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STEVENS
INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

Systems Engineering Transformation
Surrogate Pilot Experiments: Doing Everything in Models to Demonstrate the Art-of-the-Possible

Sponsor: NAVAIR and CCDC-AC

By
Dr. Mark Blackburn

www.sercuarc.org

Presented to: INCOSE North Texas Chapter Meeting
April 14, 2020

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Abstract

- NAVAIR characterized the Systems Engineering Transformation (SET) Framework for a Digital Engineering (DE)-enabled acquisition. This presentation discusses the Surrogate Pilot use cases, models and lessons learned in assessing the SET Framework for collaboration between government and industry.

- This is an evolving version of a briefing that summarizes the Systems Engineering Transformation (SET) Surrogate Experiments. It provides an overview to set the context of the SET Framework concept and Functional Areas. Research is one of the functional areas that was defined along with an evolving set of objectives that are being used to guide the experiments, and trace the results to the objectives.

- These experiments are being conducted by a team of NAVAIR Subject Matter Experts, SERC Collaborators from Stevens Institute and Georgia Tech, and a Surrogate Contractor from Altair. The ongoing results and lessons learned are captured on the All Partners Network (APAN.org @ https://community.apan.org/wg/navair-set/set-surrogate-pilot/) and being shared with Industry and Government.

- This briefing is Distribution A.

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Research Tasks and Collaborator Network

RT-48
- Mark Blackburn (PI), Stevens
- Rob Cloutier (Co-PI) - Stevens
- Eirik Hole - Stevens
- Gary Witus – Wayne State

RT-118
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- Rob Cloutier - Stevens
- Eirik Hole - Stevens
- Gary Witus – Wayne State

RT-141
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Gary Witus – Wayne State

RT-157
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Roger Blake - Stevens
- Mark Austin – Univ. Maryland
- Leonard Petnga – Univ. of Maryland

RT-170
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Deva Henry - Stevens
- Paul Grogan - Stevens
- Steven Hoffenson - Stevens
- Mark Austin – Univ. of Maryland
- Leonard Petnga – Univ. of Maryland
- Maria Coelho (Grad) – Univ. of Maryland
- Russell Peak – Georgia Tech.
- Stephen Edwards – Georgia Tech.
- Adam Baker (Grad) – Georgia Tech.
- Marlin Ballard (Grad) – Georgia Tech.

RT-168 – Phase I & II
- Mark Blackburn (PI), Stevens
- Dinesh Verma (Co-PI) – Stevens
- Ralph Giffin
- Roger Blake - Stevens
- Mary Bone – Stevens
- Andrew Dawson – Stevens (Phase I)
- Rick Dove
- John Dzielski, Stevens
- Paul Grogan - Stevens
- Deva Henry – Stevens (Phase I)
- Bob Hathaway - Stevens
- Steven Hoffenson - Stevens
- Eirik Hole - Stevens
- Roger Jones – Stevens
- Benjamine Kruse - Stevens
- Jeff McDonald – Stevens (Phase I)
- Kishore Pochiraju – Stevens
- Chris Snyder - Stevens
- Gregg Vesonder – Stevens (Phase I)
- Lu Xiao – Stevens (Phase I)
- Brian Chell (Grad) – Stevens
- Luigi Ballarinni (Grad) – Stevens
- Harsh Kevadia (Grad) – Stevens
- Kunal Batra (Grad) – Stevens
- Khushali Dave (Grad) – Stevens
- Rob Cloutier – Visiting Professor
- Robin Dillon-Merrill – Georgetown Univ.
- Ian Grosse – Univ. of Massachucetts
- Tom Hagedorn – Univ. of Massachusetts
- Todd Richmond – Univ. of Southern California (Phase I)
- Edgar Evangelista – Univ. of Southern California (Phase I)

RT-195
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Ralph Giffin - Stevens
- Benjamin Kruse - Stevens
- Russell Peak – Georgia Tech.
- Stephen Edwards – Georgia Tech.
- Adam Baker (Grad) – Georgia Tech.
- Marlin Ballard (Grad) – Georgia Tech.
- Donna Rhodes - MIT
- Mark Austin – Univ. Maryland
- Maria Coelho (Grad) – Univ. Maryland

WRT-1008
- Mark Blackburn (PI), Stevens
- Mary Bone - Stevens
- Benjamin Kruse - Stevens
- Bill Rouse – Stevens/Georgetown
- Russell Peak – Georgia Tech.
- Selcuk Cimtalay – Georgia Tech.
- Adam Baker (Grad) – Georgia Tech.
- Marlin Ballard (Grad) – Georgia Tech.
- Alanna Carnevale (Grad) – Georgia Tech.
- William Stock (Grad) – Georgia Tech.
- Donna Rhodes - MIT
- Mark Austin – Univ. Maryland
- Maria Coelho (Grad) – Univ. Maryland

ART-002
- Mark Blackburn (PI), Stevens
- Dinesh Verma (Co-PI) – Stevens
- Kunal Batra – Stevens
- Mary Bone - Stevens
- John Dzielski, Stevens
- Steven Hoffenson - Stevens
- Steve Hespelt - Stevens
- Roger Jones - Stevens
- Benjamin Kruse - Stevens
- Chris Snyder - Stevens
- Brian Chell (Grad) – Univ. Maryland
- Ian Grosse – Univ. of Massachucetts
- Tom Hagedorn – Univ. of Massachusetts

Organization

- WHAT: Context and Scope of NAVAIR SE Transformation
- HOW: Use Evolving Surrogate Pilot and Experiments to Demonstrate Art-of-the-Possible
- HOW: Transformation Elements Moving from Documents to Models
- HOW: Phase II Objectives (FY19) Aligns with SE Transformation (SET) Priorities
- HOW WELL: Contributing Modeling Examples to Support Workforce Development demonstrating Art-of-the-Possible

WHAT:
Context and Scope of NAVAIR SE Transformation

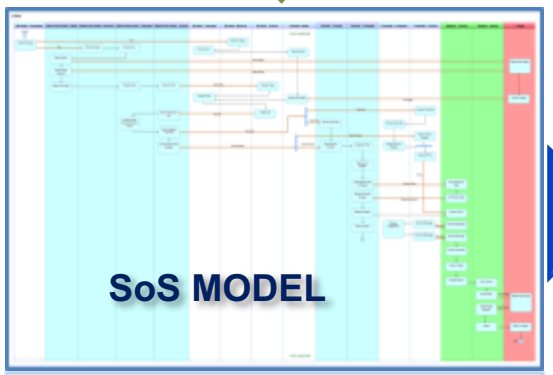
Research in the Context of

Surrogate Pilot Experiments

Capability Based Acquisition - Outpacing the Threat
Digital Thread enables rapid delivery of Integrated Capabilities

Integration and Interoperability (I&I)

Integrated Warfare Analysis establishes CONEMPS and Effects-Chains

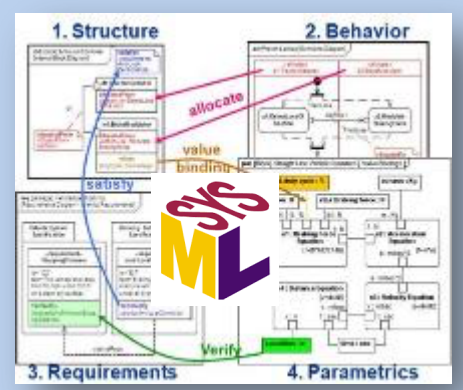


CONEMPS and Effects Chains are modeled at the System of Systems (SoS) level

System models form "Constructive" basis for LVC M&S environment

SE TRANSFORMATION

SYSTEM MODELS



Systems are developed in a Model-Based environment

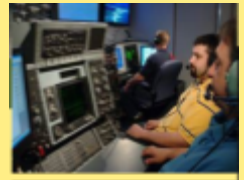
Capabilities-Based T&E

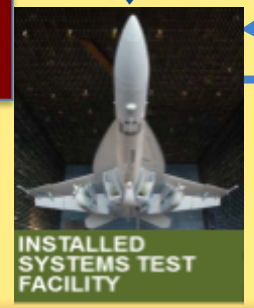
Constructive | Virtual | Live


DIGITAL MODELING

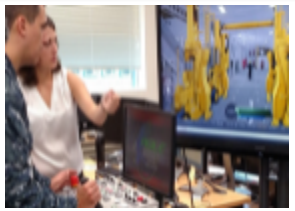

HARDWARE IN THE LOOP


FLIGHT TEST


INTEGRATION LABORATORY


INSTALLED SYSTEMS TEST FACILITY

Focus is Here



LVC-based Training maximizes Fleet proficiency

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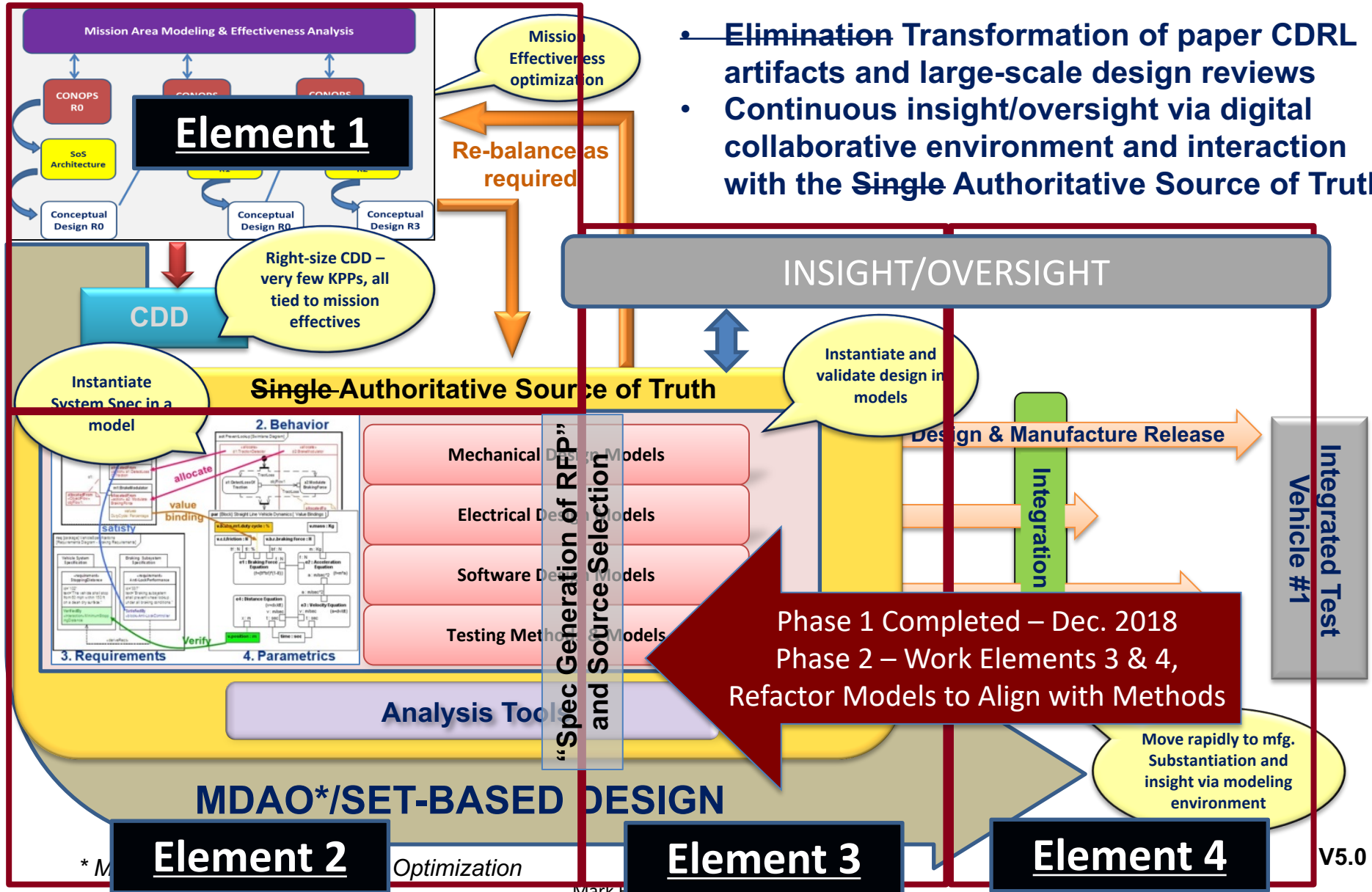
Surrogate Pilot focus is on Characterizing Assessing, and Refining SET Framework for Model-Based Acquisition

SET Framework Concept Initially Rolled Out 2016

- ~~Elimination~~ Transformation of paper CDRL artifacts and large-scale design reviews
- Continuous insight/oversight via digital collaborative environment and interaction with the ~~Single~~ Authoritative Source of Truth



CDRL: Contract Data Requirements List

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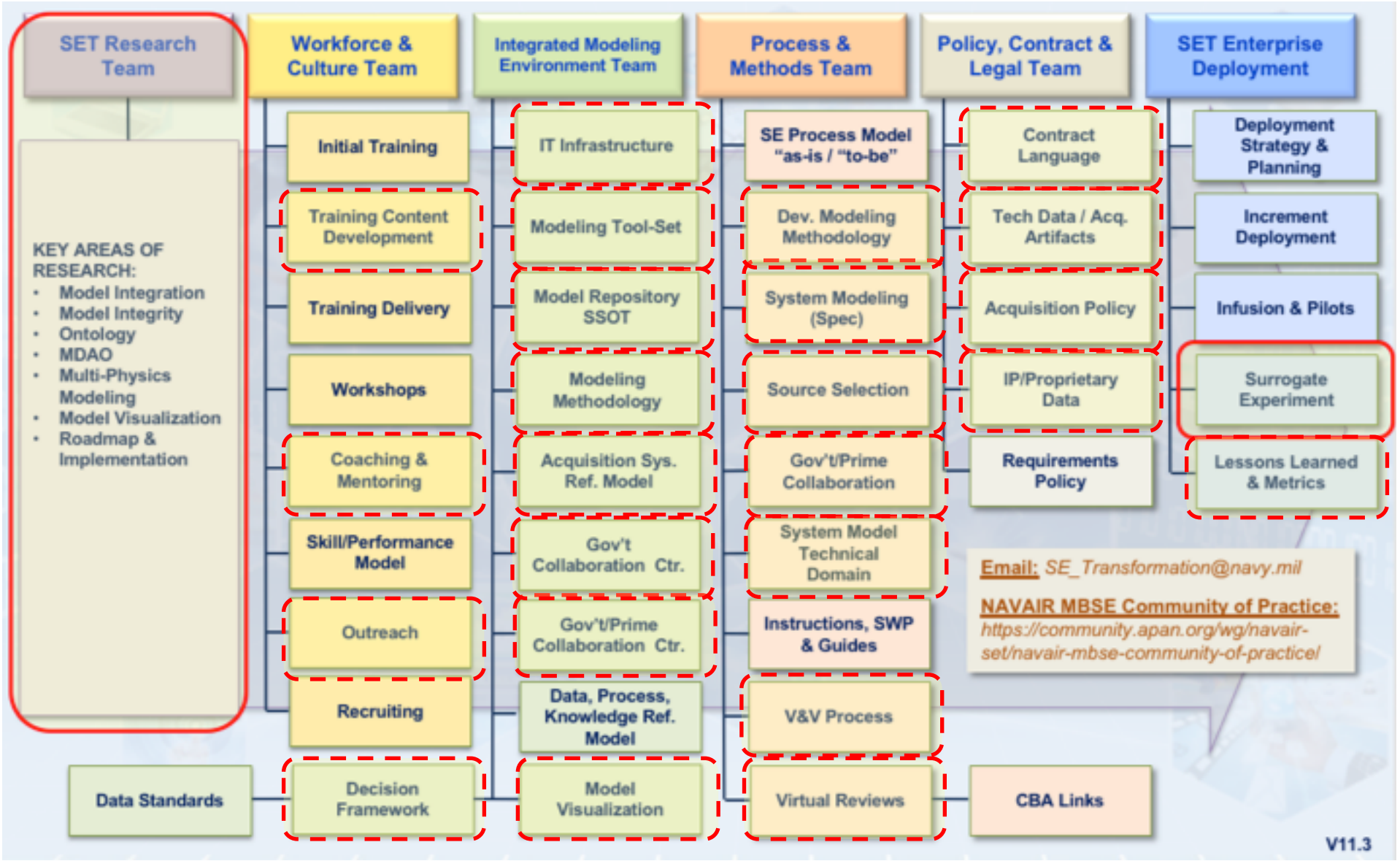
Research and Surrogate Experiment contributes broadly to SET Functional Areas



