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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
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11th Annual SERC Sponsor Research Review
November 19, 2019
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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.

Research Tasks and Collaborator Network

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

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RT-170
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- Paul Grogan - Stevens
- Steven Hoffenson - Stevens
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- 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.

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- Roger Blake - Stevens
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- Eirik Hole - Stevens
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- 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
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- Stephen Edwards – Georgia Tech.
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- Marlin Ballard (Grad) – Georgia Tech.
- Donna Rhodes - MIT
- Mark Austin – Univ. Maryland
- Maria Coelho (Grad) – Univ. Maryland

WRT-1008
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- Russell Peak – Georgia Tech.
- Selcuk Cimtalay – Georgia Tech.
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- Alanna Carnevale (Grad) – Georgia Tech.
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- Mark Austin – Univ. Maryland
- Maria Coelho (Grad) – Univ. Maryland

ART-002
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- Kunal Batra – Stevens
- Mary Bone - Stevens
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- Steven Hoffenson - Stevens
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- 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

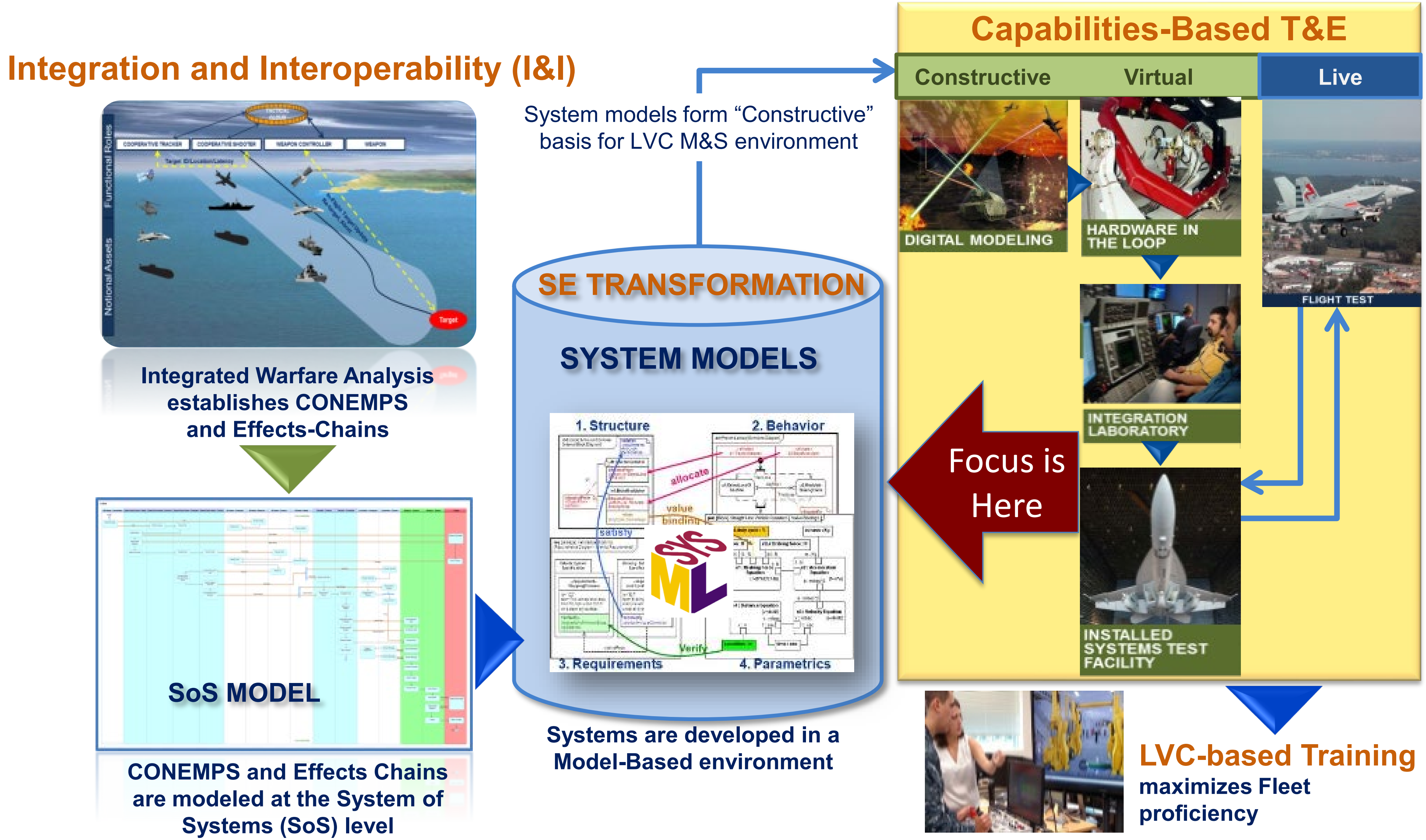
- WHAT: Context and Scope of NAVAIR SE Transformation
- HOW: Use Evolving Surrogate Pilot and Experiments to Demonstrate Art-of-the-Possible
- HOW: Transformation Elements Moving from Documents to Models
- HOW: Phase II Objectives (FY19) Aligns with SE Transformation (SET) Priorities
- HOW WELL: Contributing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



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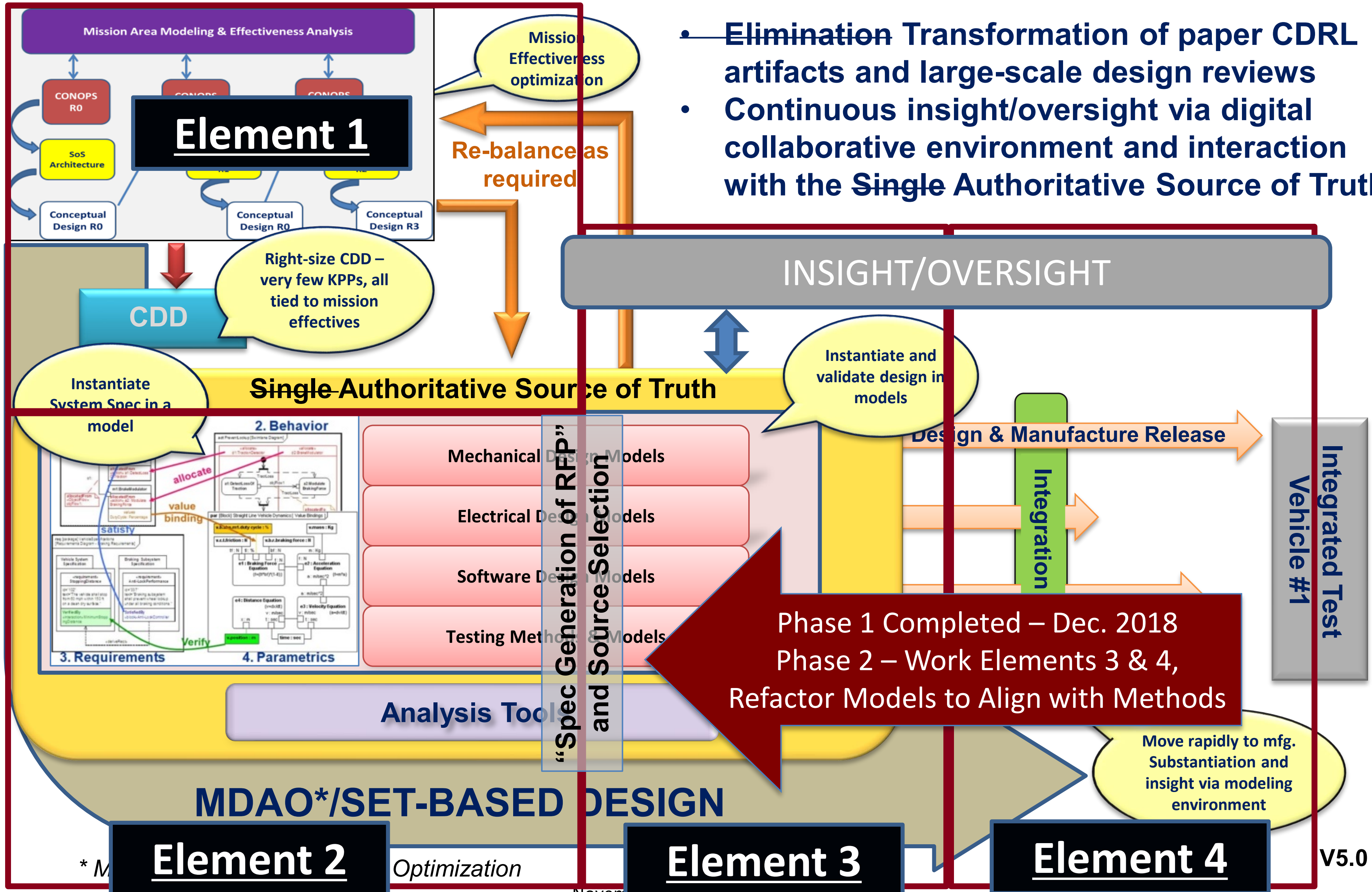
Surrogate Pilot focus is on Characterizing Assessing, and Refining SET Framework for Model-Based Acquisition

