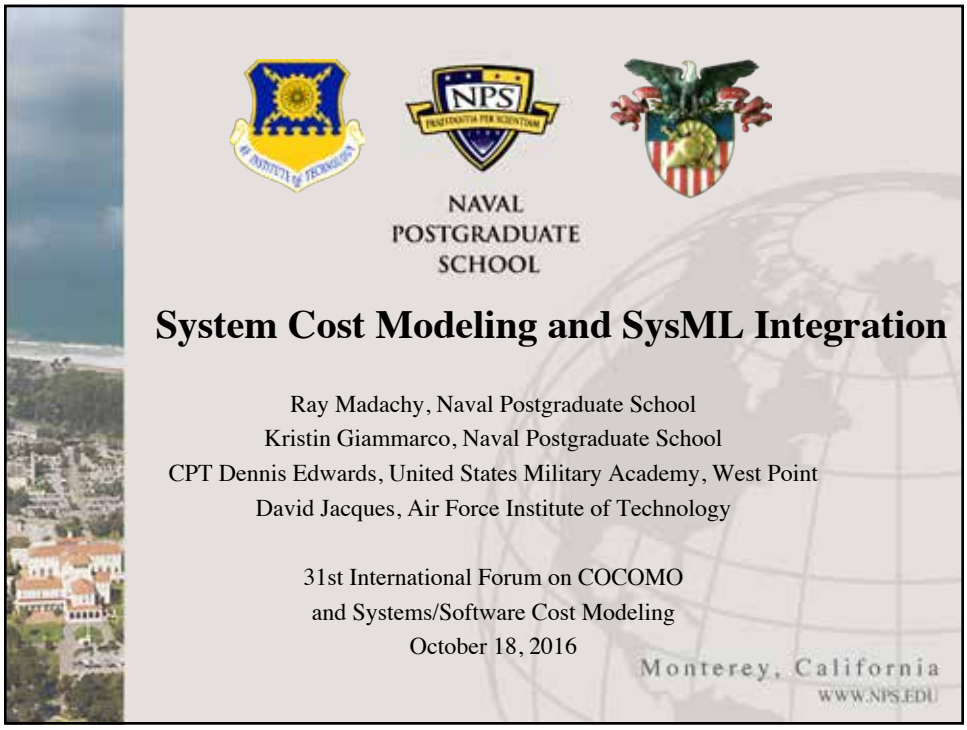
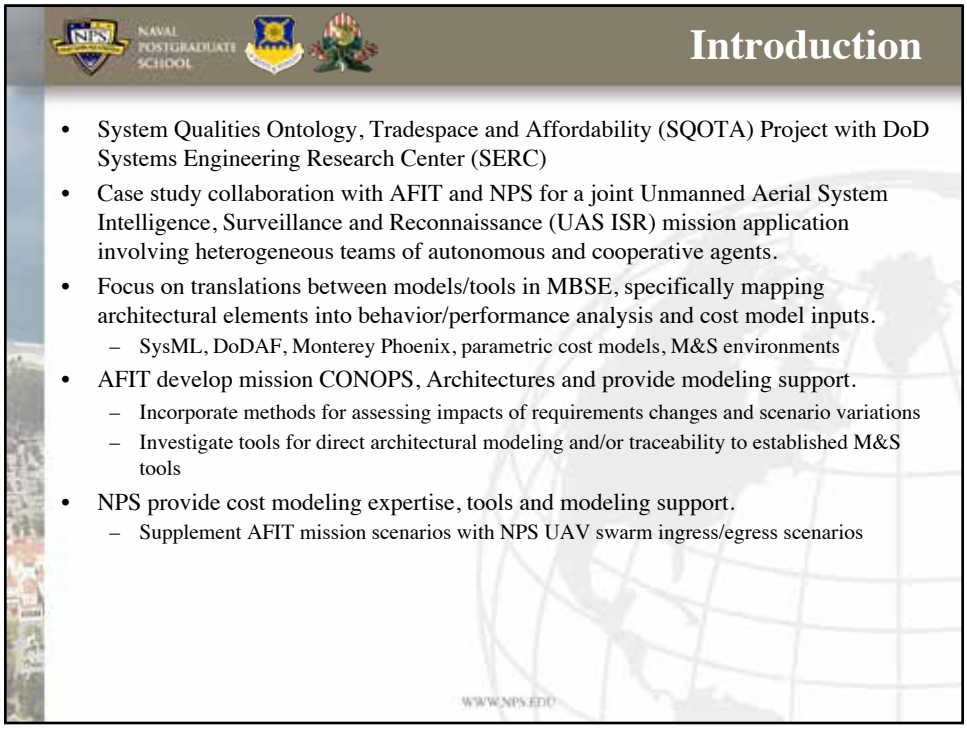

