

# Transforming Systems Engineering through Model Centric Engineering

**Sponsors: NAVAIR and ARDEC**

**By**

**Dr. Mark Blackburn**

**10<sup>th</sup> Annual SERC Sponsor Research Review**

**November 8, 2018**

**FHI 360 CONFERENCE CENTER**

**1825 Connecticut Avenue NW, 8th Floor**

**Washington, DC 20009**

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**RT-48**

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

**RT-118**

Mark Blackburn (PI), Stevens  
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  
Benjamin 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 Massachusetts  
Tom Hagedorn – Univ. of Massachusetts  
Todd Richmond – Univ. of Southern California (Phase I)  
Edgar Evangelista – Univ. of Southern California (Phase I)

**RT-176**

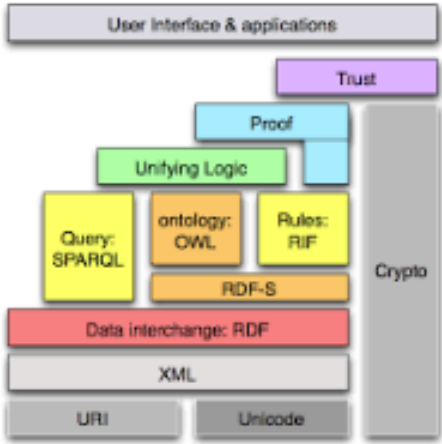
Kristin Giammaro (PI) – NPS  
Ron Carlson (Co-PI), NPS  
Mark Blackburn (Co-PI), Stevens  
Mikhail Auguston, NPS  
Rama Gehris, NPS  
Marianna Jones, NPS  
Chris Wolfgeher, NPS  
Gary Parker, NPS

**RT-195**

Mark Blackburn (PI), Stevens  
Mary Bone - Stevens  
Ralph Giffin - Stevens  
Bob Hathaway- 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

- Perspectives and status RT-170/195 - NAVAIR
  - Systems Engineering Transformation (SET) Framework
    - A new operational paradigm between government and industry
  - Using a prototype Collaborative Authoritative Source of Truth
  - Surrogate pilot experiment(s) for assessing/refining the SET Framework
    - Developed methods for linking Mission models, System models, and SOW Evaluation models & Surrogate contractor refinement of system models to formalize source selection – and more
  - Navy and DoD Ontology Suite (not discussed)
- Perspectives and status RT-168 – ARDEC
  - Prototype an Interoperability and Integration Framework (IoIF) to formalize Decision Framework concept using SysML, Semantic Web Technologies (SWT), Decision Ontology, OpenMBEE with Visualizations
  - Uses cases applying Multidisciplinary Design Analysis and Optimization (MDAO) for Graphical CONOPS, Mission, and System levels trades

## Semantic Web Technologies



Enforces **Modeling Methods**

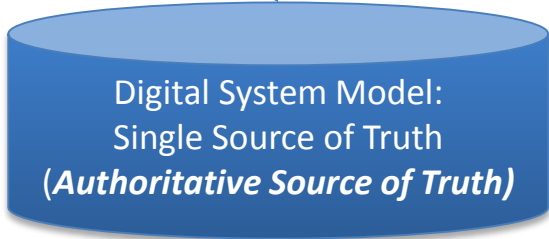
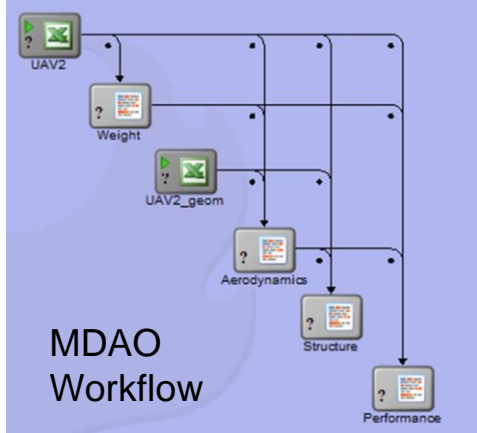
Underlying technologies for reasoning about completeness and consistency **Across Domains** in modeling tool agnostic way