- ~~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

SET Framework Concept Initially Rolled Out 2016



CDRL: Contract Data Requirements List

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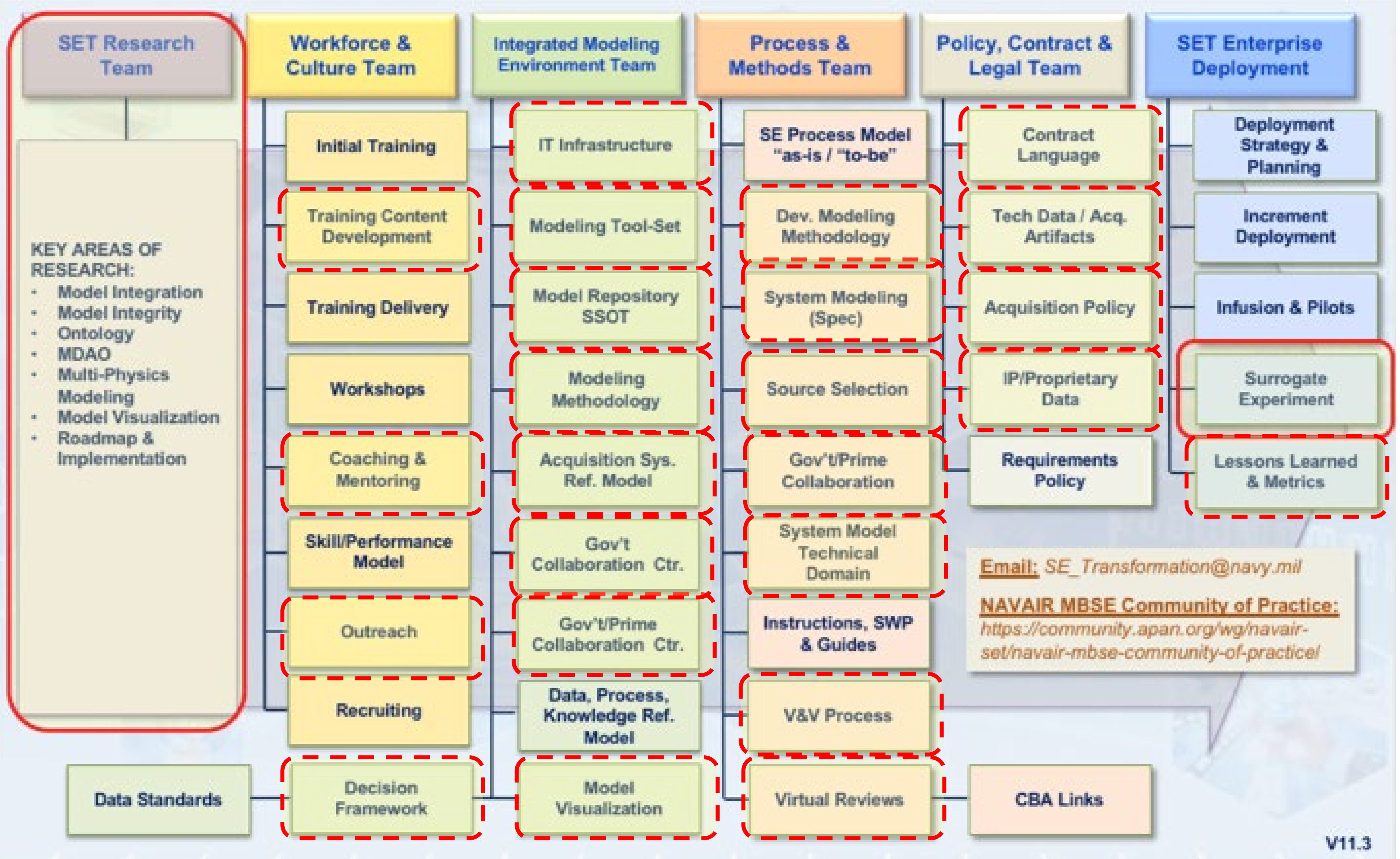
Research and Surrogate Experiment contributes broadly to SET Functional Areas



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

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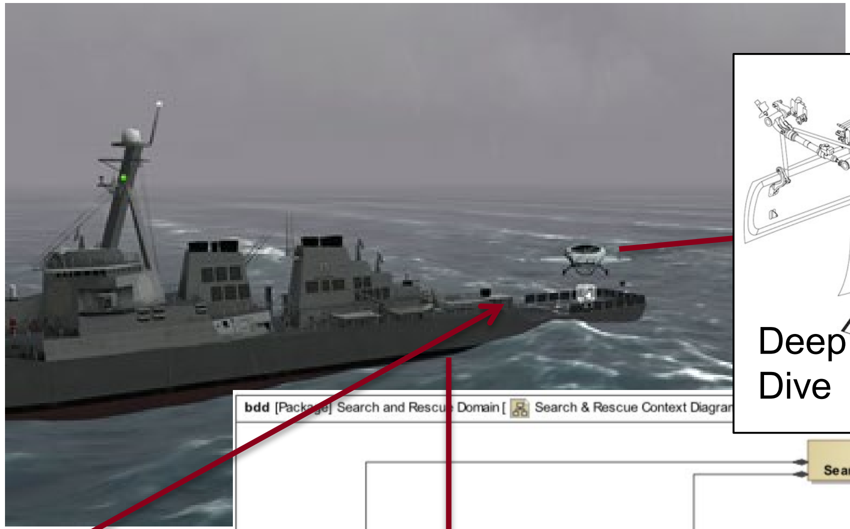
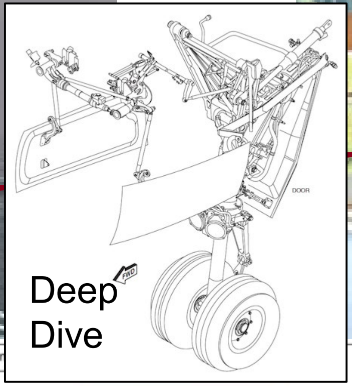
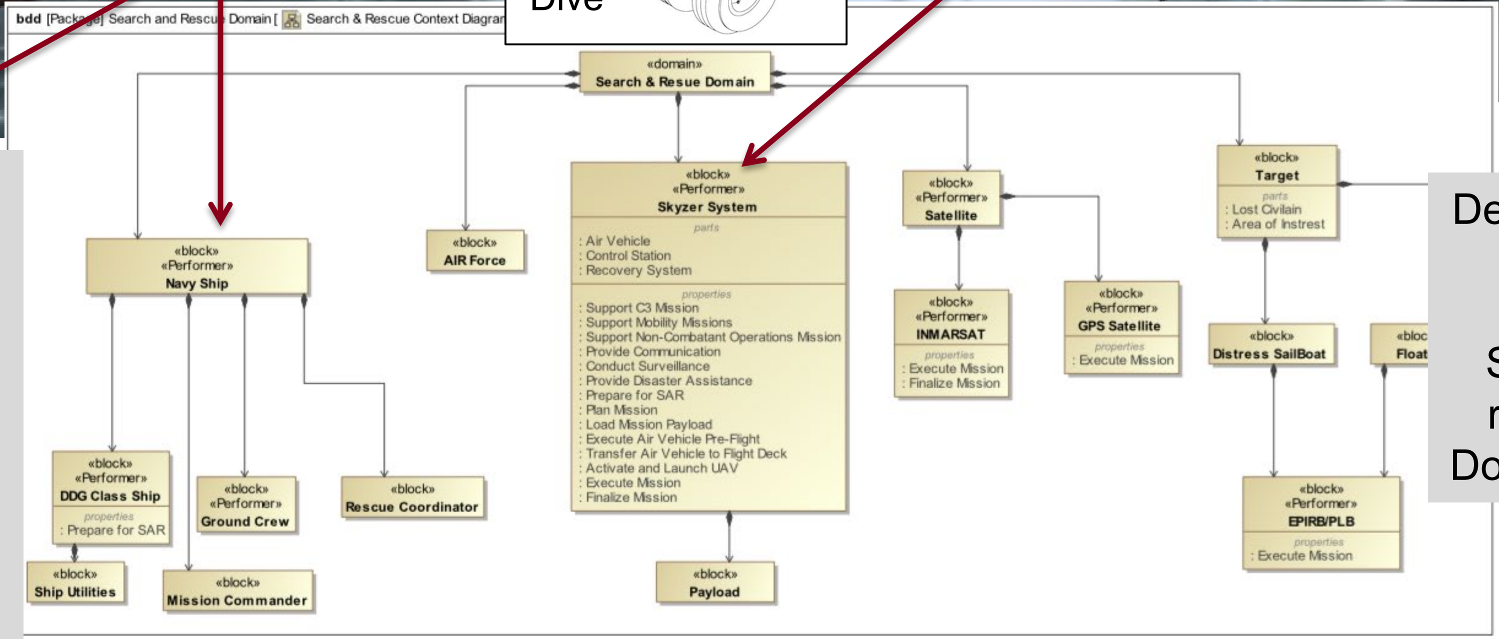
Surrogate Pilot Scenario: Skyzer UAS & Launch and Recovery for Landing Gear Deep Dive

Graphical CONOPS Scenario: Search & Rescue

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





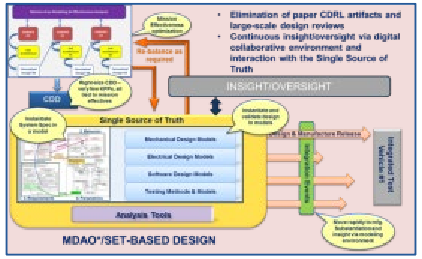


Phase II is adding ship-based Launch and Recovery Capability & Deep Dive supports Airworthiness Use Case

