33rd Annual INCOSE international symposium
hybrid event
Honolulu, HI, USA
July 15 - 20, 2023

Integration of Magic Cyber-Systems Engineer (Cameo Systems Modeler) with Simulink for Co-Orbital Engagement Mission Engineering

Diego Rangel - Naval Postgraduate School
Saulius Pavalkis - Dassault Systemes
Oleg Yakimenko - Naval Postgraduate School

Outline

- Objective
- Background
- COE Mission Modeling using SysML
- Inter-Platform Communication Framework
- CSM/MATLAB Integration
- GUI Implementation
- Example of COE Mission Analysis
- Conclusions

Objective

Show how to enhance mission analysis using a **system model** developed in Cameo Systems Modeler (CSM) by integrating it with an **analytical model** developed in the MATLAB/Simulink development environment.

Background

Background: Context

DoD pushes implementing a digital engineering paradigm to model and analyze systems, processes, missions

This involves:

- the effective usage of modern MBSE tools
- Integration of descriptive and analytical models to achieve higher fidelity

Background: Expected Benefits

- Reduction of misinformation
- Reduction of rework
- Reduction of the design flaws
- More realistic analysis
- Acceleration of learning curves
- Facilitation of trade-offs
- Quicker and cheaper way to evaluate design variations
- **Bridge design silos**

Background: Defense Systems

Why is this important for developing defense systems?

- Accommodation of the rapid changes in its intended deployment and operational usage;
- Expansion to the new warfare domains (e.g. Space Warfare);
- Necessity to capture interaction between tactics and requirements.

Co-Orbital Engagement (COE) Mission Modeling using SysML

COE Mission Modeling using SysML

Methodology

- Vignettes
- MOEs
- MOPs

Data generation

Capability Gap Definition

- Mission Engineering Thread
- Operational Requirements
- Define Architectures
- Define Mission Analysis Parameters and Scenarios

COE Mission Modeling using SysML

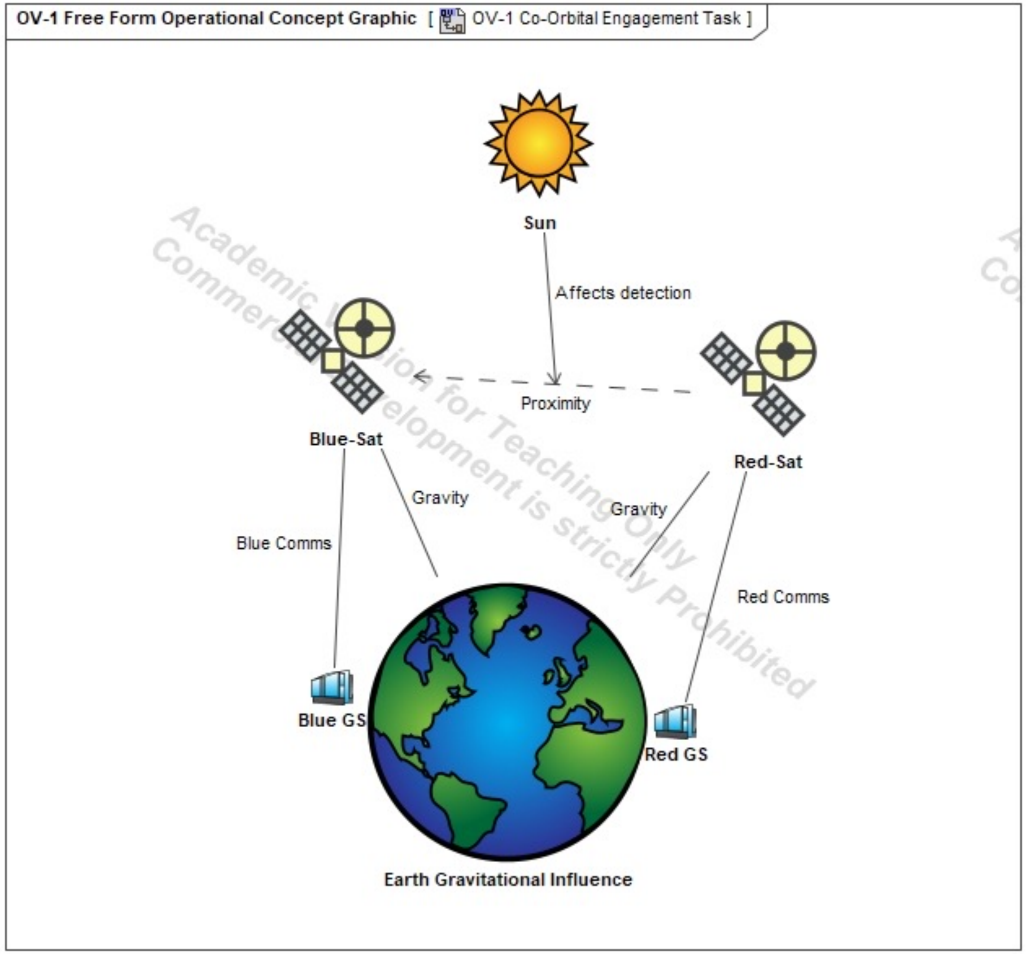
Mission Vignette

Assessment of current and potential ASAT capabilities

	China	Russia	U.S.	France	India	Iran	Japan	North Korea
LEO Co-Orbital	Y	G	Y	R	R	R	R	R
MEO/GEO Co-Orbital	Y	Y	Y	R	R	R	R	R
LEO Direct Ascent	G	Y	Y	R	Y	R	R	R
MEO/GEO Direct Ascent	Y	Y	Y	R	R	R	R	R
Directed Energy	Y	Y	Y	Y	R	R	R	R
Electronic Warfare	G	G	G	Y	Y	Y	R	Y
Space Situational Awareness	G	G	G	Y	Y	Y	Y	R

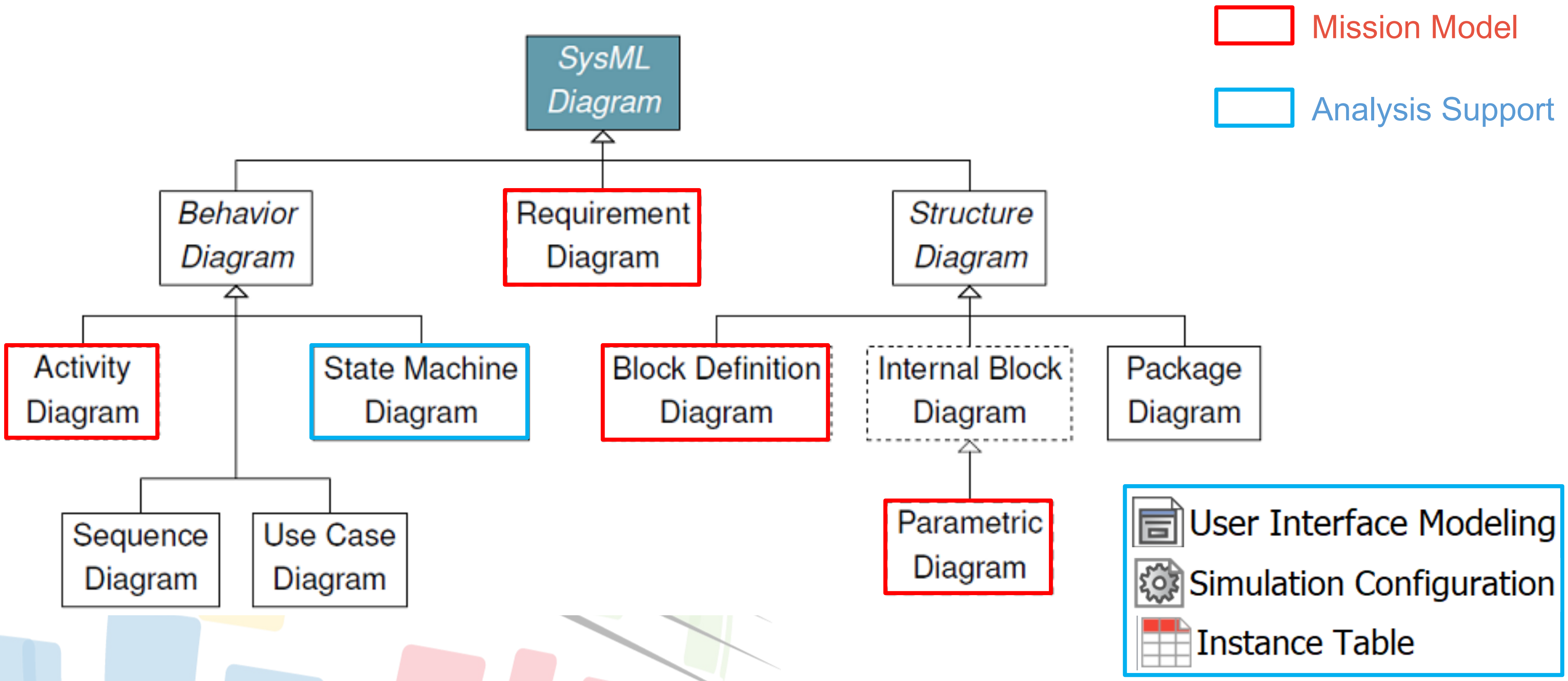
Legend: none R some Y significant G

Source: Secure World Foundation (2021)



