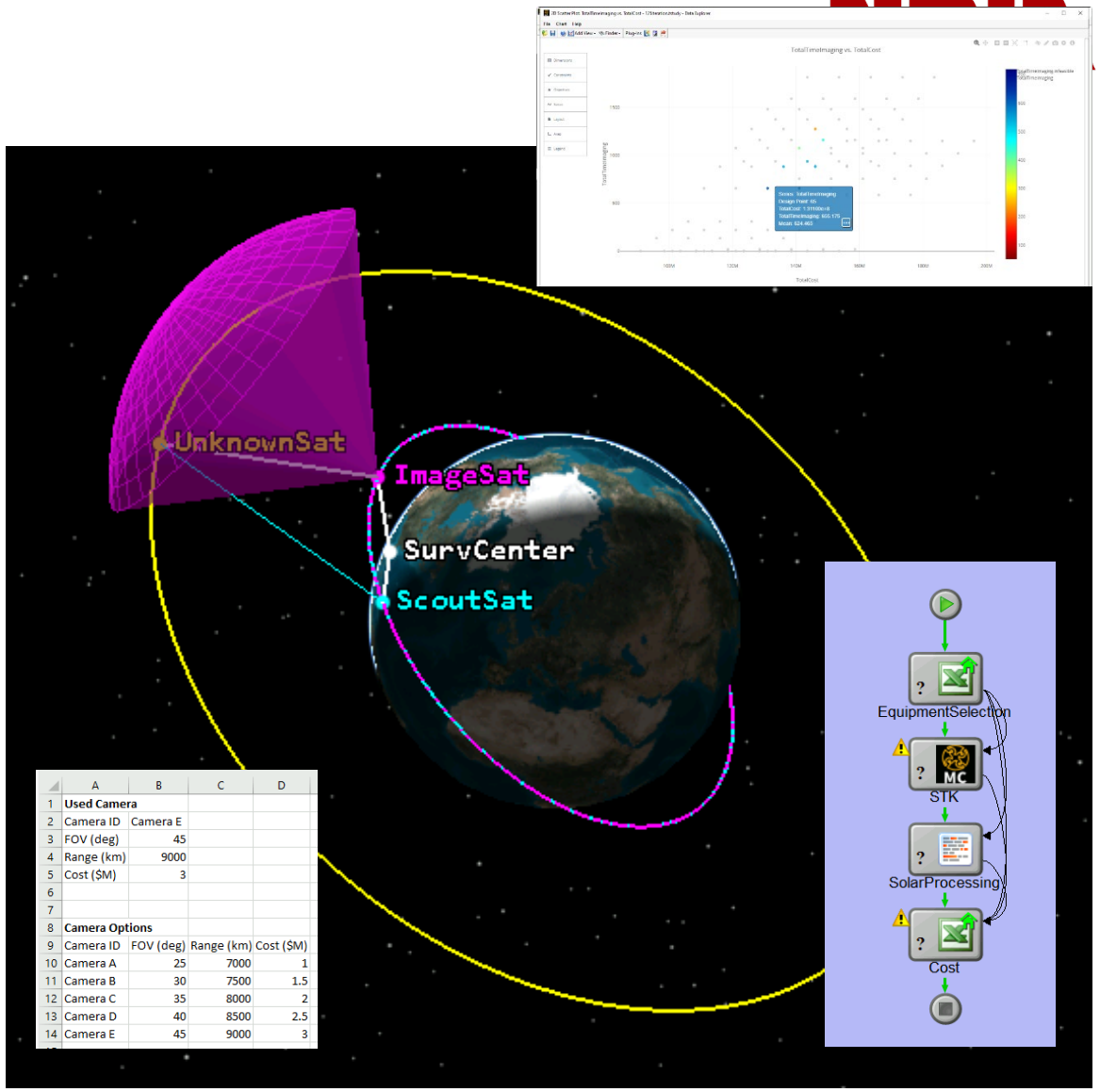


Section Header

NOTIONAL USE CASE

Example Demo – Notional RFP

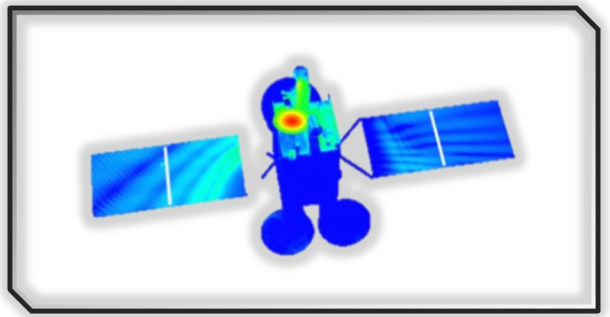
- **RFP Overview:**
  - Design two satellites in LEO that image unknown satellites
  - ScoutSat must first identify an unknown satellite before notifying ImageSat via ground relay to begin taking images
- **RFP Requirements:**
  1. Total cost of mission shall be less than **$150M**
  2. Total imaging 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



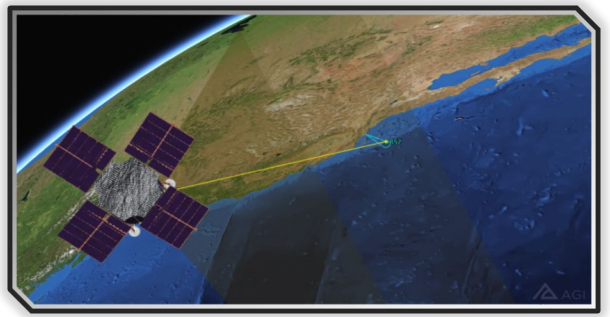
	A	B	C	D
1	**Used Camera**			
2	Camera ID	Camera E		
3	FOV (deg)	45		
4	Range (km)	9000		
5	Cost ($M)	3		
6				
7				
8	**Camera Options**			
9	Camera ID	FOV (deg)	Range (km)	Cost ($M)
10	Camera A	25	7000	1
11	Camera B	30	7500	1.5
12	Camera C	35	8000	2
13	Camera D	40	8500	2.5
14	Camera E	45	9000	3

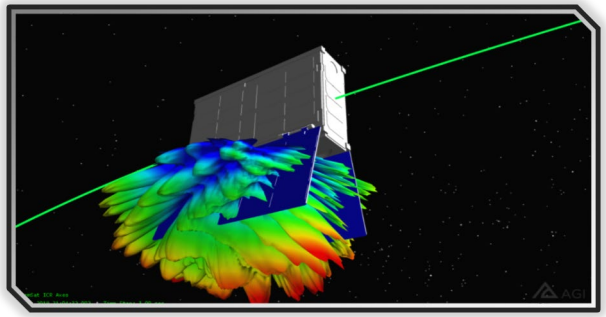
Design Reference Mission (DRM)

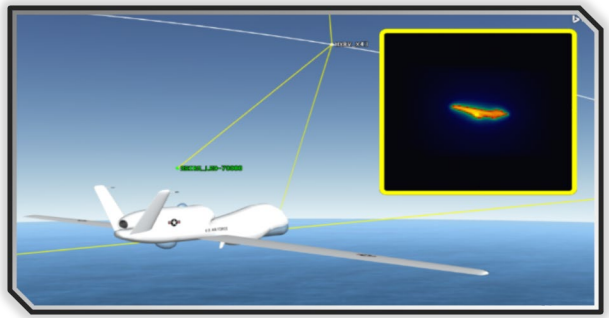
A series of **representative mission profiles** that **sufficiently describe the intended system use** across its nominal and most stressful operating conditions.

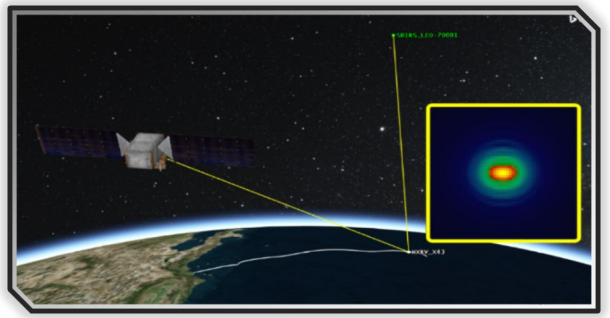


The DRM is used to **evaluate system performance** and **guide development efforts**.