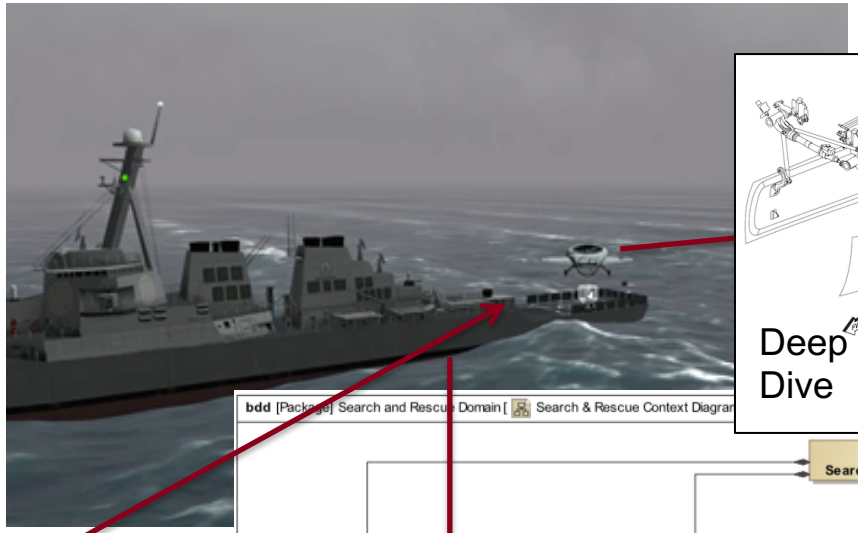
HOW:
Use Evolving Surrogate Pilot and Experiments to Demonstrate Art-of-the-Possible

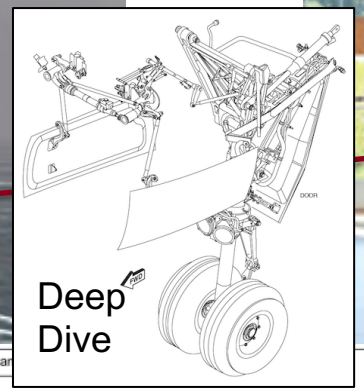
- **Doing "Everything" in Models to show we can**
- **Operating in a Collaborative Environment**
- **Using an Authoritative Source of Truth**

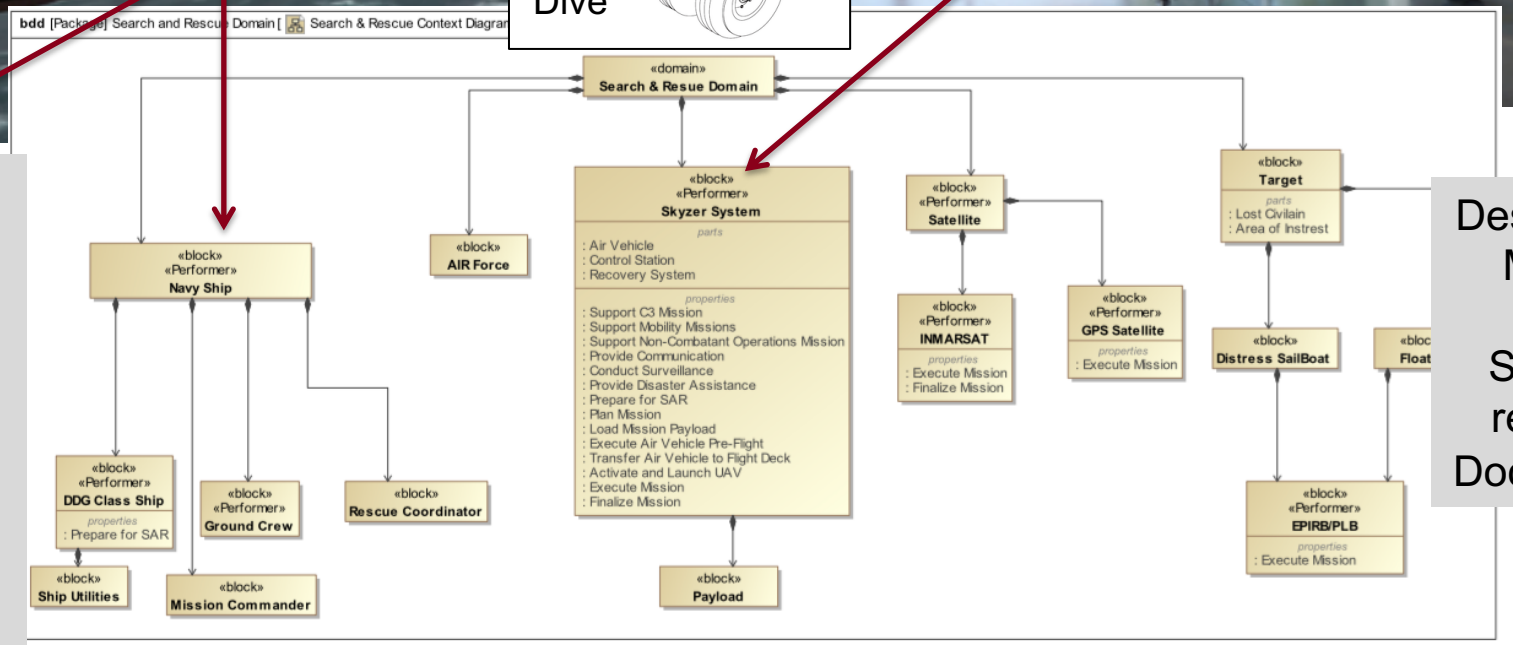
Surrogate Pilot Scenario: Skyzer UAS & Launch and Recovery for Landing Gear Deep Dive

Graphical CONOPS Scenario: Search & Rescue

Performance constraints force Multi-physics Design considerations - similar to Bell Eagle Eye





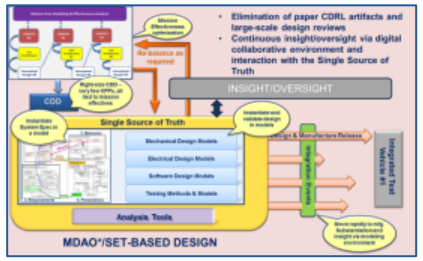


Skyzer System & Mission Models developed using SysML

Phase II is adding ship-based Launch and Recovery Capability & Deep Dive supports Airworthiness Use Case

Descriptive Model (e.g., SysML) replace Documents

Research Use Cases for Surrogate Pilot and Experimental System (Skyzer)



Surrogate Pilot Use Cases (UC)

Collaboration in Authoritative Source of Truth UC

Assess SE Framework Concept

We are Collaborating in AST

Skyzer is Experimental UAS System using Authoritative Source of Truth (AST)

Project Plan Model UC

Mission Model UC

Uses

System Model UC

Uses

Contractor(s) System Model(s) UC

Links

Contractor Design Model UC

Source Selection UC & Models

Everything done in models to demonstrate "Art of the Possible"

Phase 1 Complete
Phase 2 – Work Elements 3 & 4

Mission Models
System Models
SOW Models
Evaluation Model
Based on Standards

RFI

RFP

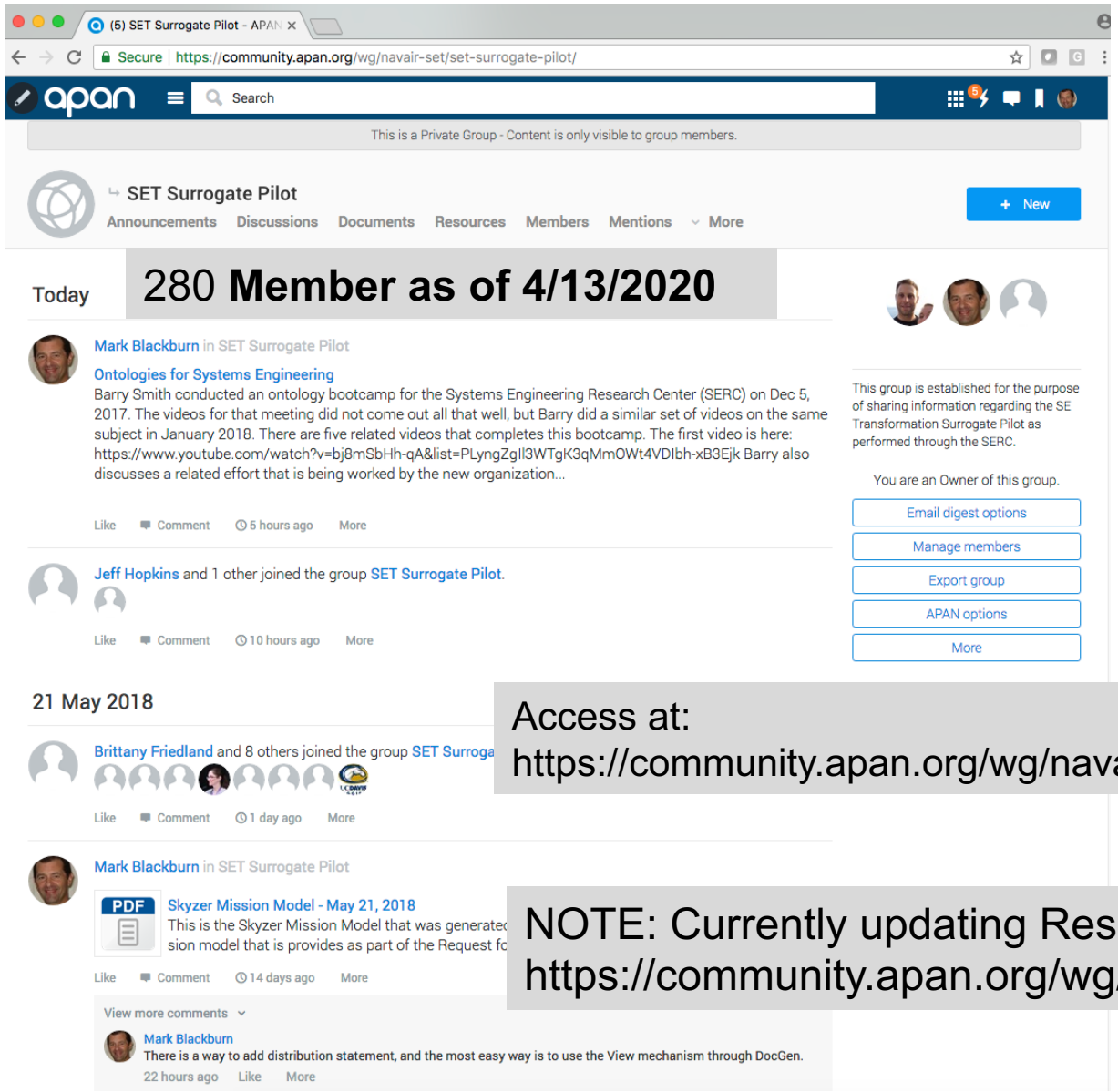
GFI

RFP Response Extends GFI

Proposal for Design Models focused to demonstrate aspects for Producability Decisions involving **Multi-physics**

GFI: Government Furnished Information

Continuous Updates of Discussion Threads Provided on Public All Partners Network



- Briefings
- Videos
- Models
- Discussion threads
- Instructs to see models on AWS

Access at:
https://community.apan.org/wg/navair-set/set-surrogate-pilot/

NOTE: Currently updating Research Group for Phase II
https://community.apan.org/wg/navair-set/research/

HOW:
Transformation Elements
Moving from Documents to Models

- **Developing/demonstrating Methods for Mission and System models**
- **Using models collaboratively in Authoritative Source of Truth**
- **Using OpenMBEE/DocGen to Generate Views for Stakeholder and Discipline-Specific Subject Matter Experts**

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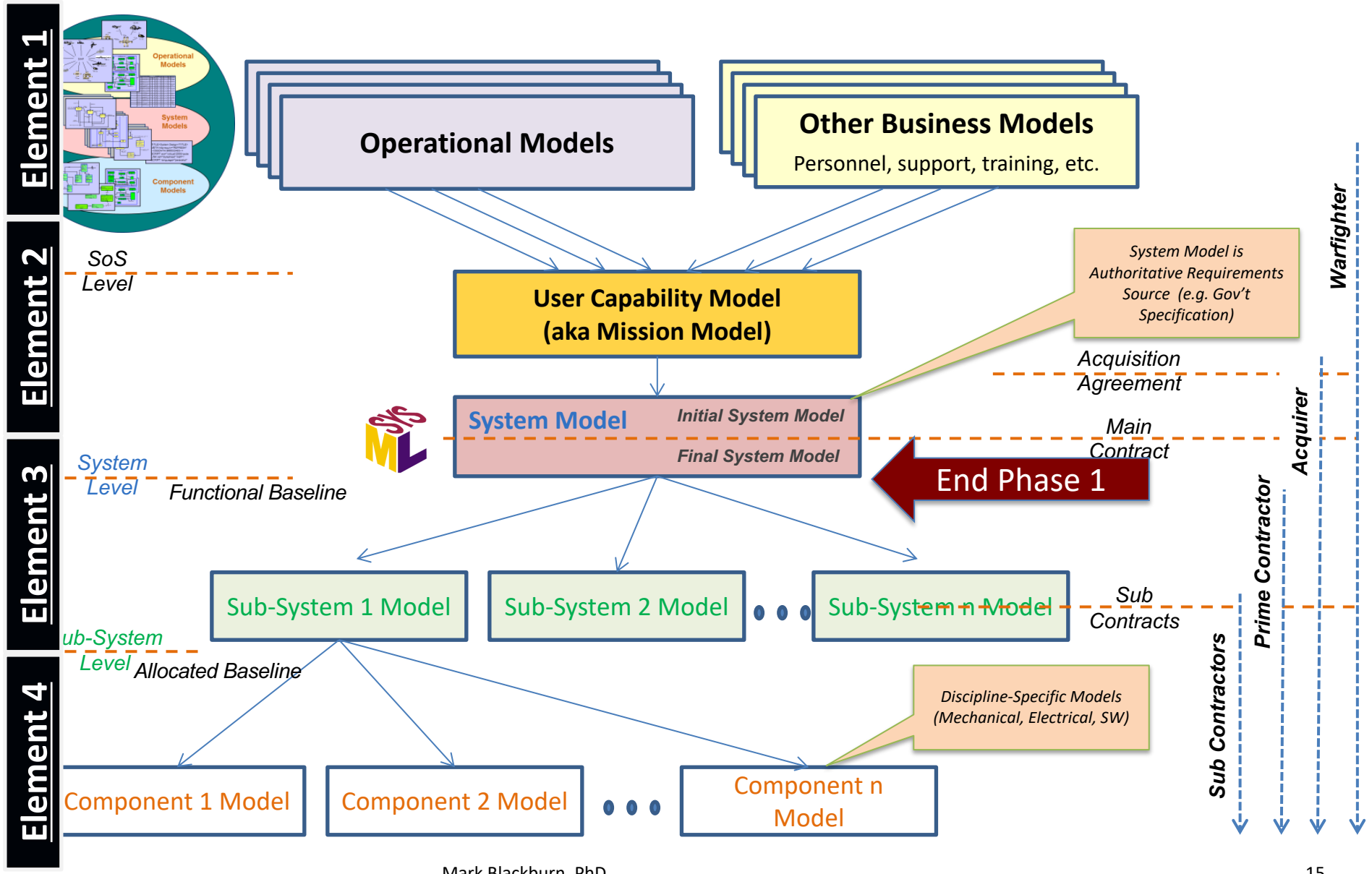
Skyzer Demonstrates Formalizing the Use of Models and Methods for the SET Framework Elements

Phase 2 focused on Elements 3 & 4 of SET Framework: How to reduce time by using models to better understand a maturing design