## Modeling Methodologies



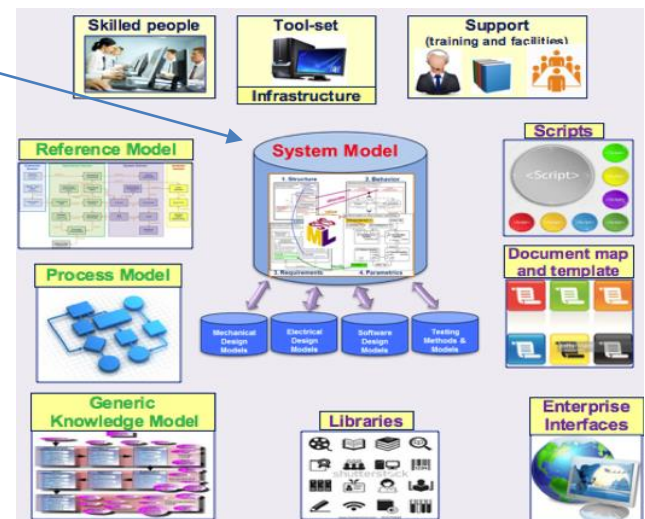
Guides proper usage to ensure **Model Integrity** (trust in model results) for decision making

## Multidisciplinary Design, Analysis and Optimization MDAO



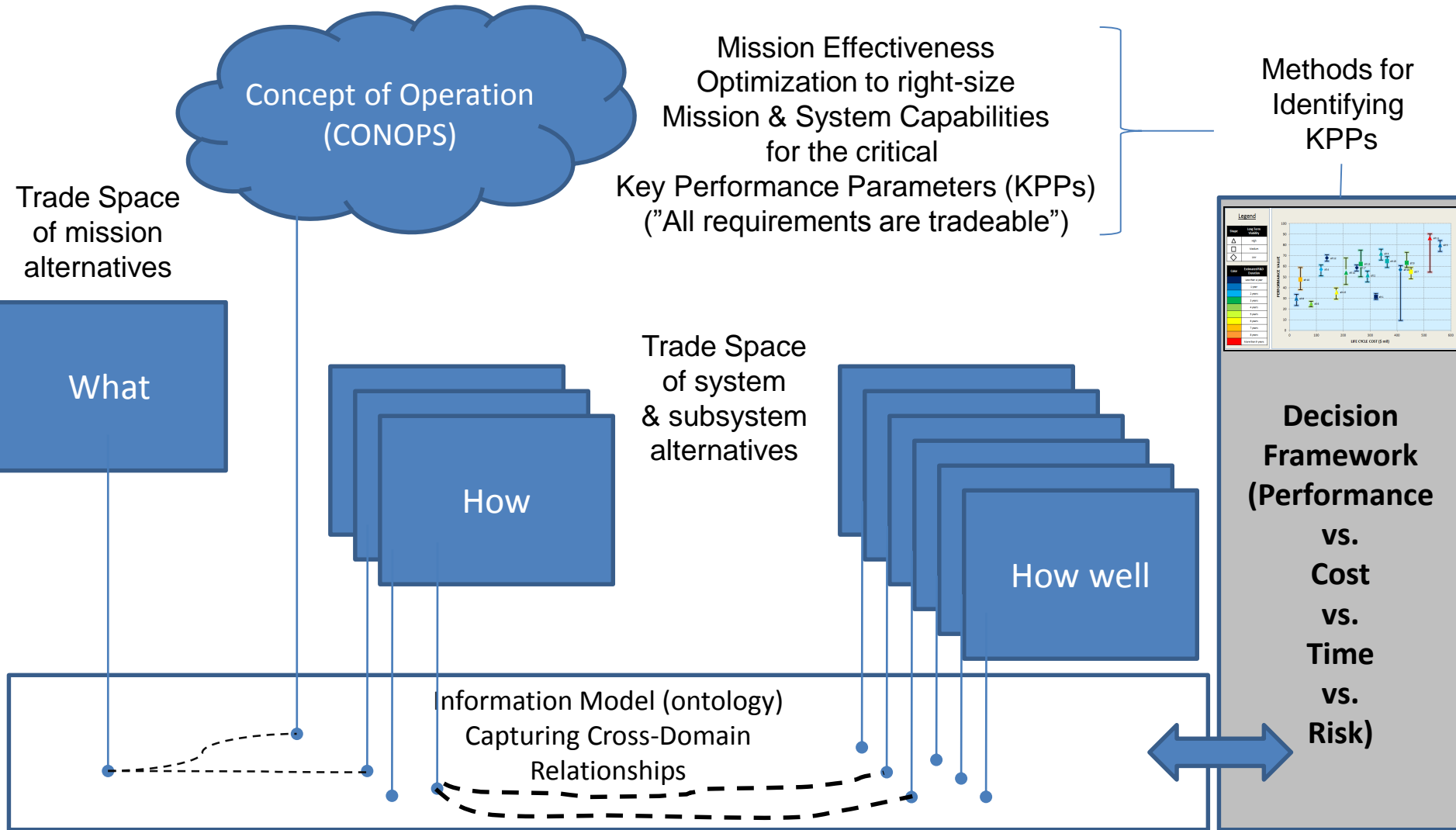
Provides optimization analysis **Across Domains** to support KPP and alternatives trades at mission, system, & subsystem levels