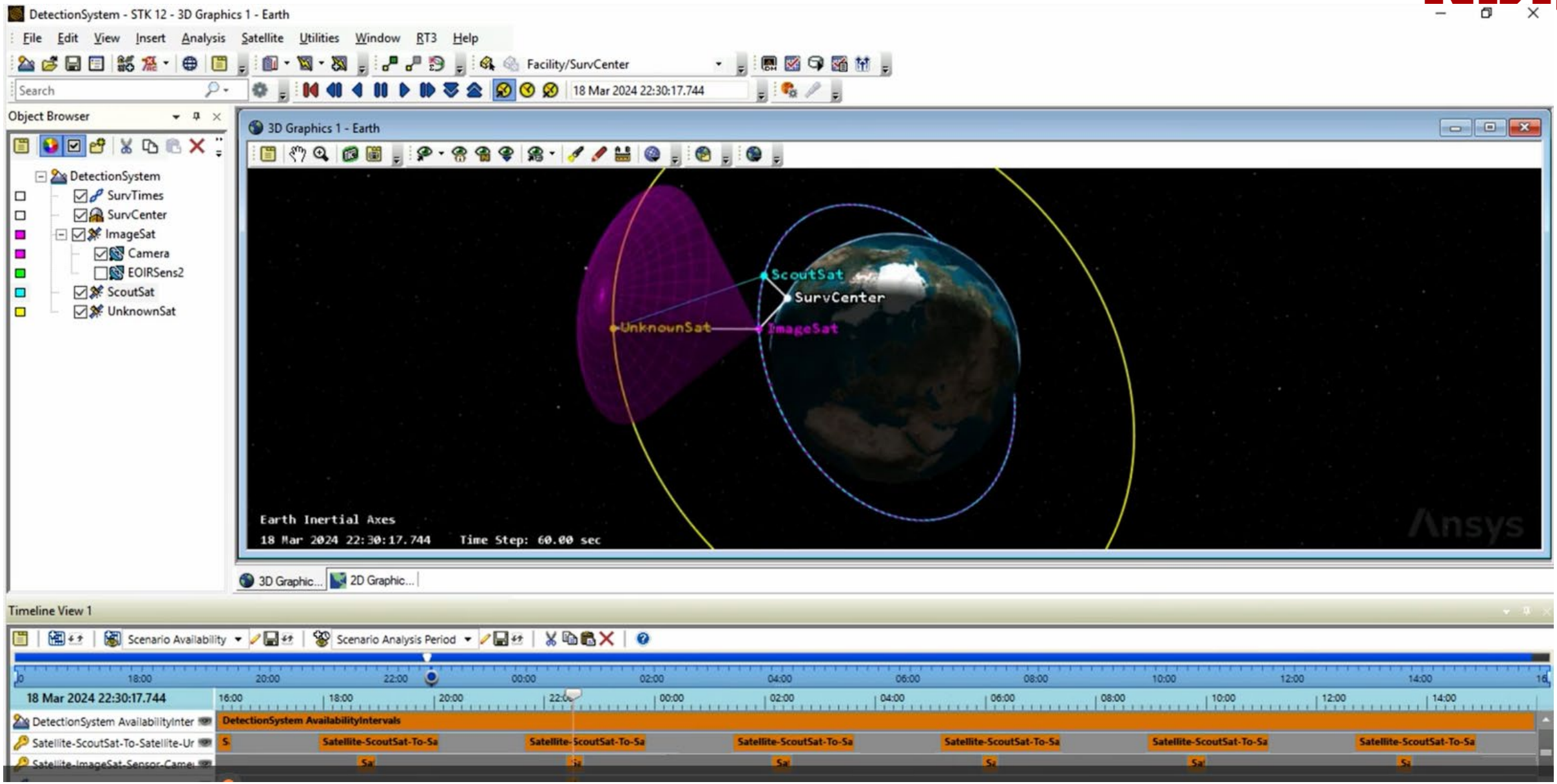




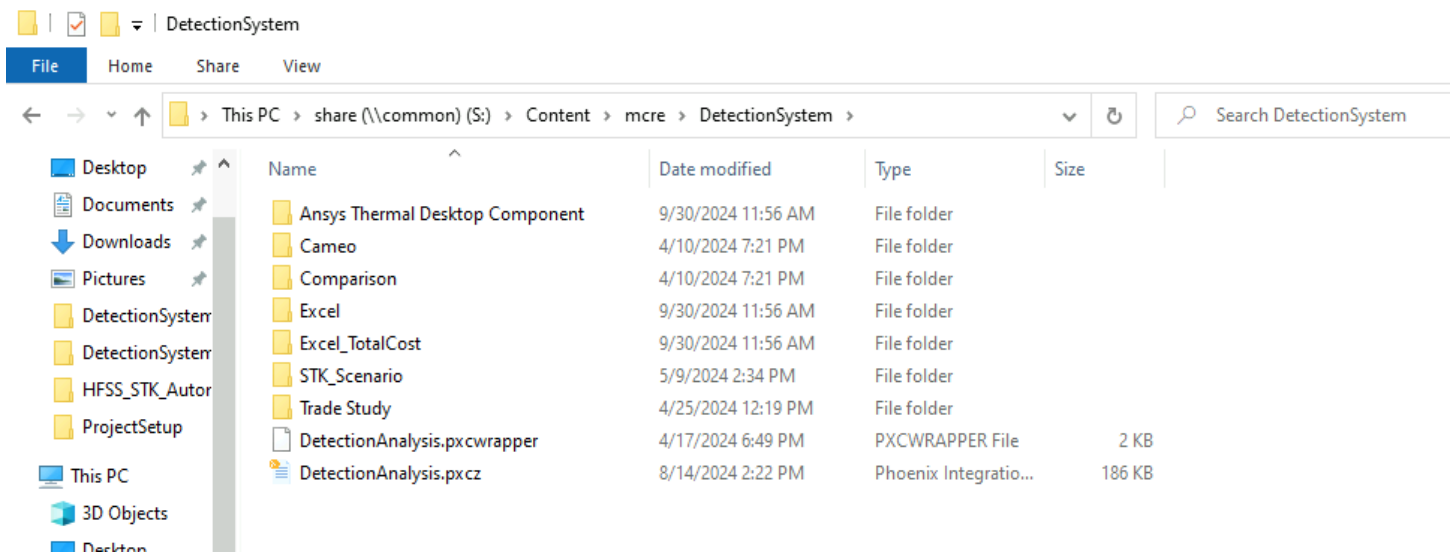




Mission Scenario



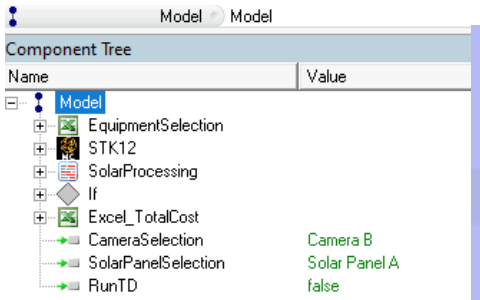
Ansys DELAB

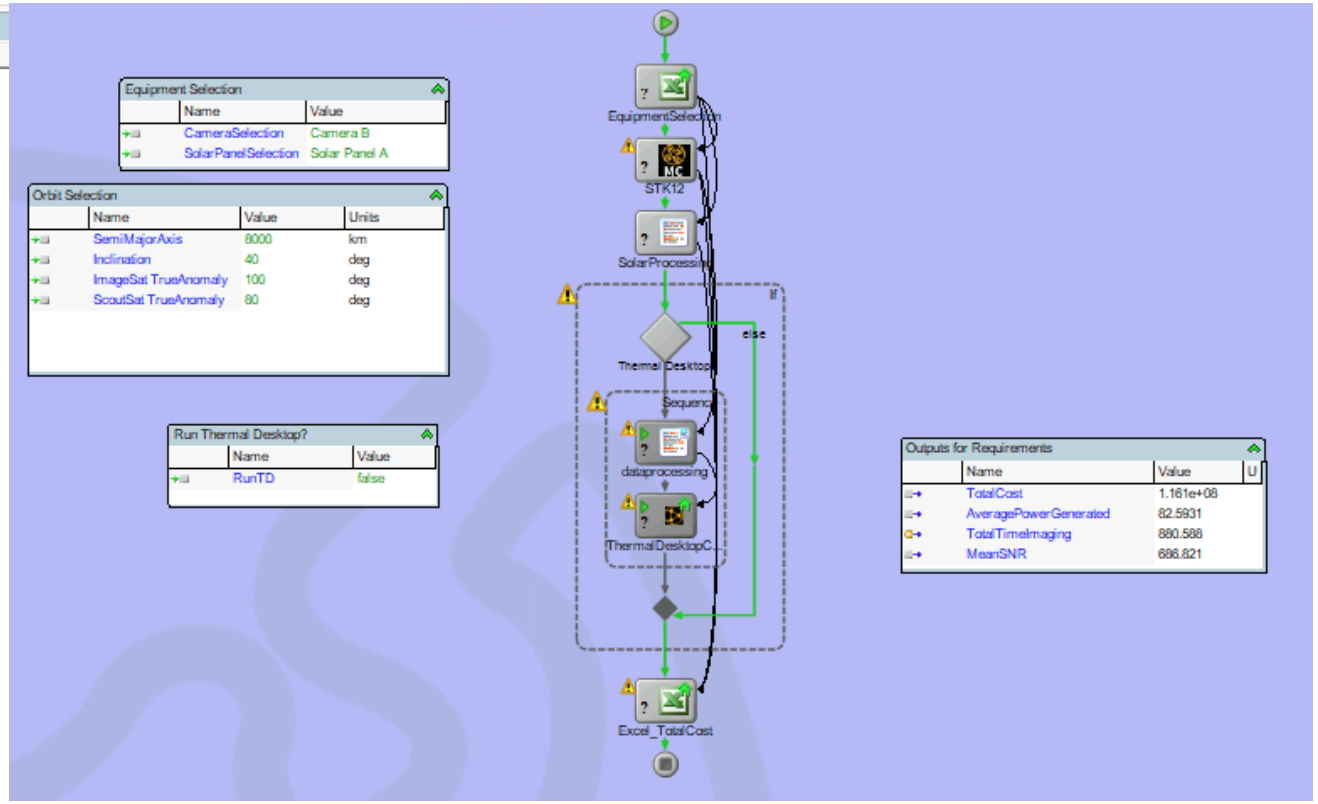


- Logging into the Ansys Digital Engineering Lab Machines which are VMs hosted using AWS or Azure resources.
- The files needed for my workflow are shown below.

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.

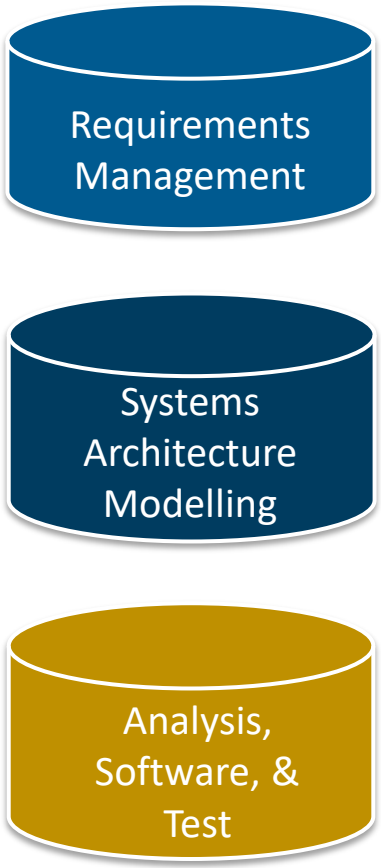




Model-Based Systems Engineering Approach

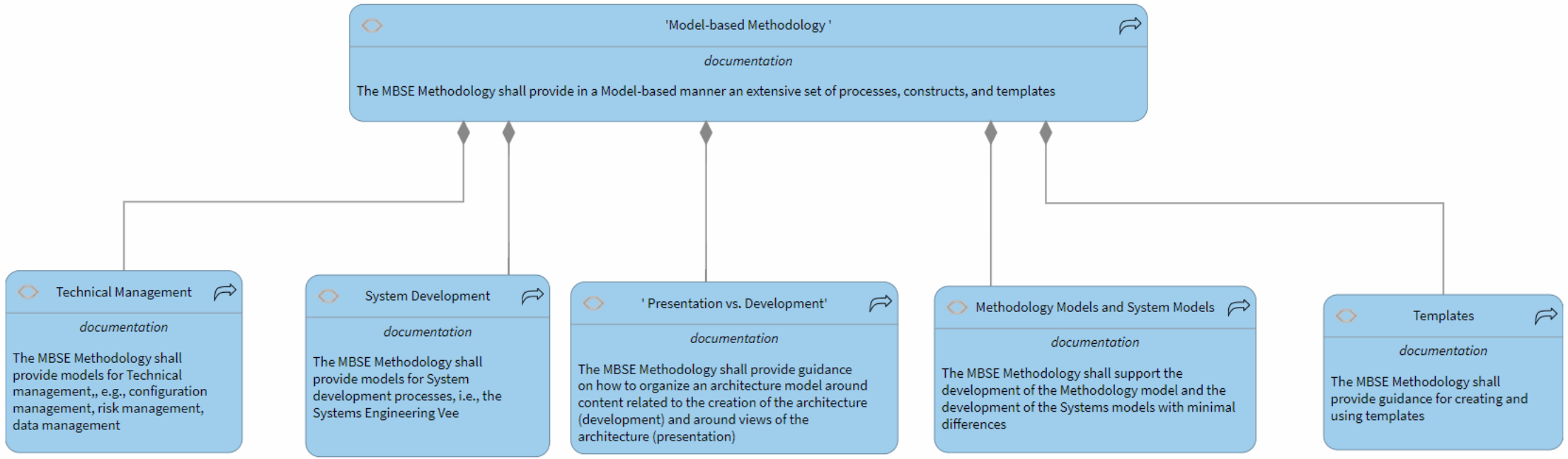