Mark Blackburn, PhD

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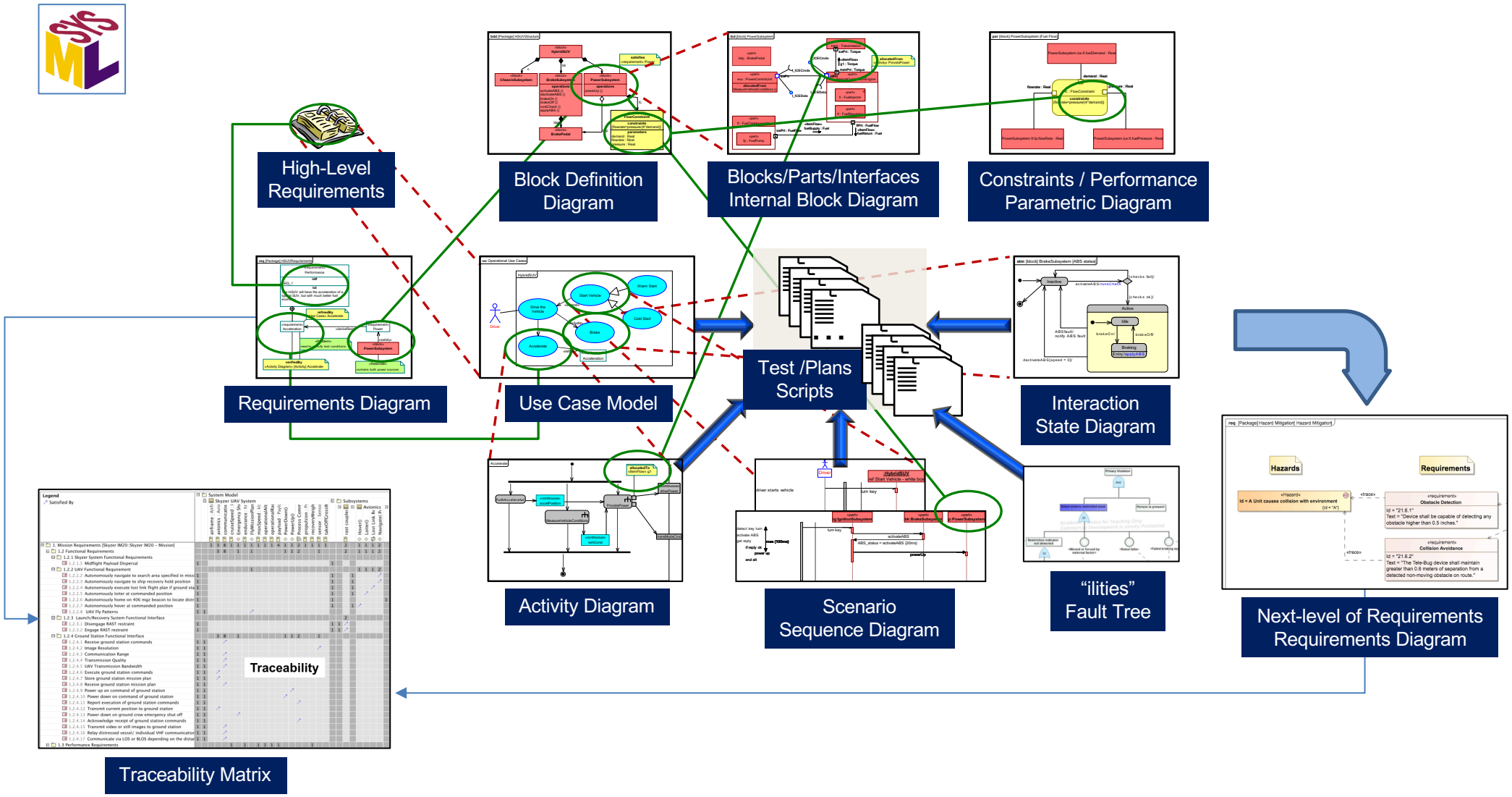
How MBSE Strengthens SE by Characterizing the Analysis of Structure, Behavior and Interfaces



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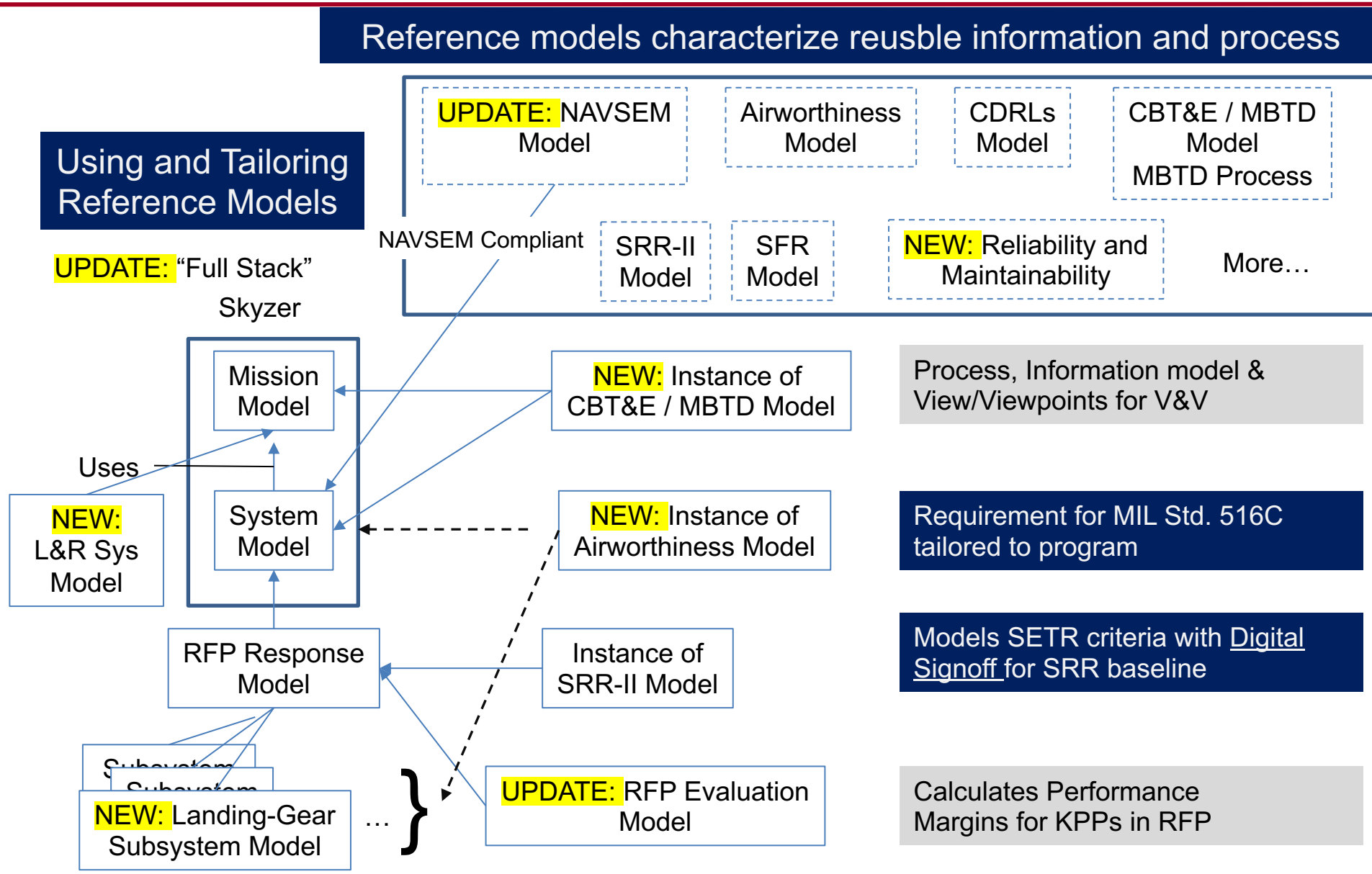
"Full Stack" of Models using Digital Signoff for Transformed SETR Criteria Represented in a Model



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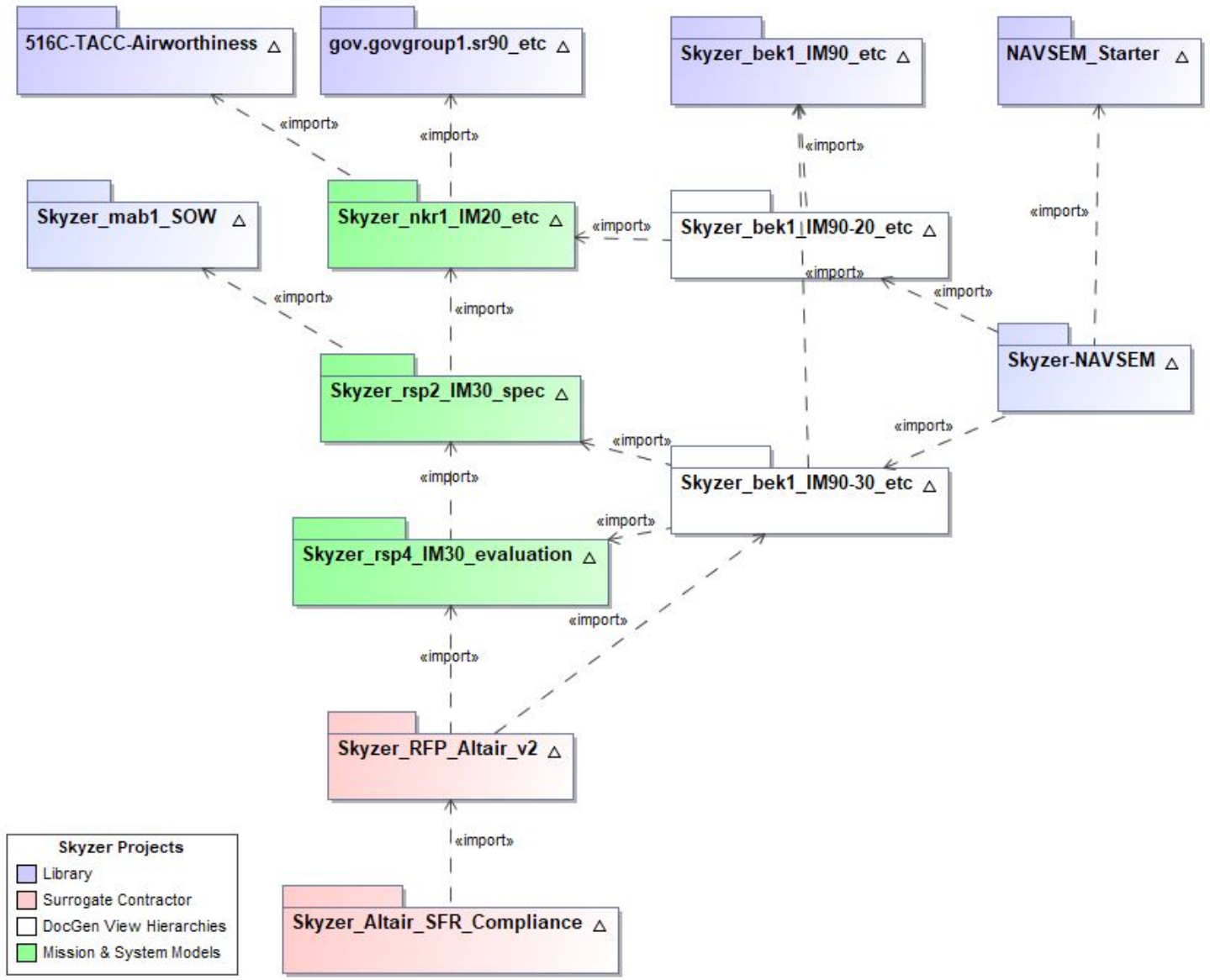
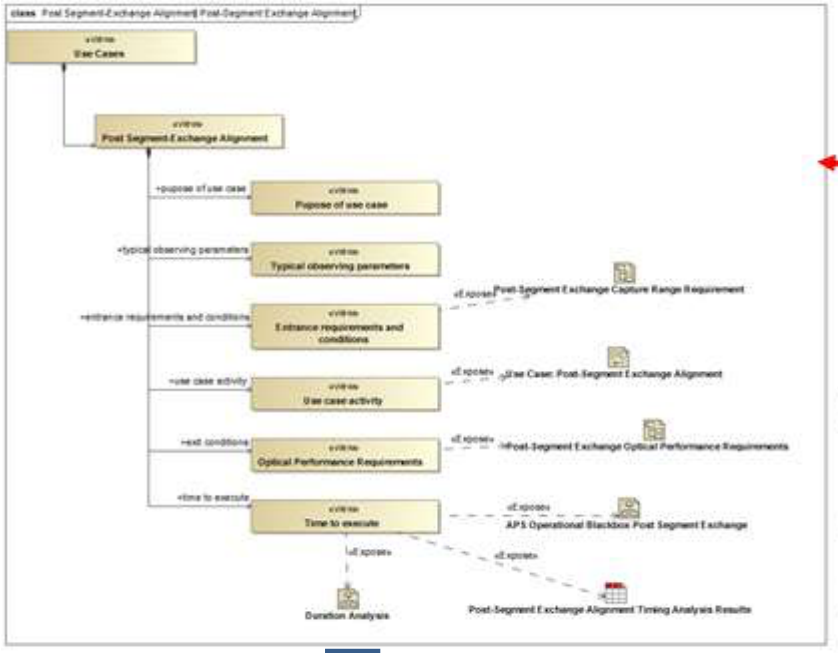
Model Organization – All Models Linked to Establish Authoritative Source of Truth

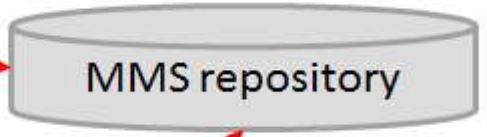


Leverage Capabilities of OpenMBEE as Part of Integrated Modeling Environment

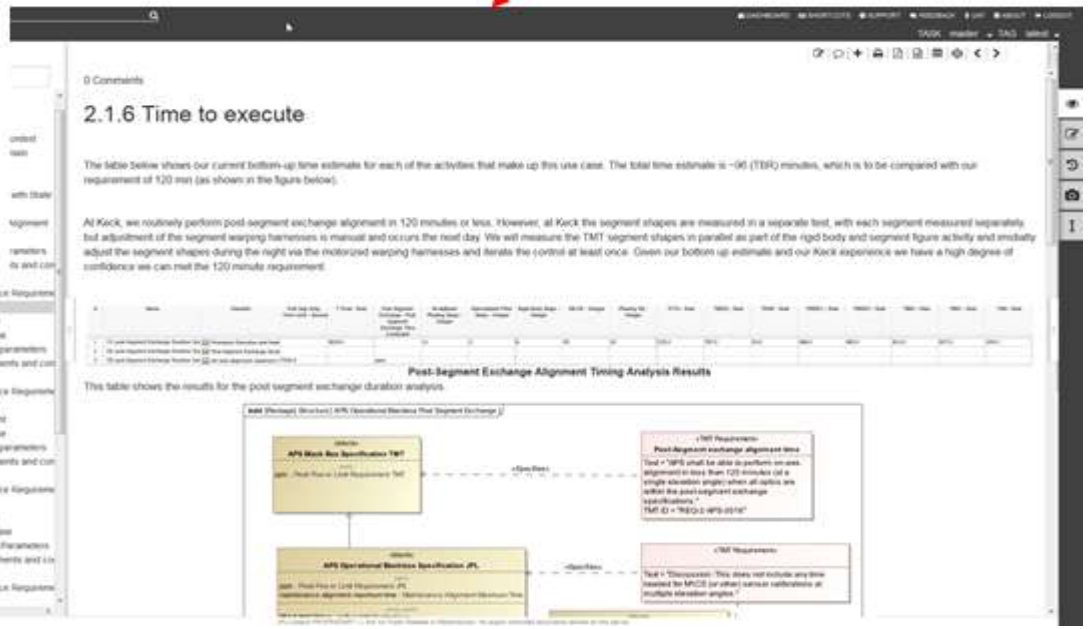
Model Development Kit/DocGen
View and Viewpoint Hierarchy