## Integrated Modeling Environment



# ARDEC Research Examples & Interoperability and Integration Framework (IoIF)





Reasoning about completeness and consistency of information across domains



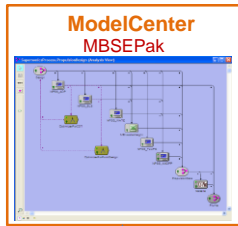




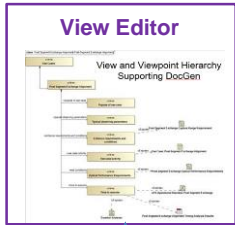
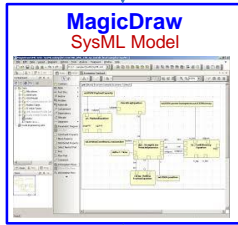
# Interoperability and Integration Framework (IoIF) using Semantic Web Technologies

- Uses OpenMBEE, SysML Models and ModelCenter (MDAO) and a Decision Ontology to support Visualization of Tradespace

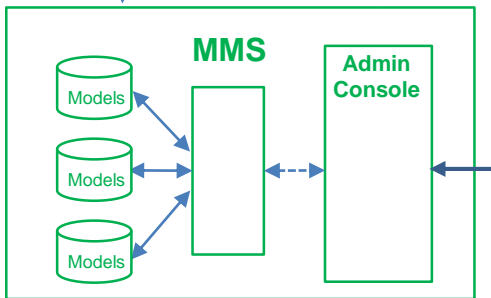
## MDAO



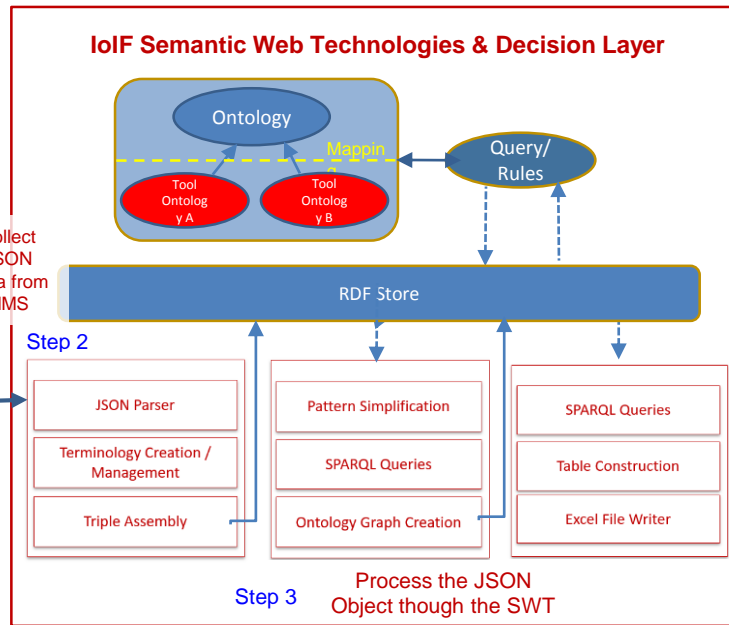
**Docker Installer for OpenMBEE**



Step 1 Store Data into MMS



## Interoperability and Integration Framework (IoIF)



OpenMBEE: Model Management System (MMS), View Editor, Model Development Kit (DocGen)

## Alternative Analysis Visualizations Views

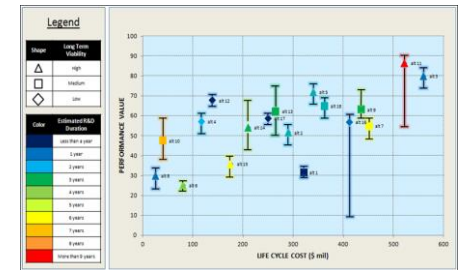
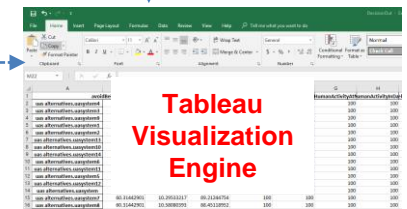