COE Mission Modeling using SysML

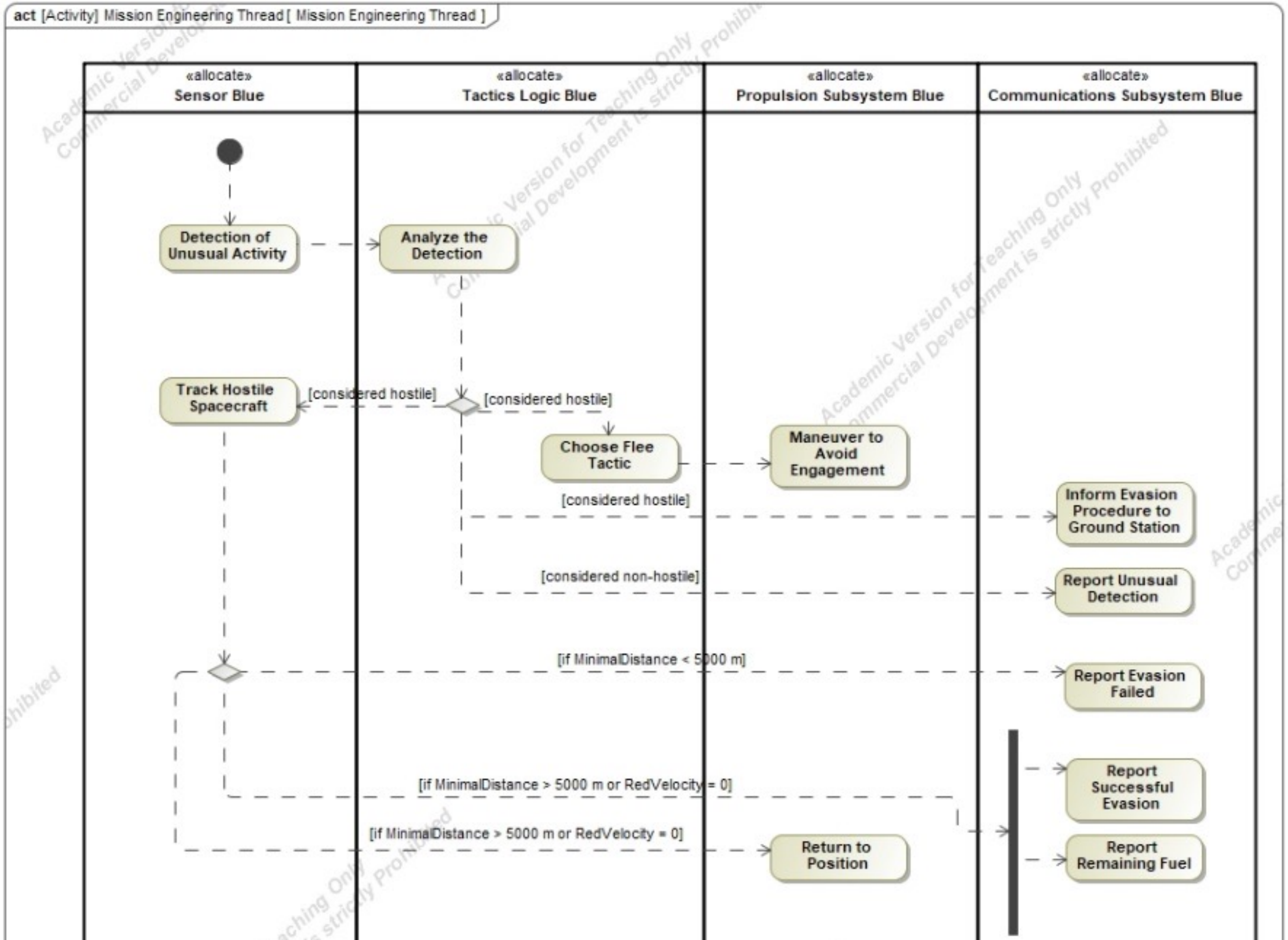
Diagrams Used for Mission Modeling



COE Mission Modeling using SysML

Mission Engineering Thread

- Chain of events
- Task segmentation
- Task allocation
- SysML activity diagram

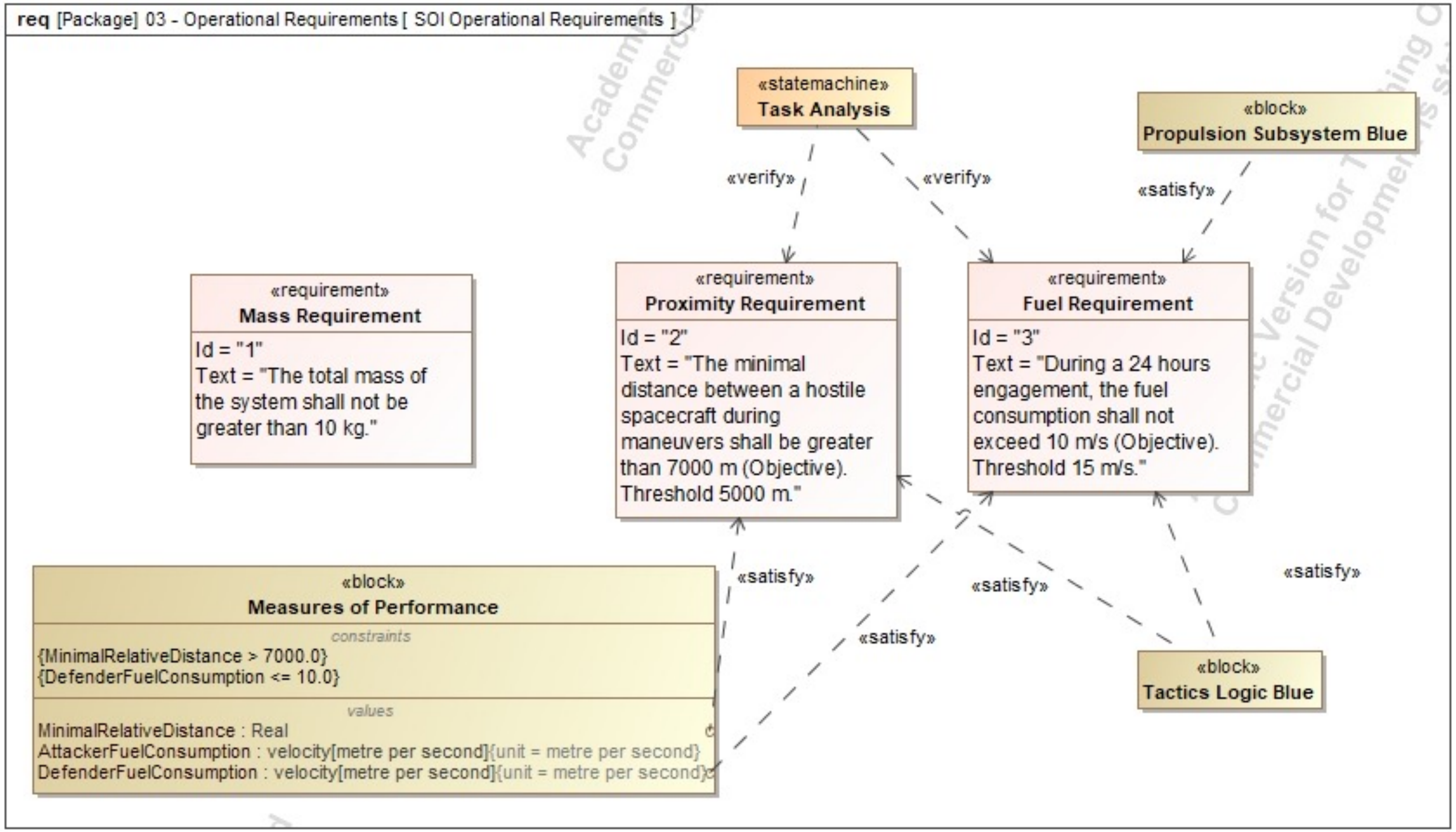


15-20 July - 2023

COE Mission Modeling using SysML

Operational Requirements

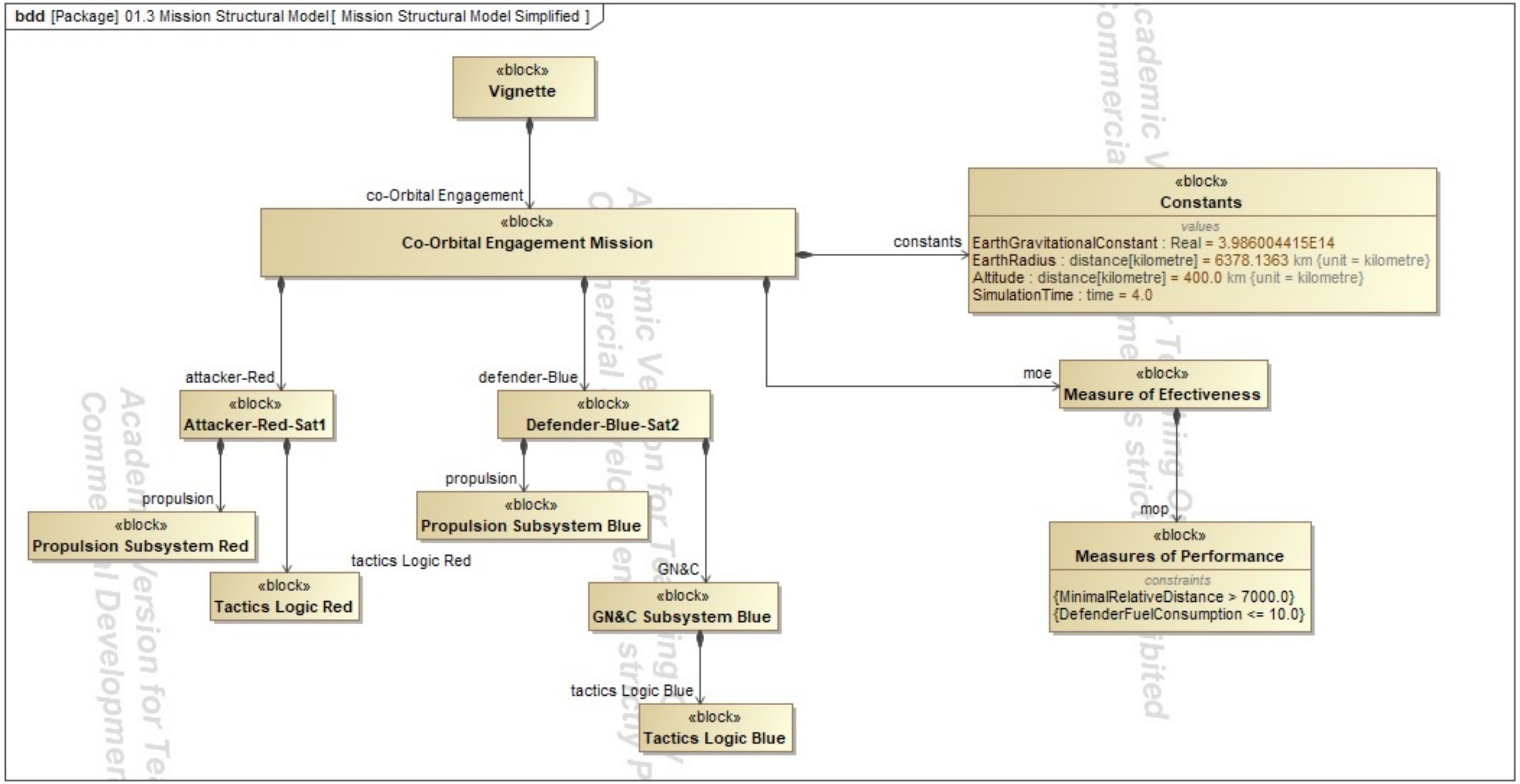
- Proximity Requirement
- Fuel Requirement