Model Management System



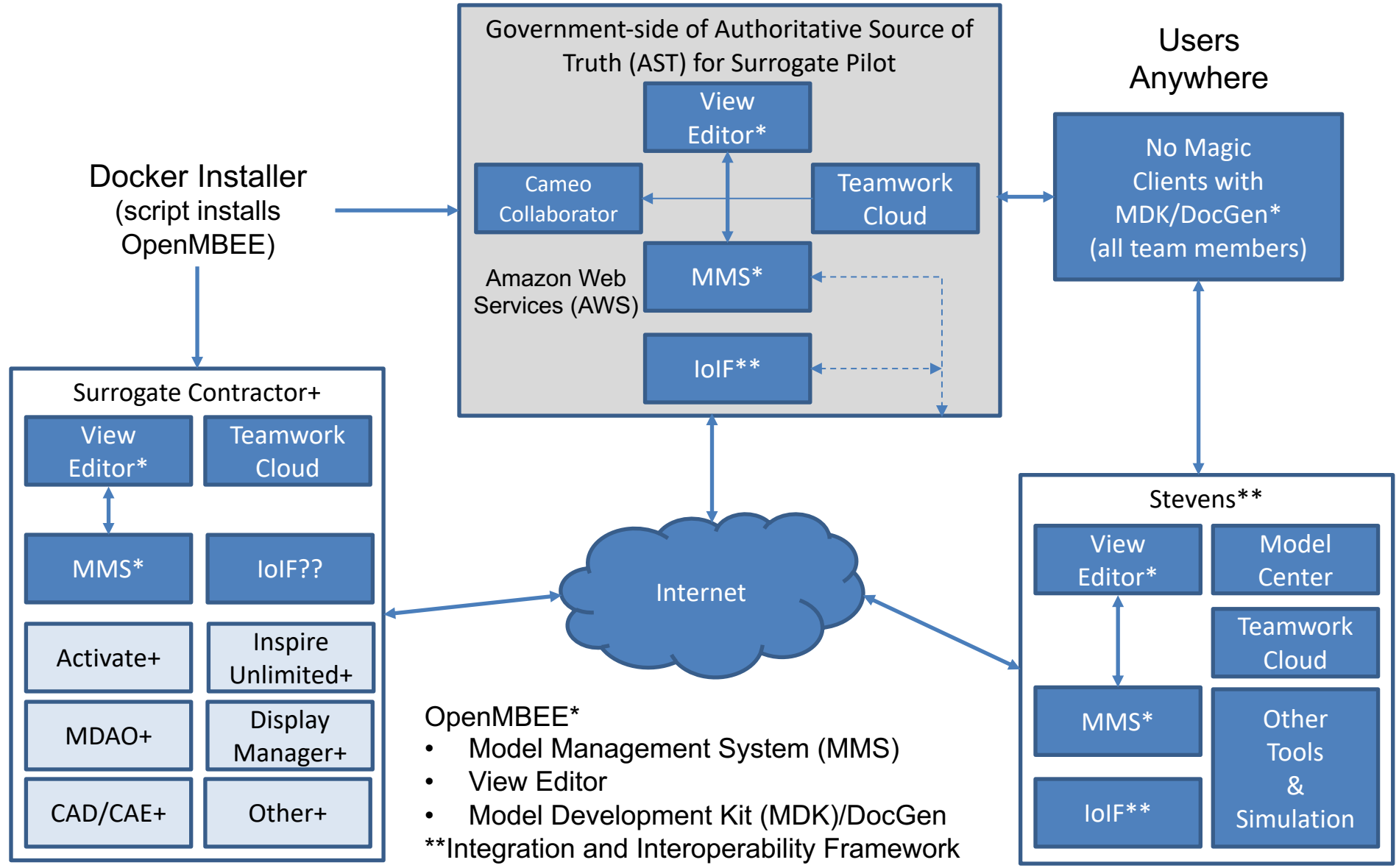
View Editor



Visualization in View Editor

(allows edits to be pushed back into model)

Elements of Authoritative Source of Truth



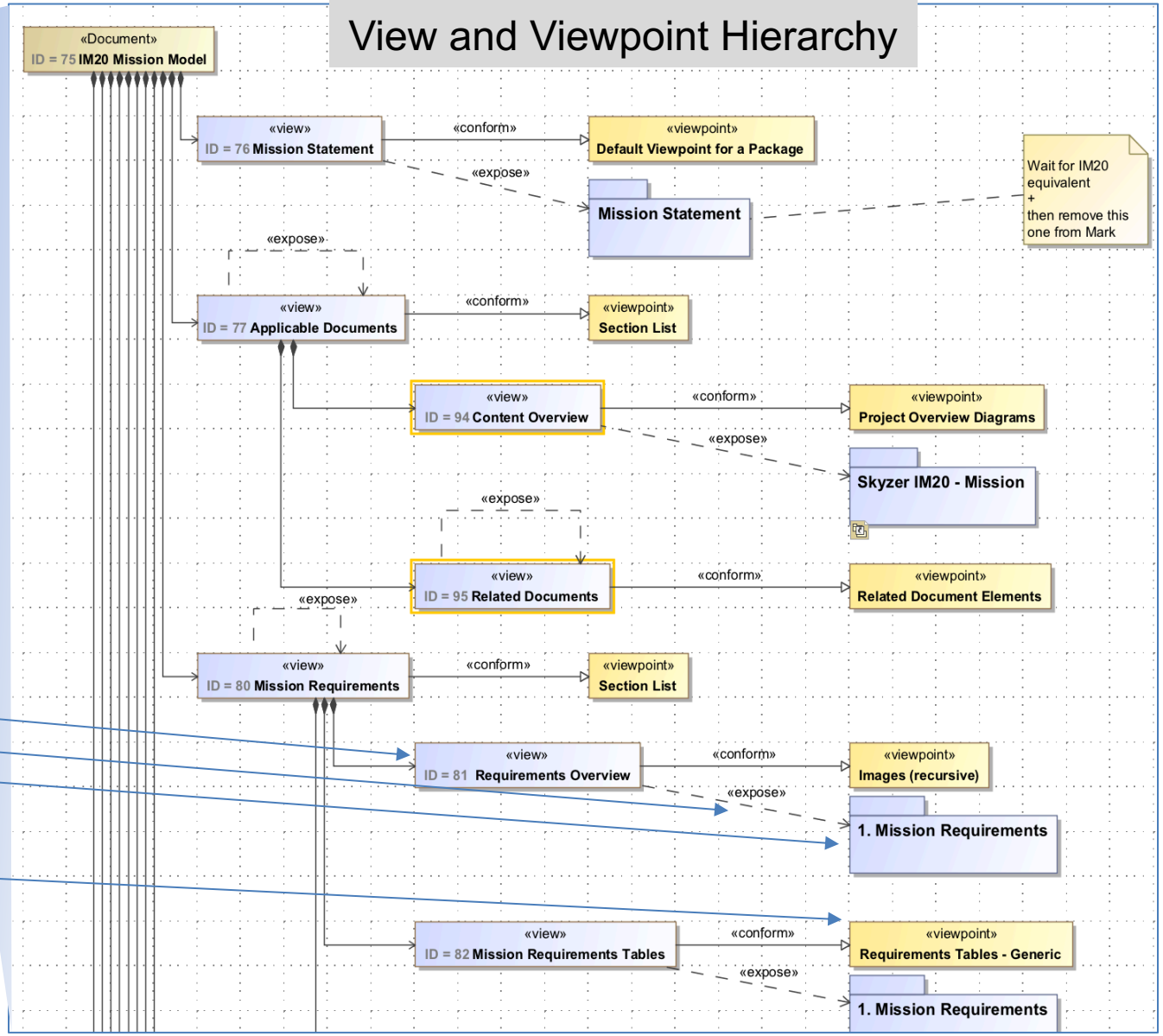
Example View and Viewpoint Hierarchy Used by DocGen

Navy Standard

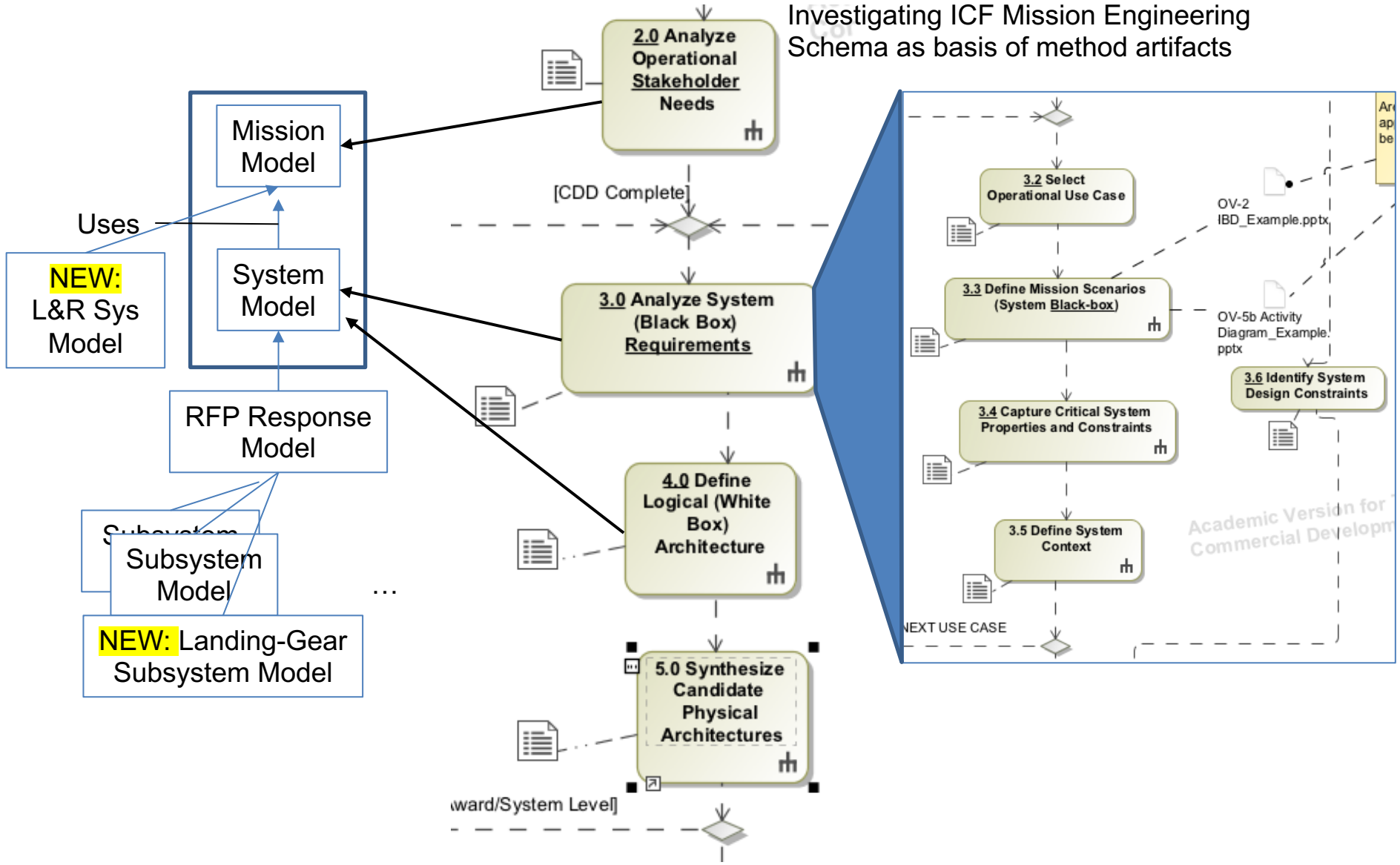
Views define “Document” Structure

View exposes Model Elements

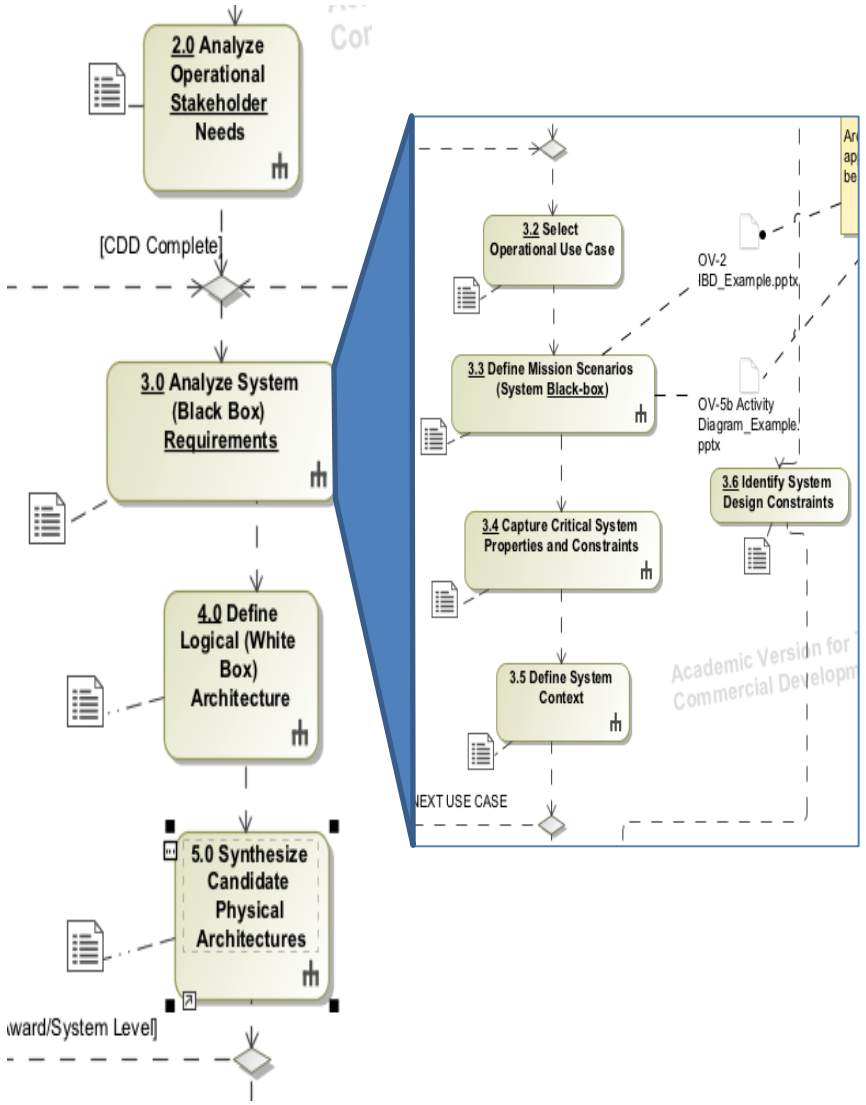
Viewpoints is “program” to extracts specific information from exposed model element to generate View