Tableau will auto update the Visualization when the Excel Data Changes  
Step 5

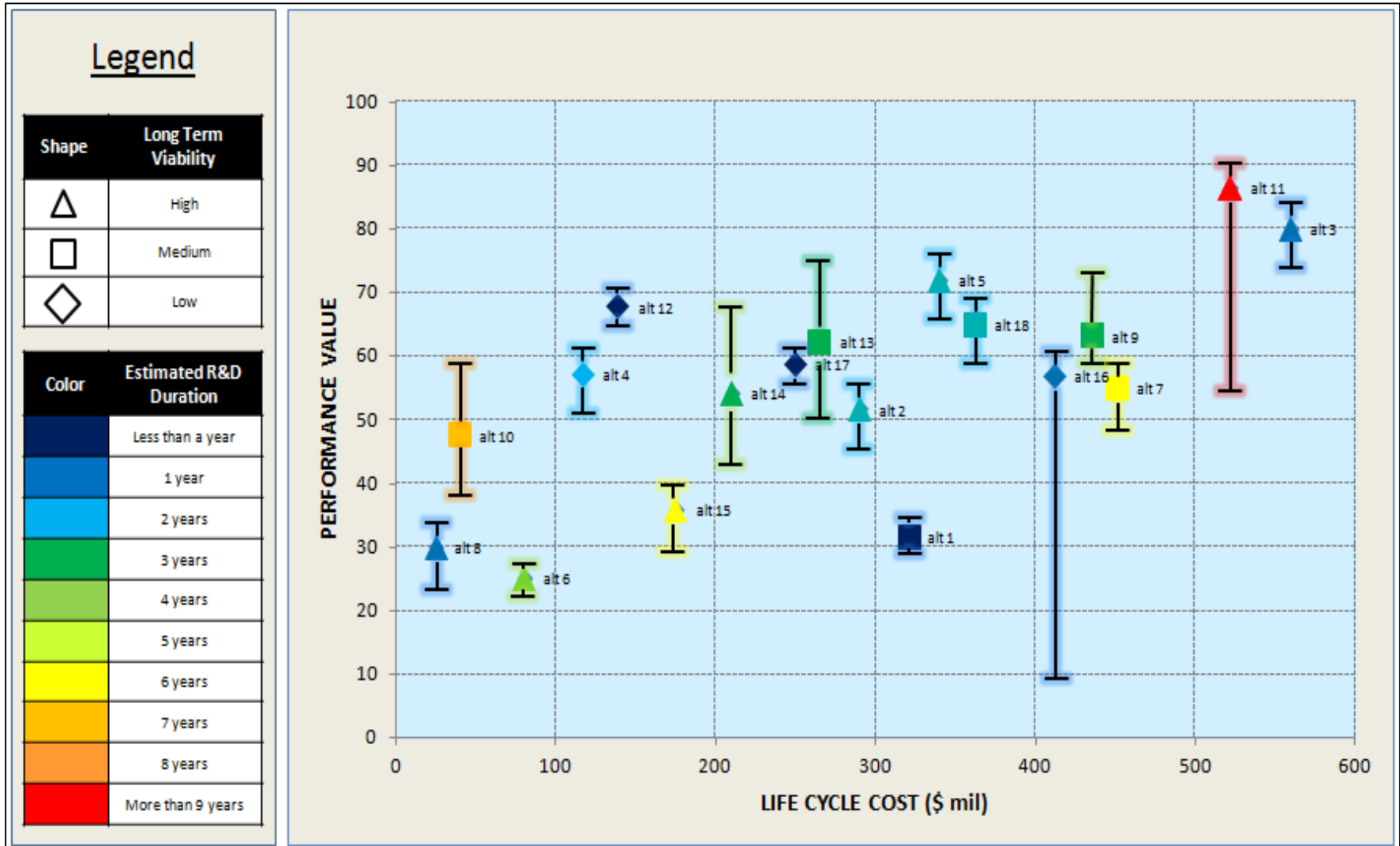
Write Data to Excel File  
Step 4

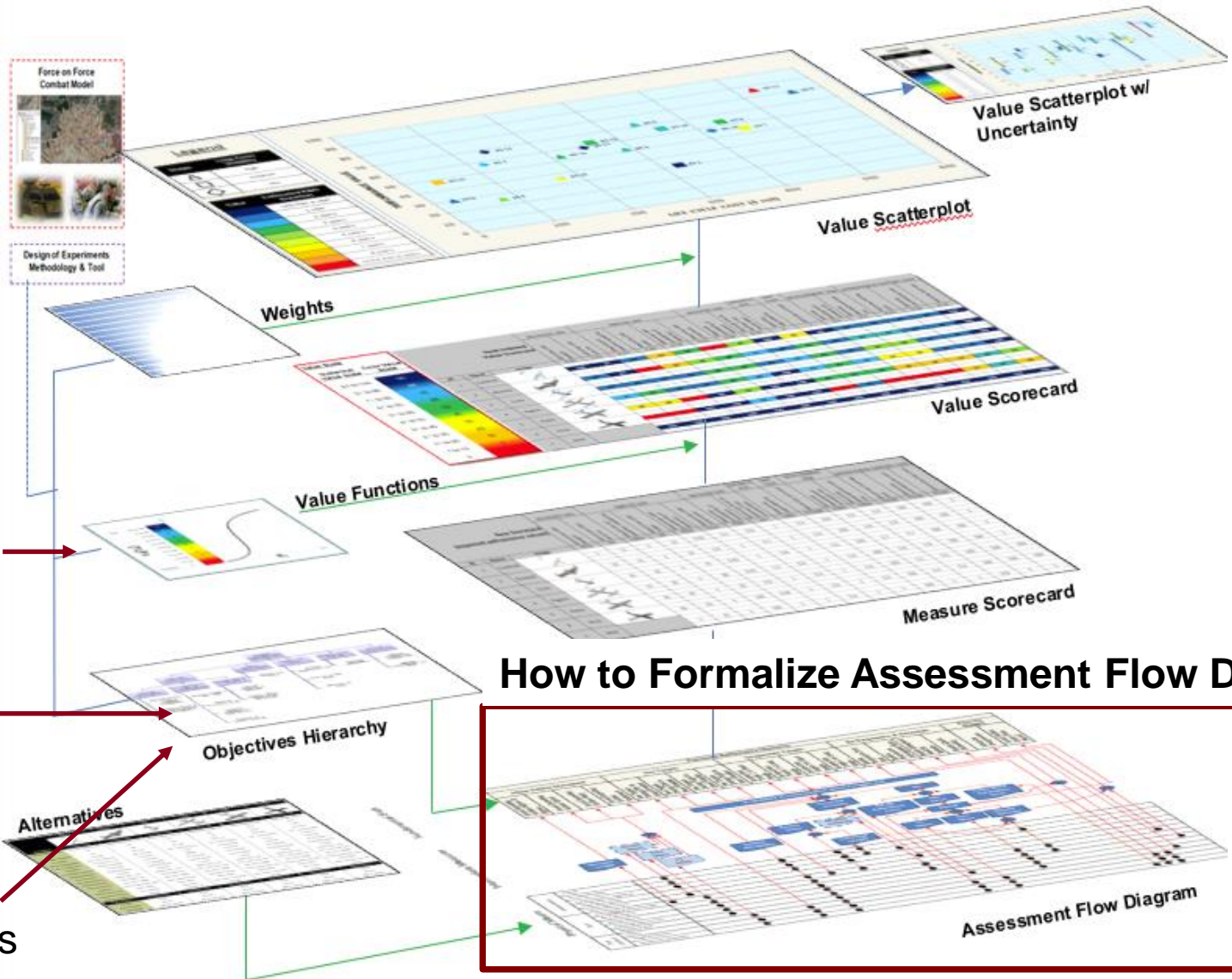


**Tableau Visualization Engine**

RDF: Resource Description Framework  