Conceptual Phase → Preliminary Phase → Detailed Design Phase → Prototype & Test

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?

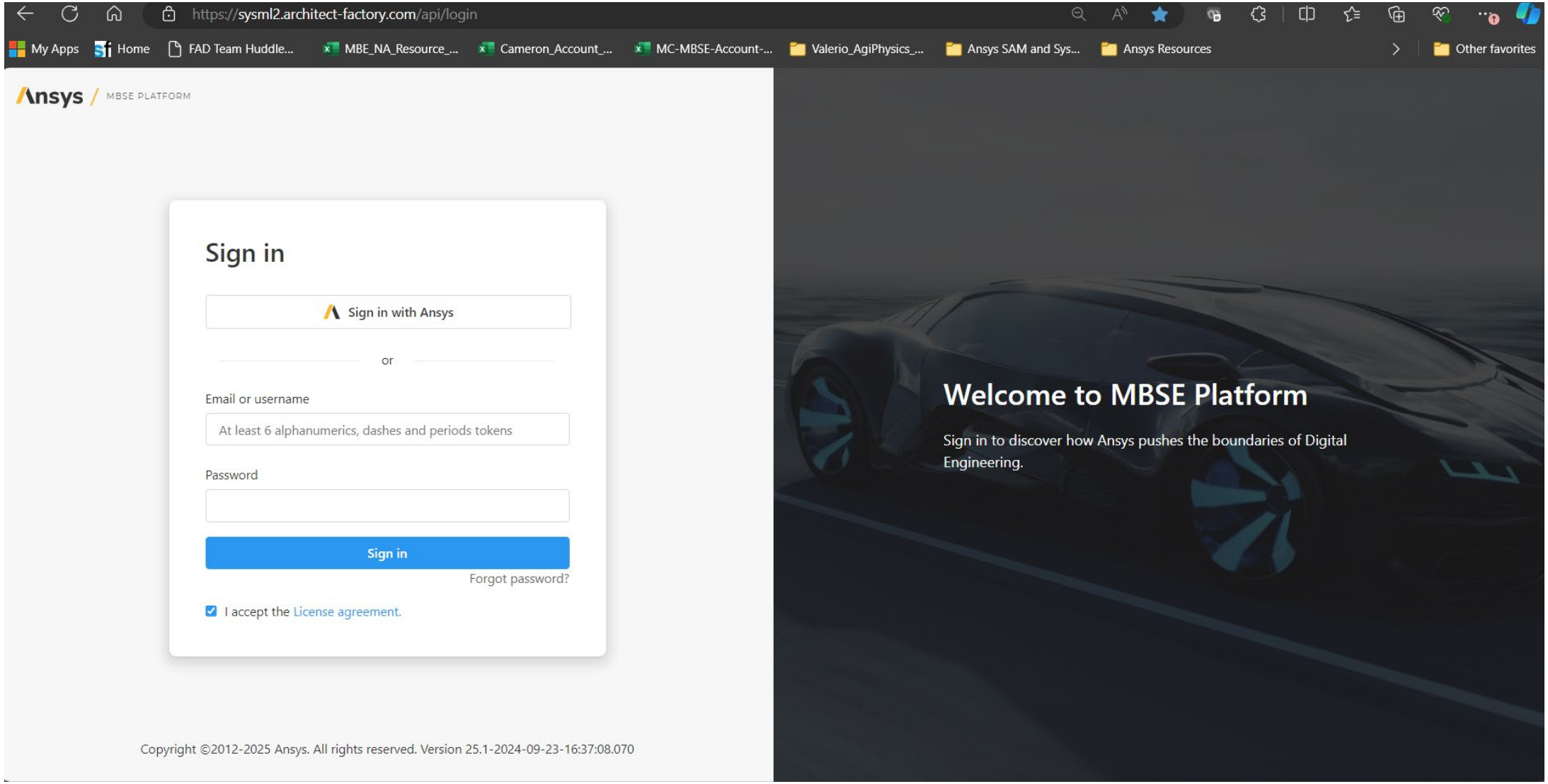
- We chose SysML v2 for our modeler because we believe that it will be significantly easier to learn, easier to use, and more powerful that SysML v1.
- Compared to SysML v1, SysML v2 was designed to be:
  - More Precise
  - More Expressive
  - More intuitive and Regular
  - More Consistent
  - Have better 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