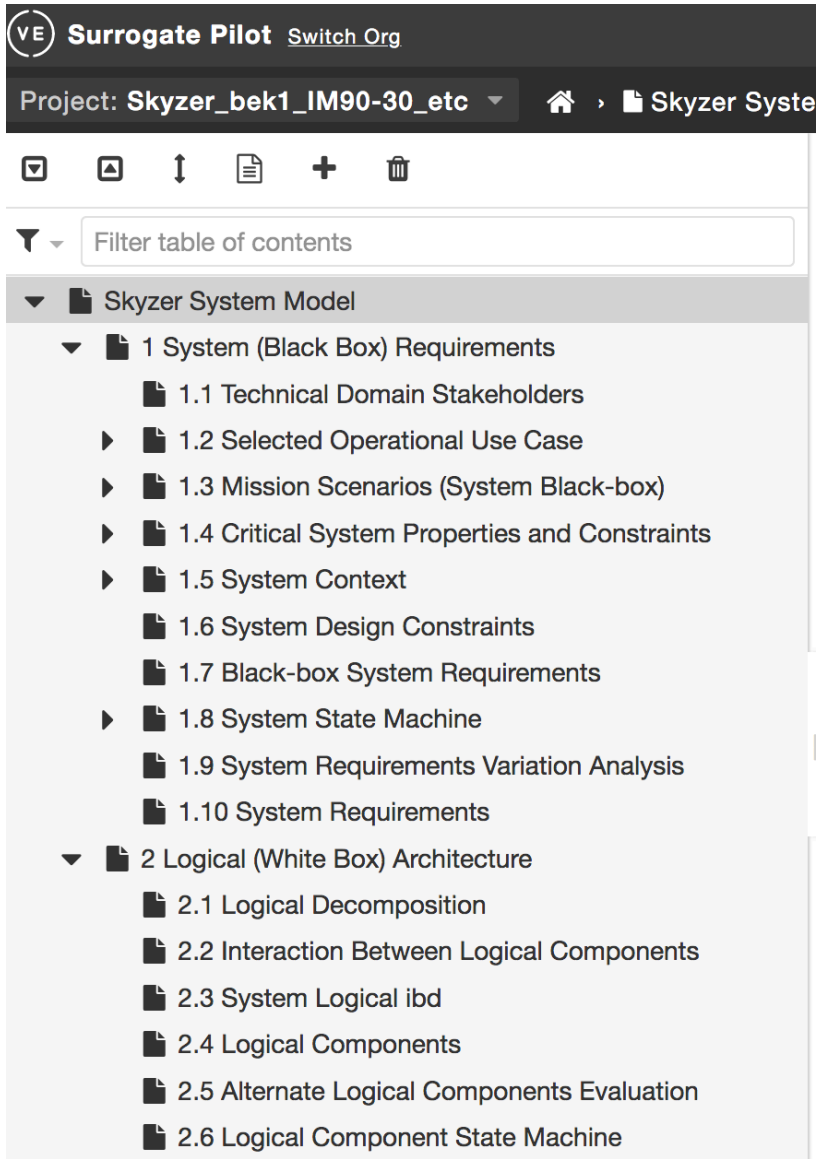


Models Need to Produce Artifacts/Work Products for NAVSEM Method

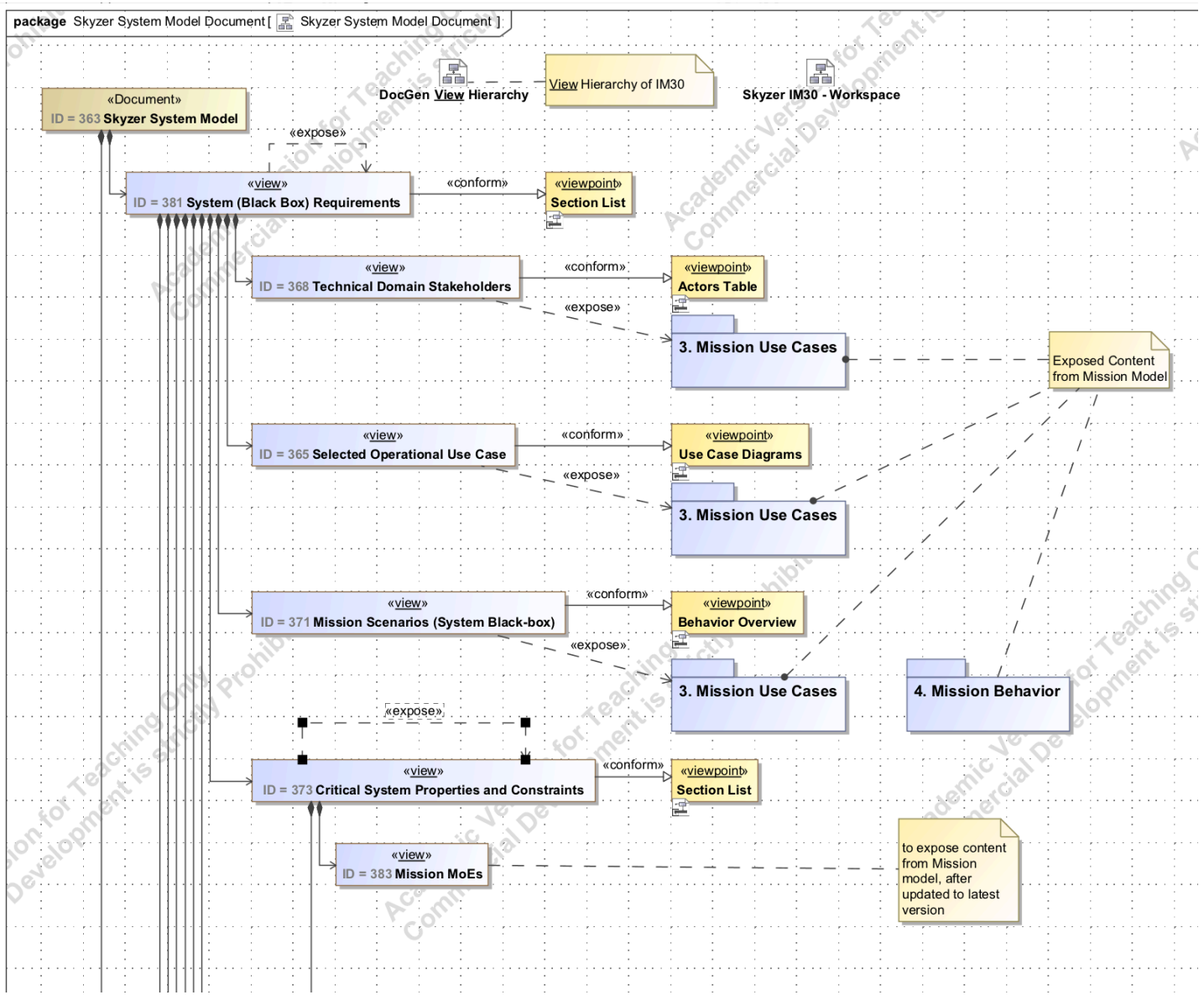


Update View and Viewpoint for Skyzer System Model

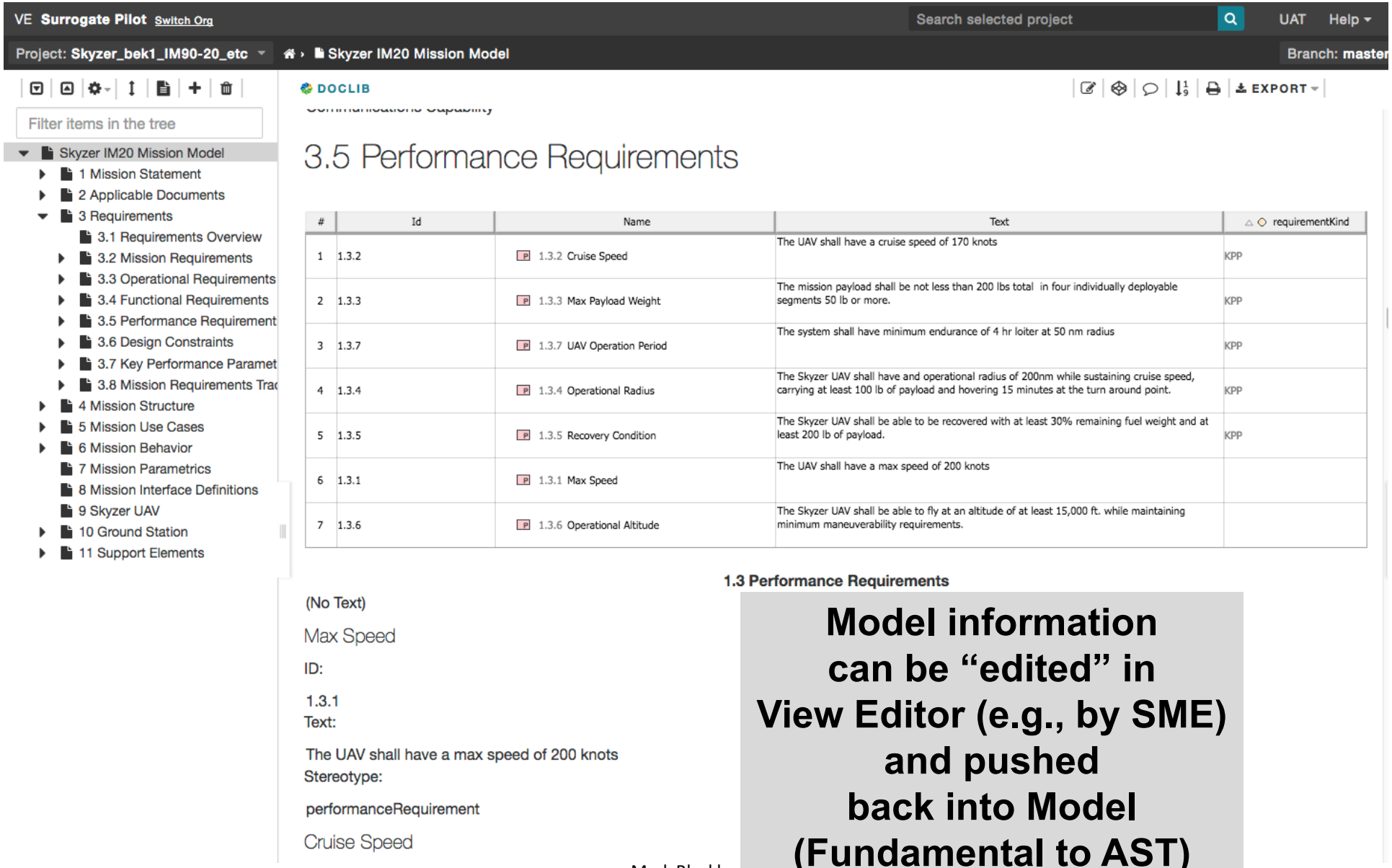




View and Viewpoint from Inside Model



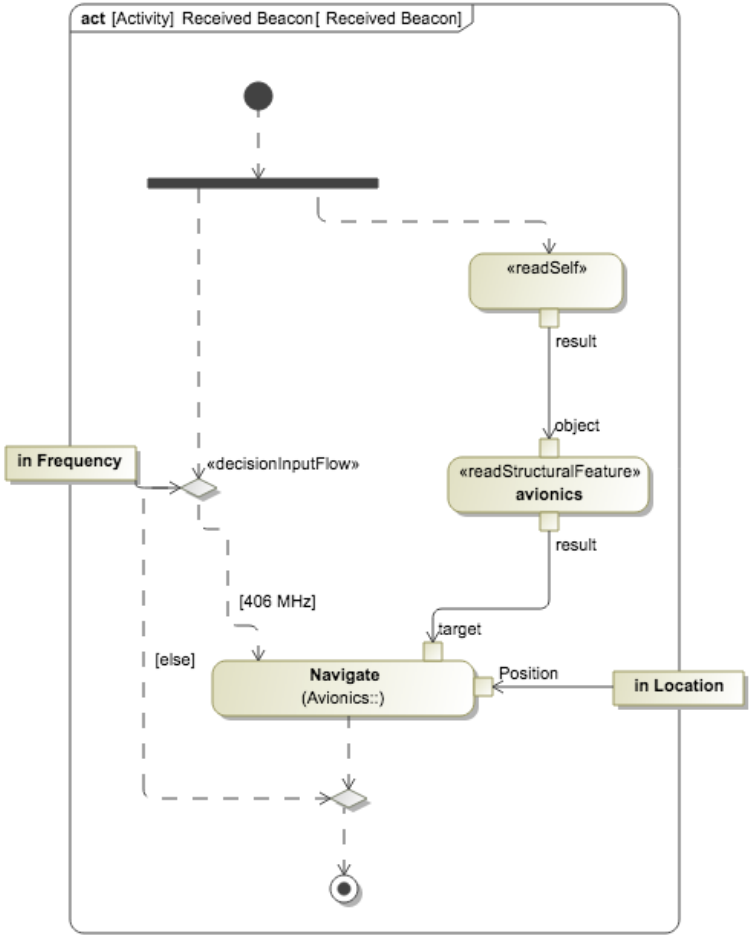
Example: View Editor shows Skyzer Mission Model View

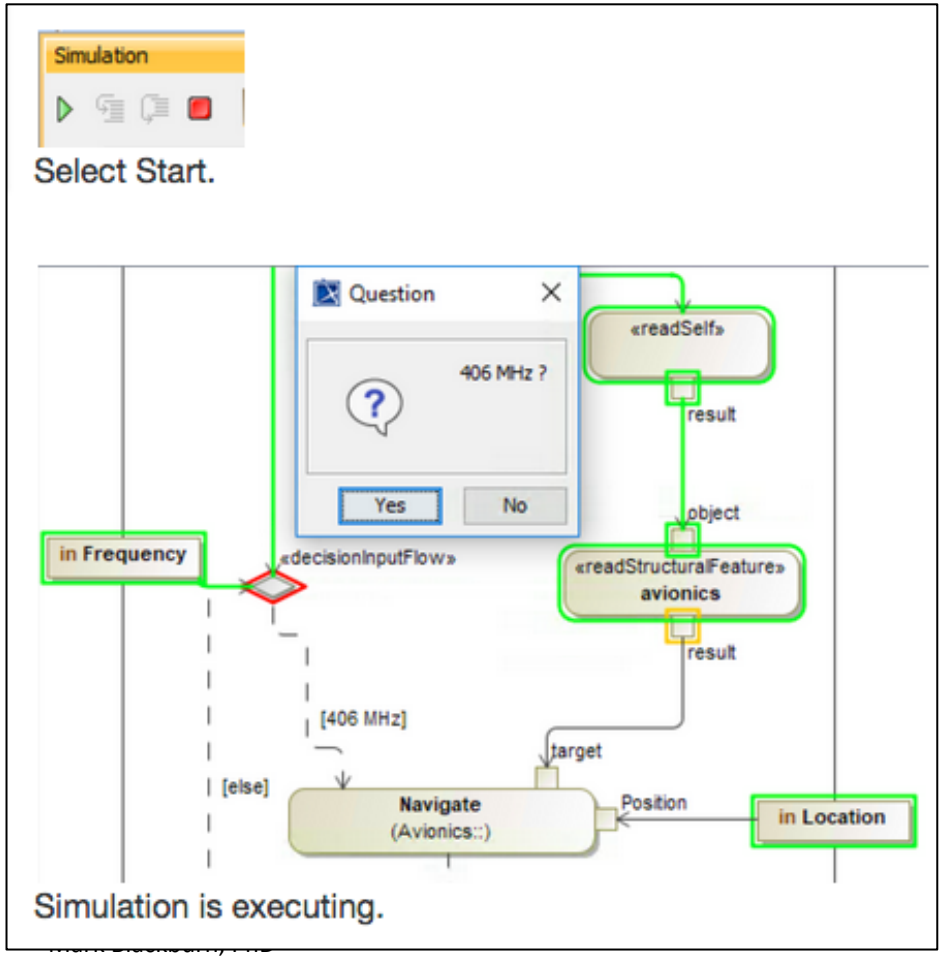


Model information can be "edited" in View Editor (e.g., by SME) and pushed back into Model (Fundamental to AST)

Mission Requirements Refined into Behaviors and Analyzed through Simulations in Skyzer System Model

- State Machine Simulation in System Model supports analysis for understanding/visualizing dynamic behaviors – getting the right model and getting the model right





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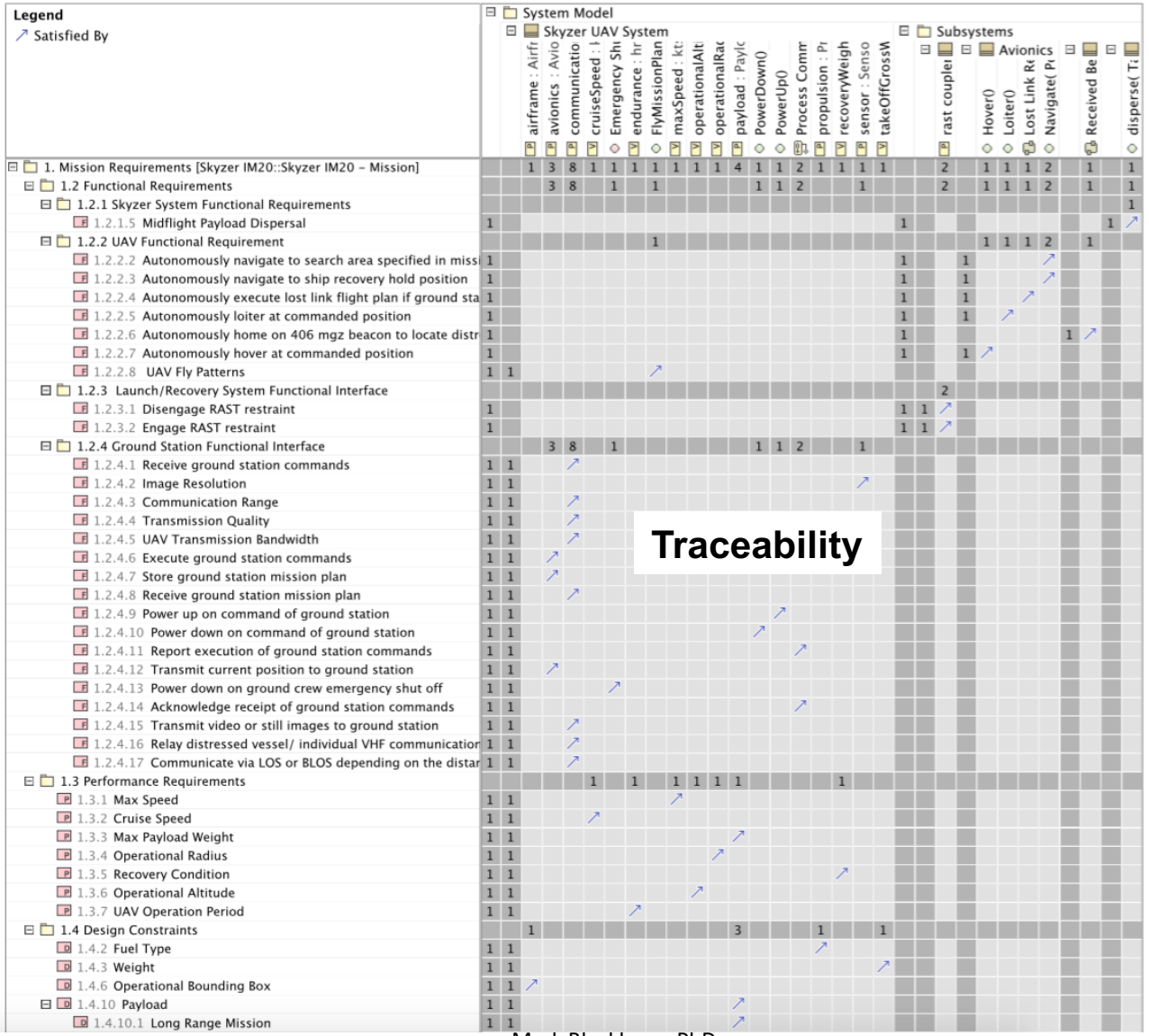
Skyzer Mission and System Requirements Traceability in Skyzer System Model