COE Mission Modeling using SysML

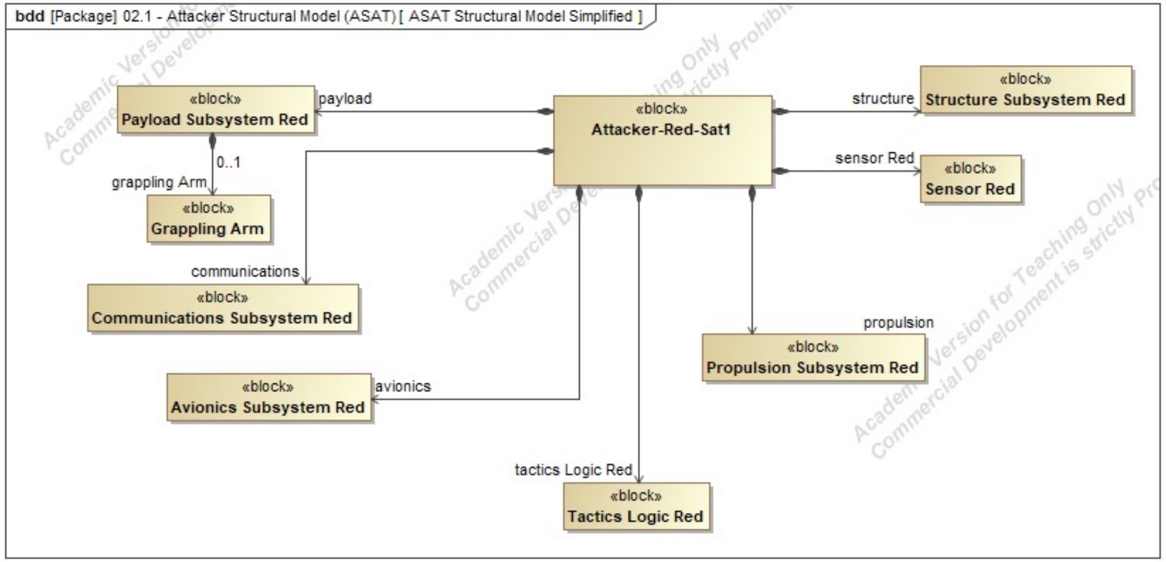
Mission Structural Model

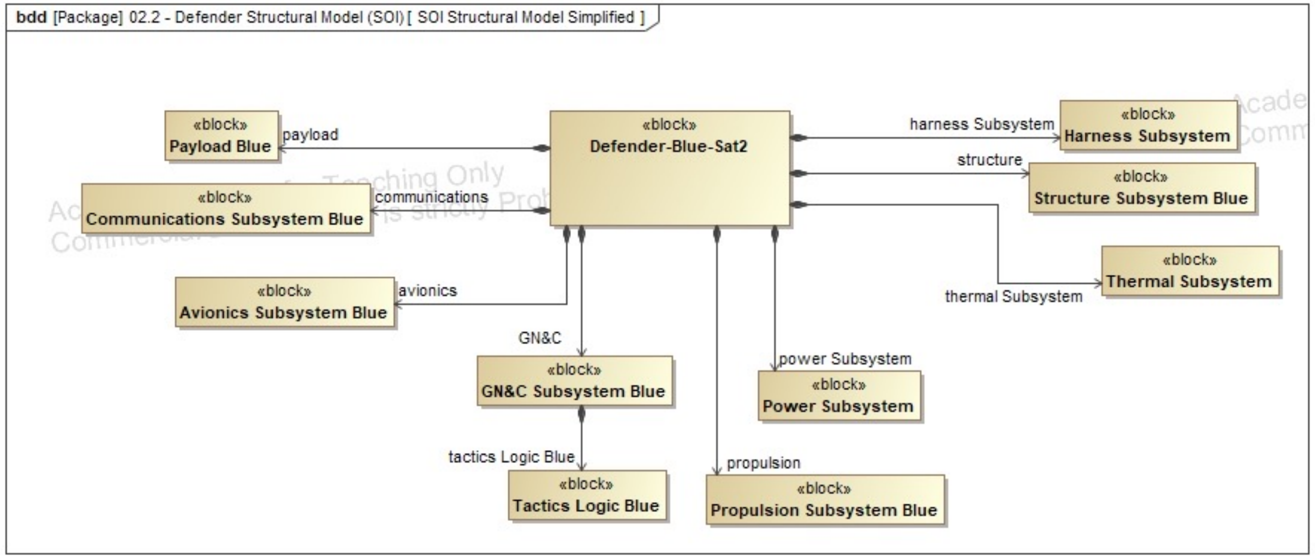
- Shows every system, entity, and metric that compose the mission;
- **Embeds the analytical model**.