NPS
NAVAL
POSTGRADUATE
SCHOOL
System Cost Modeling and SysML Integration
Ray Madachy, Naval Postgraduate School
Kristin Giammarco, Naval Postgraduate School
CPT Dennis Edwards, United States Military Academy, West Point
David Jacques, Air Force Institute of Technology
31st International Forum on COCOMO
and Systems/Software Cost Modeling
October 18, 2016
Monterey, California
WWW.NPS.EDU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Introduction
• System Qualities Ontology, Tradespace and Affordability (SQOTA) Project with DoD Systems Engineering Research Center (SERC)
• Case study collaboration with AFIT and NPS for a joint Unmanned Aerial System Intelligence, Surveillance and Reconnaissance (UAS ISR) mission application involving heterogeneous teams of autonomous and cooperative agents.
• Focus on translations between models/tools in MBSE, specifically mapping architectural elements into behavior/performance analysis and cost model inputs.
– SysML, DoDAF, Monterey Phoenix, parametric cost models, M&S environments
• AFIT develop mission CONOPS, Architectures and provide modeling support.
– Incorporate methods for assessing impacts of requirements changes and scenario variations
– Investigate tools for direct architectural modeling and/or traceability to established M&S tools
• NPS provide cost modeling expertise, tools and modeling support.
– Supplement AFIT mission scenarios with NPS UAV swarm ingress/egress scenarios
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## Overview

- Total Ownership Cost (TOC) modeling to enable affordability tradeoffs with other ilities
  - Integrated costing of systems, software, hardware and human factors across full lifecycle operations
  - Combine with other MBSE architecture-based behavior and performance analysis
- Current shortfalls for ilities tradespace analysis
  - Models/tools are incomplete wrt/ TOC phases, activities, disciplines, SoS aspects
  - No integration with physical design space analysis tools, system modeling, or each other
- Cost estimation can be improved by using the same architectural definitions for cost model inputs, without the need for independent cost modeling expertise and effort expenditure.
- Developing translation rules and constructs between MBSE methods, performance analysis and cost model inputs.
- Demonstrating tool interoperability and tailorability



## Case Study Method

- Use various MBSE methods and tools to evaluate behavior and performance analysis in the face of requirements changes and System of System (SoS) architectural variations.
- Develop operational and system architectures to capture sets of UAS military scenarios for cooperative swarms with 3 UAS group sizes
- Transition the architectures to MBSE environments.
  - SysML diagrams and executable activity models using Innoslate
- Develop cost model interfaces for components of the architectures in order to evaluate cost effectiveness in an uncertain future environment.
  - XML model files parsed automatically to extract cost model inputs
- Design and demonstrate UAS ISR tradespace including cost in integrated MBSE environment with executable models of architectures

# COSYSMO Size Inputs

| Size Type | Description |
|---|---|
| **Requirements** | The number of requirements for the system-of-interest at a specific level of design. Requirements may be functional, performance, feature, or service-oriented. |
| **Interfaces** | The number of shared physical and logical boundaries between system components or functions (internal interfaces) and those external to the system (external interfaces). |
| **Algorithms** | The number of newly defined or significantly altered functions that require unique mathematical algorithms to be derived in order to achieve the system performance requirements. |
| **Operational Scenarios** | Operational scenarios that a system must satisfy, including nominal and off-nominal threads. |

