Battle Control System of Systems (SoS) Engineering Analysis

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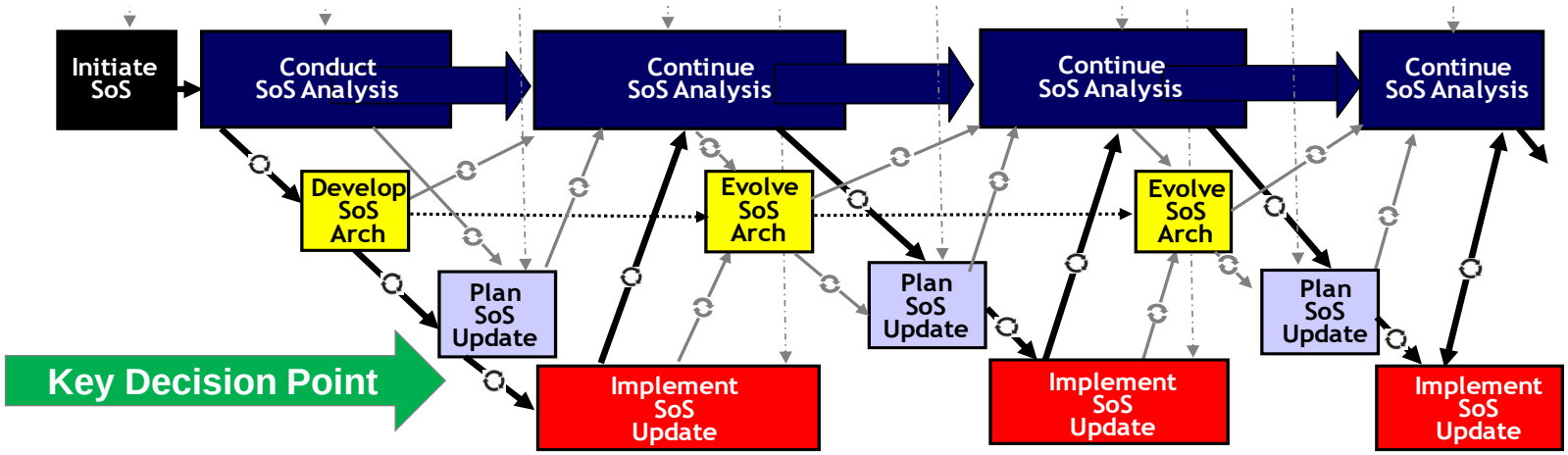
Bottom Line Up Front

- **Objective: Demonstrate utility of System of Systems (SoS) analysis capability to enable evidence-based decision making for future investments**
- **Approach: Model one air defense mission thread and show how potential system upgrades could provide operational mission benefits using an unclassified scenario and notional system performance data**
- **Results: Demonstrated ability to quantify system performance and operational mission benefits metrics of two possible enhancements to an initial baseline Use Case**
- **Future Potential: Linkage with cost modeling could permit rapid iterations in support of course of action option generation and analysis; Easily extendable to other scenarios or missions; Enhanced realism through use of authoritative program data**

System of Systems Wave Model



"An Implementers' View of Systems Engineering for Systems of Systems", Judith Dahmann et al.

- **Use SoS model to address potential changes in individual systems and the mission threads**
  - Define and analyze "as-is" architecture
  - Assess potential "to-be" options for value and impact on operational capabilities

Motivation: Evidence-Based Portfolio Decisions

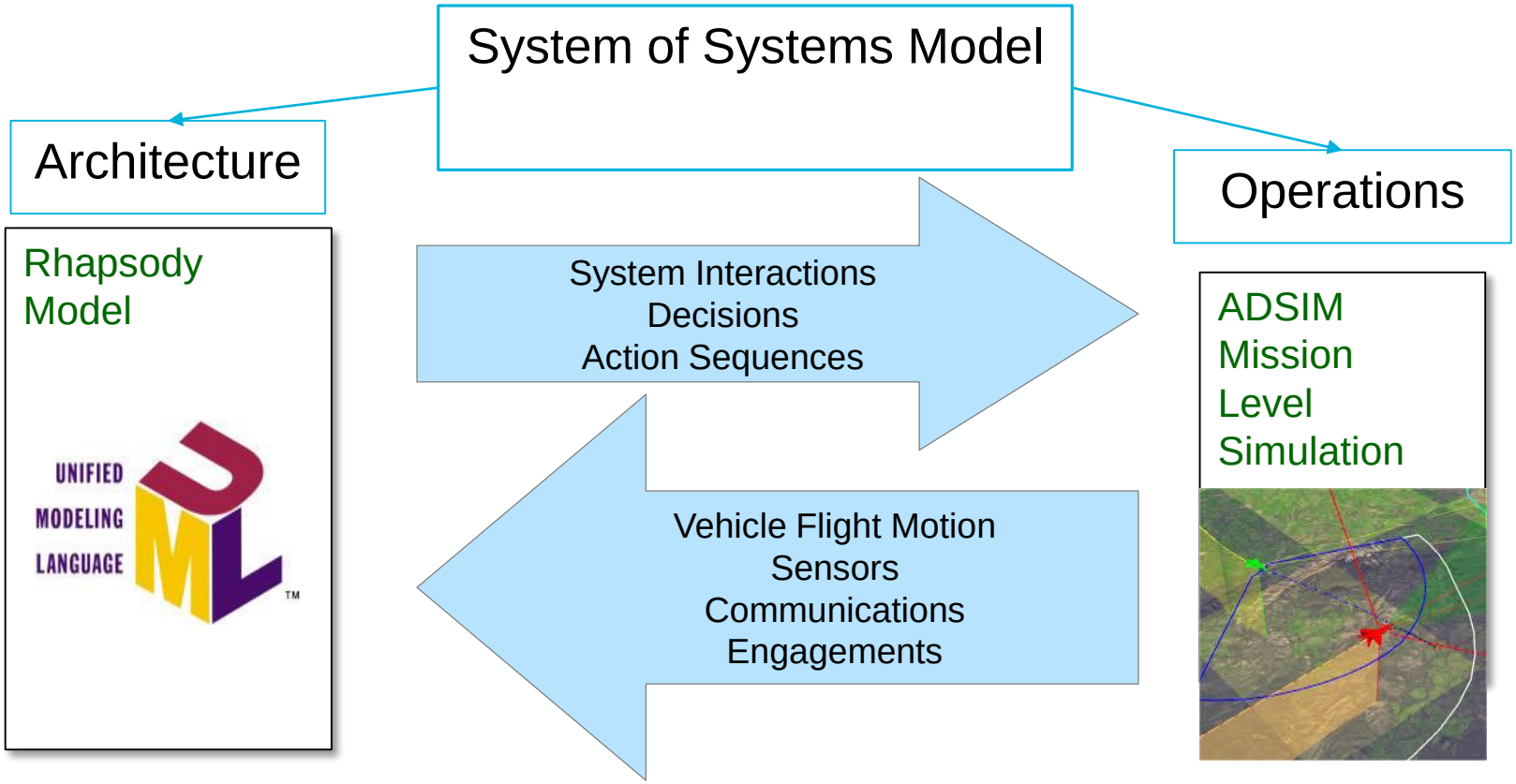
Develop an analytic platform to assist answering portfolio level questions:

- **What are the impacts of**
  - Sensor improvements
  - Communication systems improvements
  - Command and control software upgrades

    on operational mission effectiveness, schedule and cost?