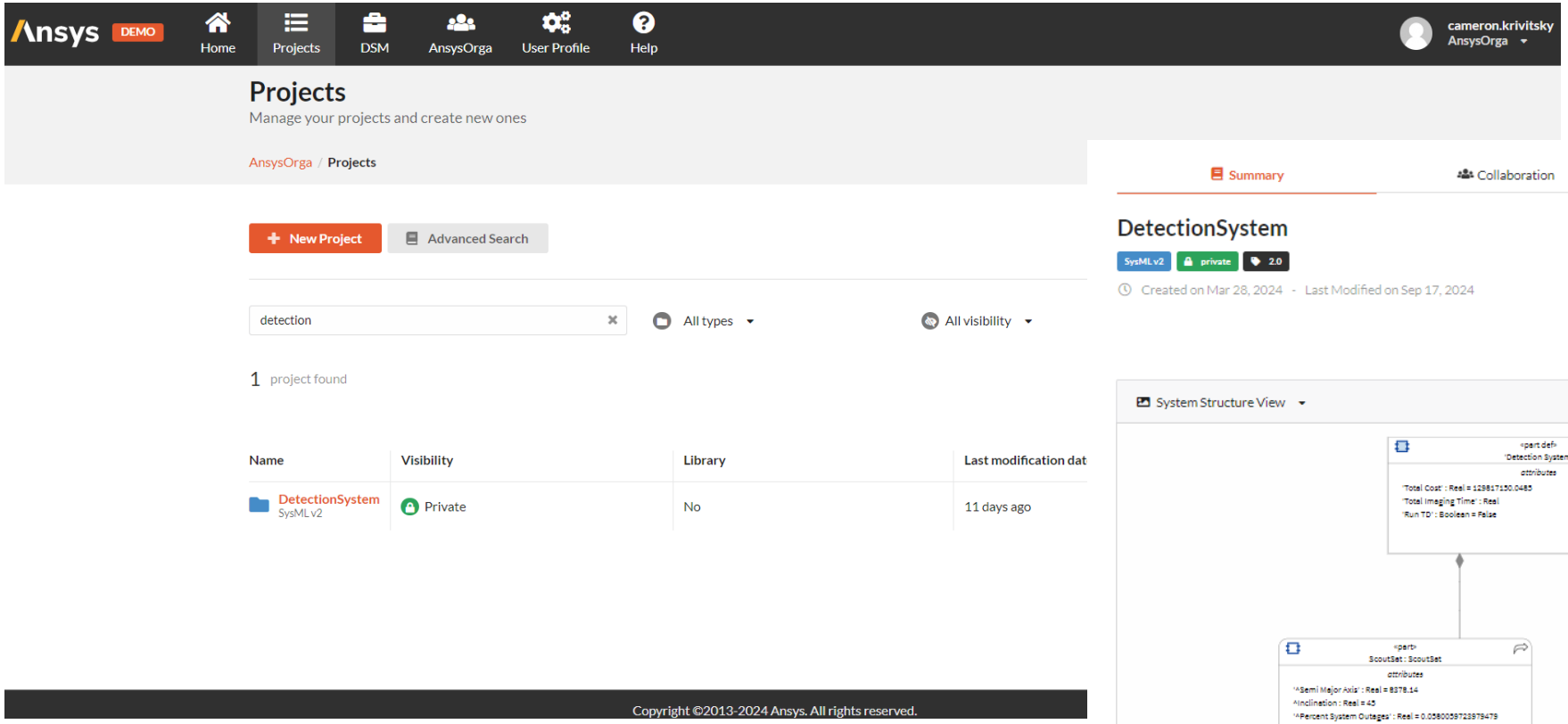
Ansys
SYSTEM ARCHITECTURE MODELER

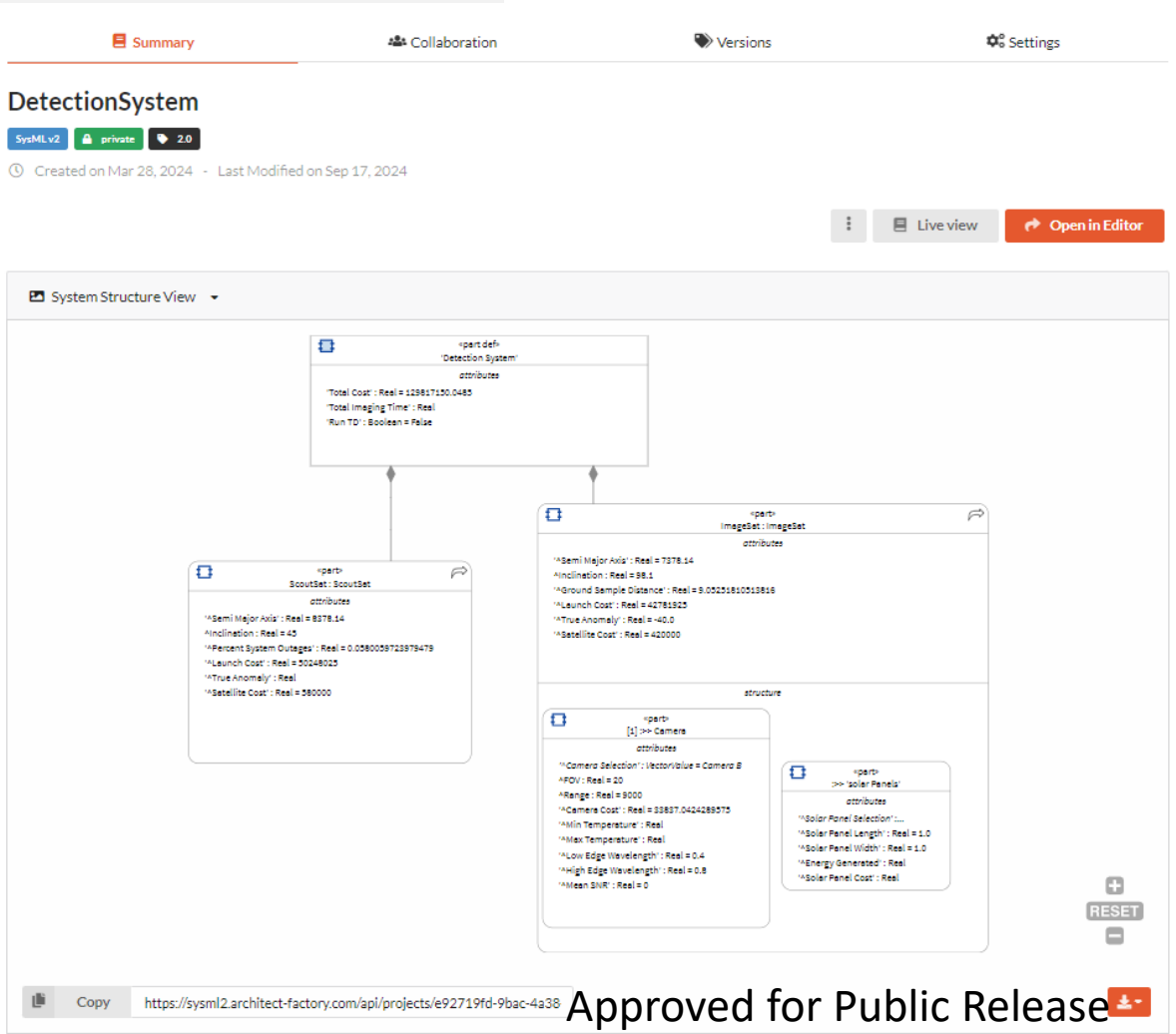
- **Cloud Native. The Ansys SAM can be installed on a public cloud (*e.g.* AWS, Azure, etc.) or installed on an on-premise server. It will be accessible to any user from a standard web browser. This means that our modeler is scalable to large numbers of users.**
- **Real-time Collaboration. A key feature 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