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

Skyzer System & Mission Models developed using SysML

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

Phase 1 Complete
Phase 2 – Work Elements 3 & 4

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

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

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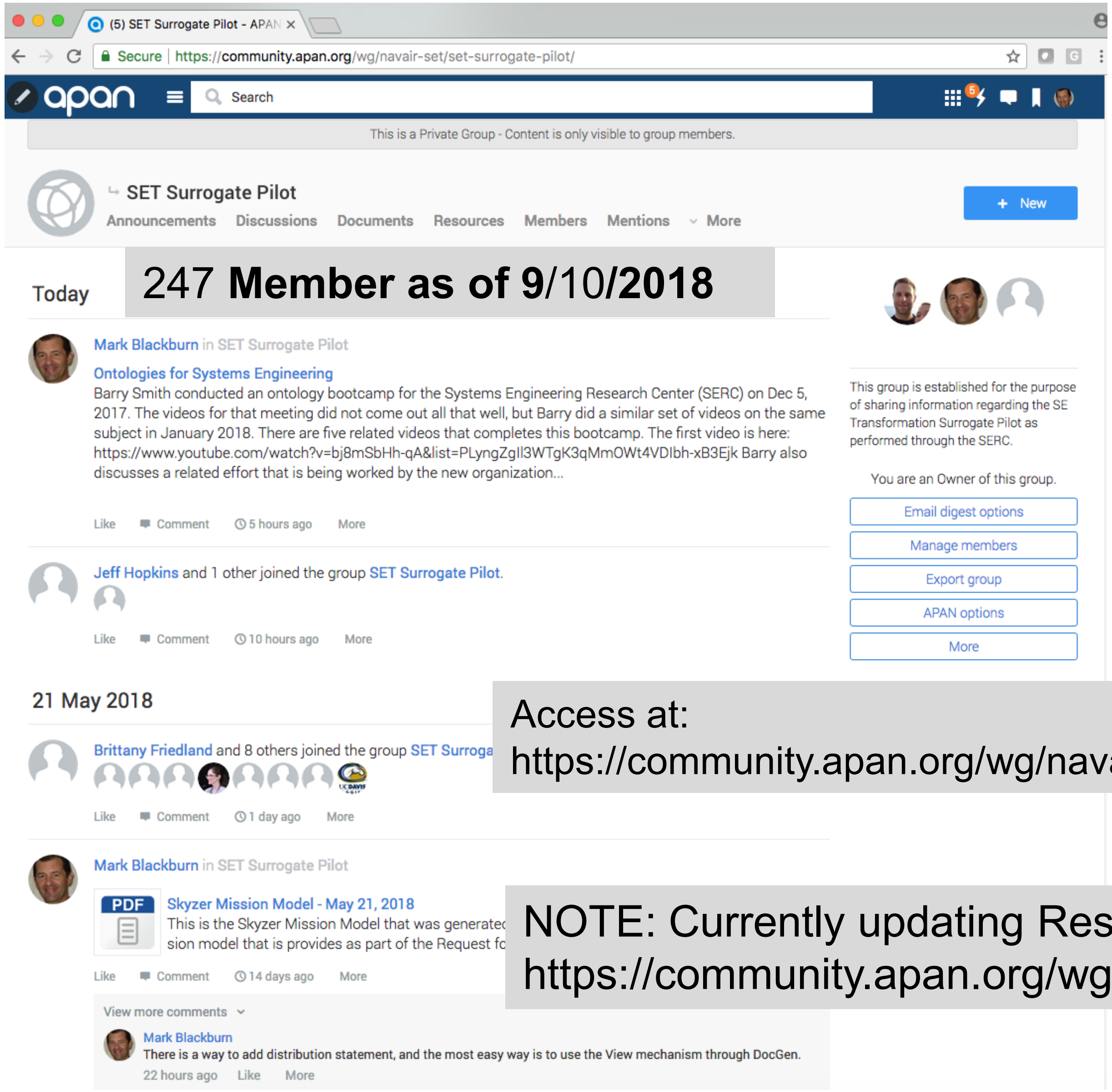


247 Member as of 9/10/2018

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

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

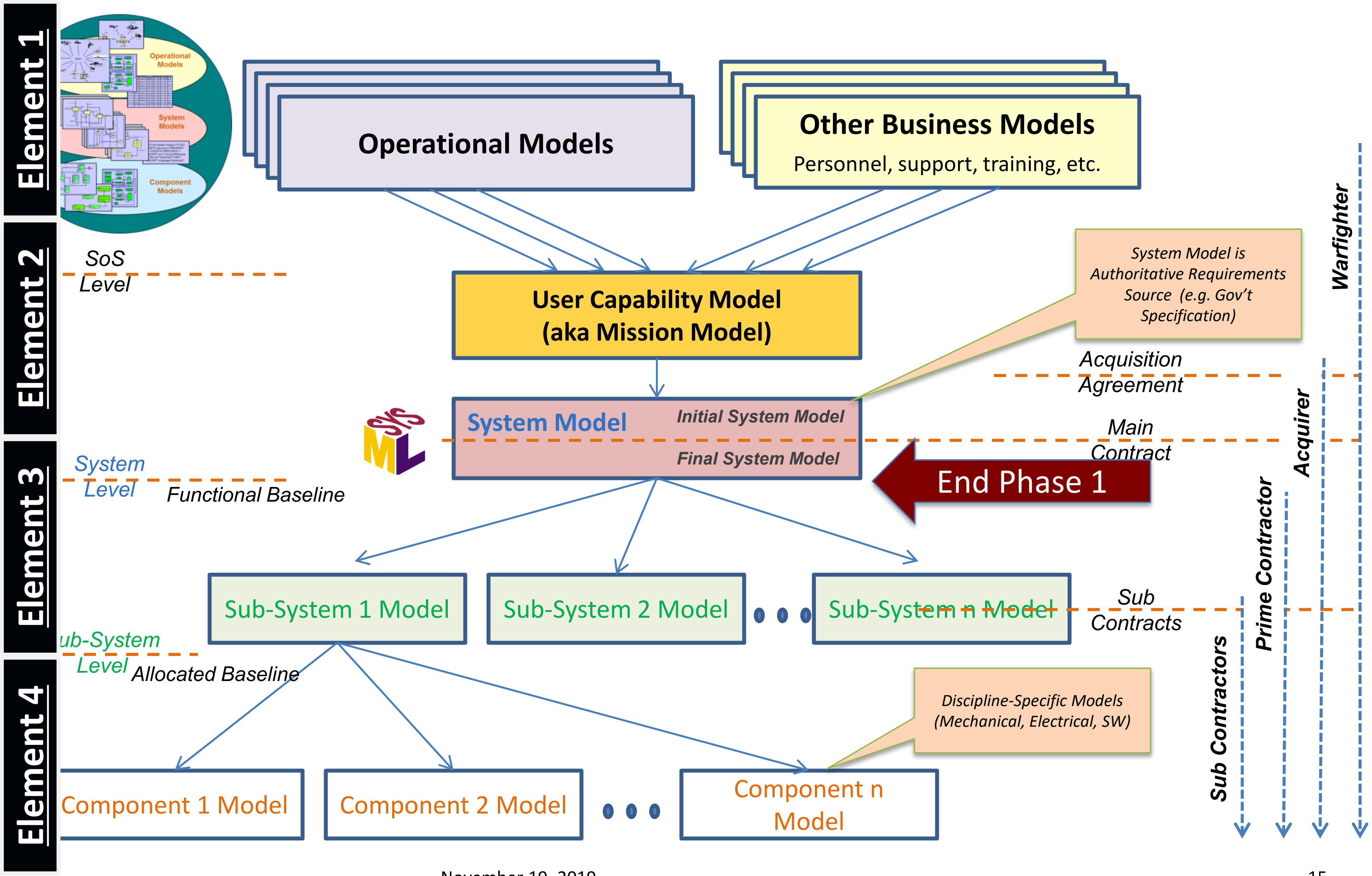
NOTE: Currently updating Research Group for Phase II
https://community.apan.org/wg/navair-set/research/

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**

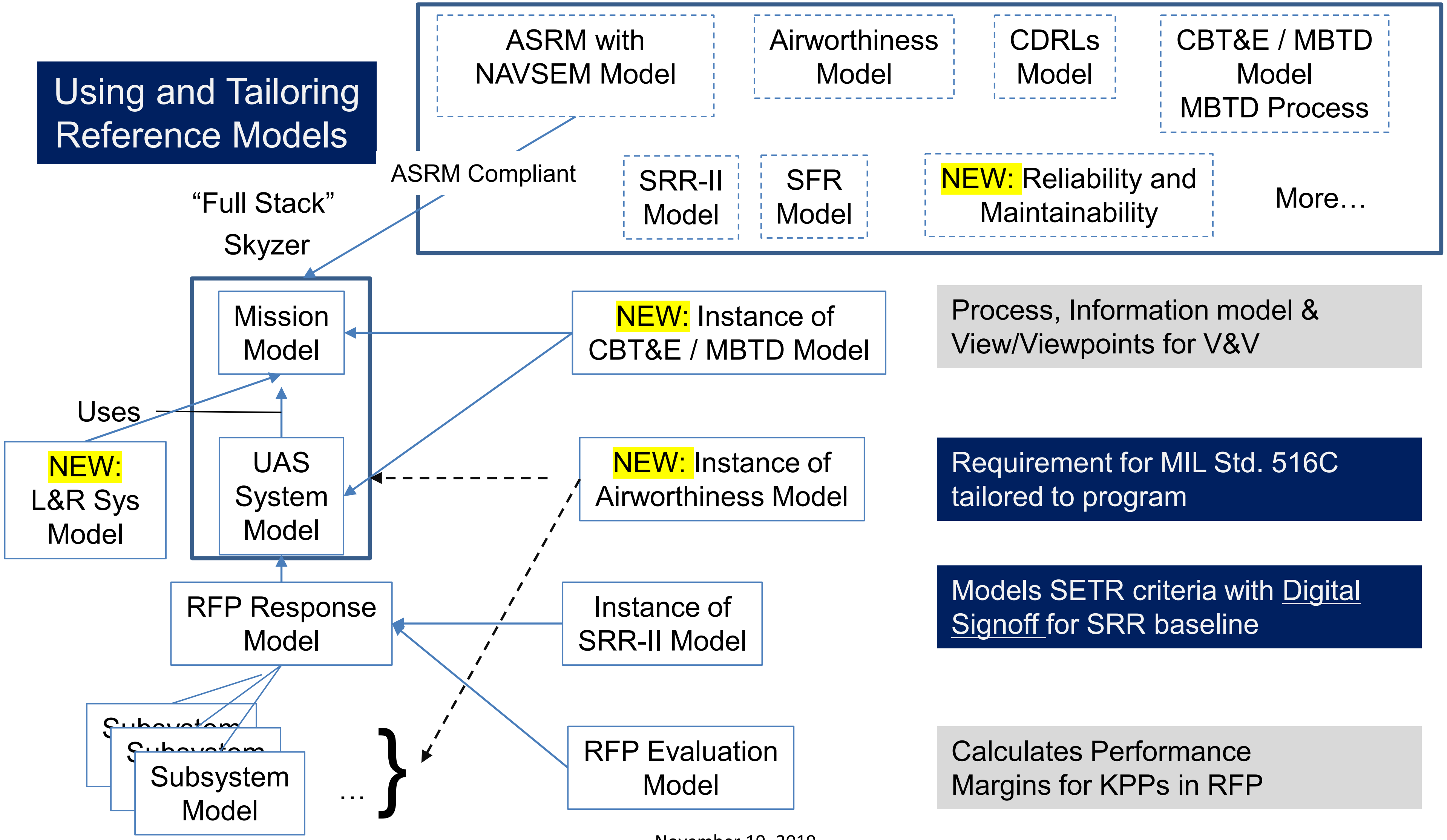
Skyzer Demonstrates Formalizing the Use of Models and Methods for the SET Framework Elements