SPARQL: Query Language for RDF

# Visualizing Alternatives – Value Scatterplot with Assessing Impact of Uncertainty\*





## How to Formalize Assessment Flow Diagram?

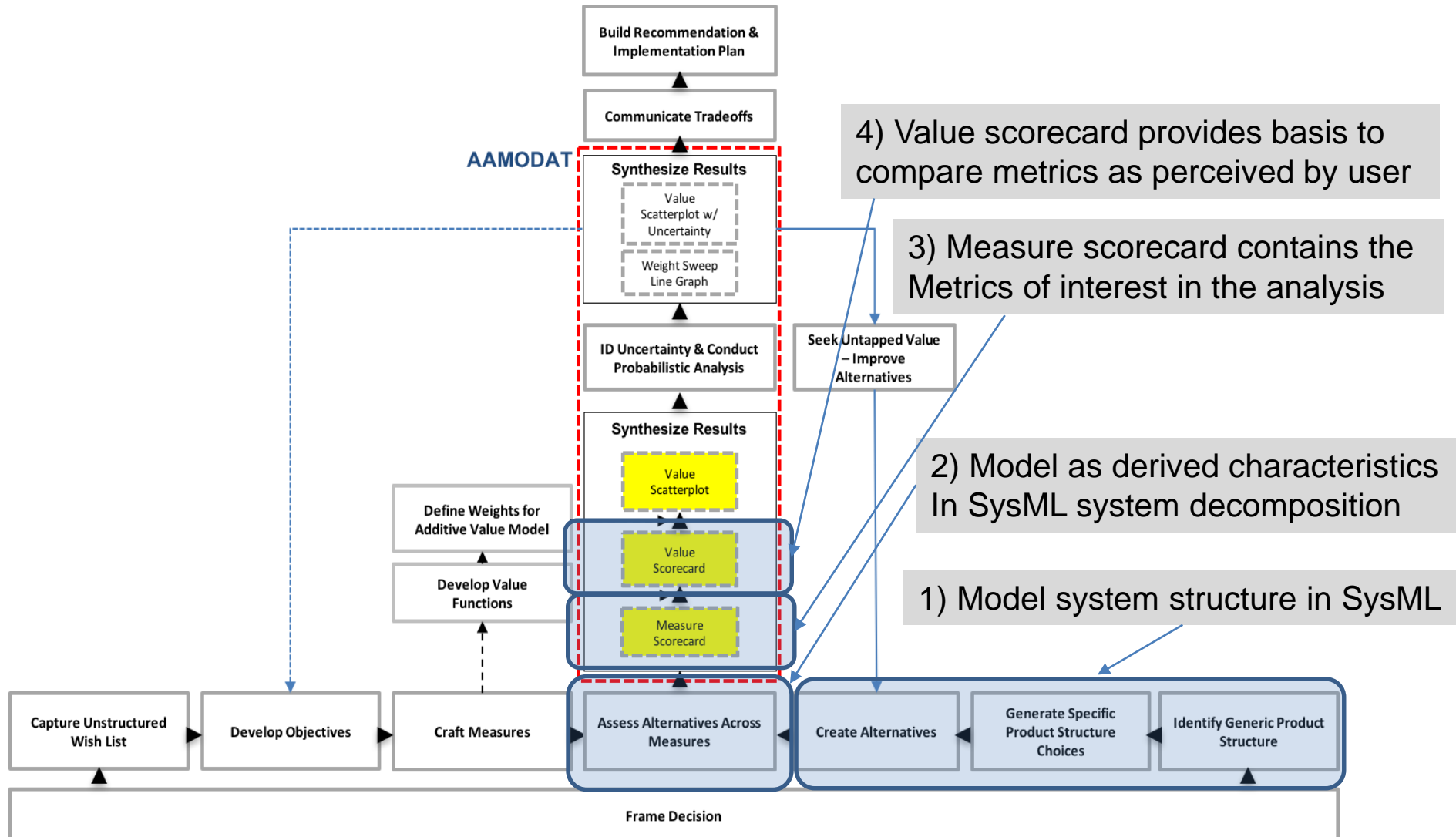
Value Functions

Identify KPPs

Objective Hierarchy of Decisions