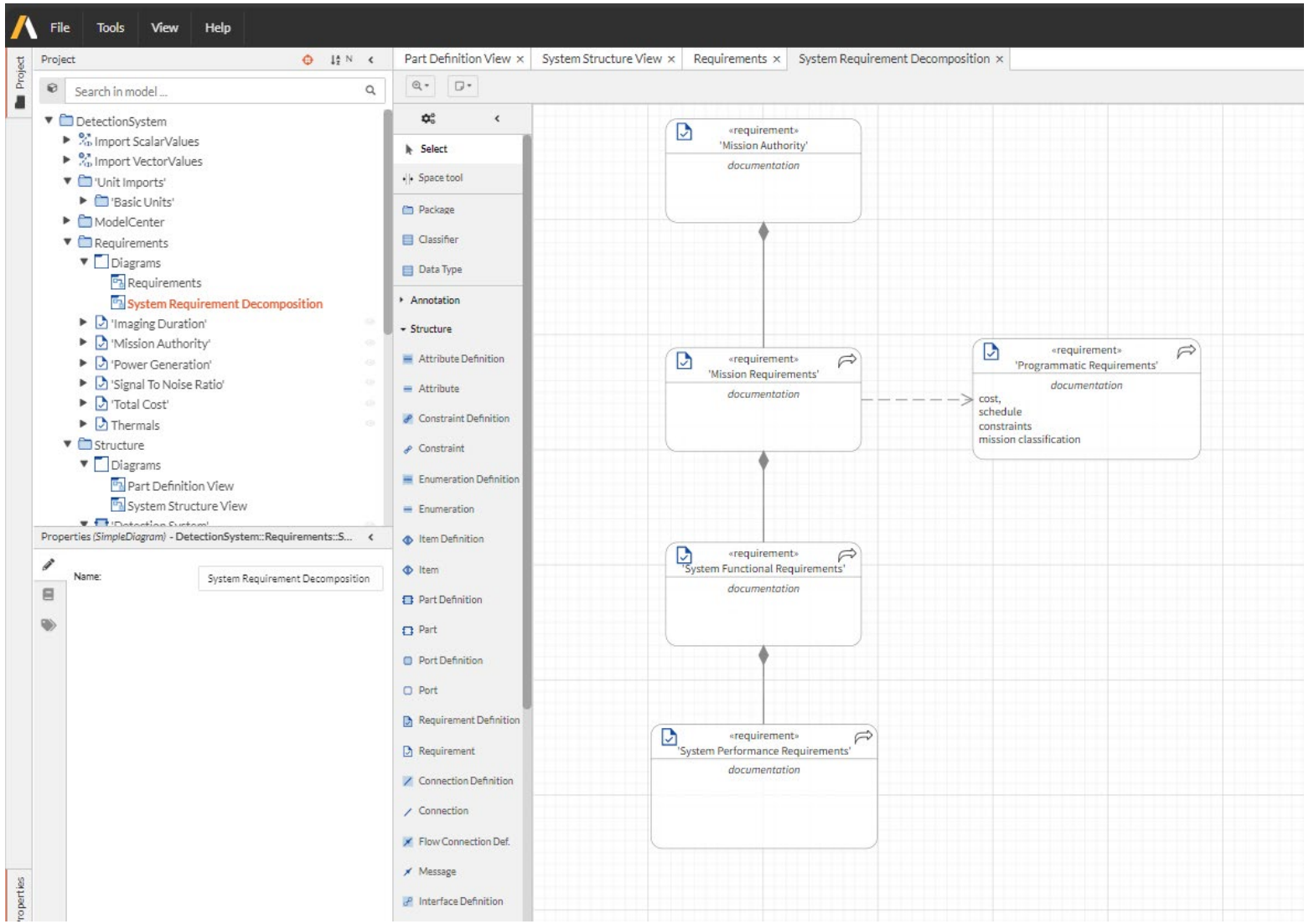


Ansys SAM Dashboard

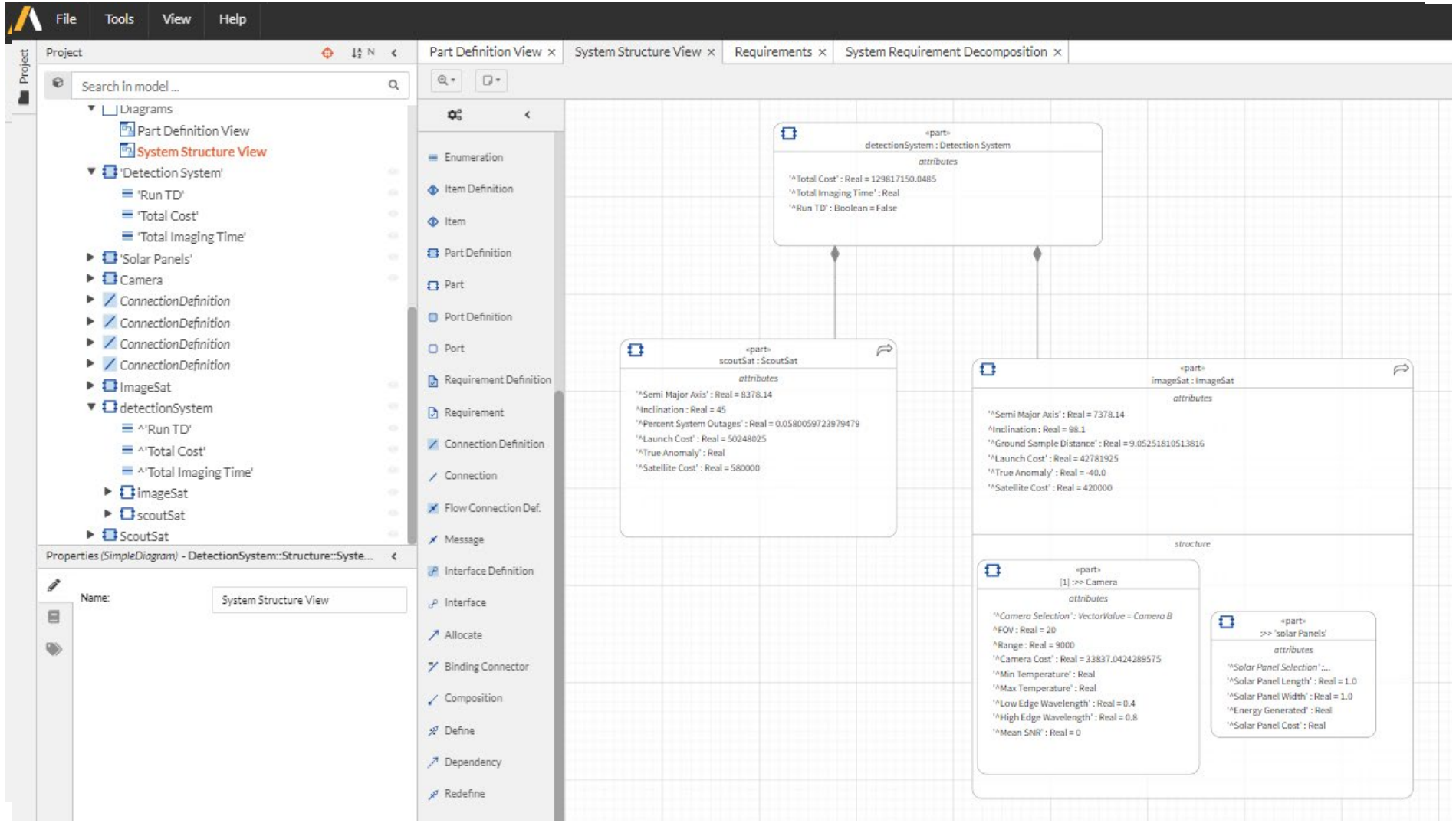




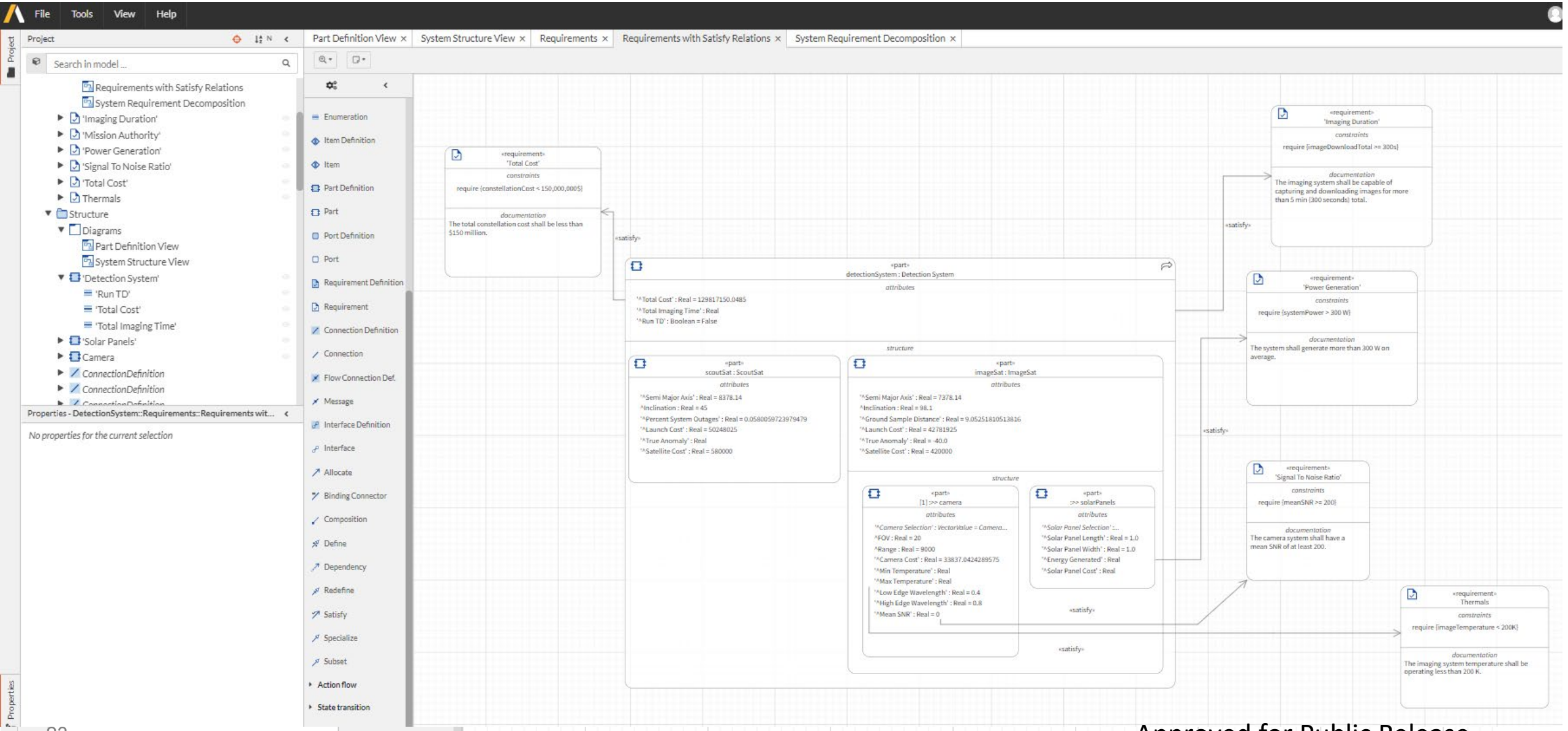
System Requirement Decomposition