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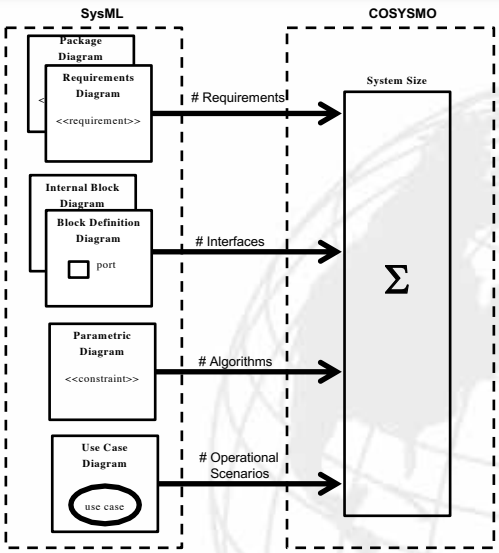
# SysML to COSYSMO Mapping

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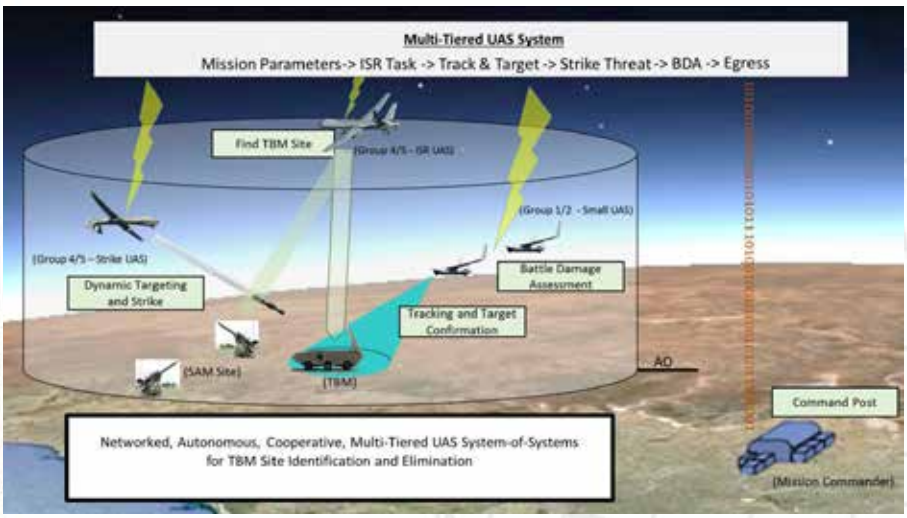
## UAS Mission Summaries

- Single UAS Search and Target Tracking (Simple Mission)
- UAS Pair Search and Target Tracking
- Find, Fix and Finish Terrorist Leadership (1)
- Find, Fix and Finish Terrorist Leadership (2)
- Mobile Missile Launcher Monitoring (1)
- Mobile Missile Launcher Monitoring (2)



## Example High-level CONOPS (OV 1)

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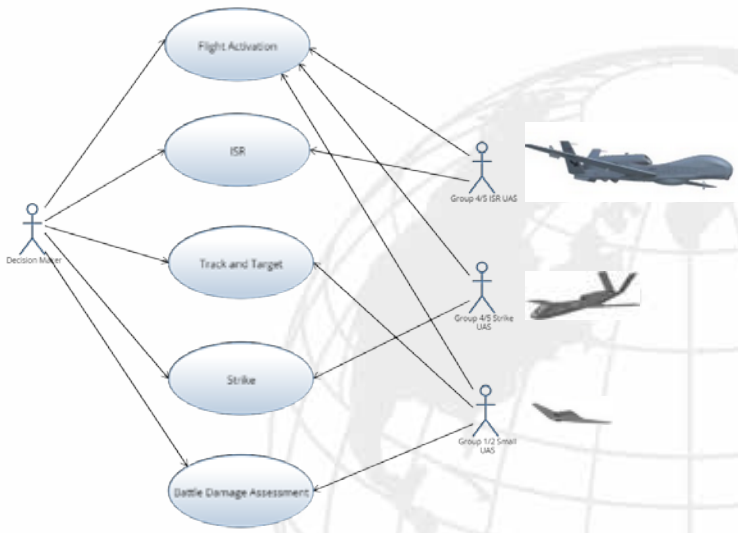
# Example Scenarios (Use Cases)