COE Mission Modeling using SysML

Subsystem-Level Structural Model

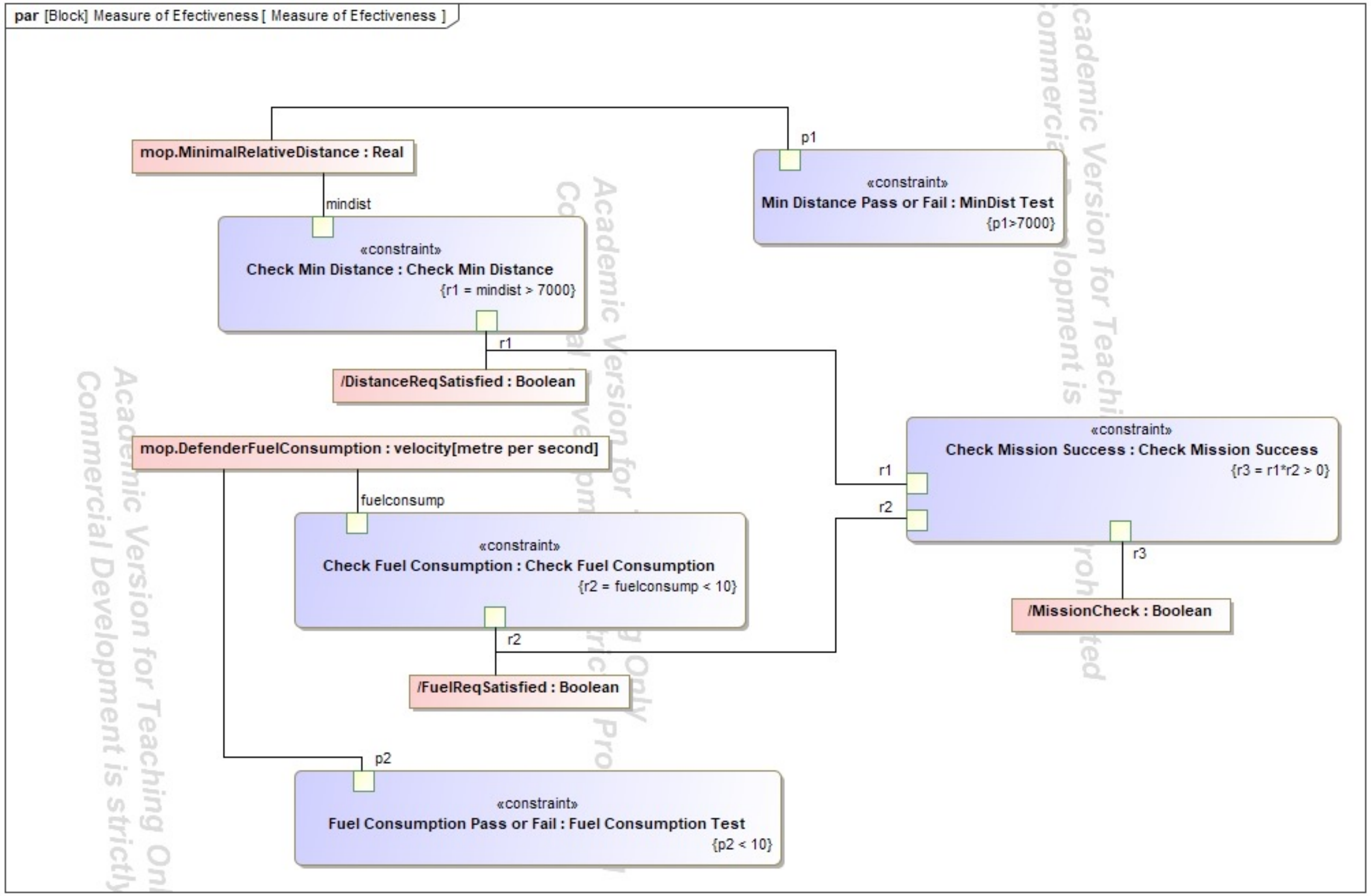




COE Mission Modeling using SysML

Parametric Diagram

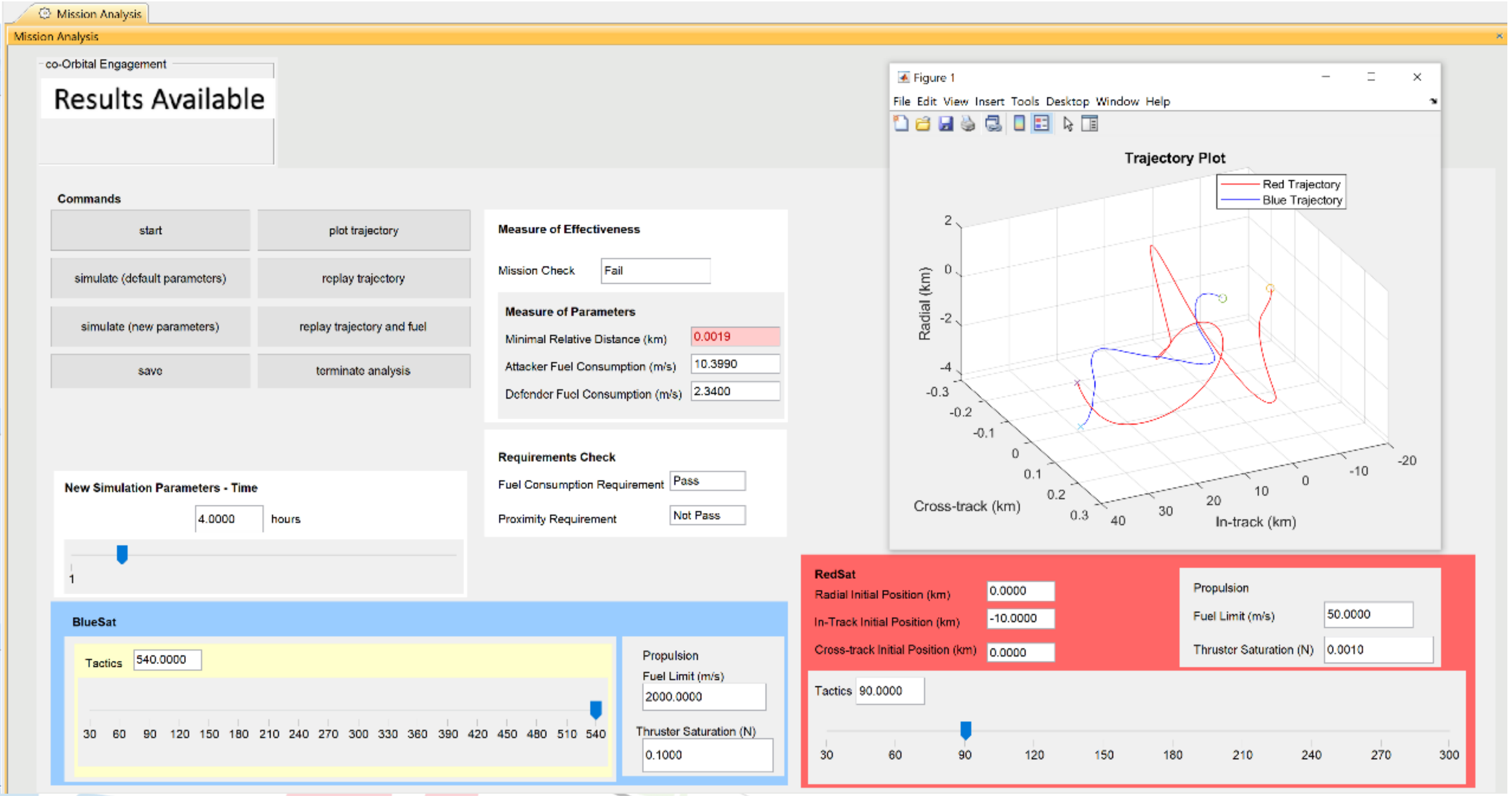
- Compares the requirements with results from the physics-based model and
- Classifies mission success or failure



Inter-Platform Communication Framework

Inter-Platform Communication Framework

Graphical User Interface

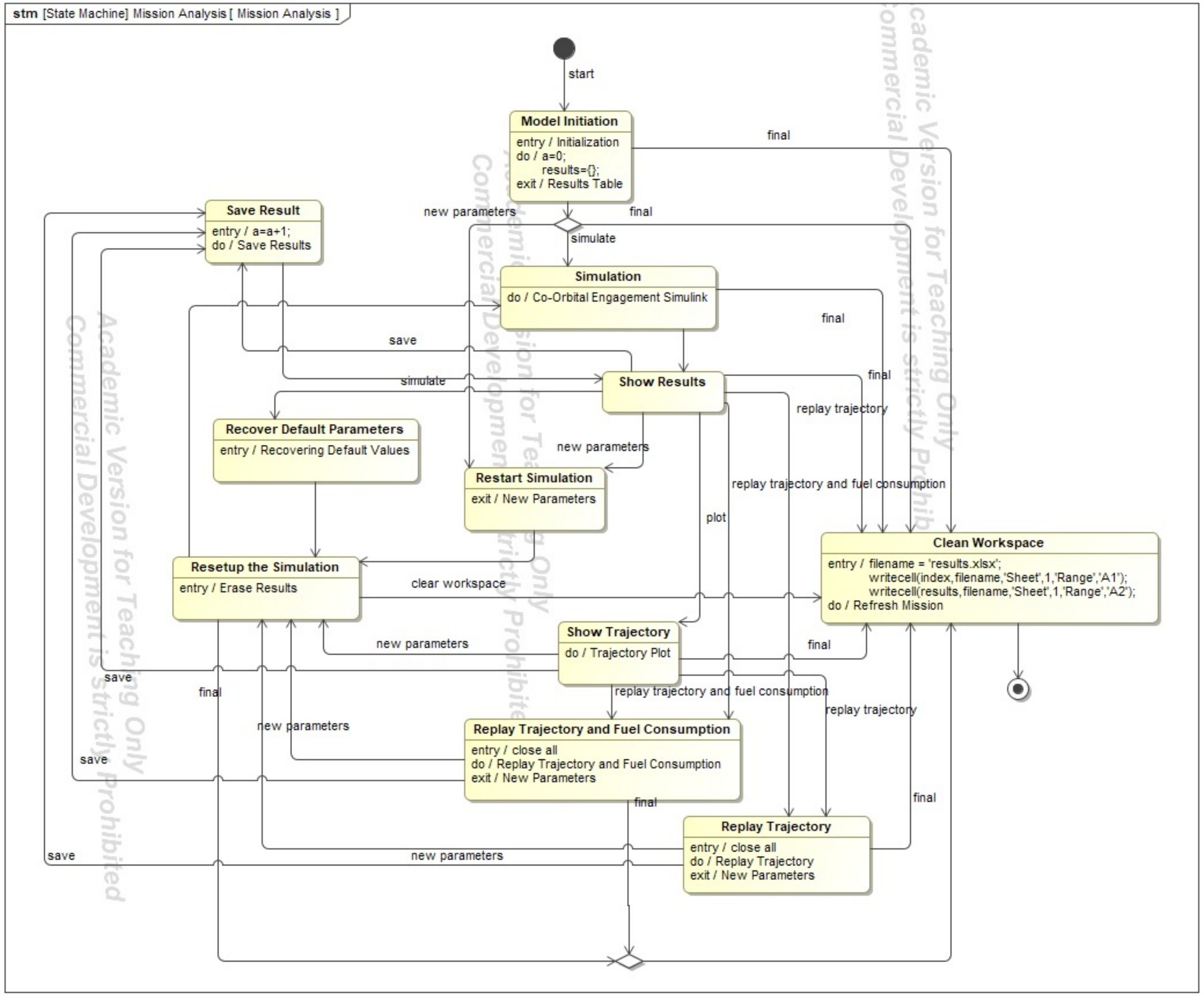


Inter-Platform Communication Framework

State Machine Diagram

Underlies the GUI Analysis to

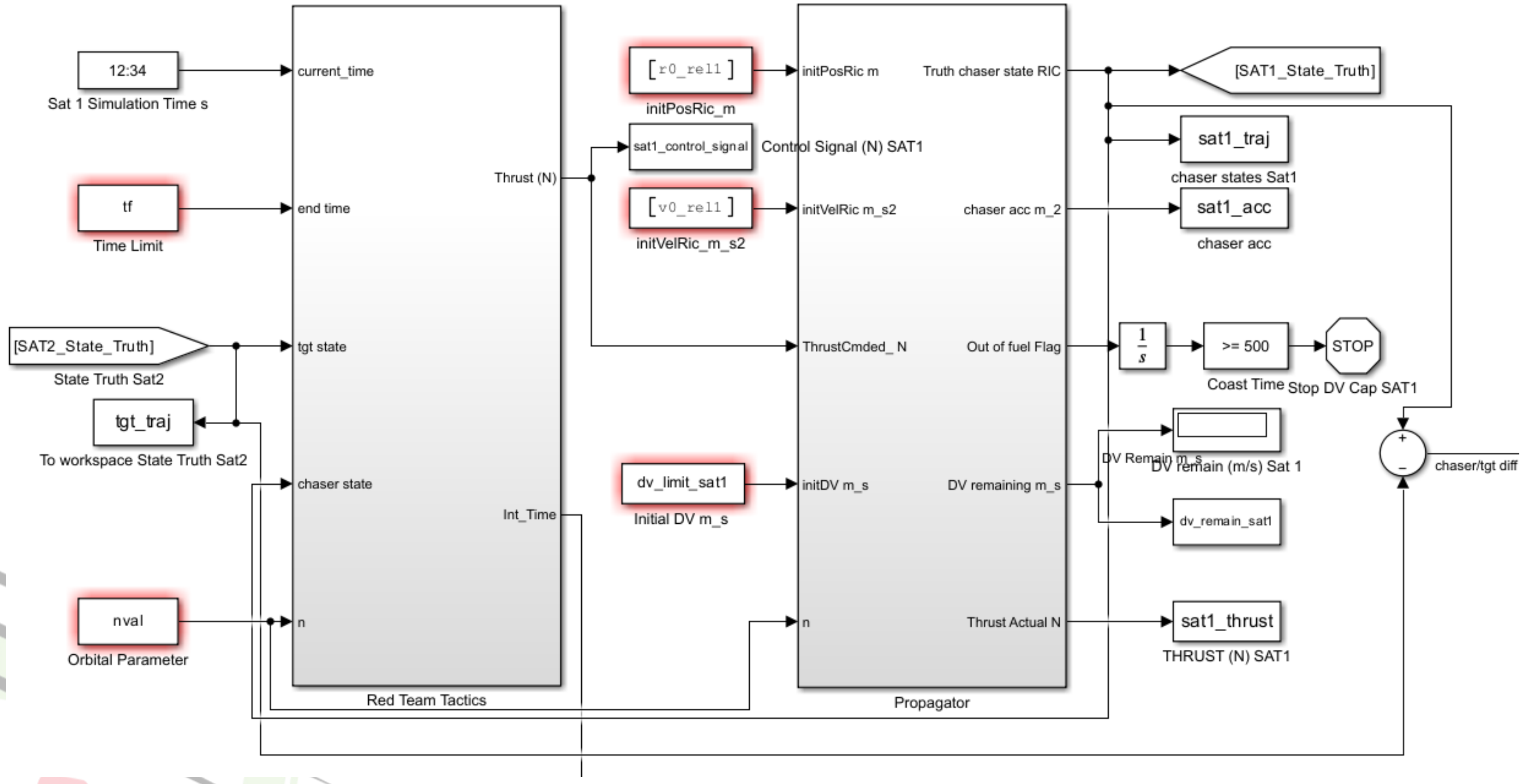
- command transition
- allow different simulations
- take advantage of MATLAB graphical features