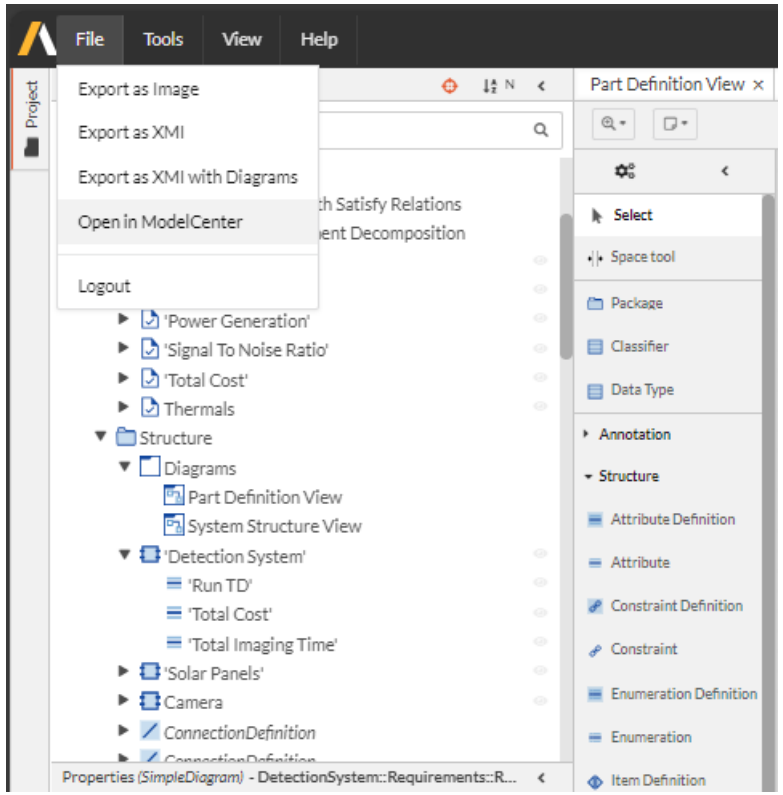
System Structure with Definition and Usages

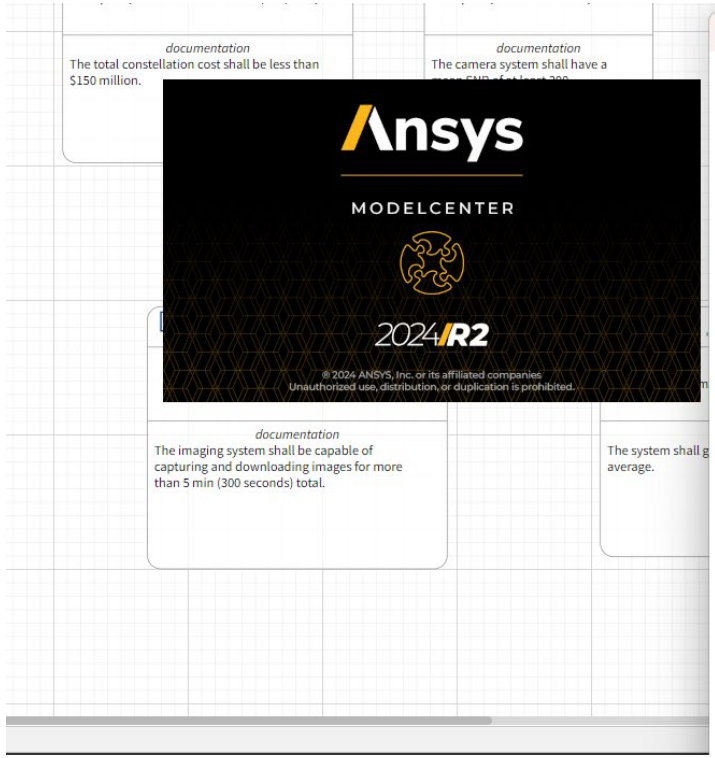


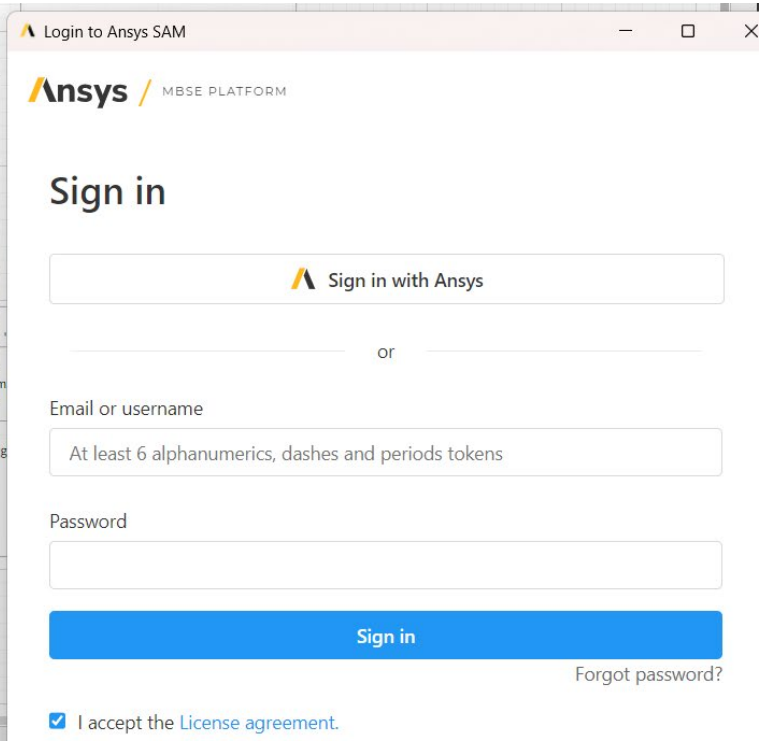
Requirements Depicted and Structure Allocated