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

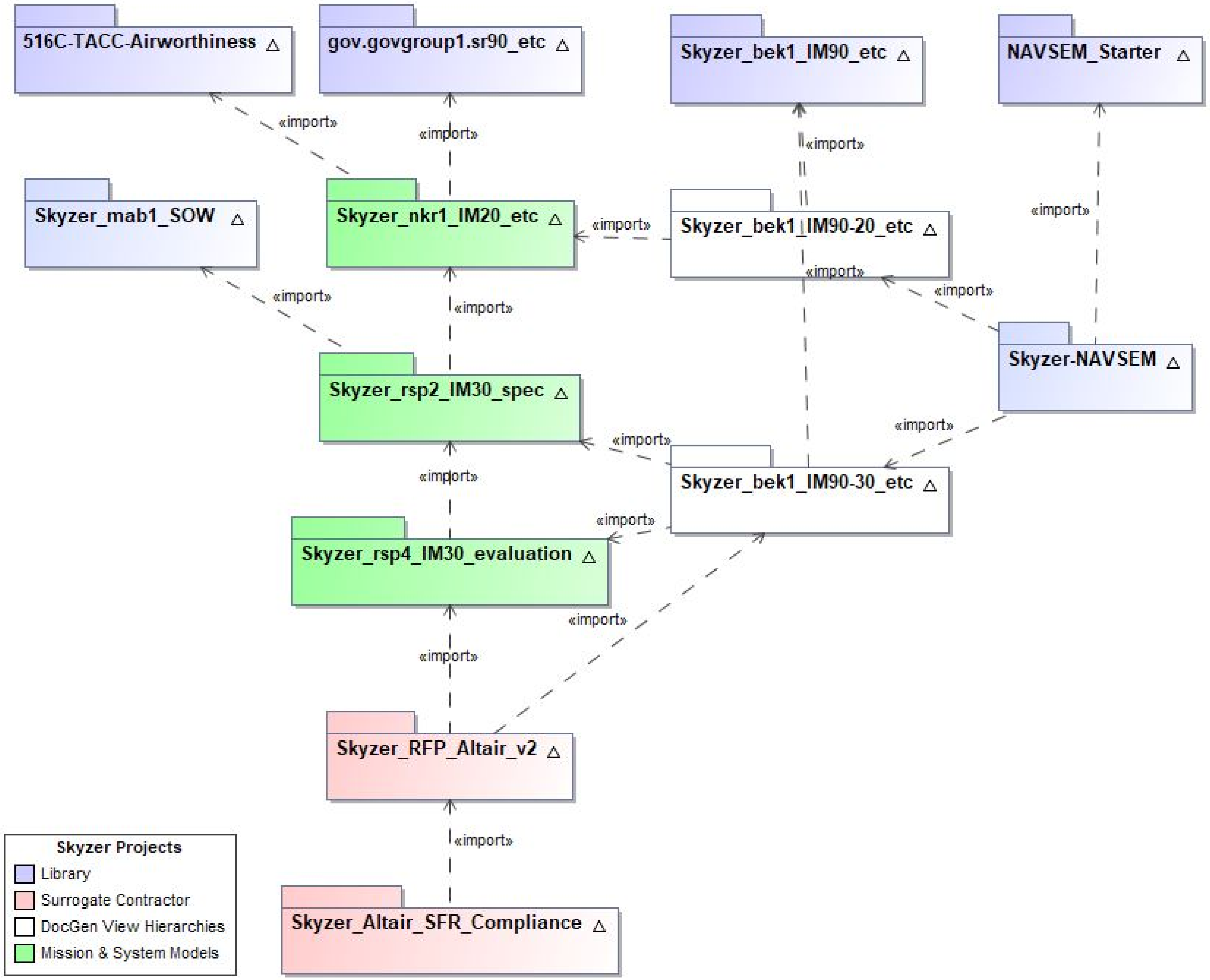


"Full Stack" of Models using Digital Signoff for Transformed SETR Criteria Represented in a Model

Reference models characterize reusble information and process

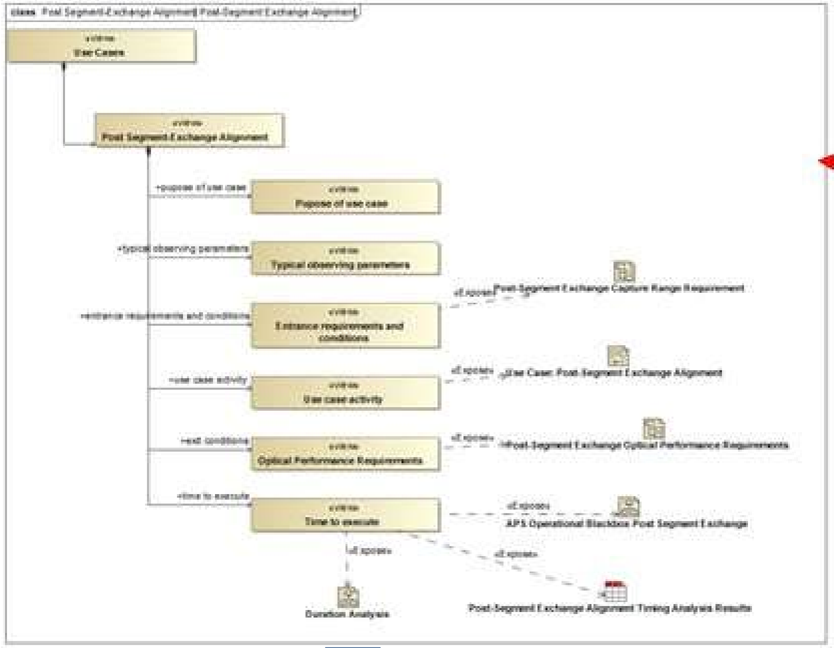


Model Organization – All Models Linked to Establish Authoritative Source of Truth

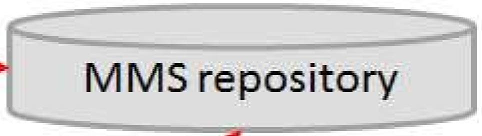


Leverage Capabilities of OpenMBEE as Part of Integrated Modeling Environment

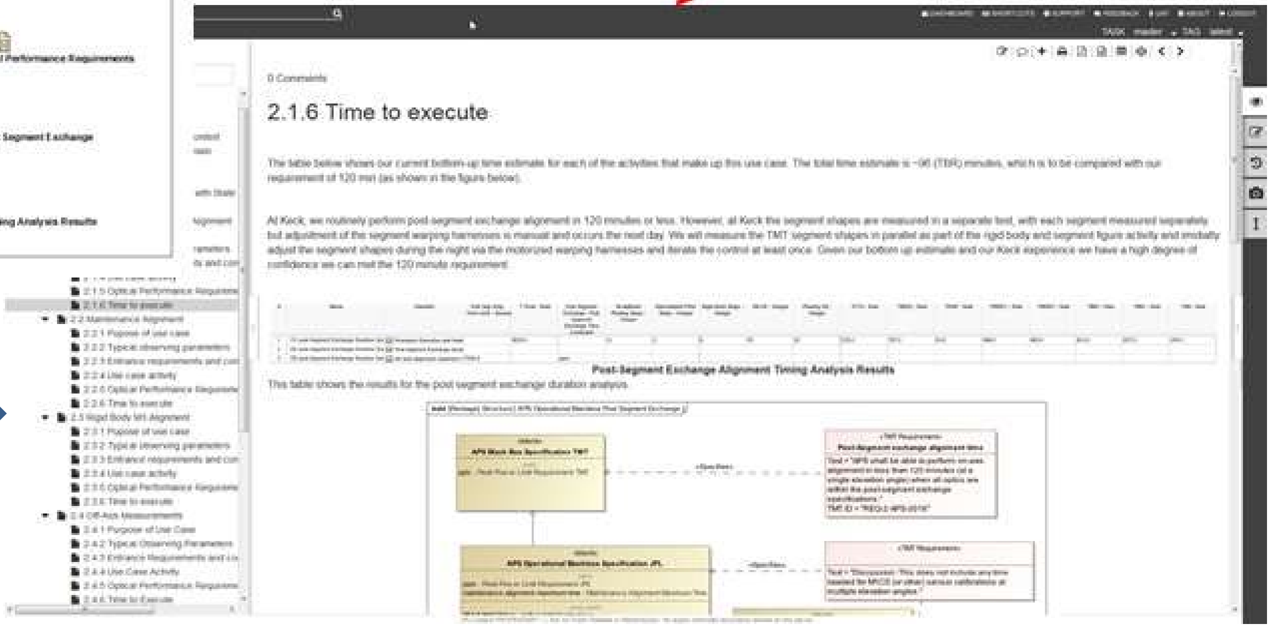
Model Development Kit/DocGen
View and Viewpoint Hierarchy