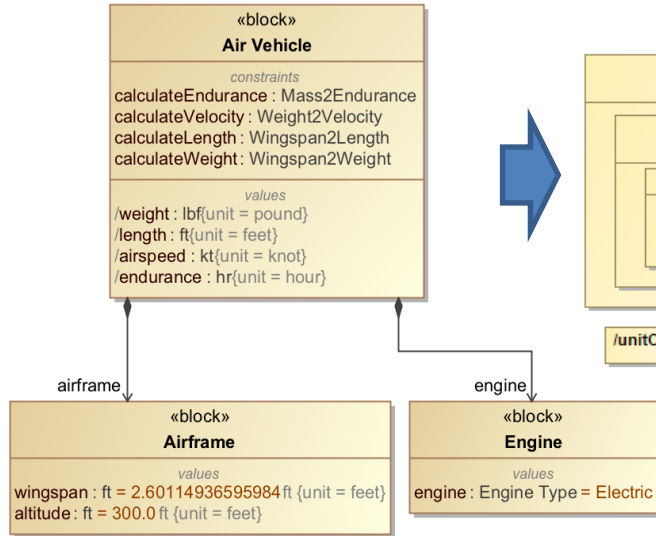


# Steps to Formalize Decision Support Model Construct using SysML and ModelCenter

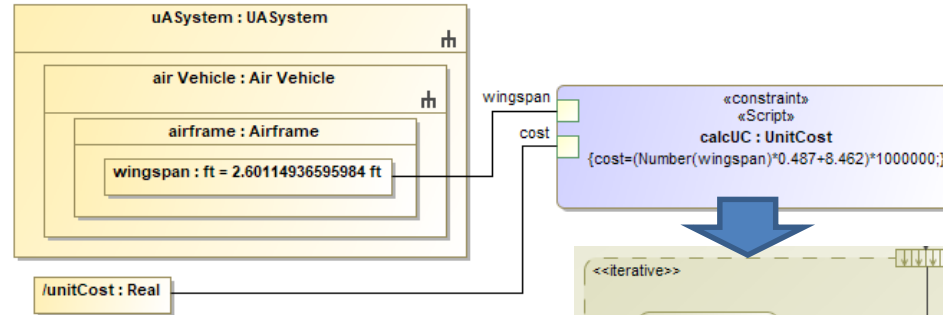




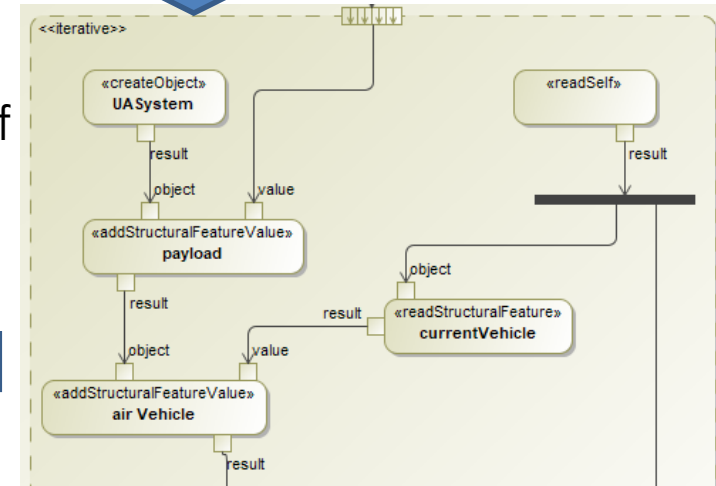
- Design Variables/Attributes in Block Hierarchy



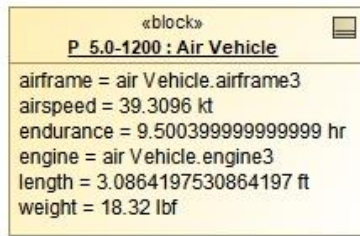