Inter-Platform Communication Framework

Analytical COE Model

- Physics-based representation of system's behavior
- Totally developed in Simulink environment
- Legacy model

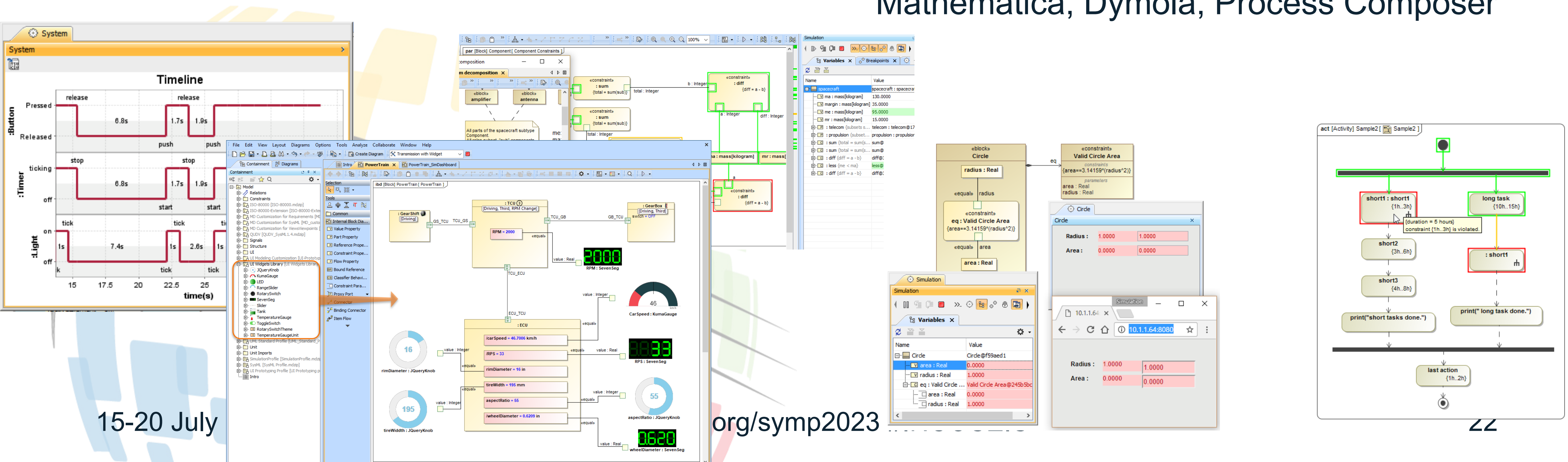


CSM/MATLAB Integration

Model Execution With MAGIC MODEL ANALYST / CAMEO SIM TOOLKIT

- Standards based model execution and analysis
- Model and system logic debugging
- Trade Studies
- Monte Carlo Simulation
- Integrations:

  MATLAB, Simulink, Maple, FMU 2.0, Mathematica, Dymola, Process Composer



CSM/MATLAB Integration

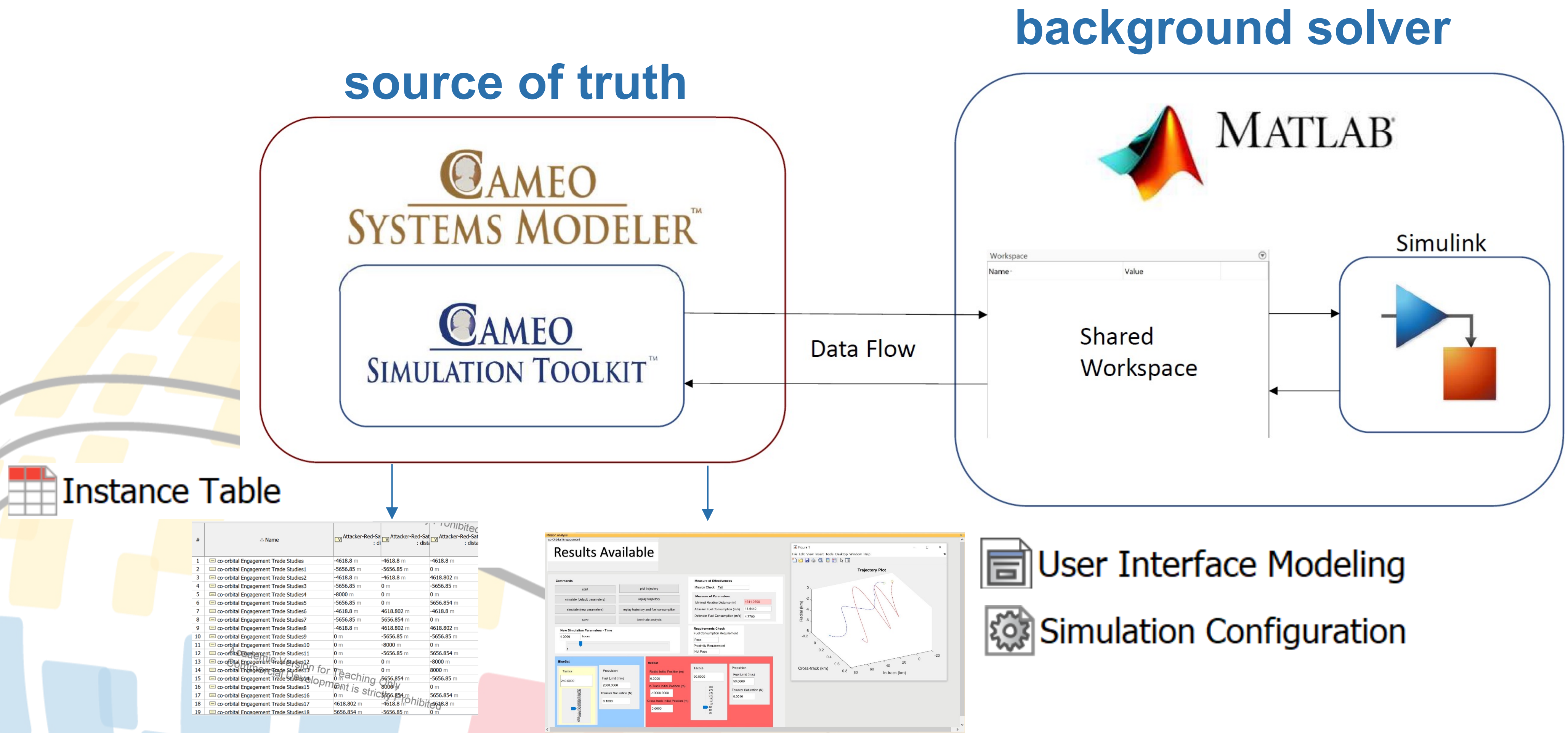
Establishing Shared Workspace

CSM/MATLAB Integration Roadmap

- Installation of the plug-in CST
- “kill matlab” command in CSM
- “matlab.engine.shareEngine” command in MATLAB
- MATLAB/Simulink models and functions stored in the right place