Model Management System

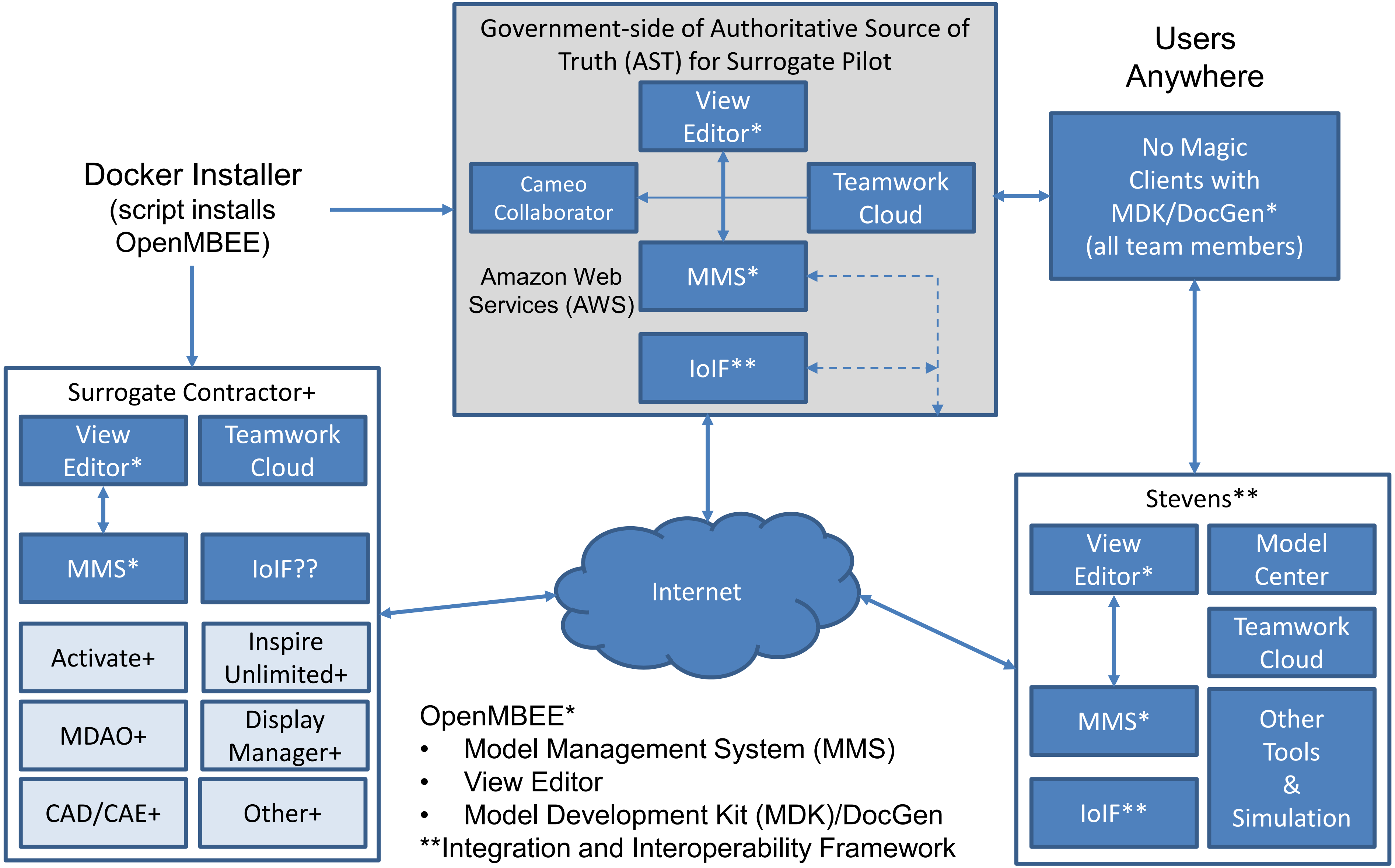


View Editor



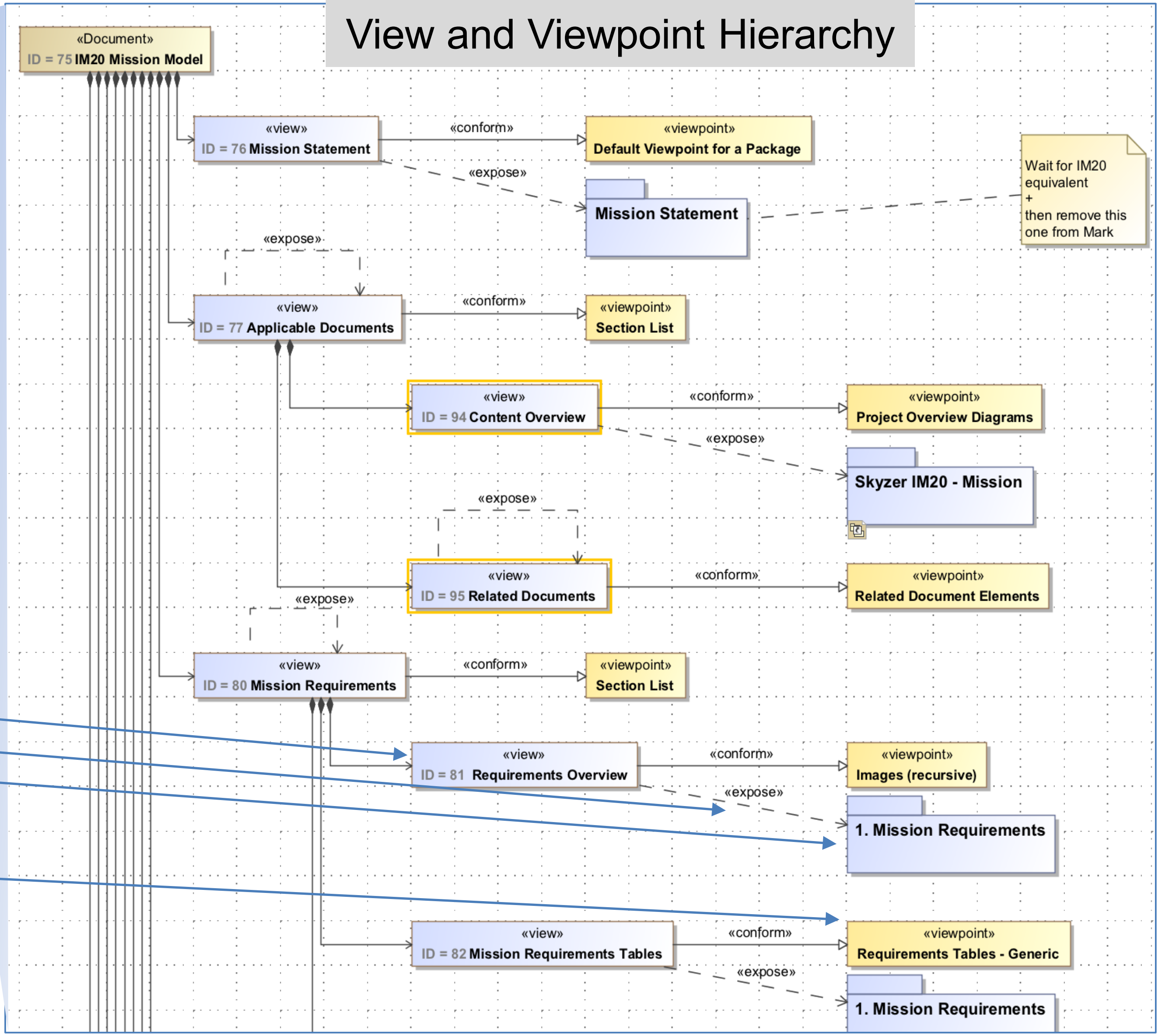
Visualization in View Editor
(allows edits to be pushed back into model)