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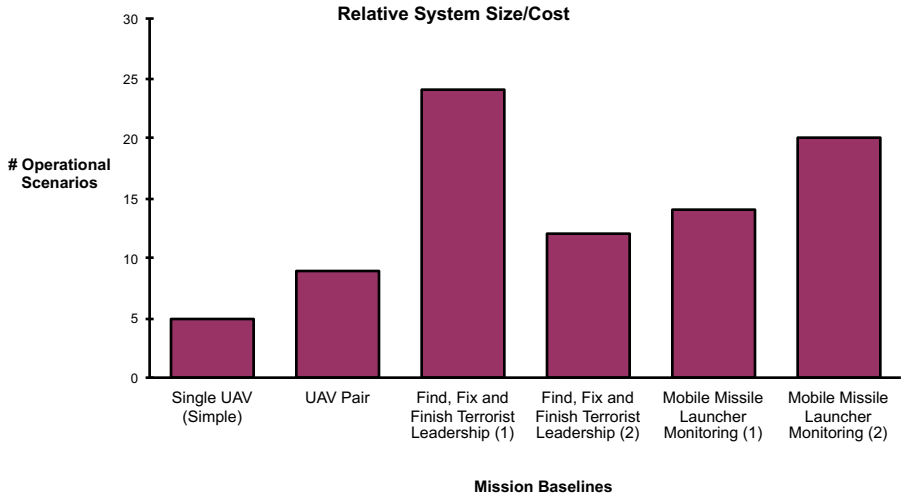
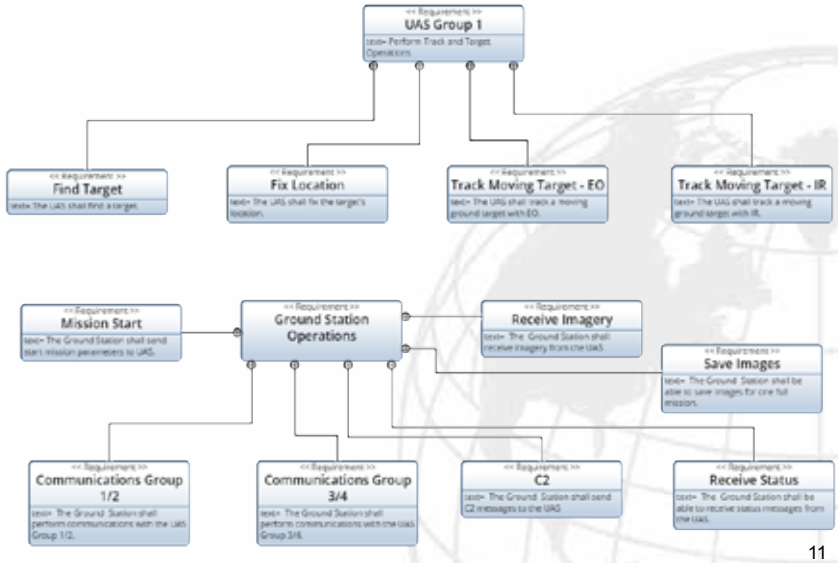
# UAV Mission Nominal Cost Comparisons