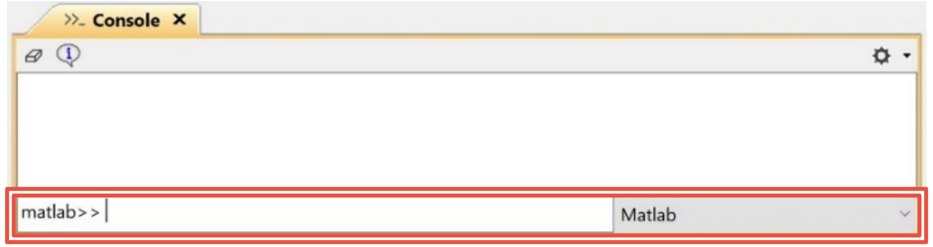
CSM/MATLAB Integration

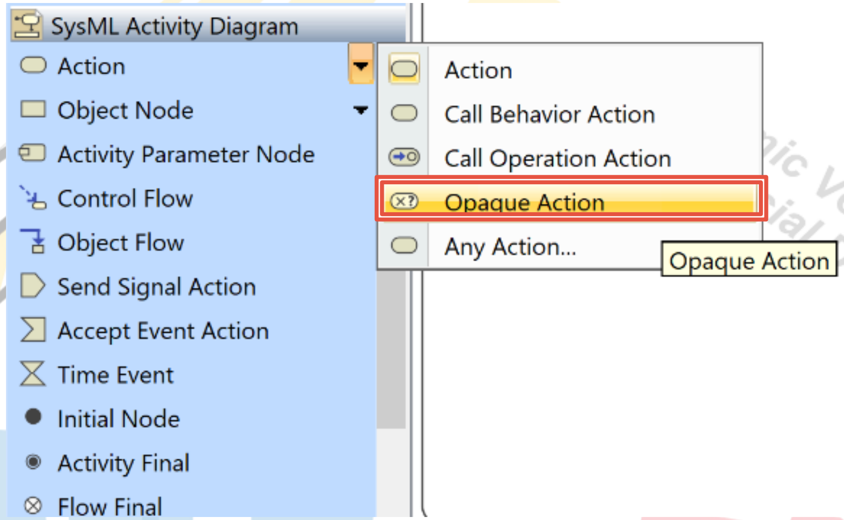
Data Flow Overview

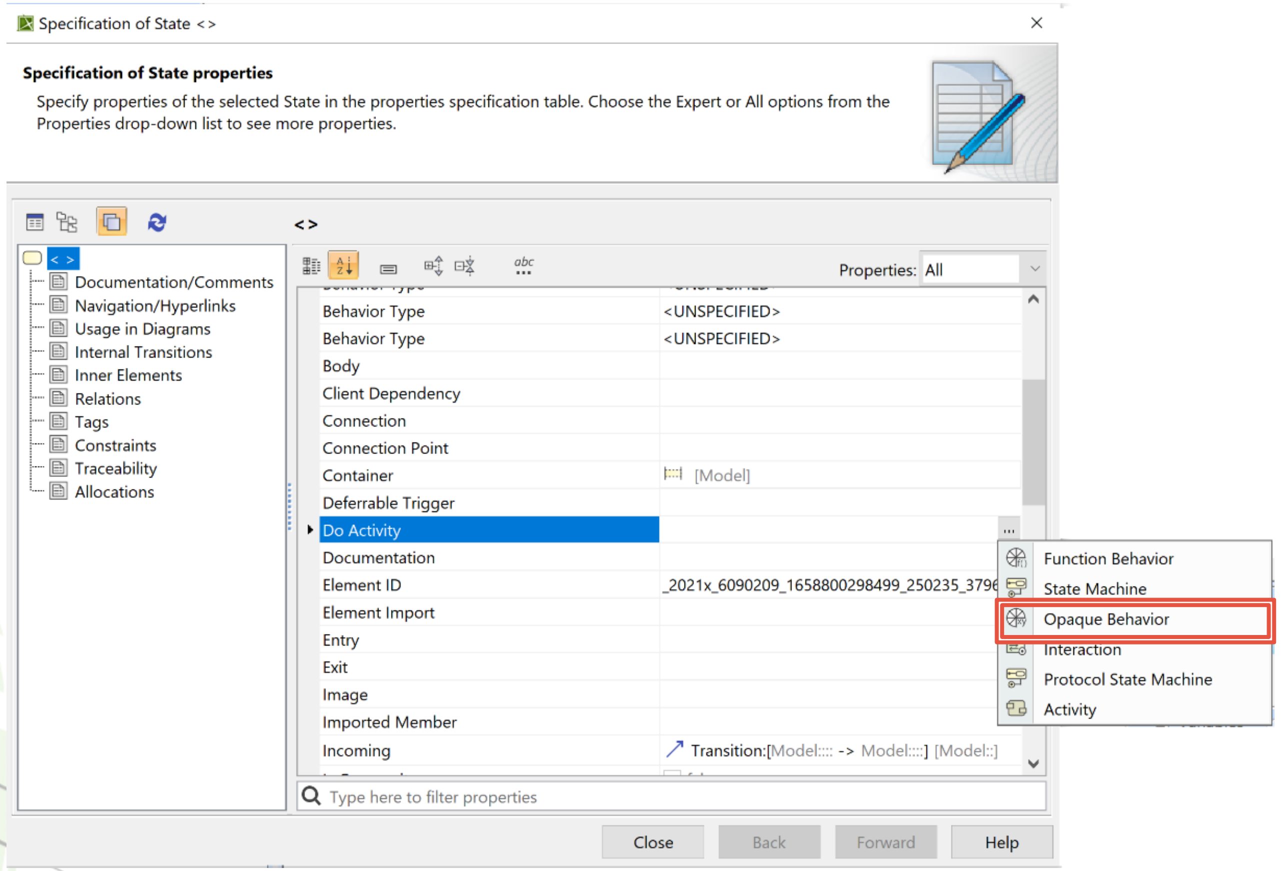


CSM/MATLAB Integration

Inter-Platform Data Sharing

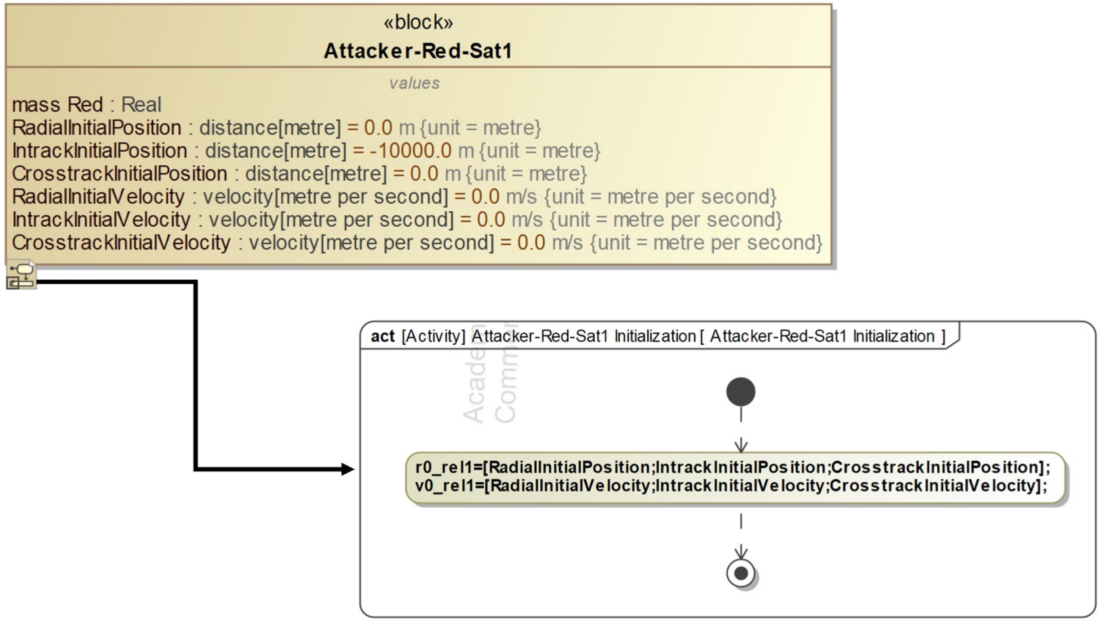


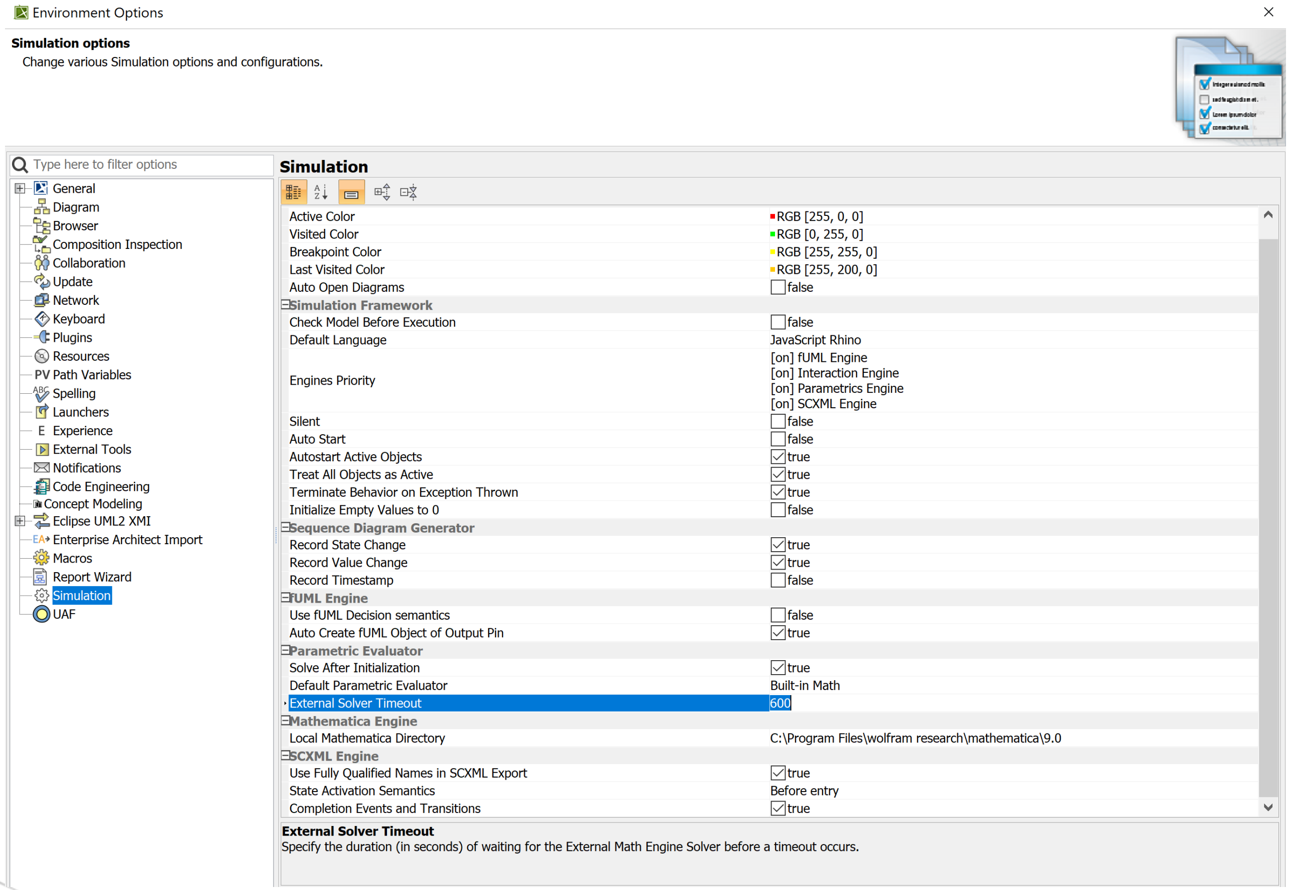




CSM/MATLAB Integration

Interoperability Challenges

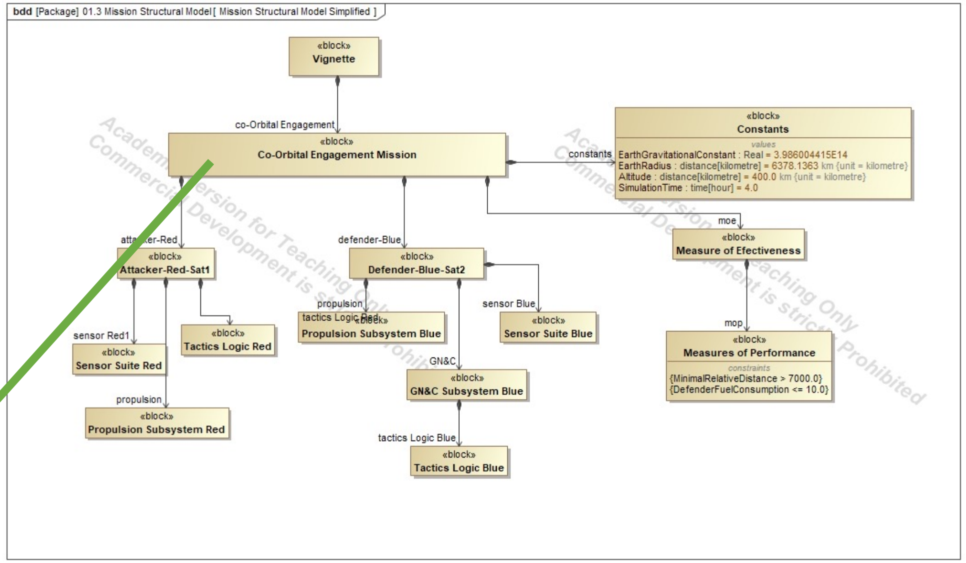


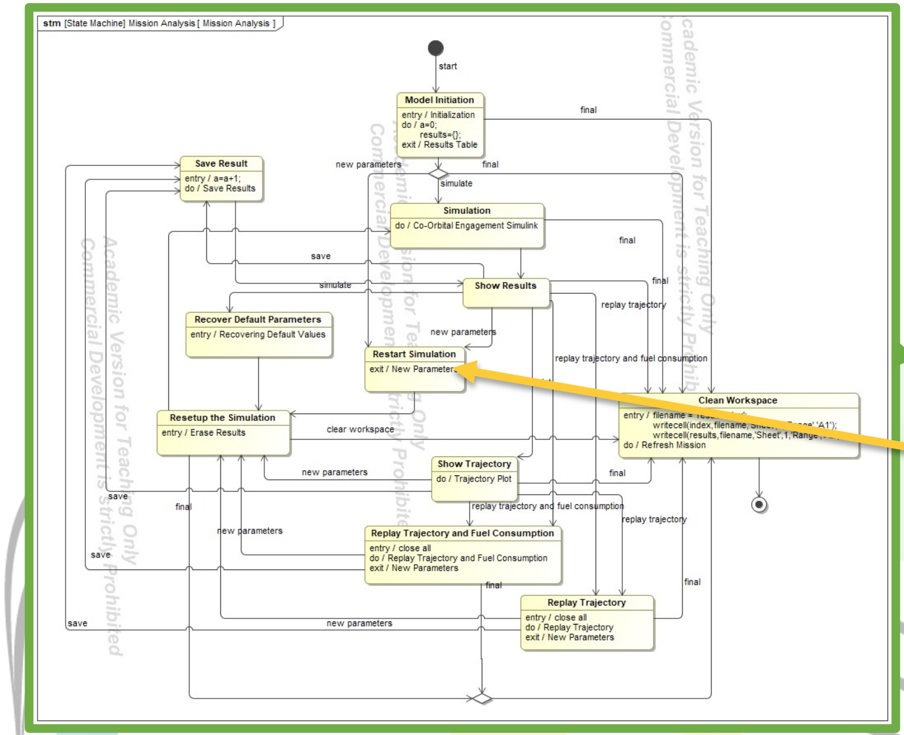


GUI Implementation

GUI Implementation

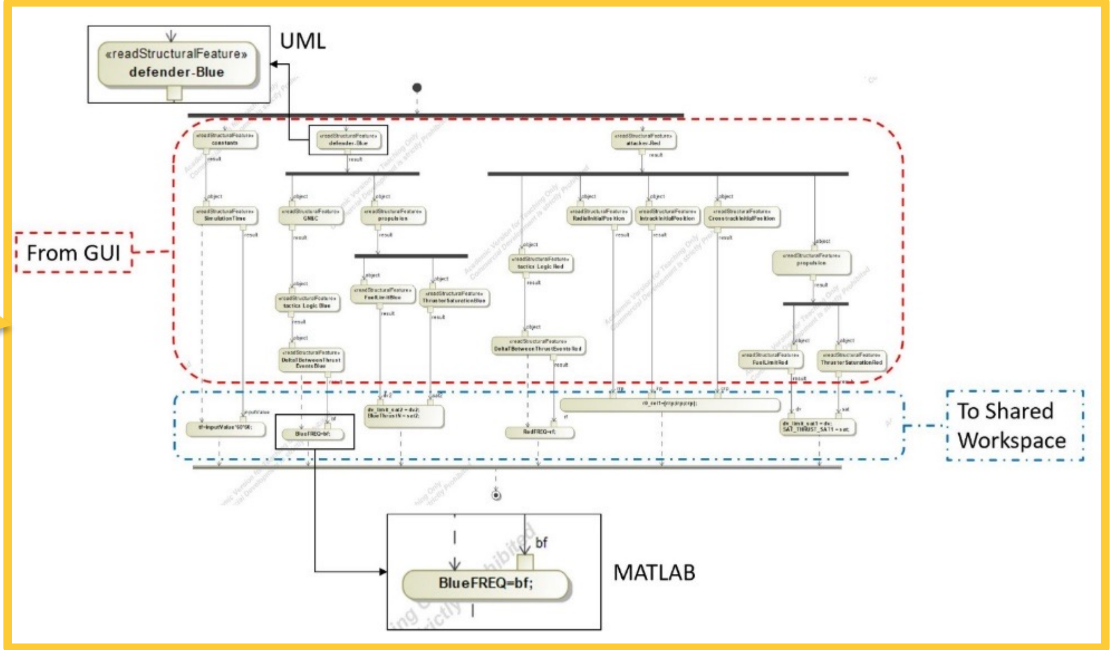
Dynamic Data Visualization





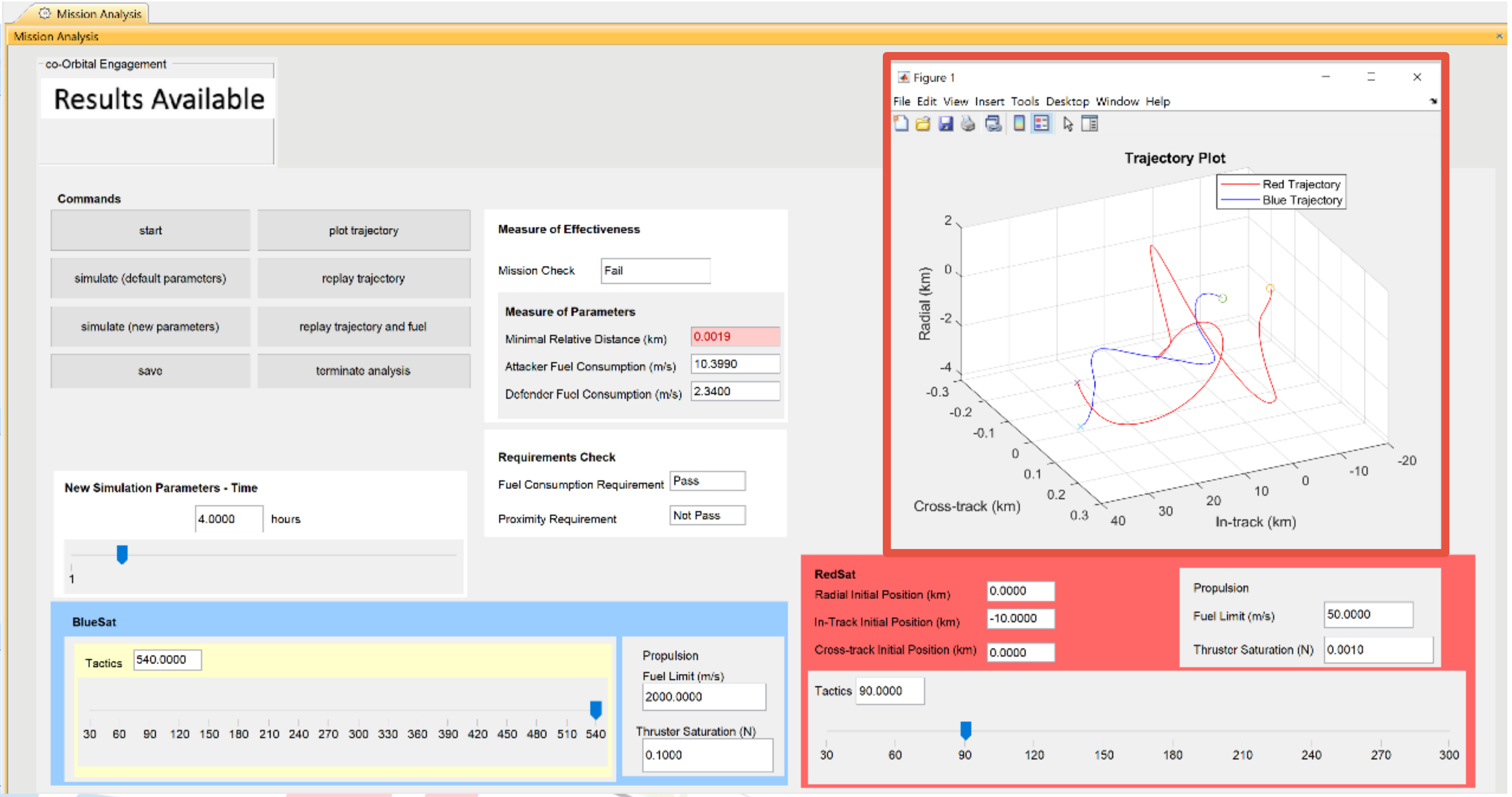
Classifier Behavior

GUI updates