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

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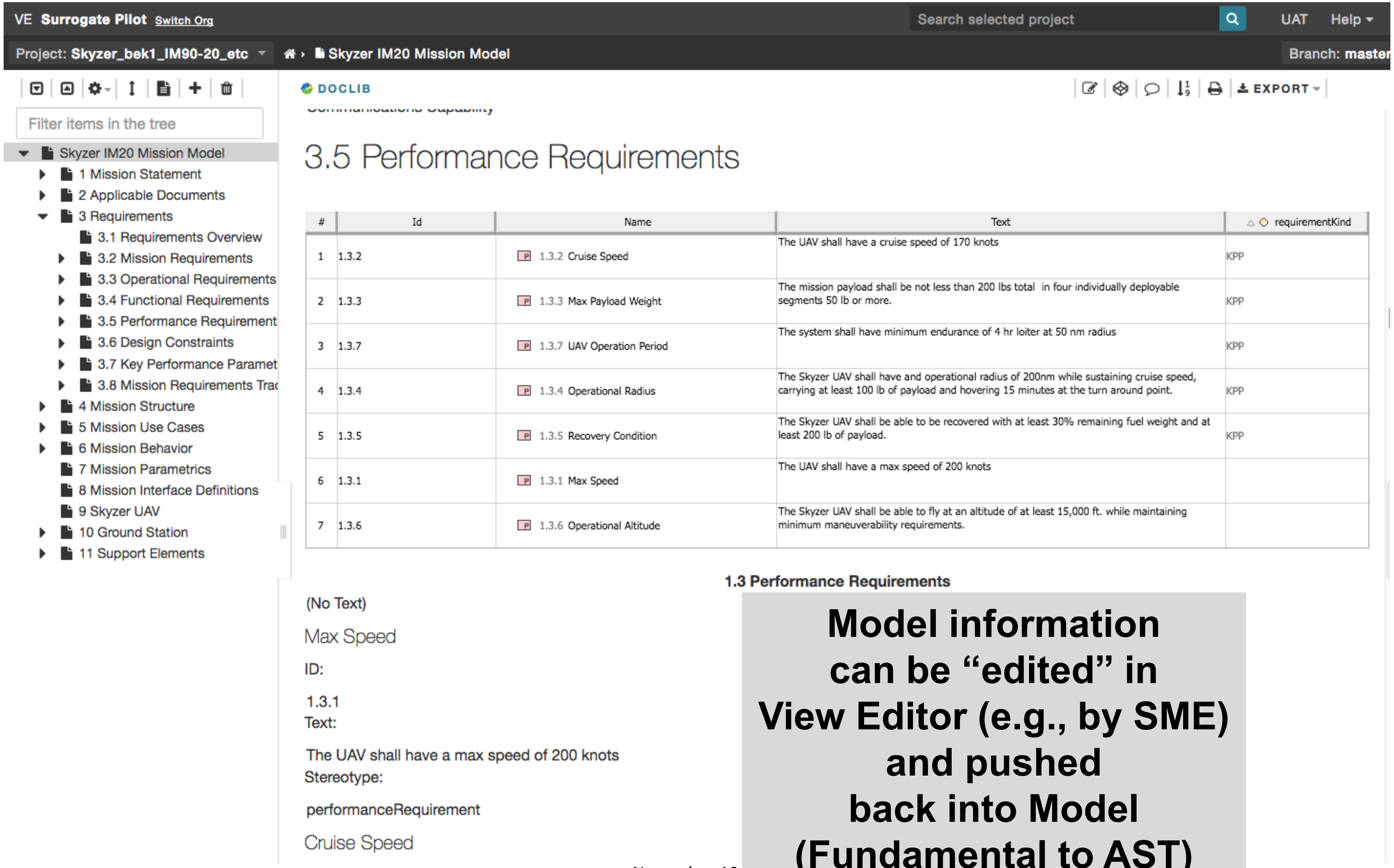
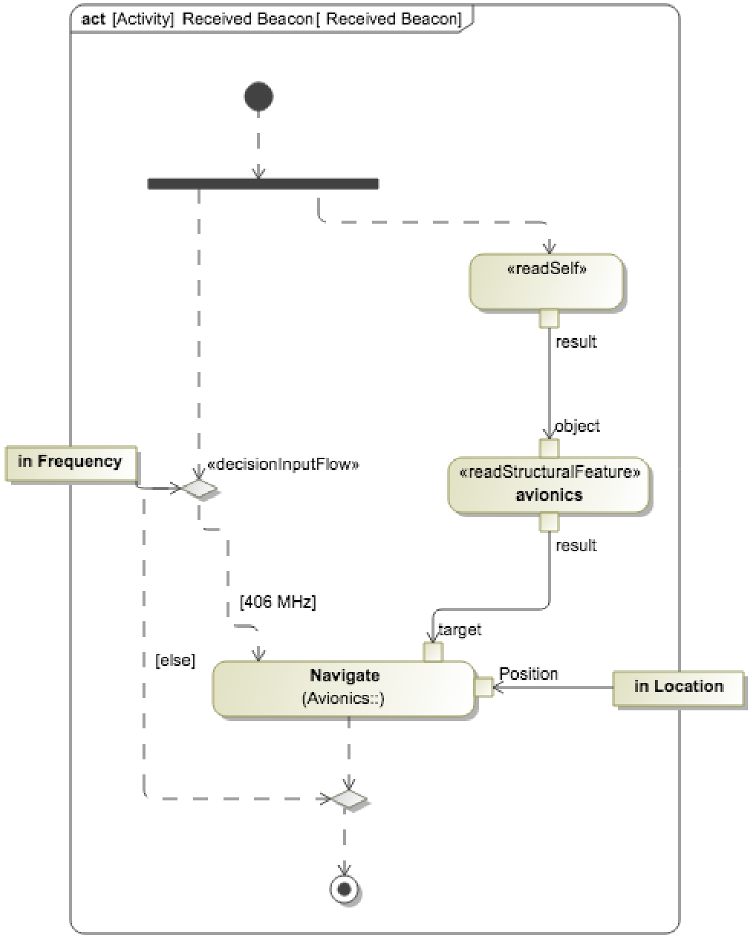
Example: View Editor shows Skyzer Mission Model View

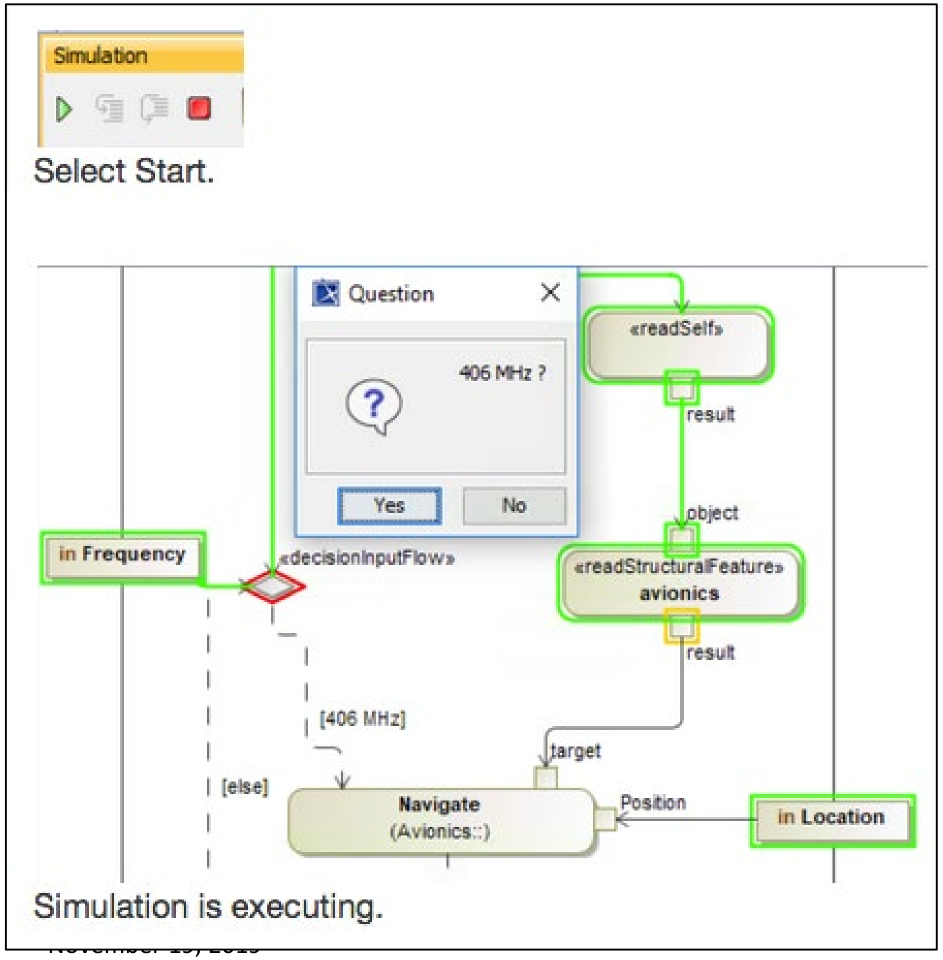


Model information can be "edited" in View Editor (e.g., by SME) and pushed back into Model (Fundamental to AST)

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

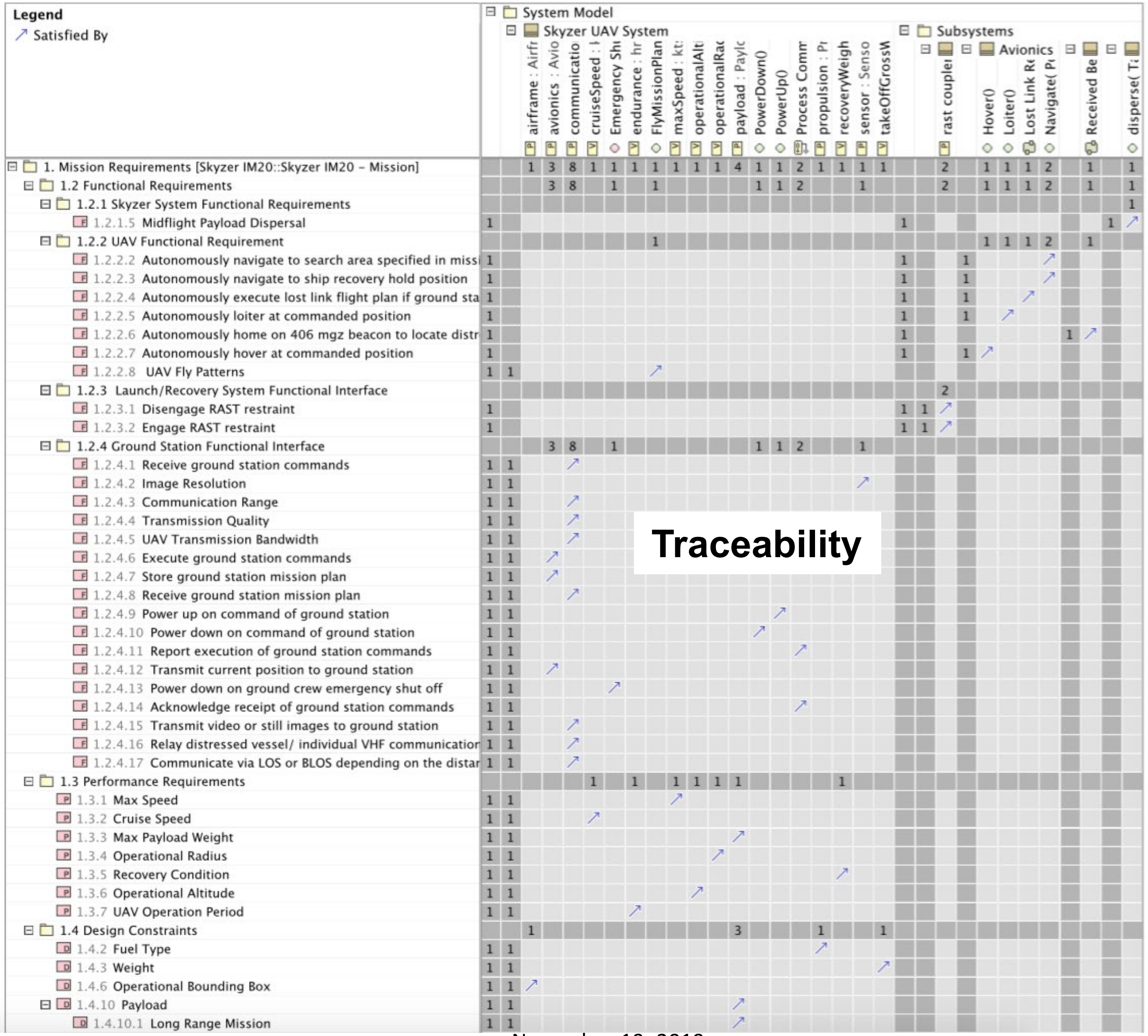
- State Machine Simulation in System Model supports analysis for understanding/visualizing dynamic behaviors – getting the right model and getting the model right