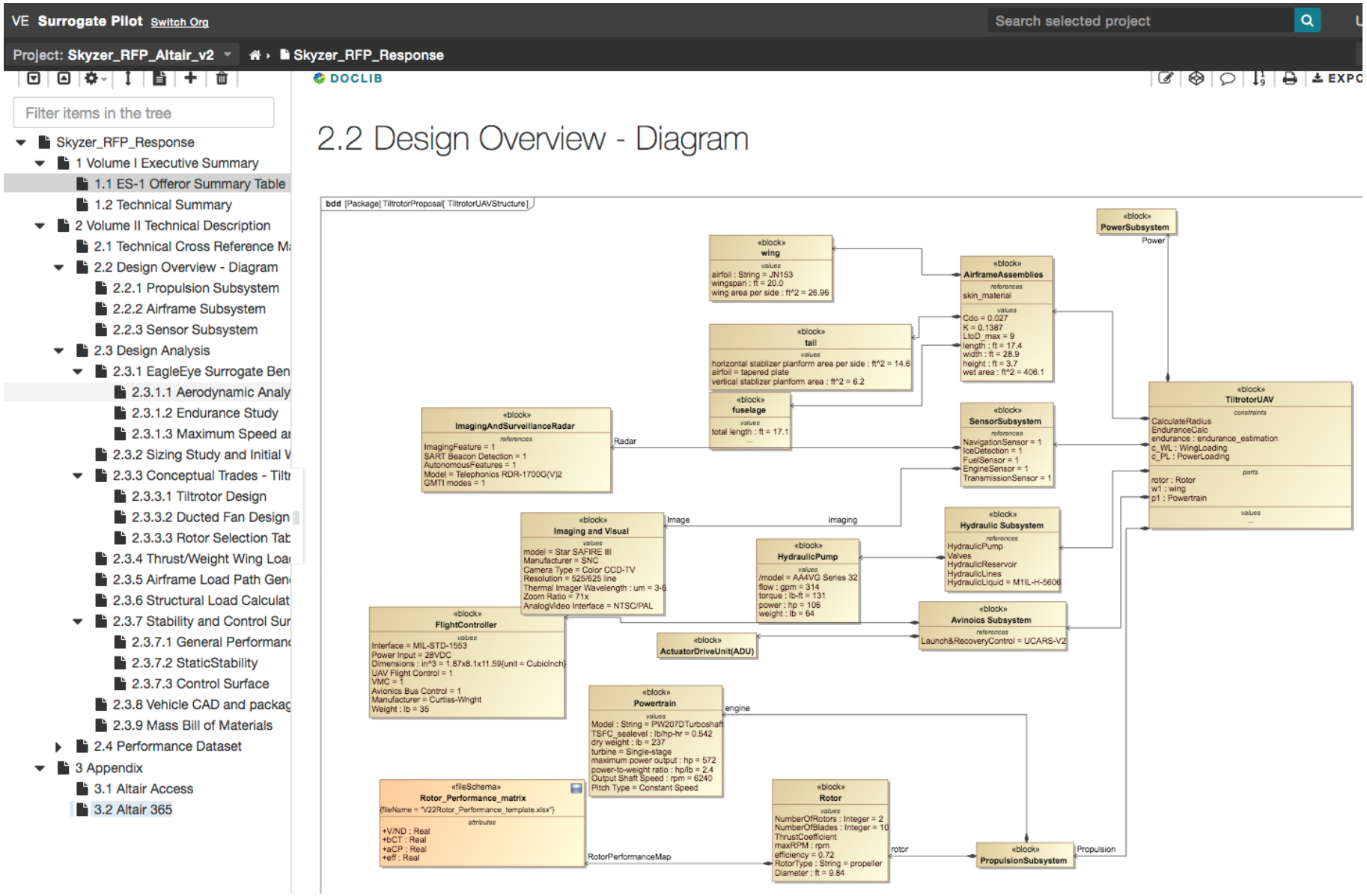
Figure 6.1. Requirements Satisfiability



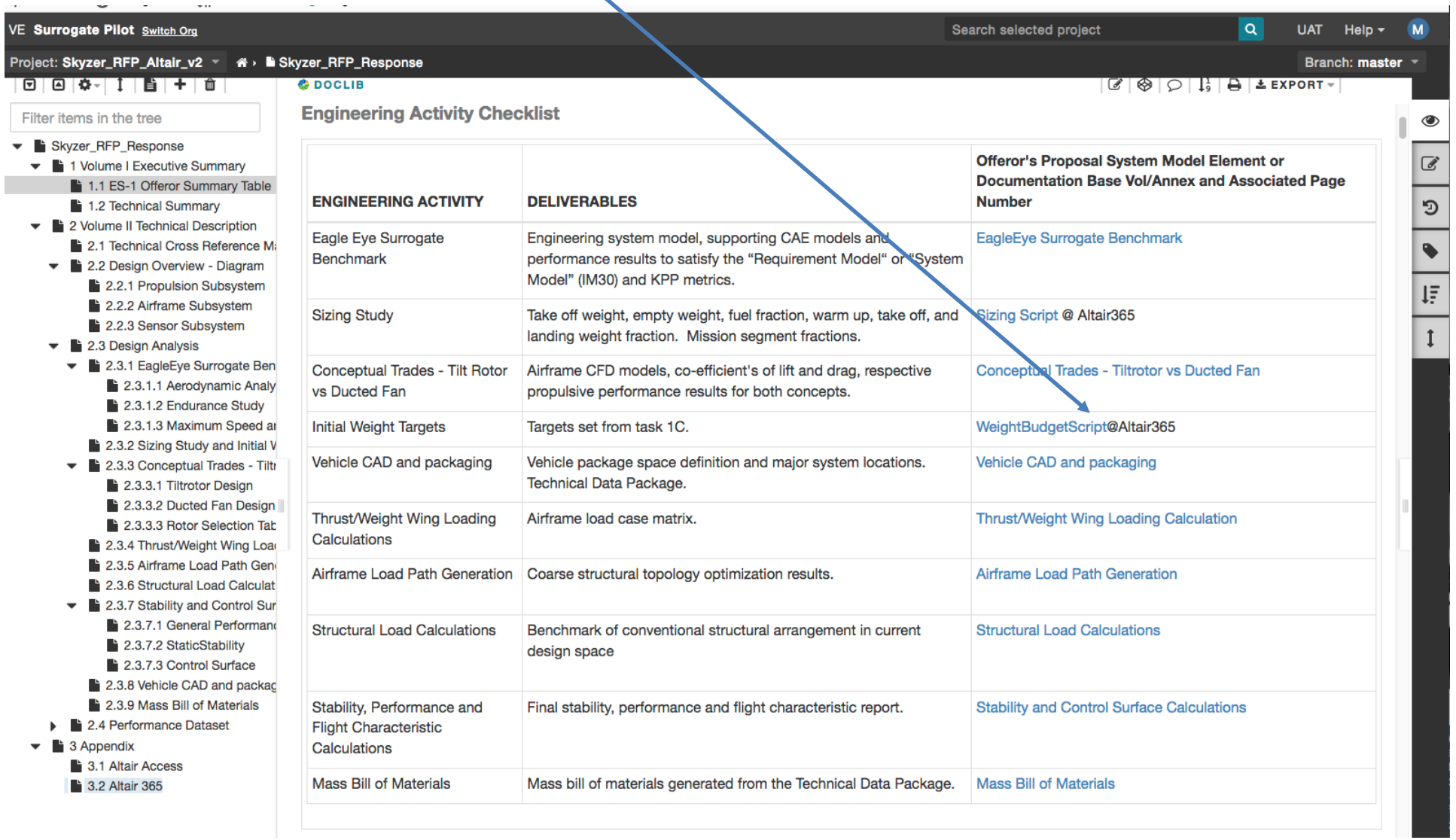
Mission Requirements

System Requirements

RFP Response Extends and Refines Skyzer System Model provided by Government as GFI



View of RFP Response Hyperlinks to Discipline-Specific Models Provided in Generated View



Surrogate Pilot RFP Response in View Editor

VE **Surrogate Pilot** Switch Org

Project: **Skyzer_RFP_Altair** › WIP

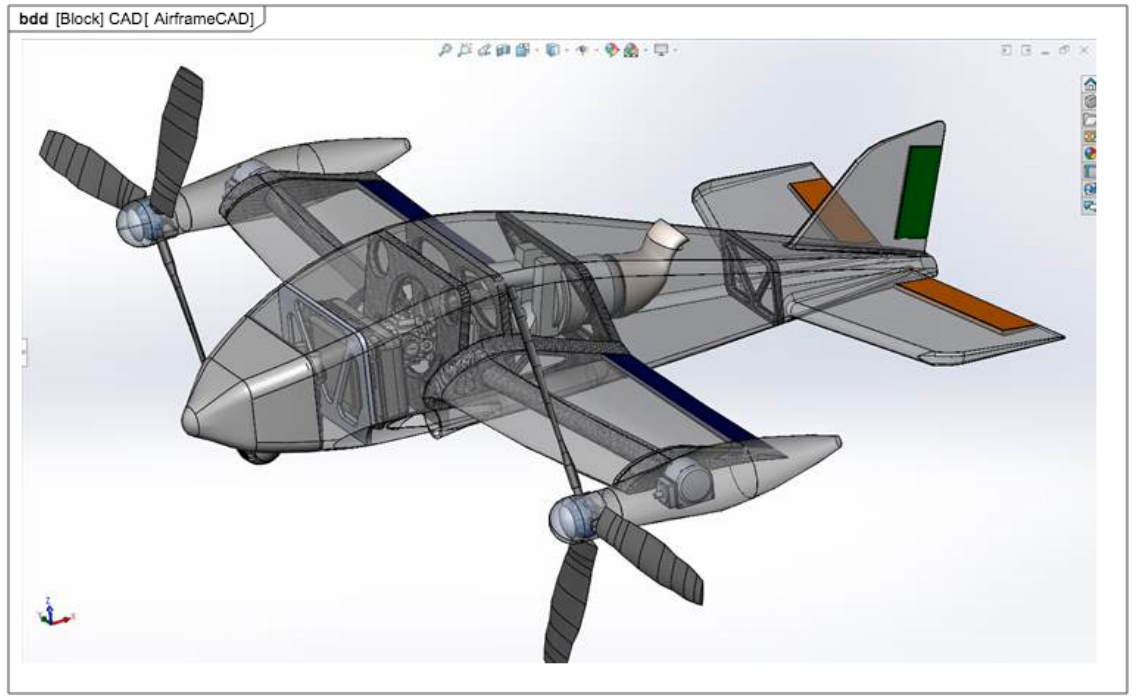
Filter items in the tree

- WIP
  - 1 Volume I Executive Summary
    - 1.1 ES-1 Offeror Summary Table
    - 1.2 Technical Summary
  - 2 Volume II Technical Description
    - 2.1 Technical Cross Reference Matrix
    - 2.2 Design Overview - Diagram
      - 2.2.1 Propulsion Subsystem
      - 2.2.2 Airframe Subsystem
      - 2.2.3 Sensor Subsystem
    - 2.3 Design Analysis
      - 2.3.1 EagleEye Surrogate Benchmark
      - 2.3.2 Sizing Study and Initial Weight Targ
      - 2.3.3 Conceptual Trades - Tiltrotor vs Du
      - 2.3.4 Vehicle CAD and packaging
      - 2.3.5 Thrust/Weight Wing Loading Calcu
      - 2.3.6 Airframe Load Path Generation
      - 2.3.7 Weight Study
      - 2.3.8 THPropulsion and Fuel System Inte
      - 2.3.9 Payload and OnBoard System Pac
      - 2.3.10 Launch and Recovery System Int
      - 2.3.11 Structural Load Calculations
      - 2.3.12 Stability, Performance and Flight
      - 2.3.13 Bill of Materials
  - 3 Appendix
    - 3.1 Altair Access
    - 3.2 Altair 365

DOCLIB

TiltrotorUAVStructure

(No Text)



AirframeCAD

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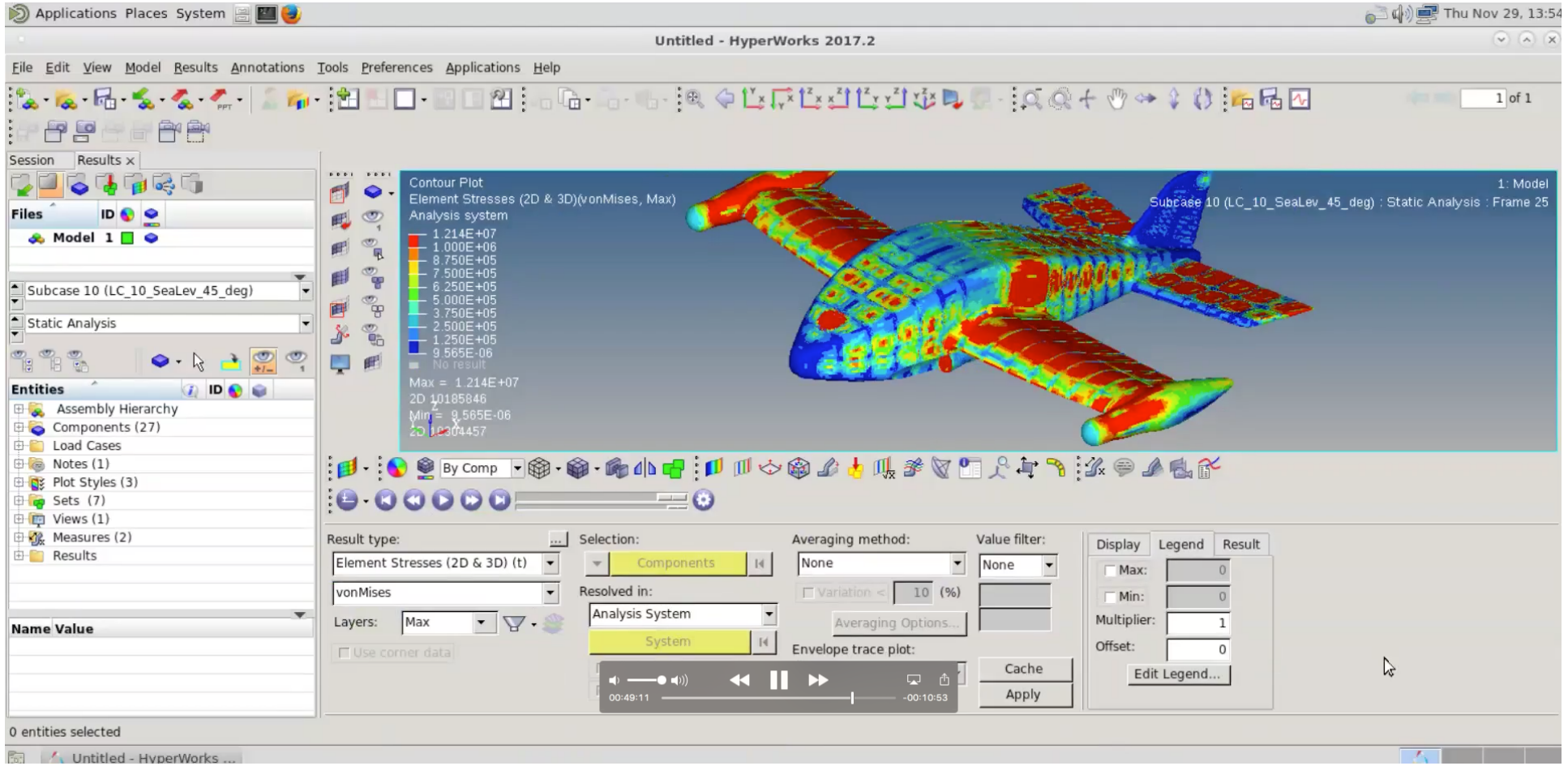
2.2.1 Propulsion Subsystem