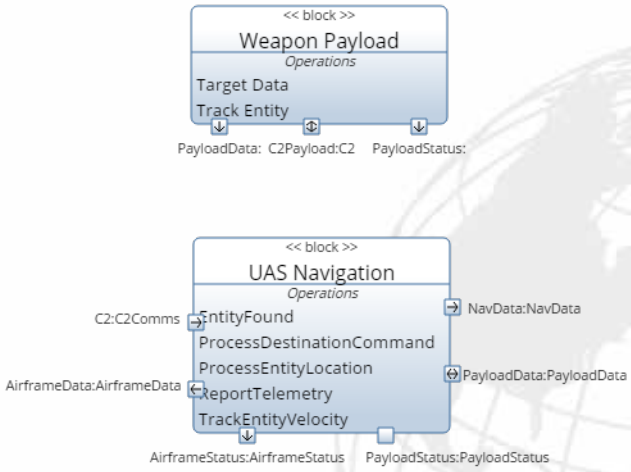
# Example Requirements



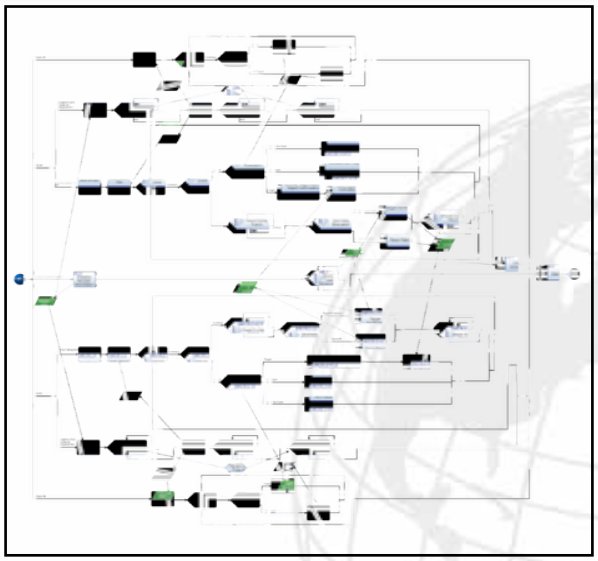





# Example Interfaces (Ports)

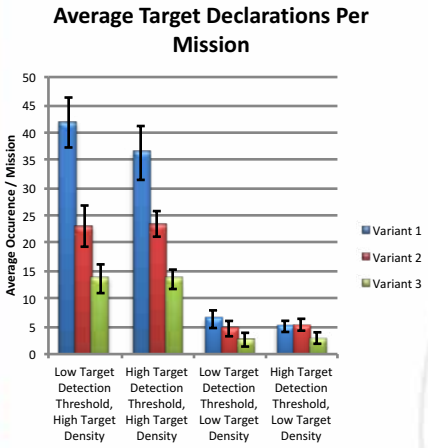


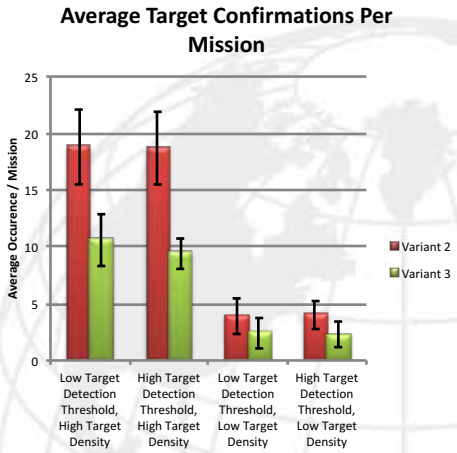
# Example Activity Model (OV-5b) for Simple UAS Mission