- **How can cost savings be realized without compromising performance?**

Analytic Approach



SoS Modeling Approach

Air Defense System of Systems

Sensors

Fighter

Use Case

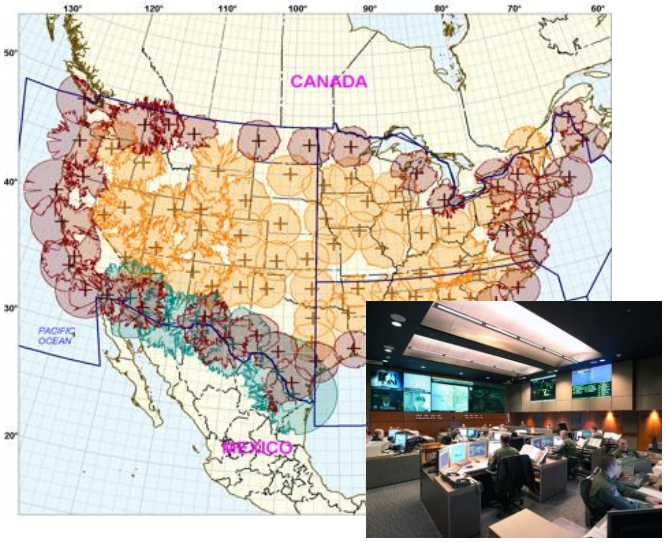
- **Rogue aircraft approaching protected facility**
  - Detection
  - Visualization
  - Identification
  - Coordination
  - Decision-making
  - Response
- **Variations modeled**
  - Baseline Case
  - Upgrade #1: Sensor with improved altitude discrimination
  - Upgrade #2: Automated a step in ID processing
  - Upgrades #1 and #2 combined

Scenario Backstory

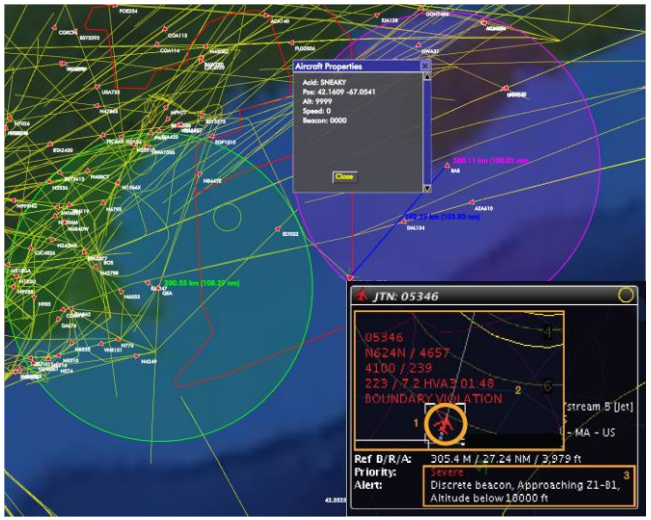
- **Private pilot plans low altitude overflight of major outdoor stadium event**
- **Files flight plan to land at nearby airfield**
- **Instead of landing, continues on to event location**
- **During event, fighters are on Combat Air Patrol (CAP)**

Technical and Operational Metrics

- **Measures of Performance (MOPs) – System Focus**
  - Coverage timelines
  - Processing delays
    - Investigation time
    - ID time
  - Decision delays



- **Measures of Effectiveness (MOEs) – Operations Focus**
  - Total ingress range into defended airspace
  - Ingress flight time



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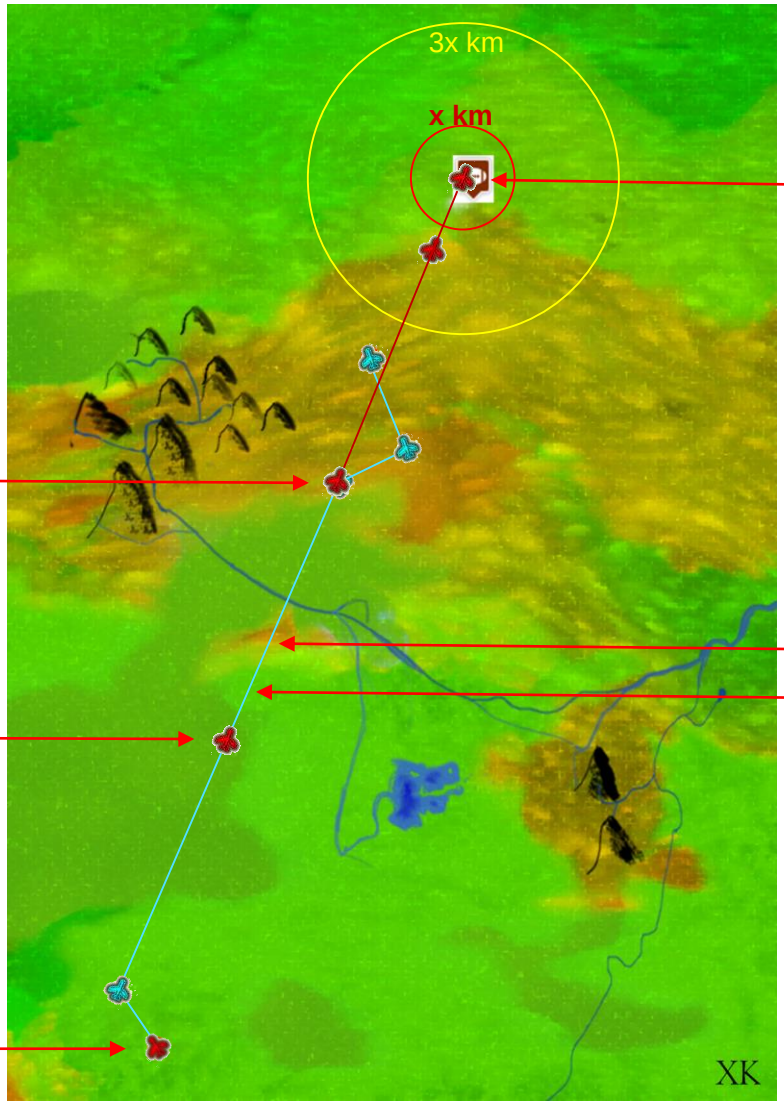
Scenario Timeline