GUI Implementation

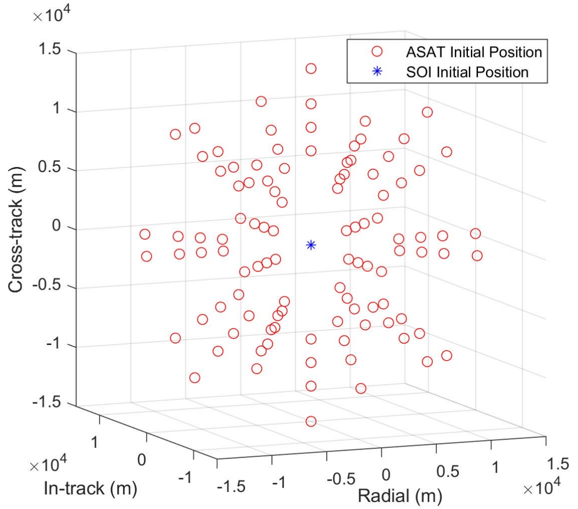
Remaining Challenges



Example of COE Mission Analysis

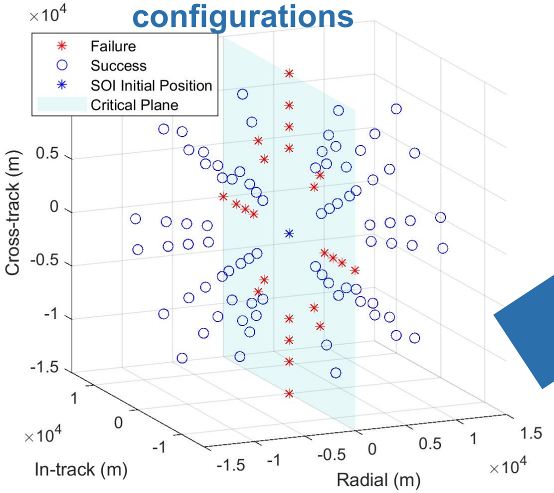
Example of COE Mission Analysis

Design Space Exploration

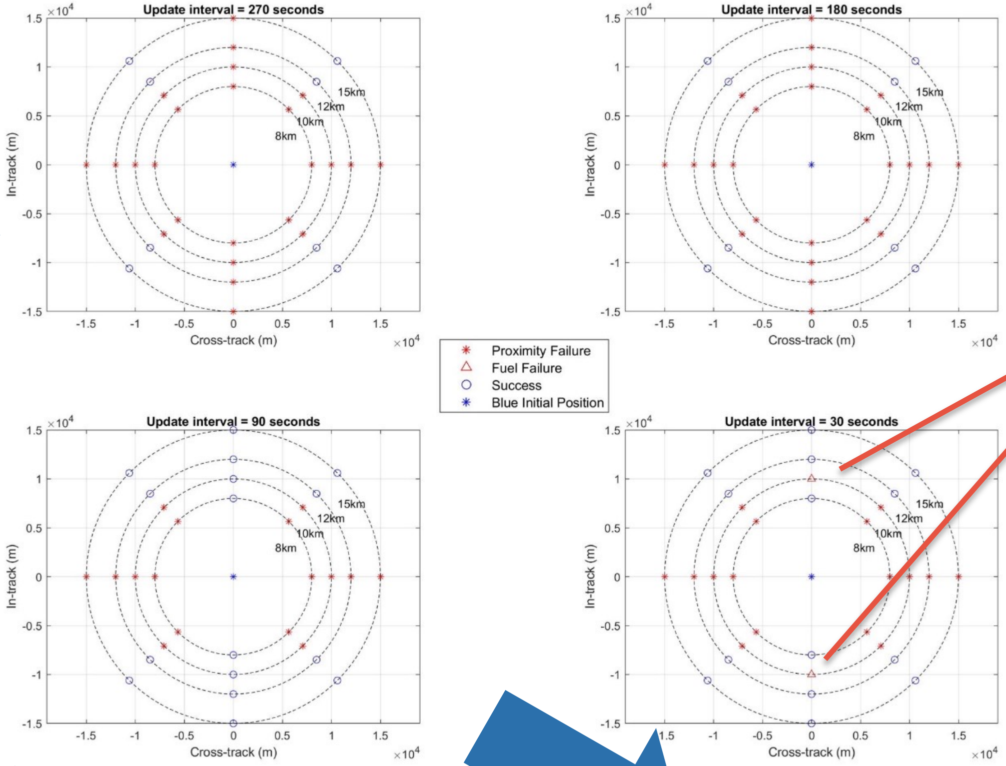


104 initial configurations (initial ASAT/SOI engagement geometry)

Identification of failed mission configurations



Example of the effect of state data update interval



Fuel Failure

Requirements review or writing of new requirements based on the results

Conclusions

Conclusions

Better understanding of the system under development

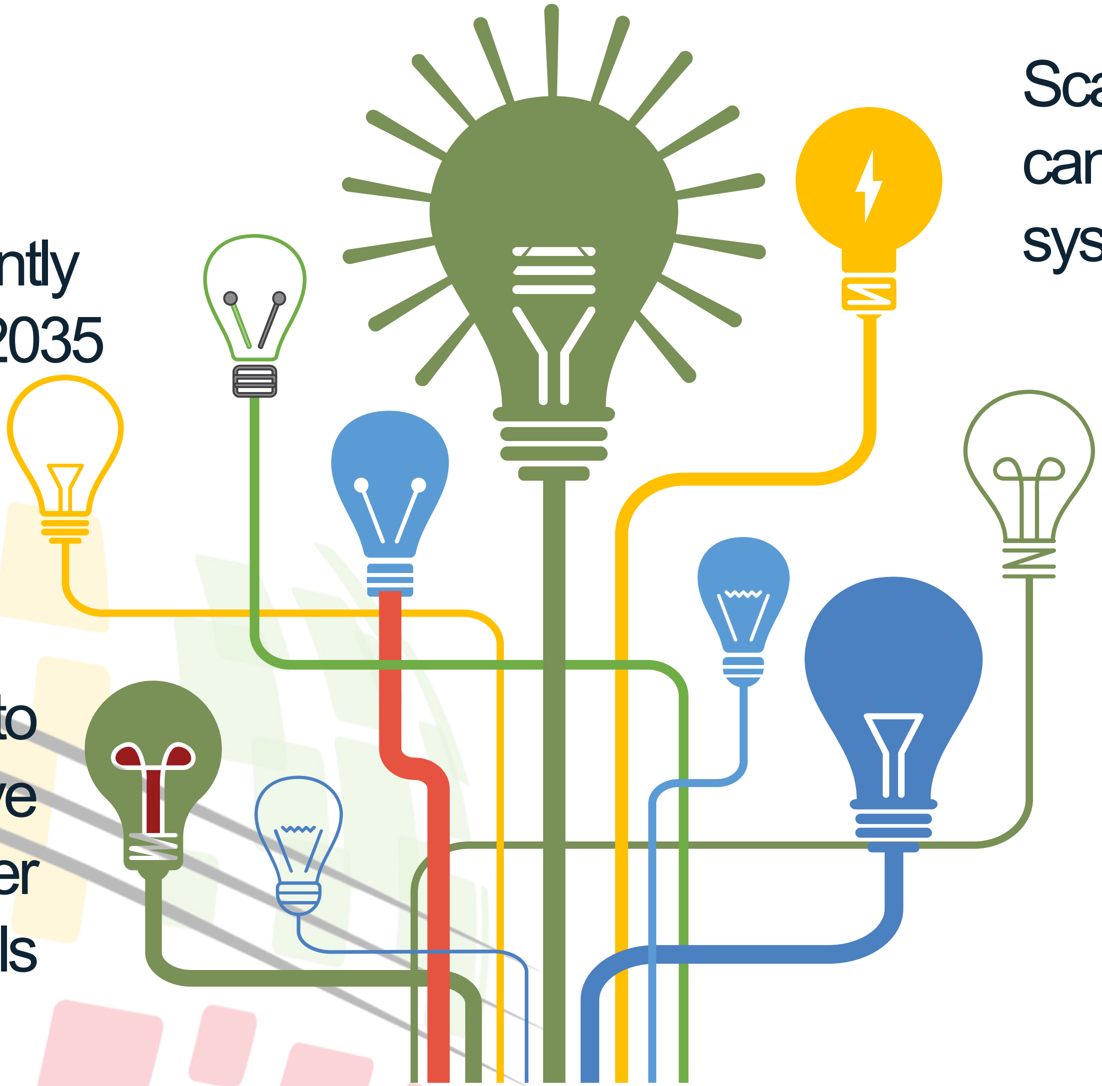
Connected models allows faster updates of information between stakeholders

One possible solution: Analytical models as a black-box nested within the descriptive model

…and improved design space exploration and requirement validation

Main Takeaways

"The Future of Systems Engineering is predominantly Model-Based." INCOSE 2035



Scalable models that can evolve during system's lifecycle

Bridge between SME and other stakeholders

It is necessary to connect descriptive models with other discipline models

33rd Annual INCOSE international symposium

hybrid event

Honolulu, HI, USA
July 15 - 20, 2023

www.incose.org/symp2023
#INCOSEIS