Skyzer Mission and System Requirements Traceability in Skyzer System Model

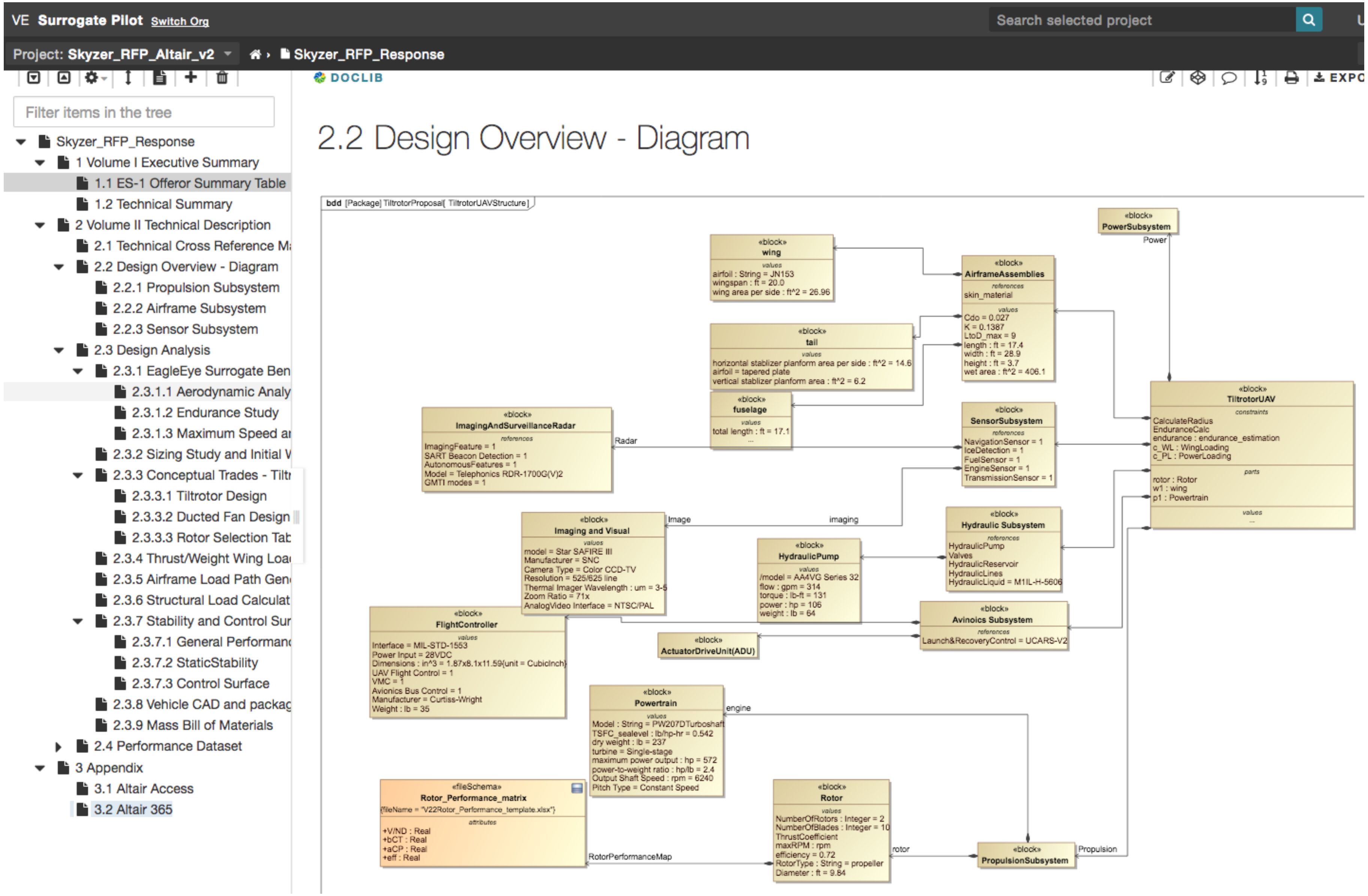
Figure 6.1. Requirements Satisfiability



System Requirements

Mission 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

VE **Surrogate Pilot** Switch Org | Search selected project | UAT | Help | M

Project: Skyzer_RFP_Altair_v2 › Skyzer_RFP_Response | Branch: master

DOCLIB | EXPORT

Filter items in the tree

- Skyzer_RFP_Response
  - 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 M
    - 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 Ben
        - 2.3.1.1 Aerodynamic Analy
        - 2.3.1.2 Endurance Study
        - 2.3.1.3 Maximum Speed a
      - 2.3.2 Sizing Study and Initial V
      - 2.3.3 Conceptual Trades - Tilt
        - 2.3.3.1 Tiltrotor Design
        - 2.3.3.2 Ducted Fan Design
        - 2.3.3.3 Rotor Selection Tab
      - 2.3.4 Thrust/Weight Wing Loa
      - 2.3.5 Airframe Load Path Gen
      - 2.3.6 Structural Load Calculat
      - 2.3.7 Stability and Control Su
        - 2.3.7.1 General Performan
        - 2.3.7.2 StaticStability
        - 2.3.7.3 Control Surface
      - 2.3.8 Vehicle CAD and packag
      - 2.3.9 Mass Bill of Materials
    - 2.4 Performance Dataset
  - 3 Appendix
    - 3.1 Altair Access
    - 3.2 Altair 365

Engineering Activity Checklist

ENGINEERING ACTIVITY	DELIVERABLES	Offeror's Proposal System Model Element or Documentation Base Vol/Annex and Associated Page Number
Eagle Eye Surrogate Benchmark	Engineering system model, supporting CAE models and performance results to satisfy the "Requirement Model" or "System Model" (IM30) and KPP metrics.	EagleEye Surrogate Benchmark
Sizing Study	Take off weight, empty weight, fuel fraction, warm up, take off, and landing weight fraction. Mission segment fractions.	Sizing Script @ Altair365
Conceptual Trades - Tilt Rotor vs Ducted Fan	Airframe CFD models, co-efficient's of lift and drag, respective propulsive performance results for both concepts.	Conceptual Trades - Tiltrotor vs Ducted Fan
Initial Weight Targets	Targets set from task 1C.	WeightBudgetScript@Altair365
Vehicle CAD and packaging	Vehicle package space definition and major system locations. Technical Data Package.	Vehicle CAD and packaging
Thrust/Weight Wing Loading Calculations	Airframe load case matrix.	Thrust/Weight Wing Loading Calculation
Airframe Load Path Generation	Coarse structural topology optimization results.	Airframe Load Path Generation
Structural Load Calculations	Benchmark of conventional structural arrangement in current design space	Structural Load Calculations
Stability, Performance and Flight Characteristic Calculations	Final stability, performance and flight characteristic report.	Stability and Control Surface Calculations
Mass Bill of Materials	Mass bill of materials generated from the Technical Data Package.	Mass Bill of Materials

Surrogate Pilot RFP Response in View Editor

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VE **Surrogate Pilot** Switch Org

Project: **Skyzer_RFP_Altair** › WIP

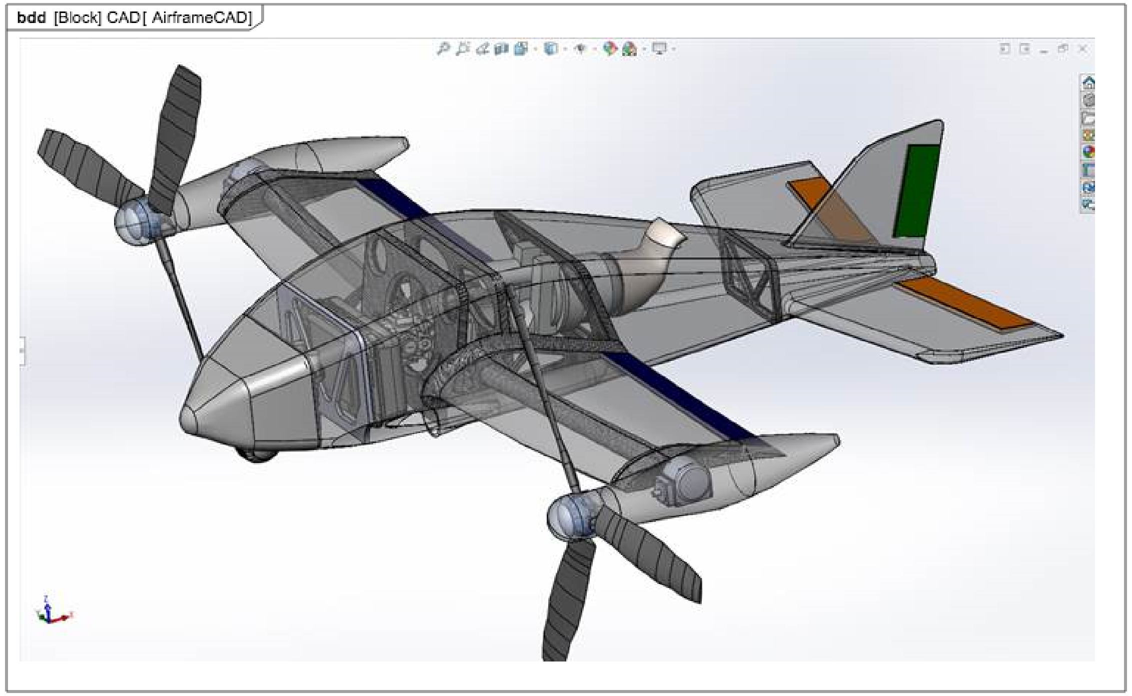
Filter items in the tree

- 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

(No Text)