500 feet above event
@ t_{final}

Missed turn @ t_4

2000 feet above flight plan
@ t_3 – baseline sensor

1000 feet above flight plan
@ t_3' – sensor upgrade

12000 ft @ t_2
(max altitude)

Takeoff @ t_1

✶ Model trigger

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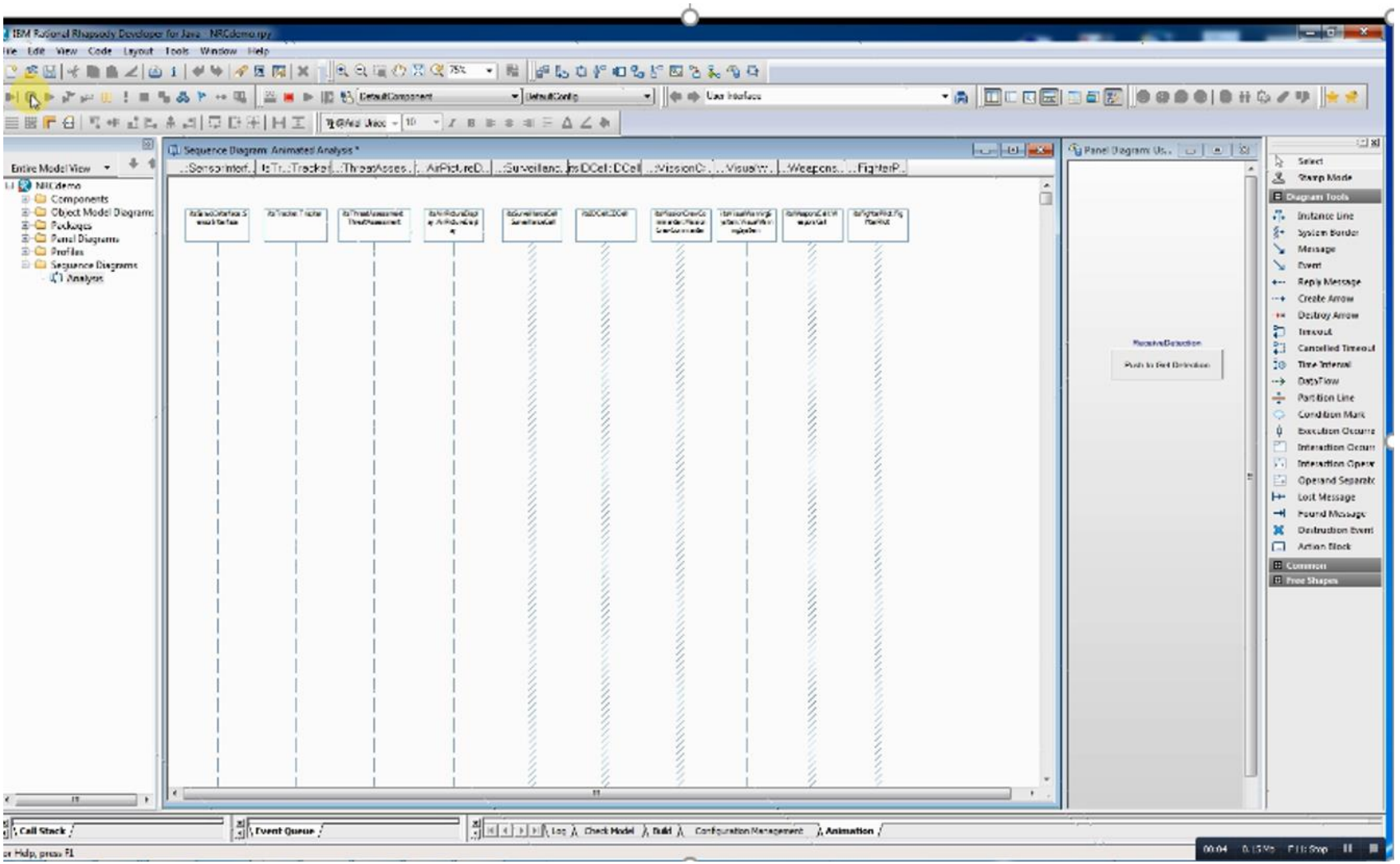
Executable Architecture (Rhapsody) 1/7



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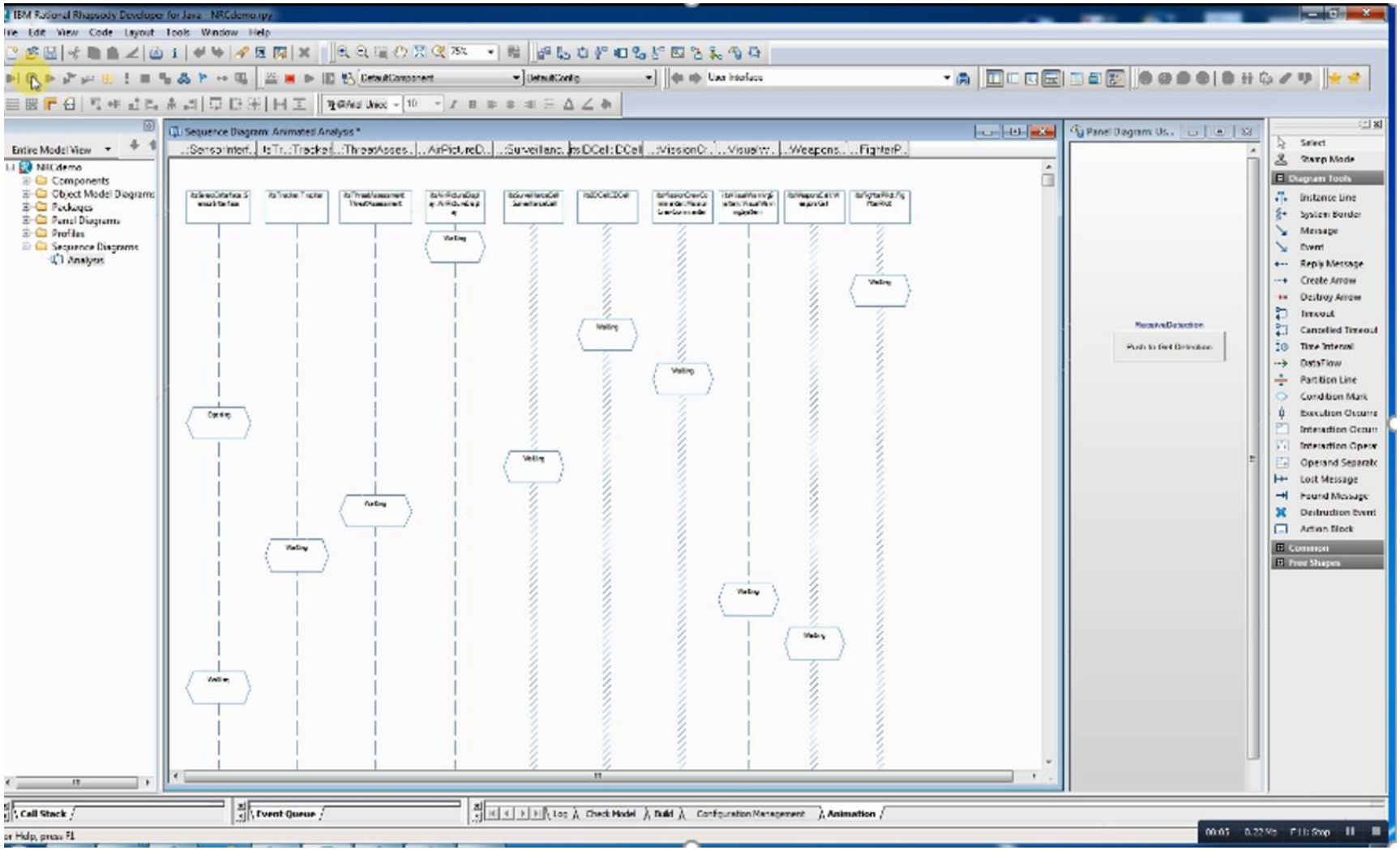
Executable Architecture (Rhapsody) 2/7