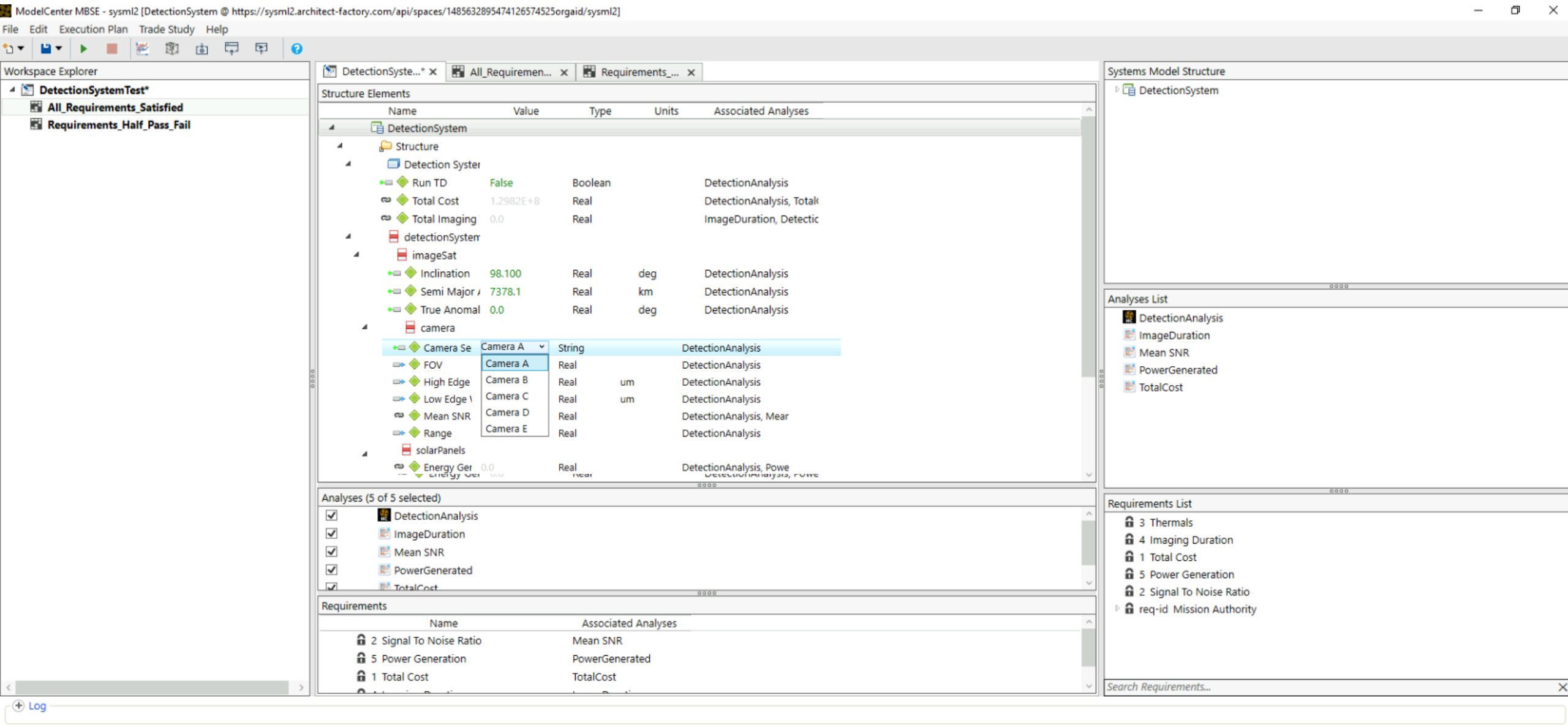
MBSE within the Ansys SAM



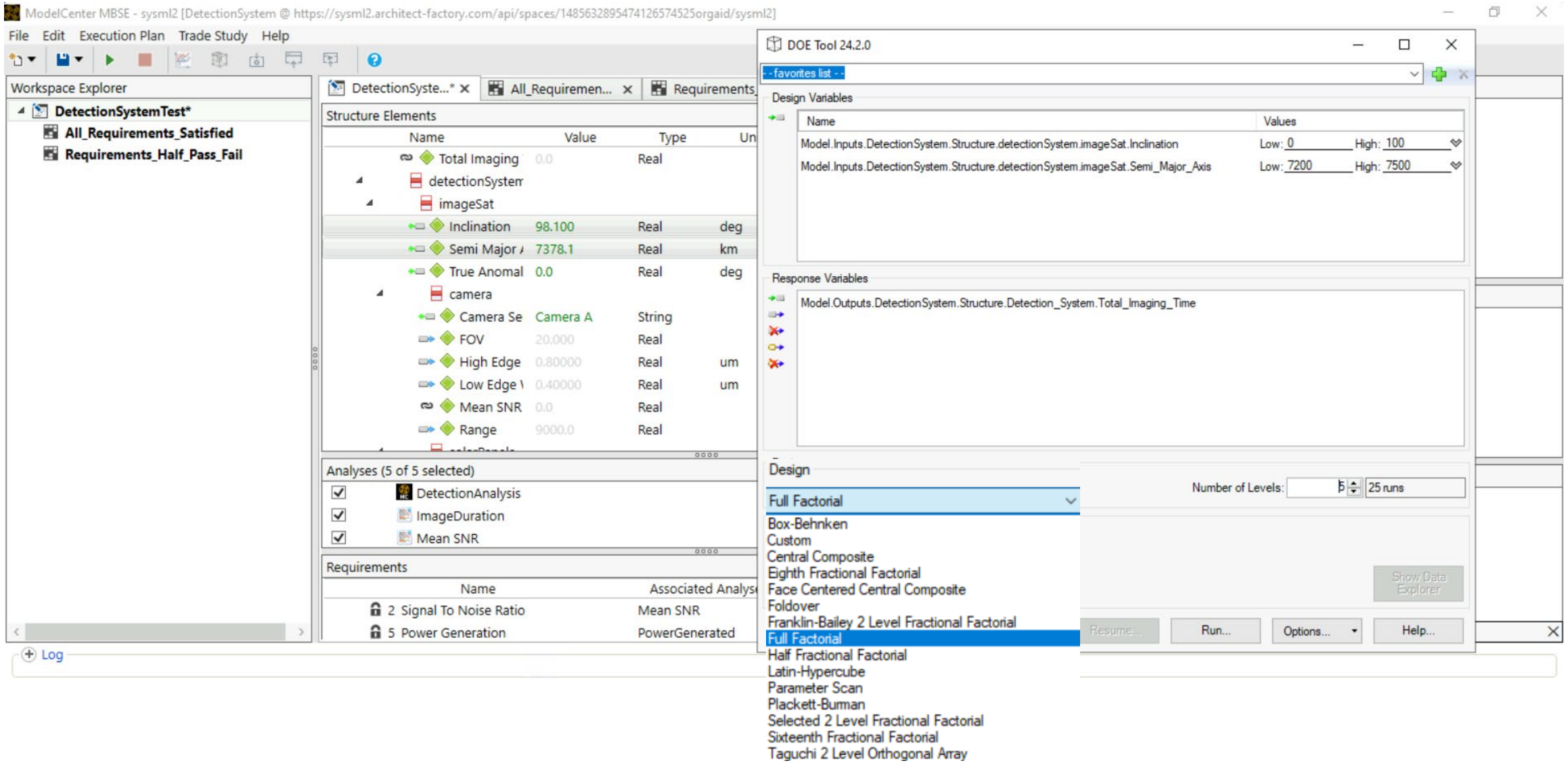




MBSE Execution Plan



Execution Plan with Design of Experiments



Data Explorer and 2D Scatter Plot

Table - 125iteration.tstudy - Data Explorer

File Chart Help

Add View Finder Plug-Ins

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.TotalTimeImaging)	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.EOIRSens2.EOIR_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