2.2.1 Propulsion Subsystem

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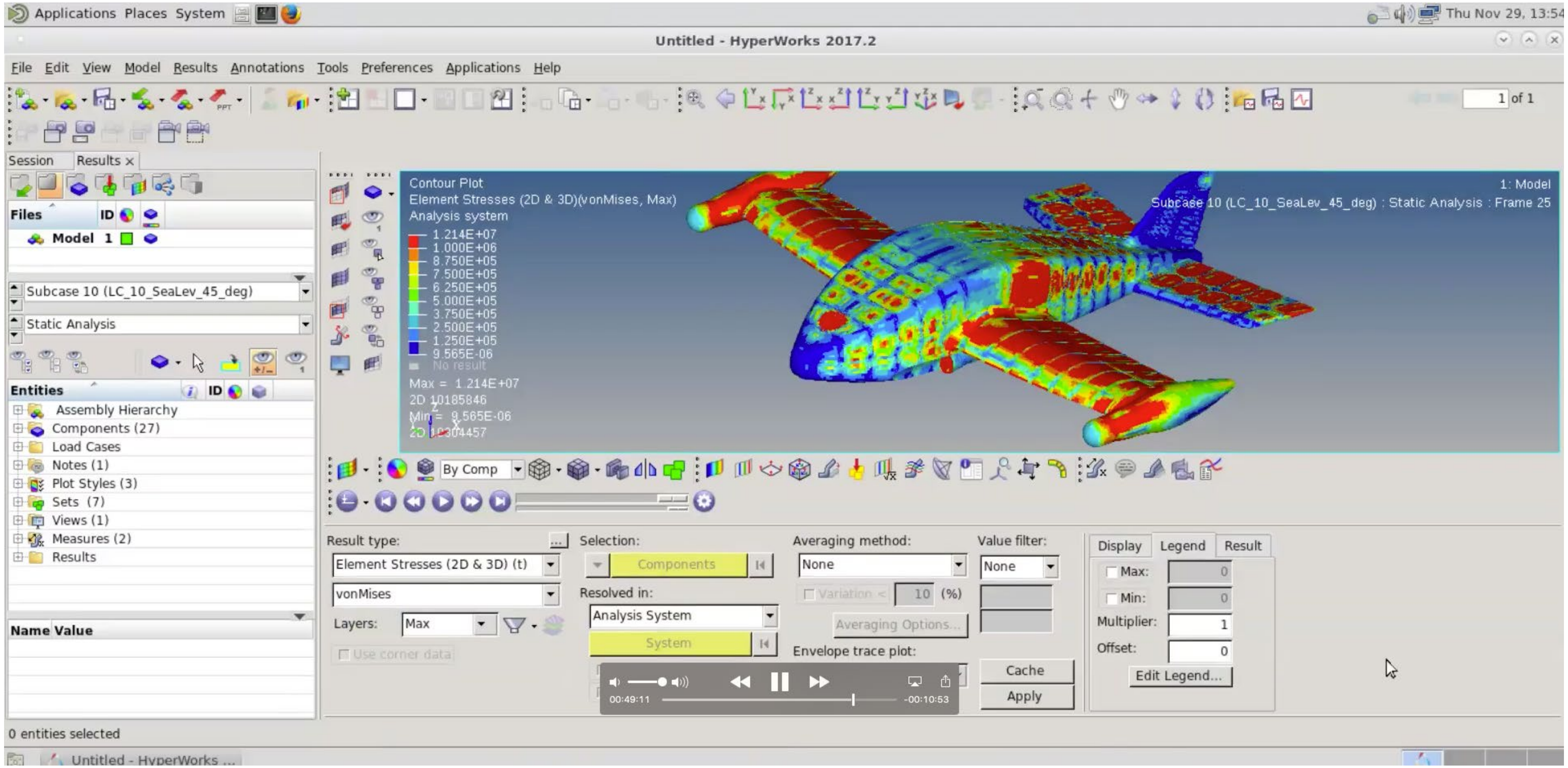
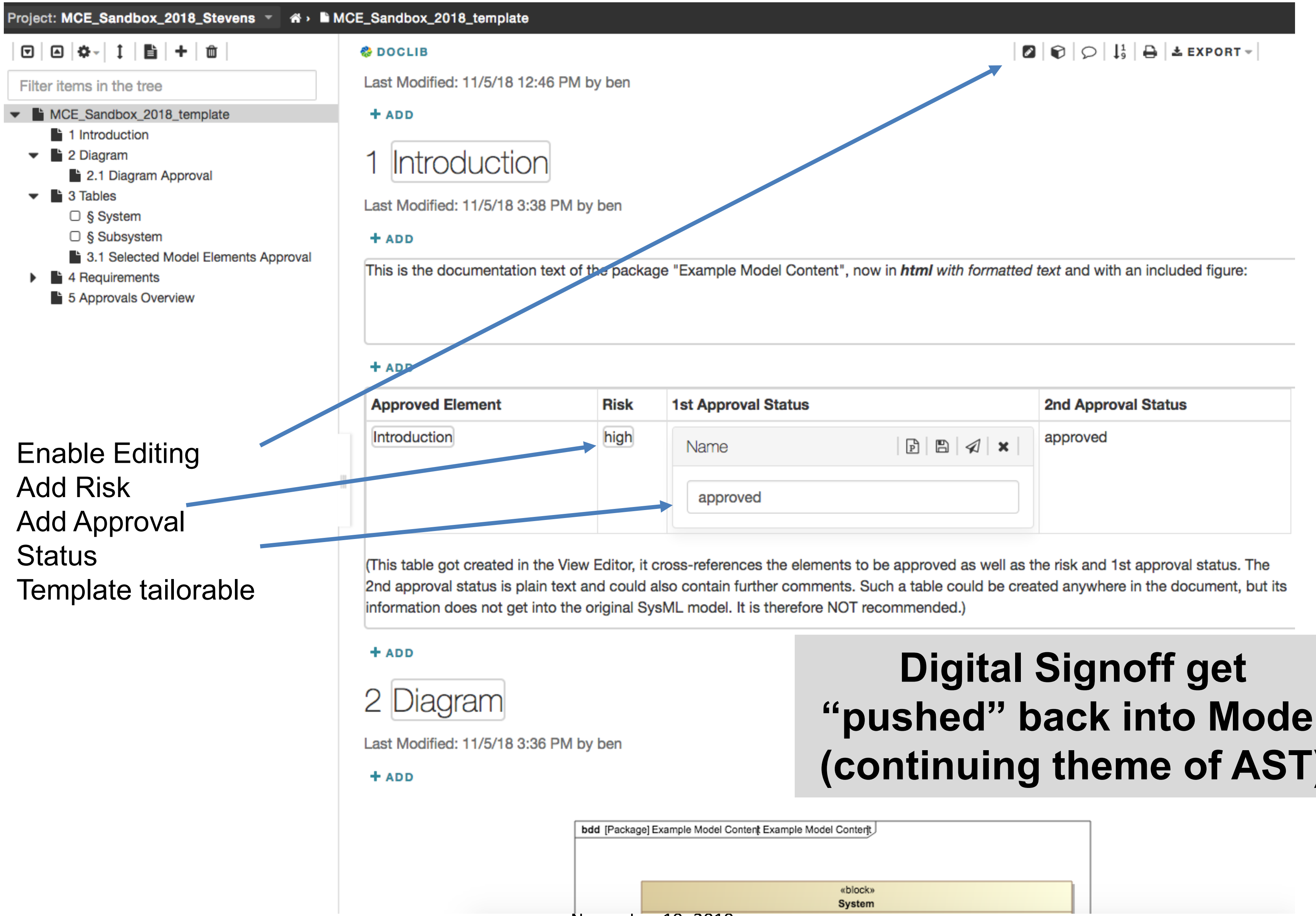
Views Provides Hyperlinks into Discipline-specific Models and Simulation Analyses

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



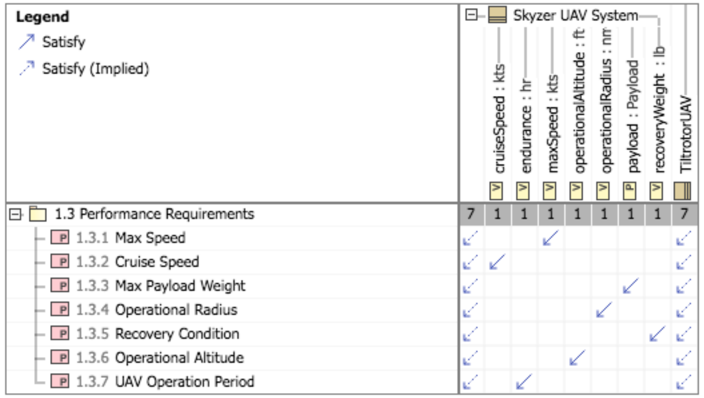
Transform CDRLs and DIDS using Digital Signoff in Model Through View Editor



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

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

VE **Surrogate Pilot** Switch Org | Search selected project | UAT | Help

Project: **Skyzer_RFP_Altair_v2** › Skyzer_RFP_Response | Branch: mast

Filter items in the tree

- Skyzer_RFP_Response
  - 1 Volume I Executive Summary
  - 2 Volume II Technical Descriptic
  - 3 Appendix

DOCLIB | EXPORT

2.1.1 Technical Cross Reference Sign Off

EXPORT CSV | FILTER TABLE

Technical Cross Reference Sign Off

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.

Thank you!

Dr. Mark Blackburn
Principal Investigator
Member of SERC Research Council
Member of OpenMBEE Leadership Team
School of Systems & Enterprises
Systems Engineering Research Center
Stevens Institute of Technology