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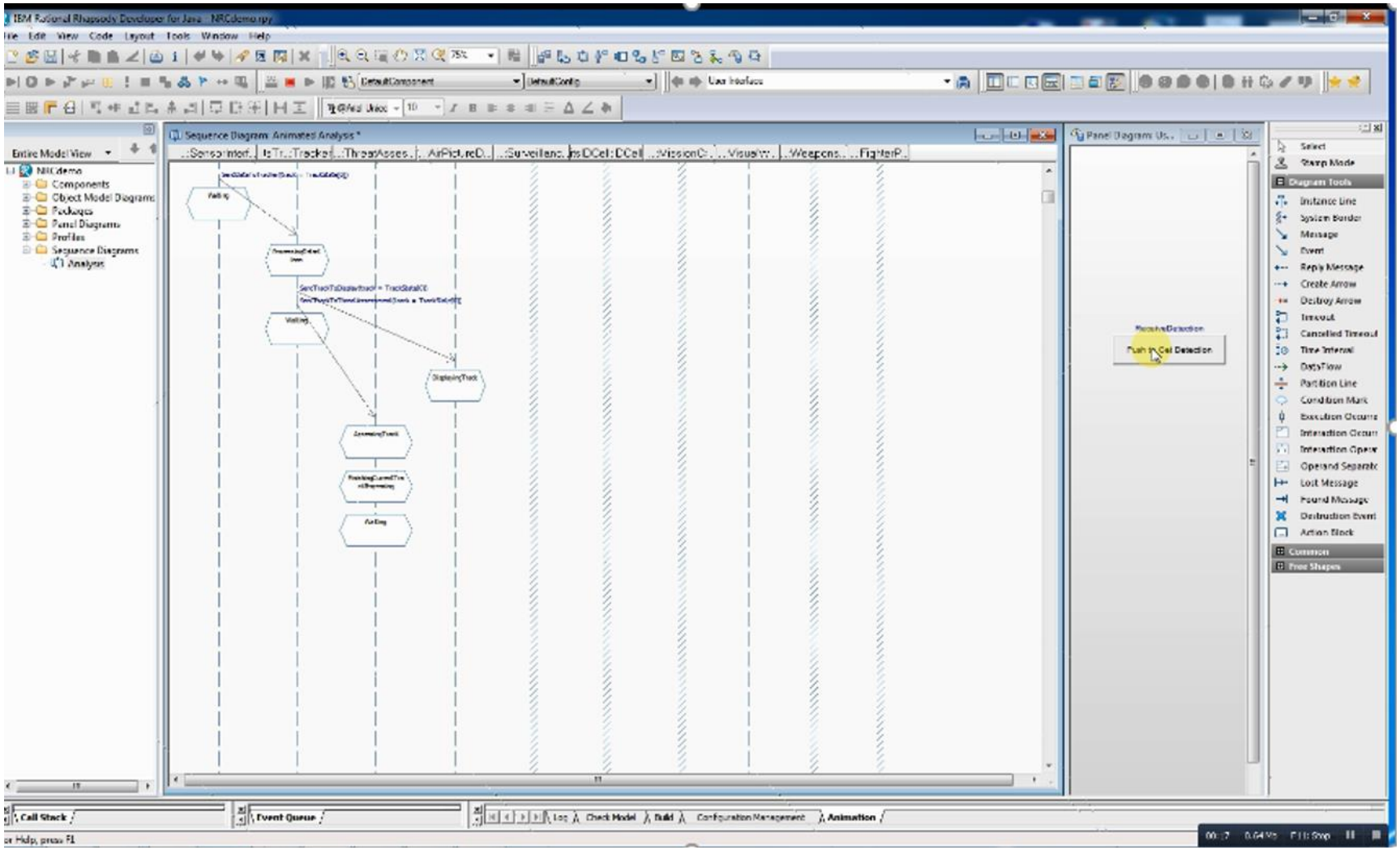
Executable Architecture (Rhapsody) 3/7