Views Provides Hyperlinks into Discipline-specific Models and Simulation Analyses

- Research currently investigating how to do reviews and Digital Signoffs in Model for Transforming CDRL/DIDs



Transform CDRLs and DIDS using Digital Signoff in Model Through View Editor

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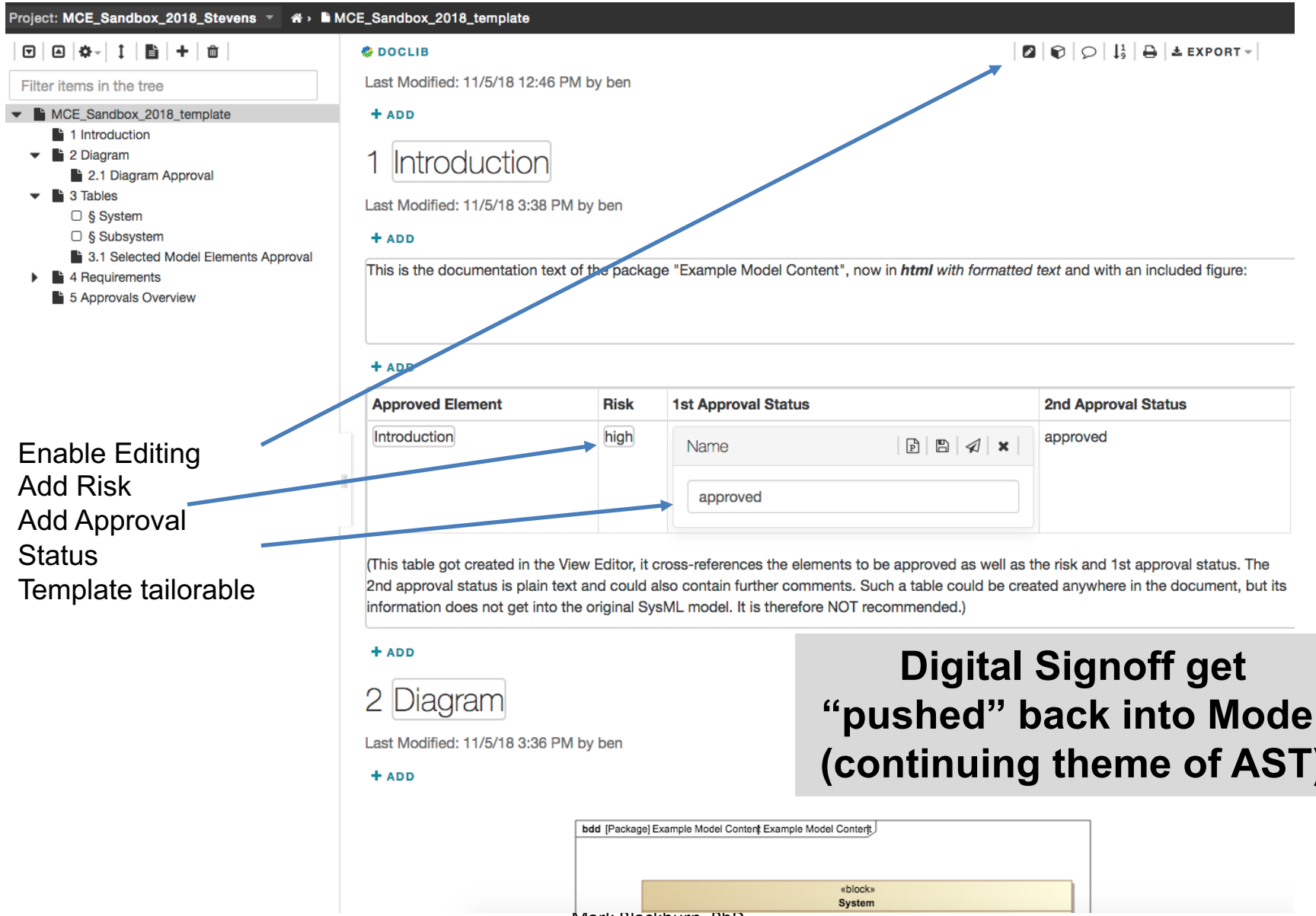
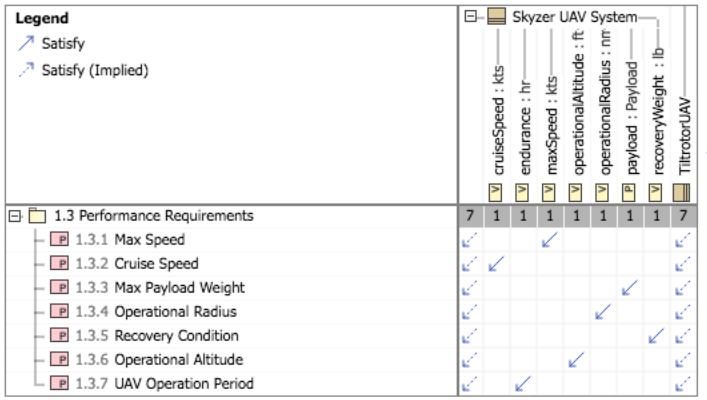
1) Enable Editing
2) Add Risk
3) Add Approval Status
4) Template tailorable



Digital Signoff get "pushed" back into Model (continuing theme of AST)

Digital Signoff for SRR-II Criteria in Skyzer RFP View



Model artifact provides evidence for SETR criteria

PerformanceRequirements

+ ADD

Performance parameters are used in Evaluation model. To maintain the evaluation process, these value can't be redefined in contractor's system model. Therefore, this performance table inherits the value properties defined in Skyzer UAV System.

+ ADD

2.5.3.1 Performance Requirements SignOff

Last Modified: 12/7/18 11:47 AM by ben

+ ADD

Criteria in existing NAVAIR Systems Engineering Technical Review (SETR) for SRR (can Digital Signoff subsume SETR)

EXPORT CSV | FILTER TABLE

Performance Requirements SignOff

Approved Elements	Risk	Approval Status	Approved By	Comment
PerformanceRequirements	medium	Value : to be defined / ✓ undefined / approved / rejected	-	Criteria SRR-II 1.f. - Requirements traceability from the CDD to the requirements baseline has been documented

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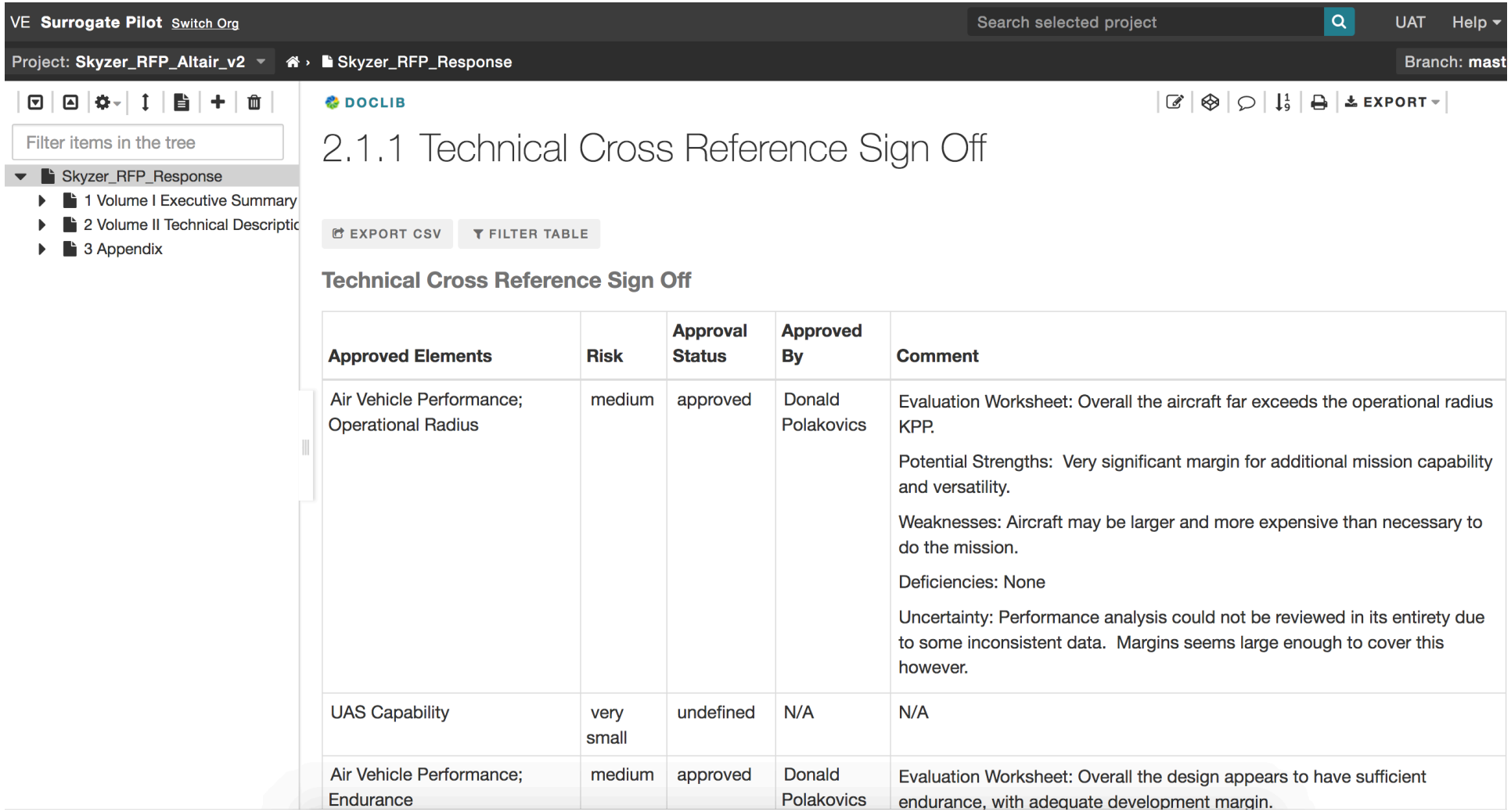
Digital Signoff of Source Selection Technical Evaluation Done In the Model that is Part of Authoritative Source of Truth



Approved Elements	Risk	Approval Status	Approved By	Comment
Air Vehicle Performance; Operational Radius	medium	approved	Donald Polakovics	Evaluation Worksheet: Overall the aircraft far exceeds the operational radius KPP. Potential Strengths: Very significant margin for additional mission capability and versatility. Weaknesses: Aircraft may be larger and more expensive than necessary to do the mission. Deficiencies: None Uncertainty: Performance analysis could not be reviewed in its entirety due to some inconsistent data. Margins seems large enough to cover this however.
UAS Capability	very small	undefined	N/A	N/A
Air Vehicle Performance; Endurance	medium	approved	Donald Polakovics	Evaluation Worksheet: Overall the design appears to have sufficient endurance, with adequate development margin.

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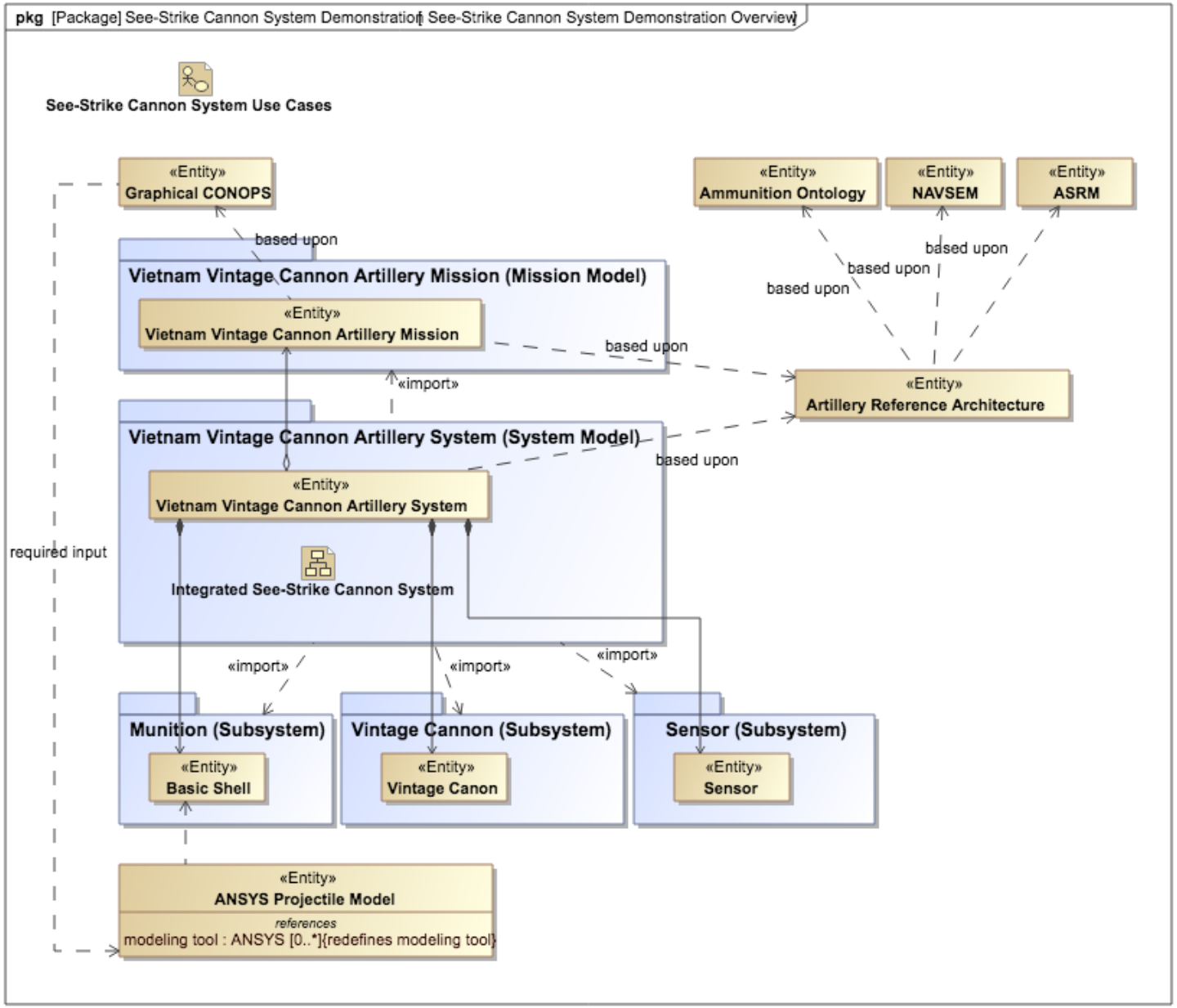
Use Case Entities (Full Stack v1) Represented in SysML Model (See Strike Cannon System)

"Full Stack"



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Use Case "Full Stack" (Update)

Reference Architecture
(no longer based on ASRM/NAVSEM)