2D Scatter Plot: TotalTimeImaging vs. TotalCost - 125iteration.tstudy - Data Explorer

File Chart Help

Add View Finder Plug-Ins

Dimensions

Constraints

Objectives

Series

Layout

Axes

Legend

Dimensions

TotalTimeImaging + −

x TotalCost

y TotalTimeImaging

color Mean

opacity

size Mean

TotalTimeImaging vs. TotalCost

Mean SNR

700

600

500

400

300

200

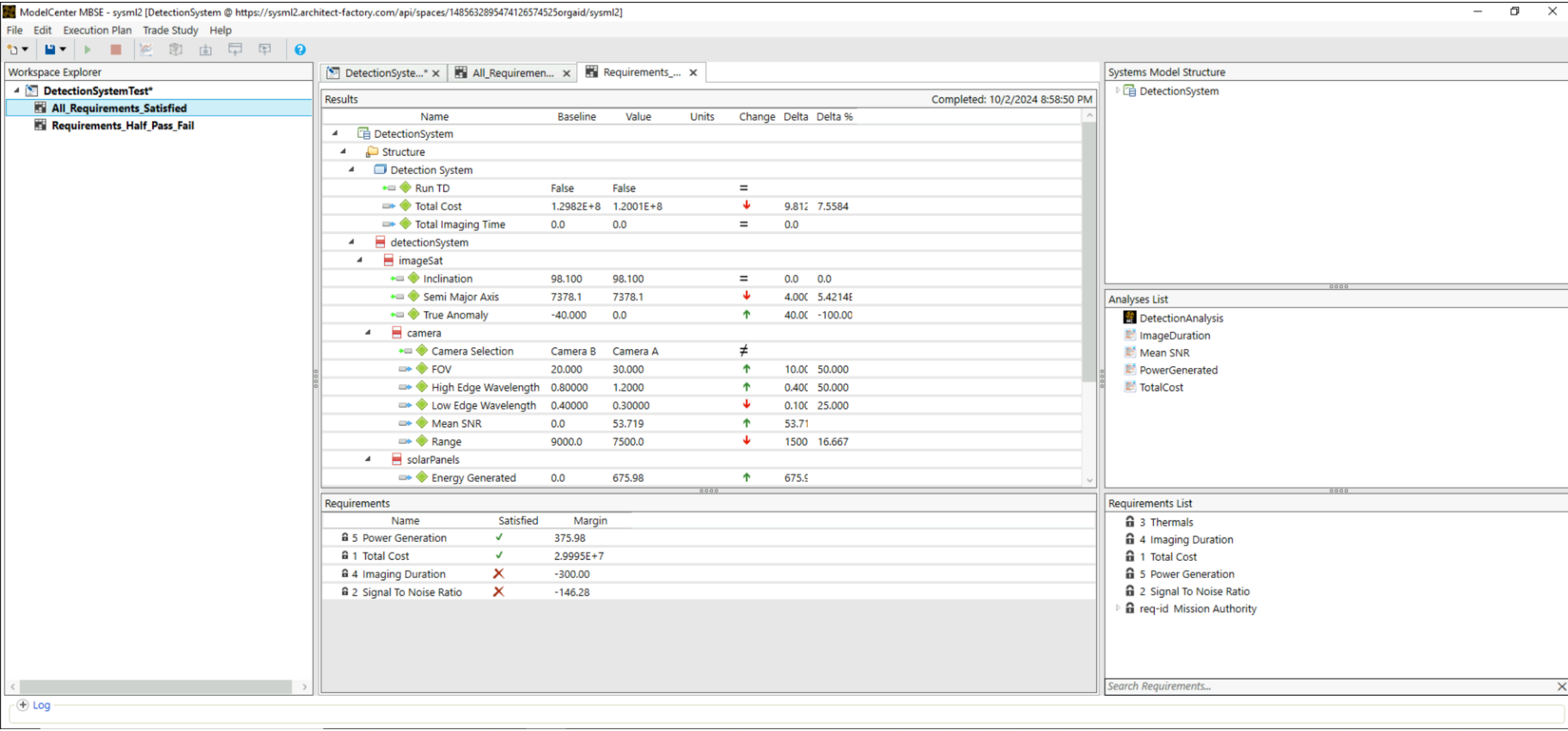
100

0

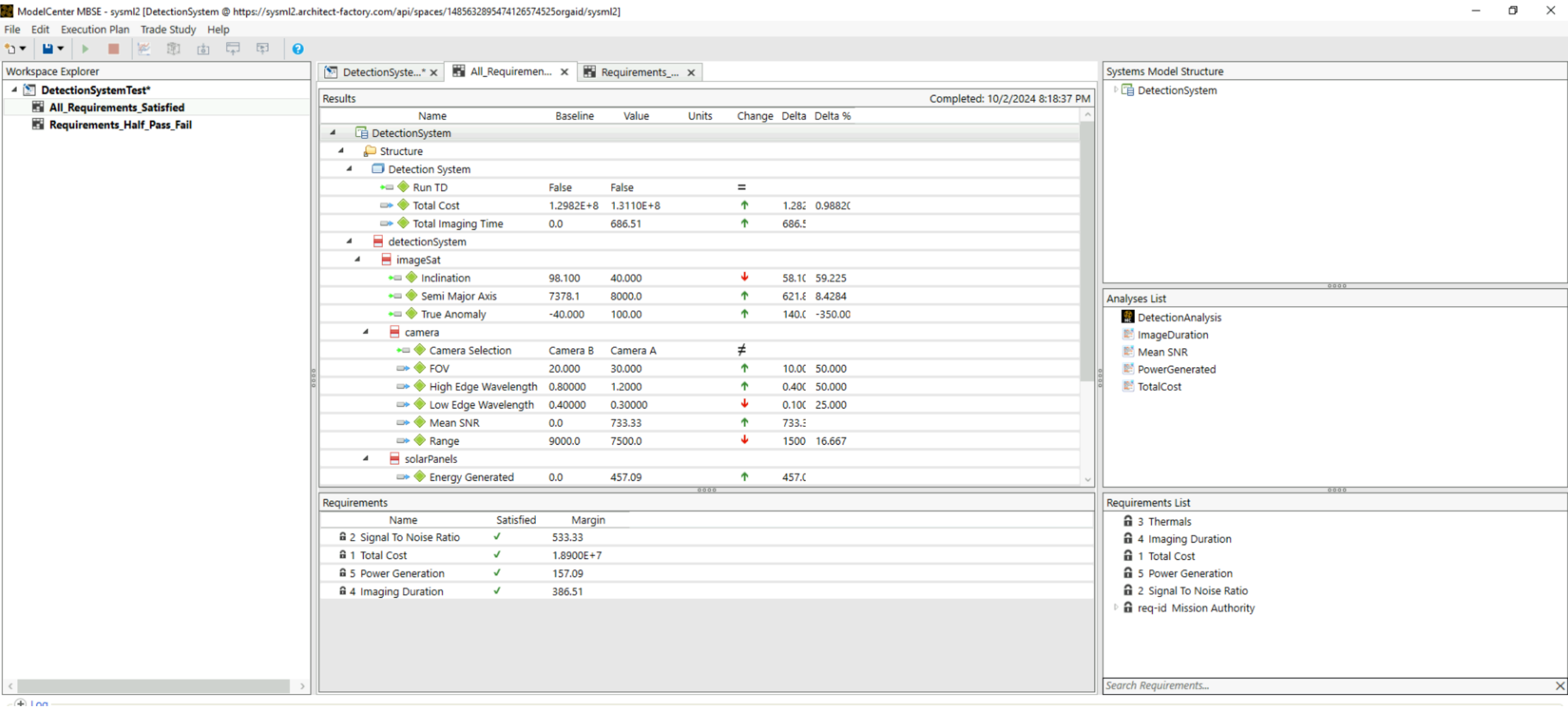
100M 120M 140M 160M 180M 200M

TotalCost

MBSE Results with Two Failed Requirements



MBSE Results with All Requirements Satisfied



Thank You!