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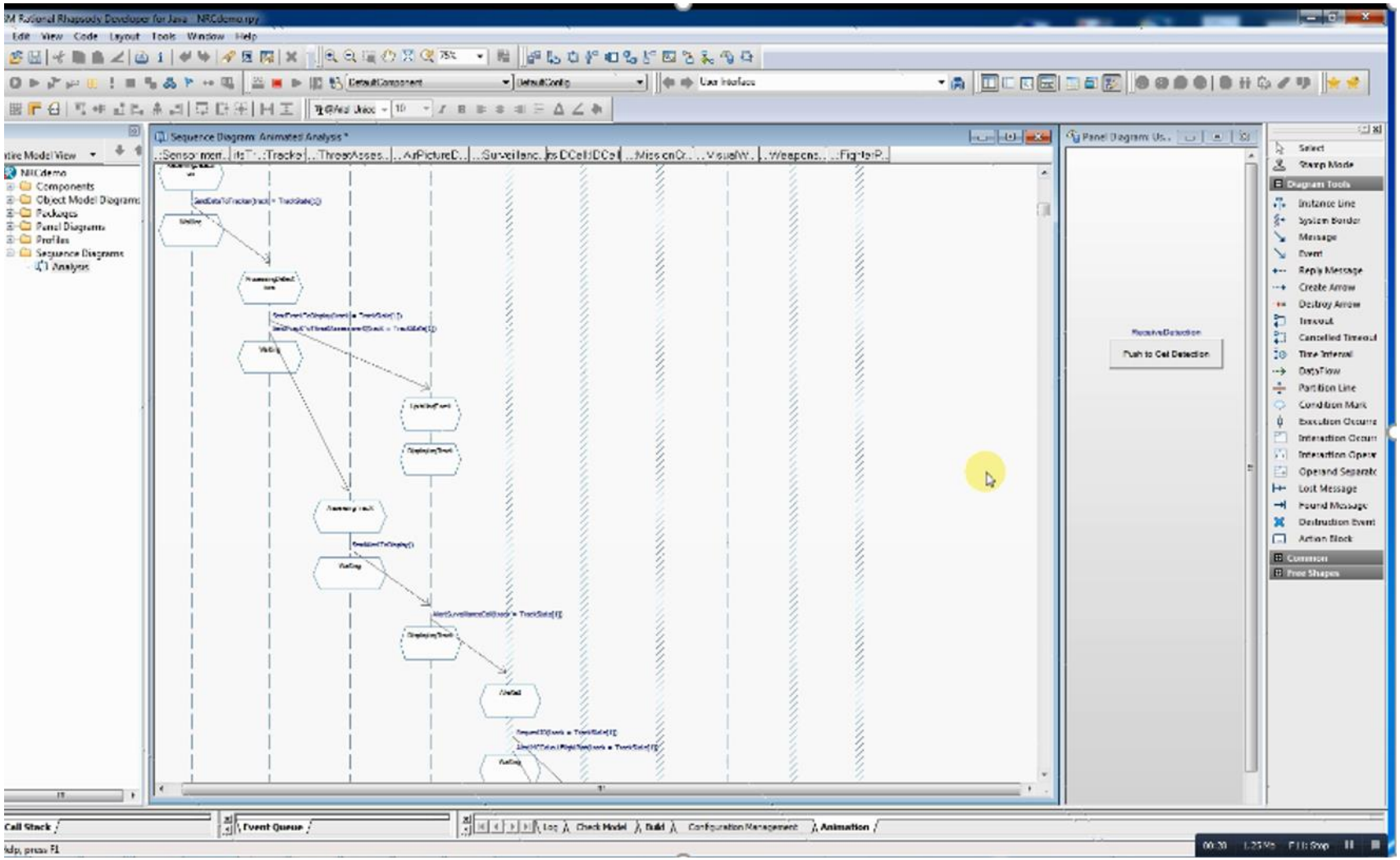
Executable Architecture (Rhapsody) 4/7



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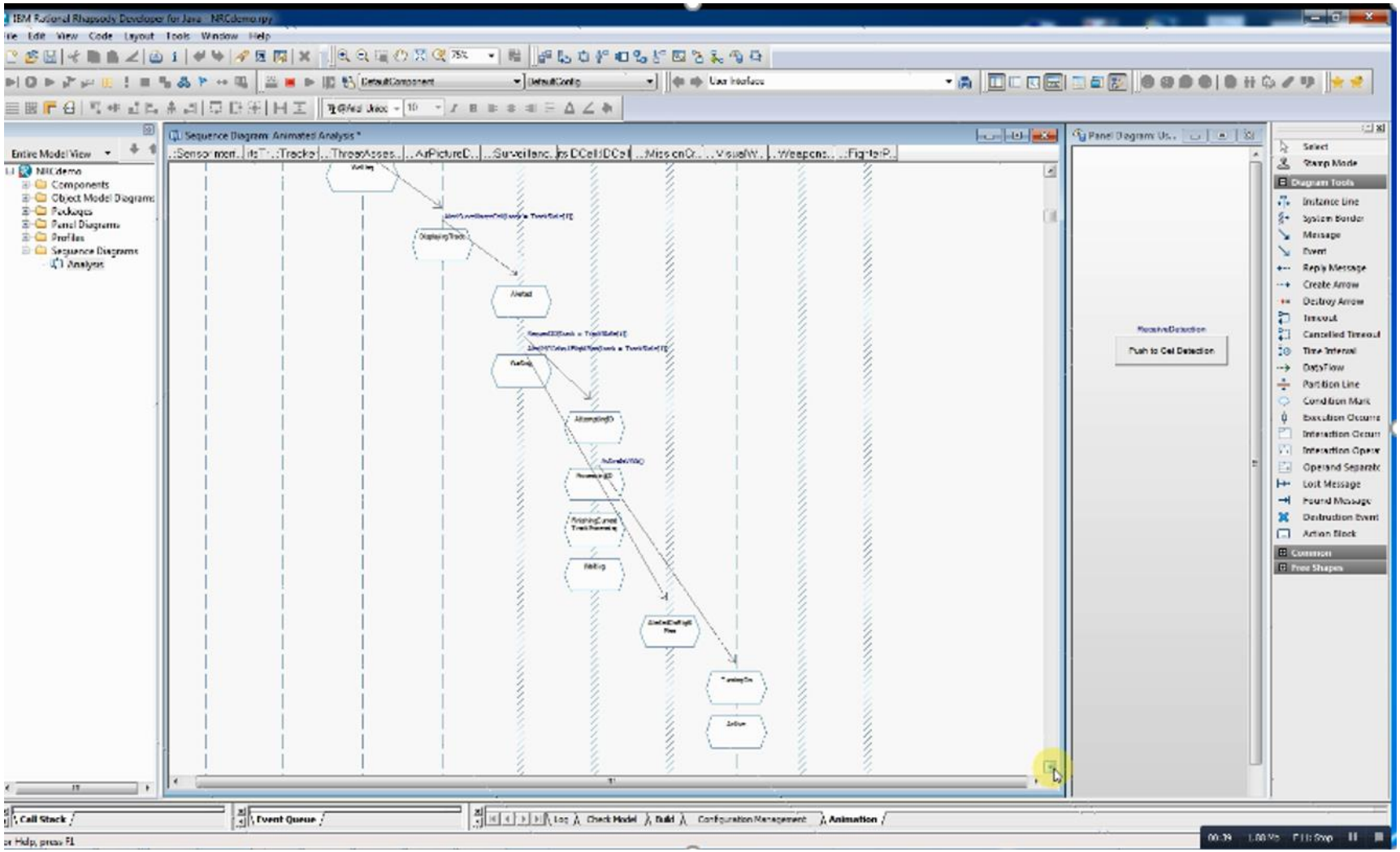
Executable Architecture (Rhapsody) 5/7