# Example Measures of Effectiveness for UAV Mission from Simulation



# XML Interface Processing

```
...
- <entity id="e4RWJH">
    <name>Flight Activation</name>
    <description/>
    <hidden>false</hidden>
    <locked>false</locked>
    <schemaClassId>C1</schemaClassId>
    <number/>
  - <doubleAttribute schemaPropertyId="P4">
      <doubleValue>0.0</doubleValue>
    </doubleAttribute>
  - <durationAttribute schemaPropertyId="P2">
      <doubleValue>1.0</doubleValue>
      <units>HOURS</units>
    </durationAttribute>
    <labelId>L60</labelId>
  - <simulationData>
      <type>SERIAL</type>
    - <controlStructure id="57bcf94d-cb13-42e5-9e5b-72dfd2a9fc17">
        <type>START</type>
      - <sucessorStructure id="fe494a8a-d37b-44d1-9ffd-614416e6111e">
          <type>END</type>
        </sucessorStructure>
      </controlStructure>
    </simulationData>
...
```

**System Size** Input Method File Input Select Input File

*UAS scenario 1.xml* contains:
**Size Type**: entity name labelId

**use case**: Battle Damage Assessment L60
**use case**: Track and Target L60
**use case**: Strike L60
**use case**: Flight Activation L60
...





# Example COSYSMO Estimate

**SysML COSYSMO**

**System Size** Input Method File Input Select Input File *distiller.xml*

| | Easy | Nominal | Difficult |
|---|---|---|---|
| # of System Requirements | 28 | 2 | 1 |
| # of System Interfaces | 29 | 2 | 1 |
| # of Algorithms | 3 | | |
| # of Operational Scenarios | 1 | | |

**System Cost Drivers**

| | | | | | |
|---|---|---|---|---|---|
| Requirements Understanding | Nominal | Documentation | Nominal | Personnel Experience/Continuity | Nominal |
| Architecture Understanding | Nominal | # and Diversity of Installations/Platforms | Nominal | Process Capability | Nominal |
| Level of Service Requirements | Nominal | # of Recursive Levels in the Design | Nominal | Multisite Coordination | Nominal |
| Migration Complexity | Nominal | Stakeholder Team Cohesion | Nominal | Tool Support | Nominal |
| Technology Risk | Nominal | Personnel/Team Capability | Nominal | | |

**Maintenance** Off

**System Labor Rates**
Cost per Person-Month (Dollars) 10000

Calculate

**Results**
**Systems Engineering**
Effort =25.8 Person-months
Schedule = 4.4 Months
Cost = $255525

## Conclusions and Future Work

- Have demonstrated architectural tradespaces with simpler UAS swarm models for further elaboration on more complex mission scenarios
- We have found a strong correspondence between SysML constructs and system size measures of requirements, interfaces, algorithms, and operational scenarios.
  - Still comparing approaches for complex algorithm representations in SysML
  - Require additional attributes for modeling complexity levels of size drivers
- Continue transcribing all UAS architectural variations into SysML for cost tradeoffs to evaluate with other Measures of Effectiveness
  - Expanded mission sets to include heterogeneous UAS teams and more complex scenarios
- Apply method and case study with other MBSE tools, evaluate and compare
- Develop a COSYSMO SysML <<namespace>> for system size entities
- Develop guidelines with examples for practitioners on modeling decomposition levels of detail
- Continue essential research on integration of MBSE methods and tools
  - SysML, Monterey Phoenix (MP), DoDAF, COSYSMO, COCOMO, COQUALMO
  - Further tool integration demonstrations with methods for file input and REST API web service
  - Organic cost computation within SysML tools as (Peak and Lane, 2014) in conjunction with extensive application models



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- D. Jacques and R. Madachy, "Model-Centric UAV ISR Analysis," presented at Systems Engineering Research Center, 7th Annual SERC Sponsor Research Review, Washington, DC, December 3, 2015.
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- CPT Dennis Edwards (USArmy), "Exploring the integration of COSYSMO with a model based system engineering methodology in early trade space analytics and decisions", M.S. thesis, NPS, June 2016
- Peak, R.S. and Lane, J.A., "SysML Building Blocks for Cost Modeling: Towards Model-Based Affordability Analysis", INCOSE International Workshop (IW14), Torrance, California, 2014