CONOPS

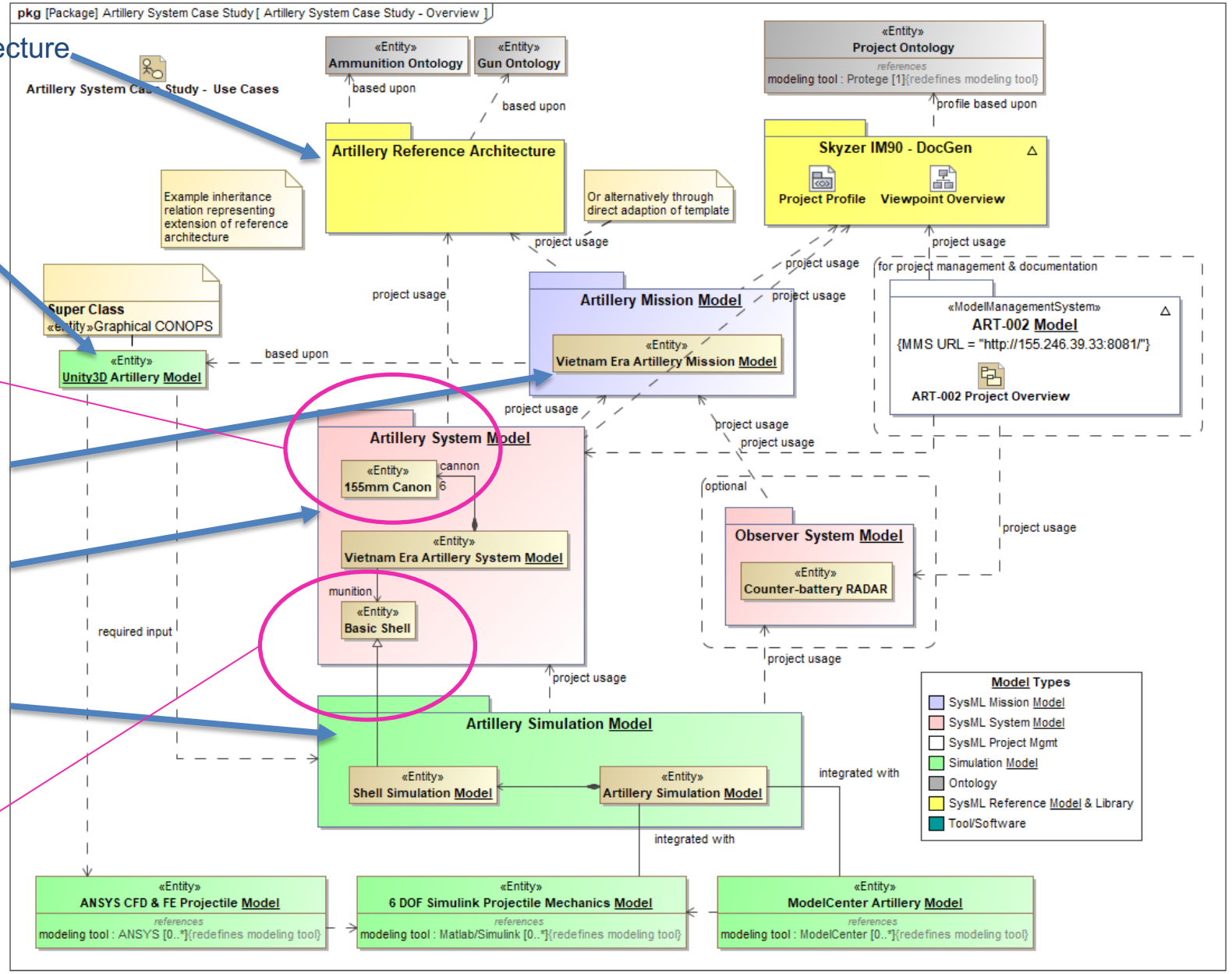
Is this a 155 or 105? Shawn gave curves reference for 105mm

Created Mission Model
(using custom profile)

System Model
(with displayed example model elements)

Separate SysML Analysis Model
(by John D.)

This should be changed to cartridge (if 105mm)



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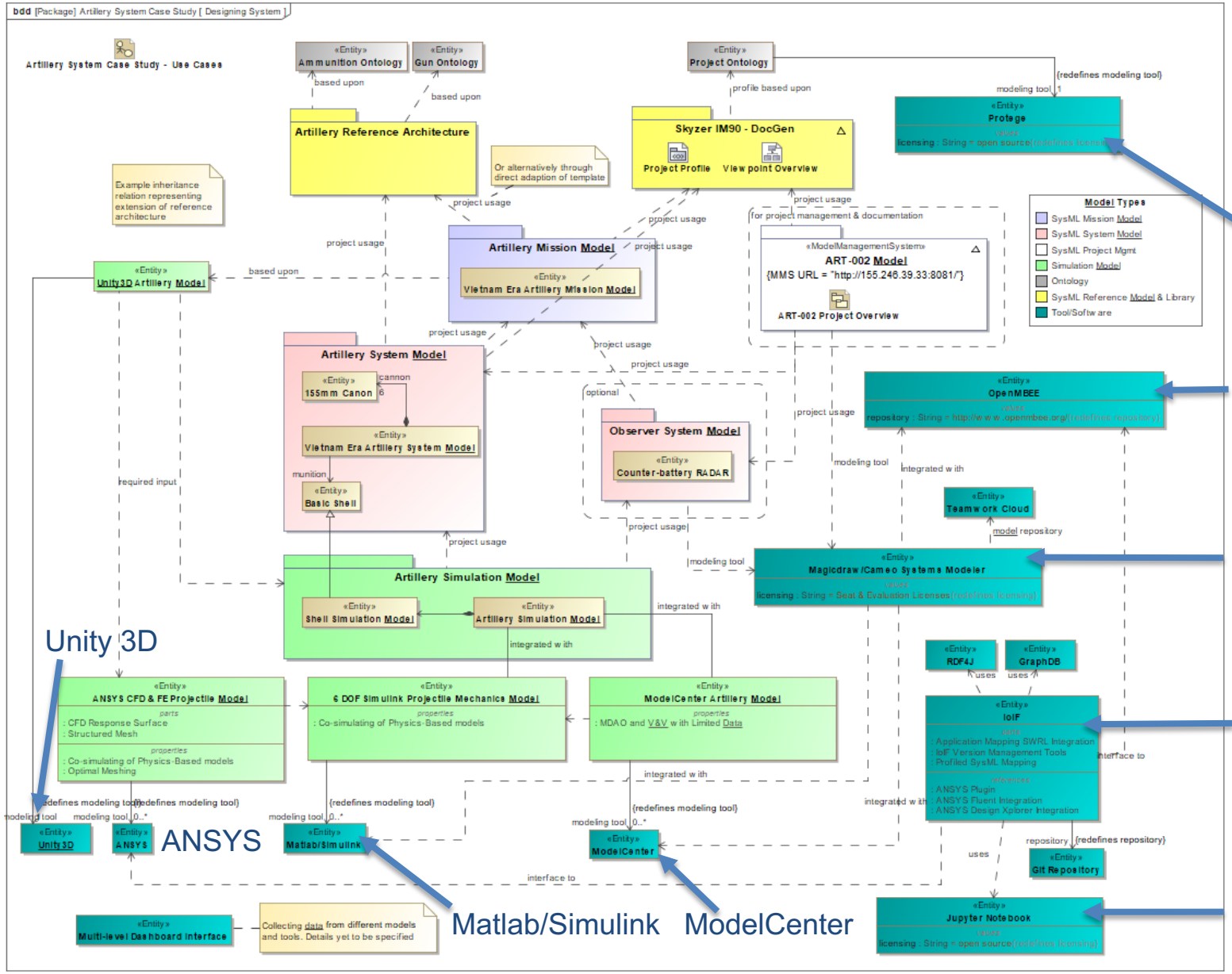
Use Case Designing System



- Used Tools:

Protegé

OpenMBEE

Magicdraw/Cameo

IoIF

Unity 3D

ANSYS

Matlab/Simulink

ModelCenter

Jupyter Notebook

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Systems Engineering Technical and Management Plan Model (Task 15)

Formalizes Task Interrelationships and Dependencies in a SysML model

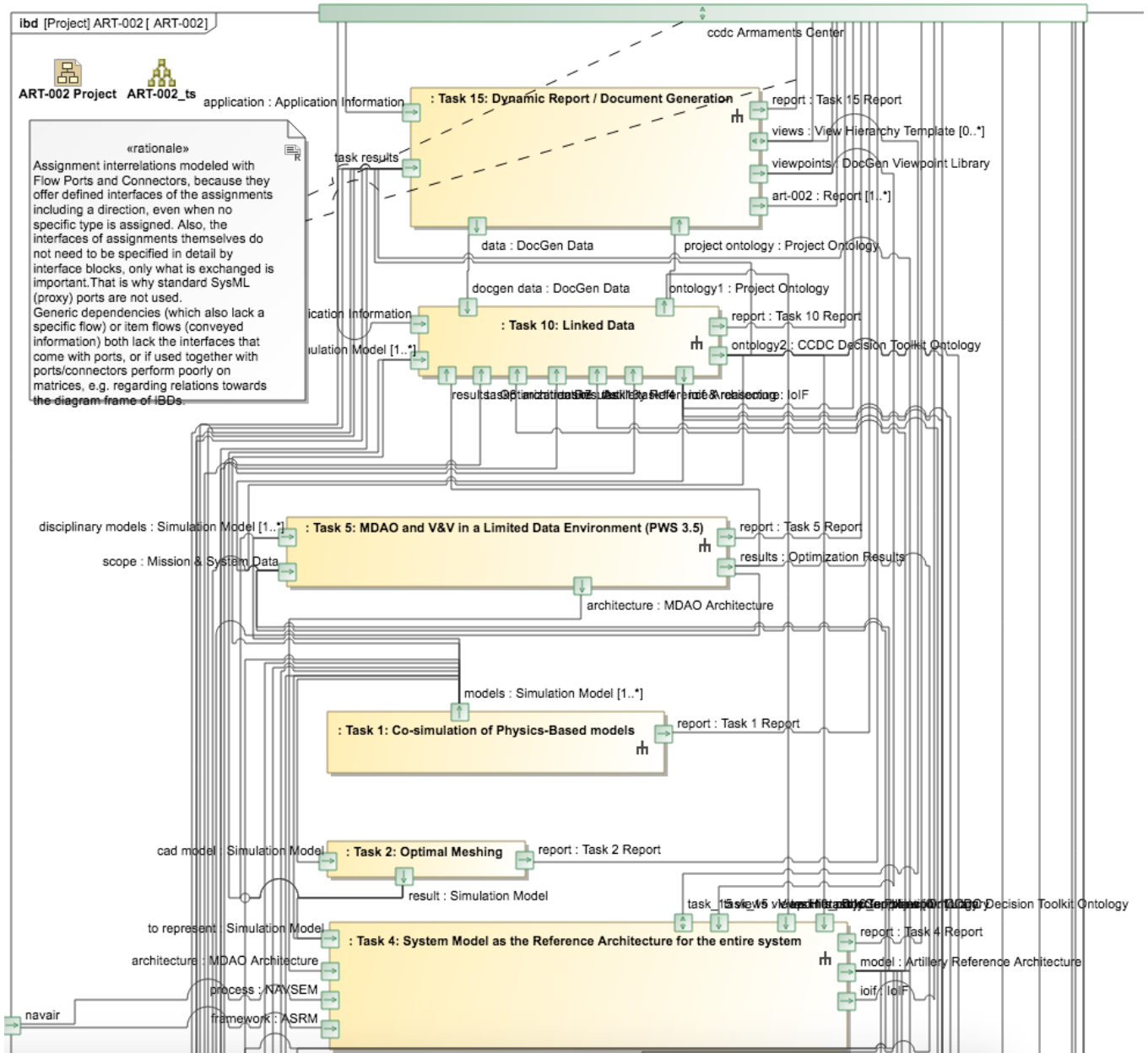
Provides systematic approach to capture accomplishments for assignments that get “pushed” back into model from View Editor

Used to automatically generate bi-monthly status

Allow sponsor comment directly in the View Editor

Project measures generated into View Editor

Proposal representation of Task Dependencies in Backup



Review: Five Goals of the Digital Engineering Strategy*

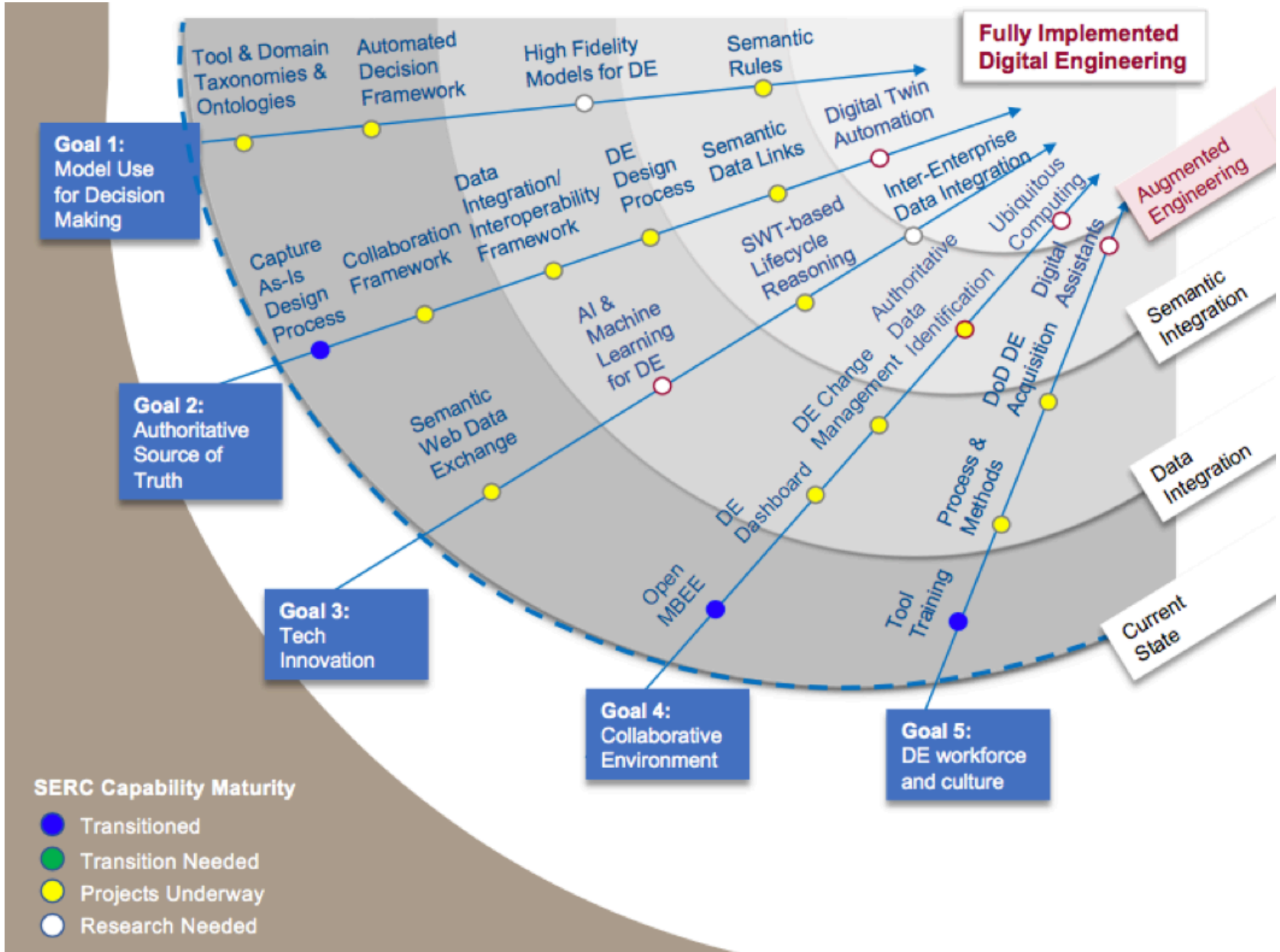
- Goal 1: Formalize the development, integration, and use of models to inform enterprise and program decision-making.
- Goal 2: Provide an enduring, authoritative source of truth.
- Goal 3: Incorporate technological innovation to improve the engineering practice.
- Goal 4: Establish a supporting infrastructure and environments to perform activities, collaborate, and communicate across stakeholders.
- Goal 5: Transform the culture and workforce to adopt and support digital engineering across the lifecycle.

* Department of Defense Digital Engineering Strategy, June 2018

Interrelationships Between Strategic DE Goals

- Technical Innovation provide enabling technologies (Goal 3) that impact other goals
  - —"Better" Descriptive Modeling technologies and methods for mission and system
  - —MBSE strengthens Systems Engineering
  - —Semantic web technologies (ontologies and reasoning)
- Using Authoritative Source of Truth (Goal 3 enabling Goal 2)
- Access and Visualization in Collaborative Environment (Goal 4)
- Model-enabled Decision Making (Goals 2 & 4 enabling Goal 1)
- We have examples for all of these, and those examples are being turned into Workforce Development training/examples (Goal 5) demonstrating the art-of-the-possible.

Digital Engineering for Systems Engineering Roadmap



Thank you!

Dr. Mark Blackburn

Principal Investigator

Member of SERC Research Council

Member of OpenMBEE Leadership Team

Member of Semantic Technologies for Systems Engineering

School of Systems & Enterprises

Systems Engineering Research Center

Stevens Institute of Technology