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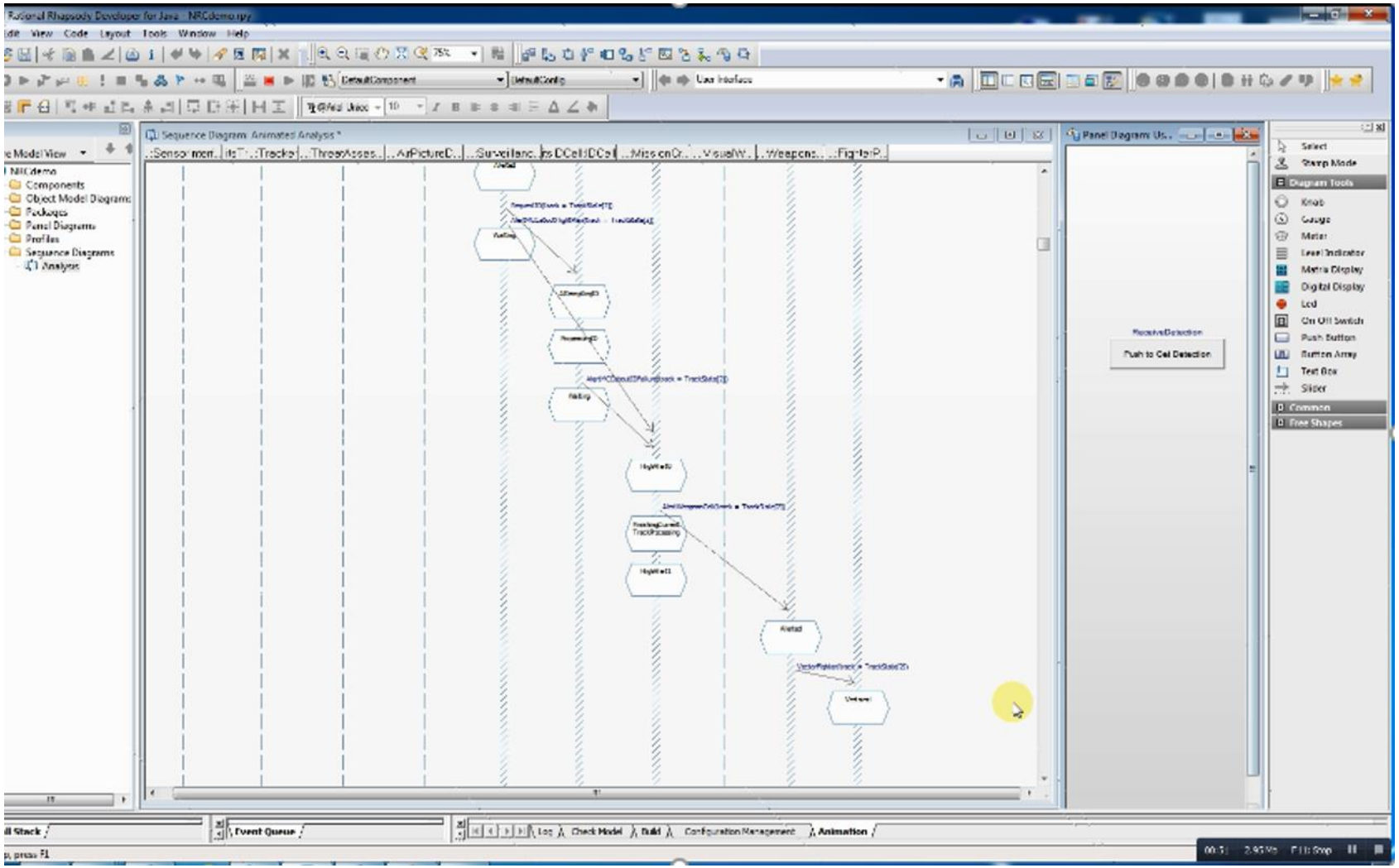
Executable Architecture (Rhapsody) 6/7



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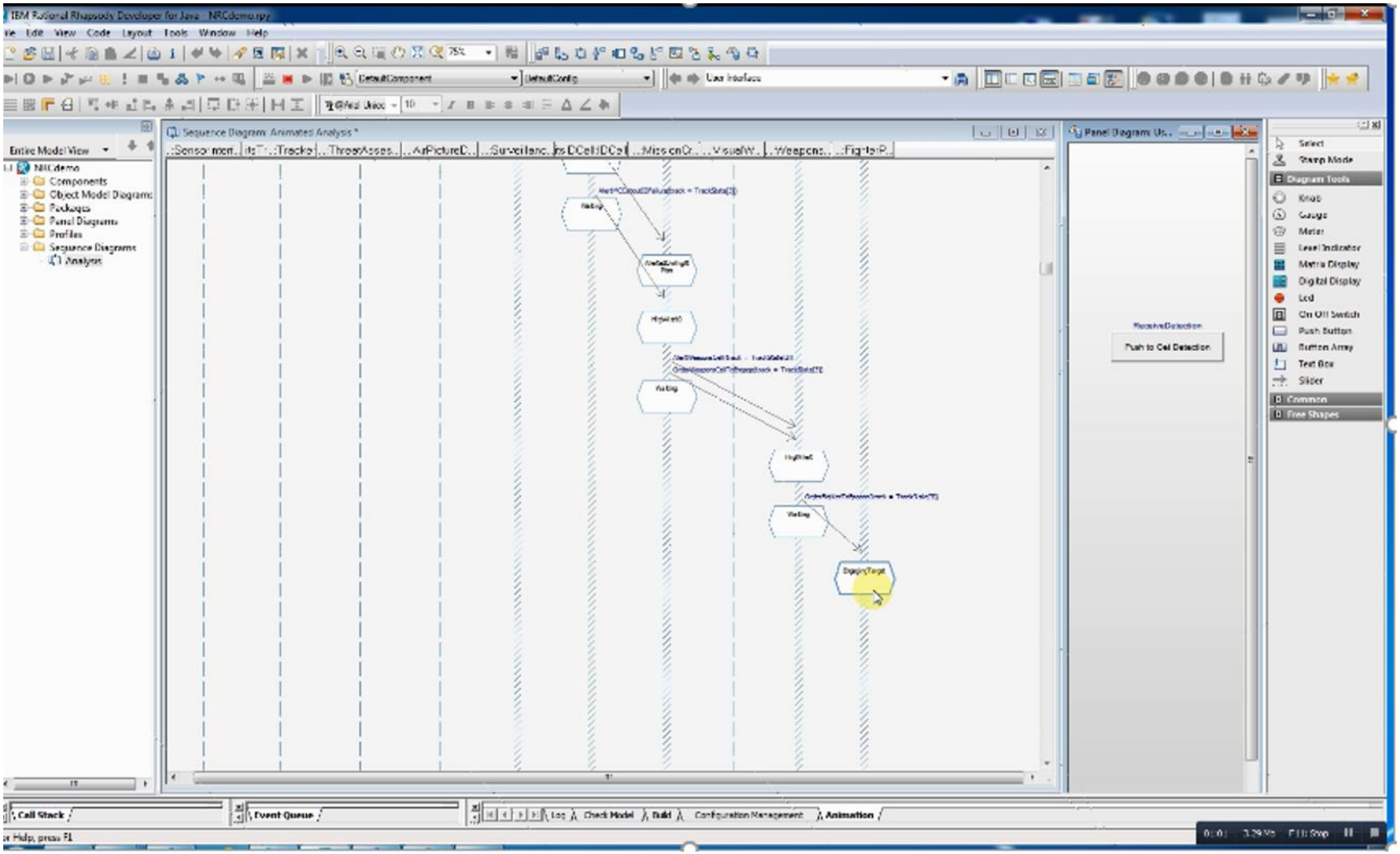
Executable Architecture (Rhapsody) 7/7



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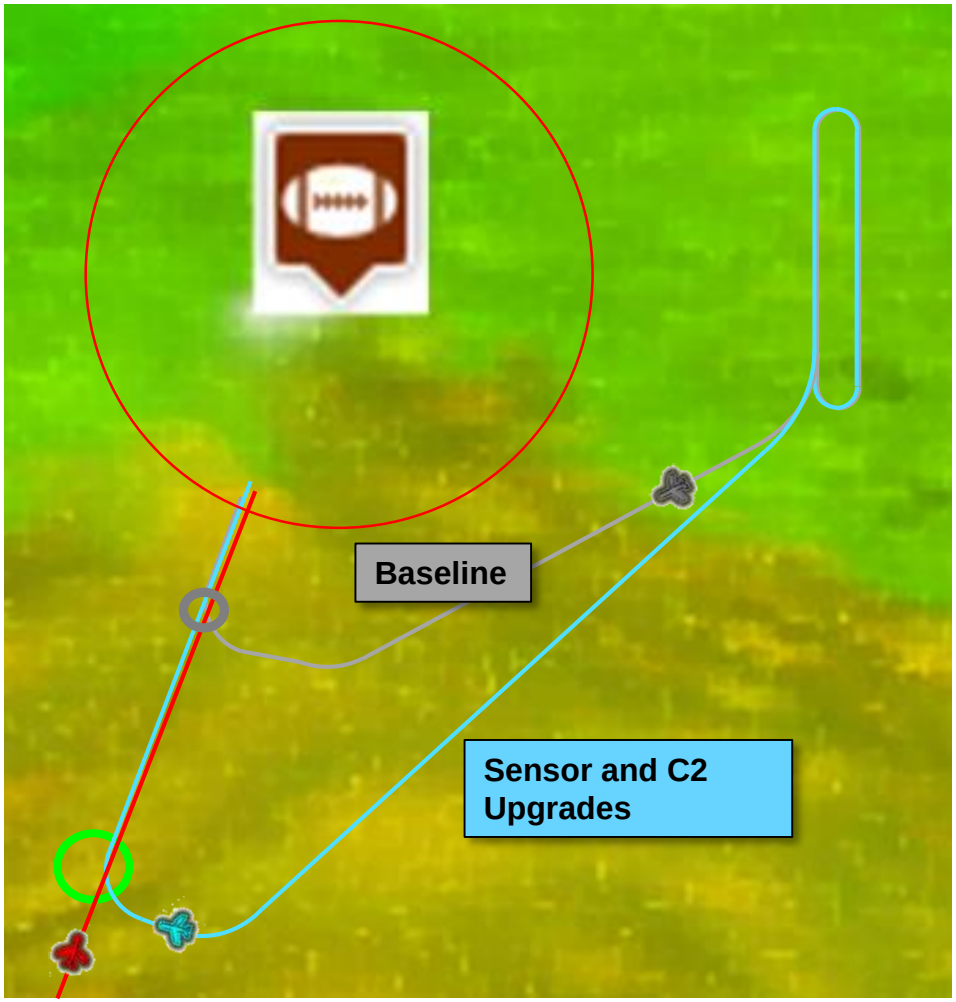
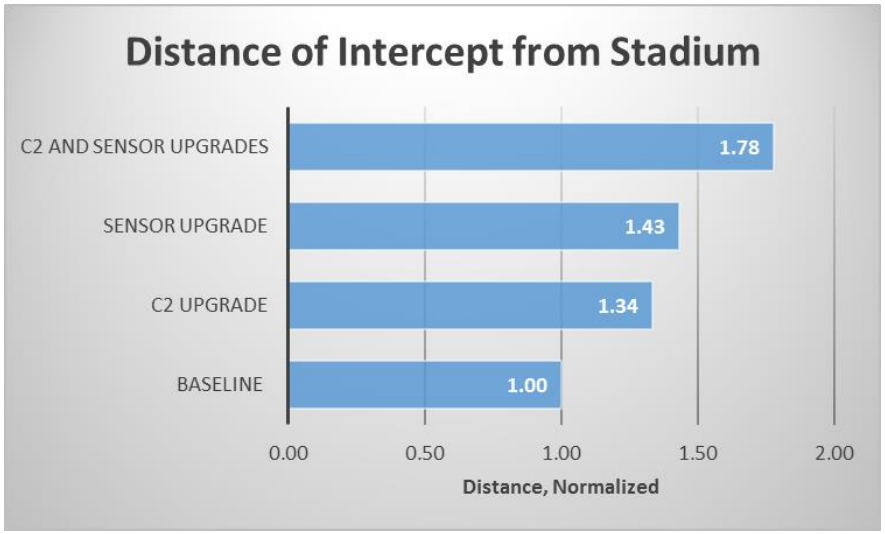
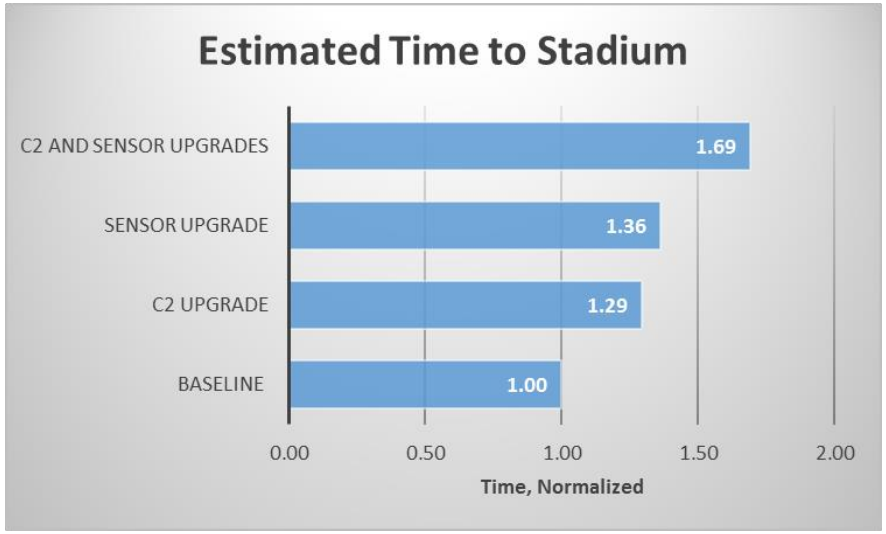
Fighter Intercept Route: Sensor and C2 Upgrades



- **Improved sensor: rogue aircraft discovered off flight plan earlier than baseline case**
- **Improved C2: it takes less time to decide to vector fighter after rogue discovered off flight plan**

MOE Summary Over All Cases





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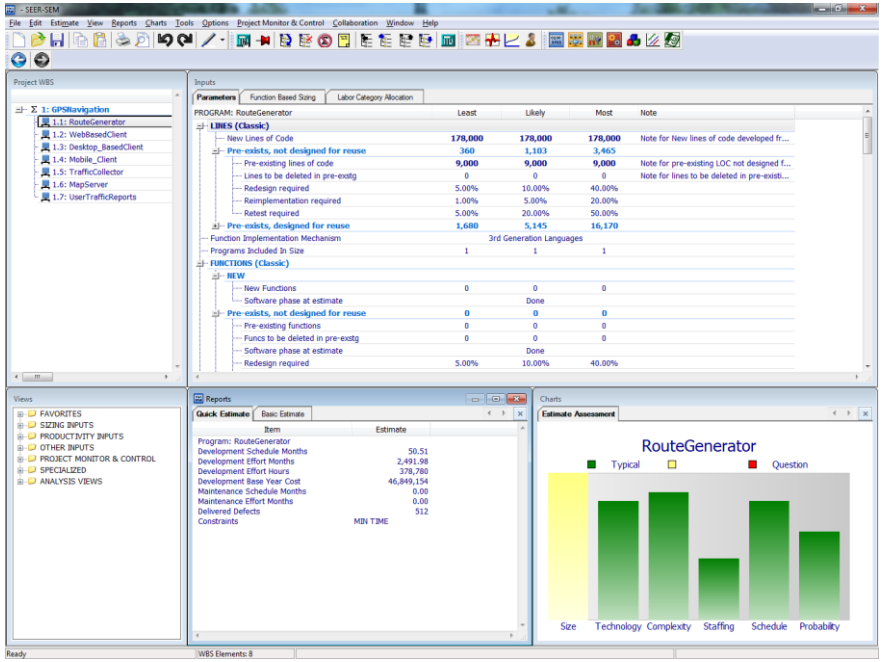
Integration of Architecture Model with Cost Estimation Tool

- **Executable architecture model is enhanced by including cost parameters:**
  - New lines of code
  - Existing lines of code
  - Platform knowledge base
  - Application knowledge base
- **Adapter utility extracts cost parameters from Rhapsody model and constructs an input to Galorath SEER-SEM**
- **Cost model is completed by Cost Estimator**
- **Affordability of various upgrades to systems and interfaces can be evaluated**

Example of SEER-SEM invoked from Rhapsody



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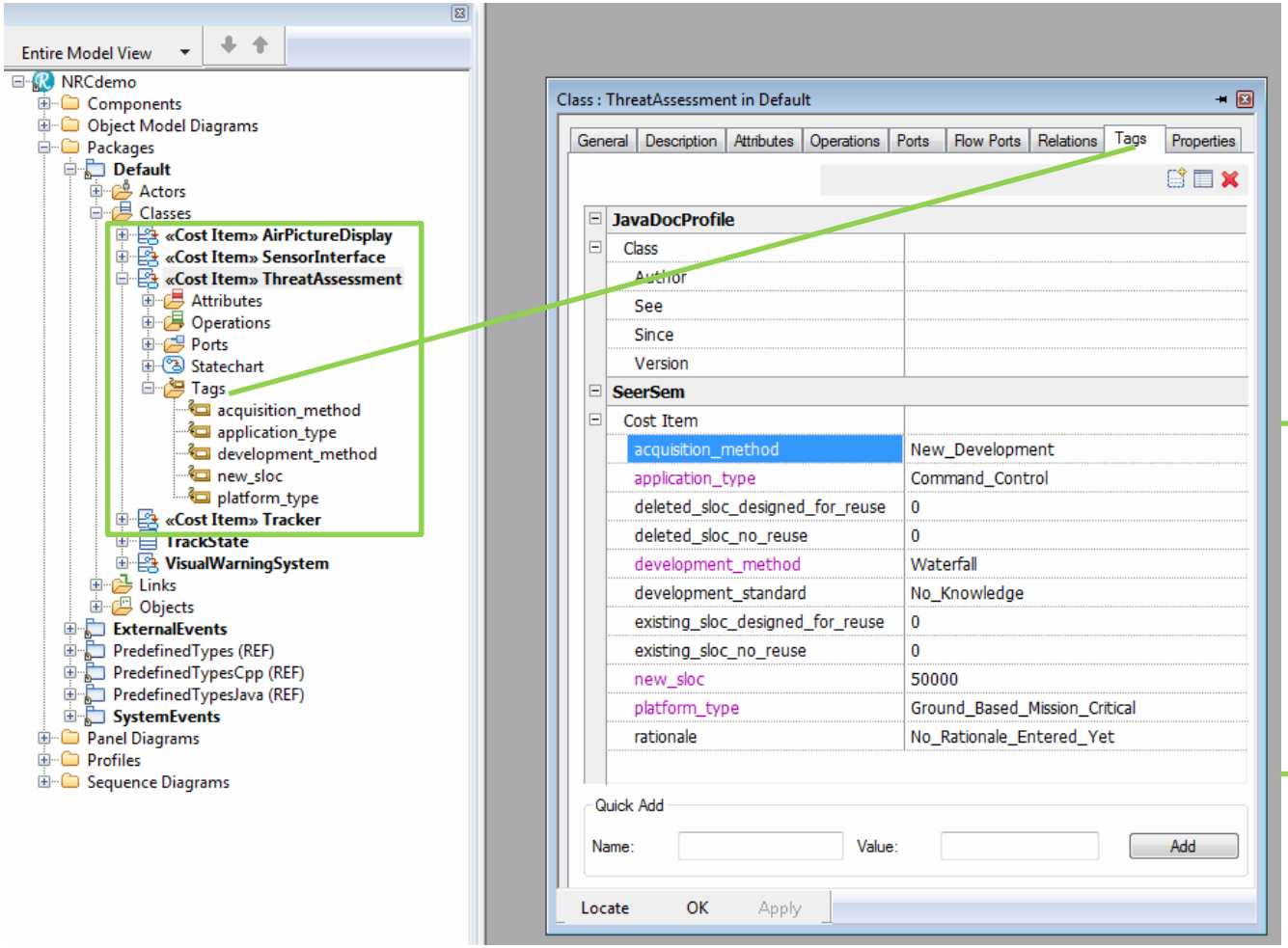
Example of Software Cost Item



SEER-SEM Sizing Parameters and Knowledge Bases

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Summary

- **Accomplishments**
  - Developed SoS-MBSE analytic capability
  - Stood up mission and architecture models
  - Defined interface between mission and architecture models
  - Executed analysis of the chosen mission thread
- **Lessons Learned**
  - SoS analysis helps identify gaps in understanding and documentation
  - Engineering workflow for SoS work is still under development
  - Engagement between MBSE, SoS and MS&A experts is crucial for making progress
- **Questions? Aleksandra Markina-Khusid at amk@mitre.org**