- Parametrics



- Generation of Alternatives



- Resulting UAS Instances

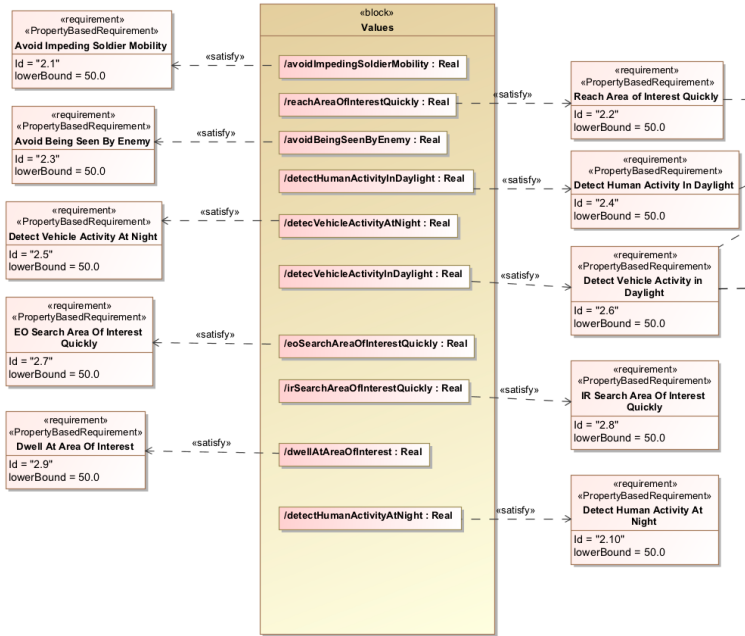


## More details provided in Webinar

Applications for Three Research Use Cases in Model Centric Engineering using ModelCenter and MBSE Pak at:

<https://www.phoenix-int.com/applications-three-research-use-cases-model-centric-engineering-using-modelcenter-mbse-analyzer/>

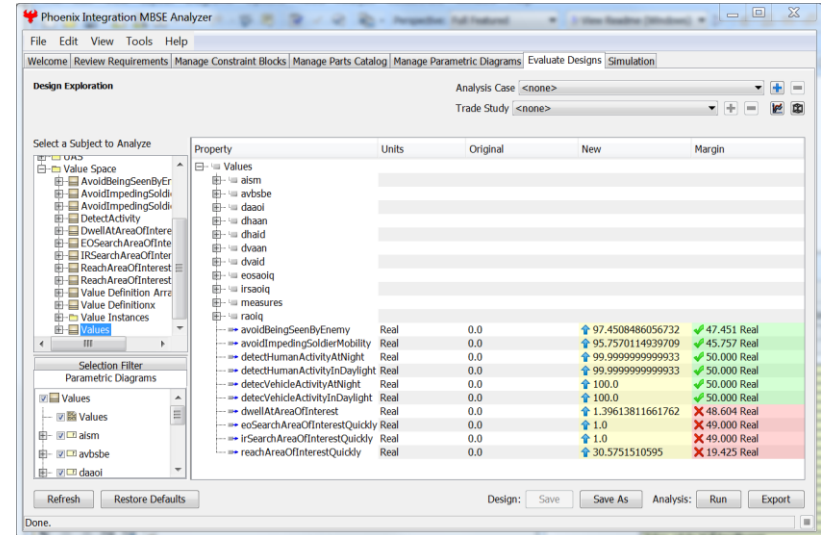
# Simulations of Model Constraints Checks Bounds on Values as Requirements



Cameo Simulation Toolkit

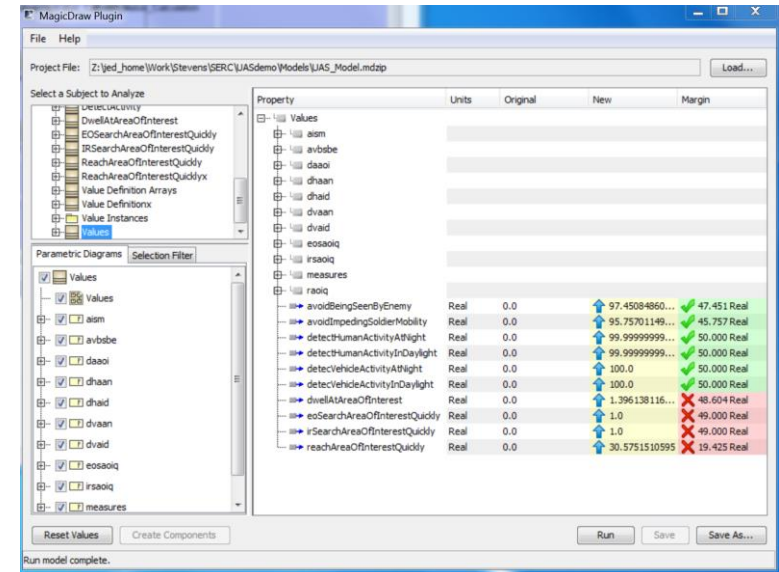
Name	Value
Values {avoidImpedingSoldierMobility ...}	Values@2a29f00e
/avoidBeingSeenByEnemy : Real	97.4508
/avoidImpedingSoldierMobility : Real	95.7570
/detectHumanActivityAtNight : Real	100.0000
/detectHumanActivityInDaylight : Real	100.0000
/detecVehicleActivityAtNight : Real	100.0000
/detecVehicleActivityInDaylight : Real	100.0000
/dwellAtAreaOfInterest : Real	1.3961
/eoSearchAreaOfInterestQuickly : Real	1.0000
/irSearchAreaOfInterestQuickly : Real	1.0000
/reachAreaOfInterestQuickly : Real	30.5752

MBSE Pak from within MagicDraw



Property	Units	Original	New	Margin
avoidBeingSeenByEnemy	Real	0.0	97.4508486056732	✓ 47.451 Real
avoidImpedingSoldierMobility	Real	0.0	95.7570114039709	✓ 45.757 Real
detectHumanActivityAtNight	Real	0.0	99.9999999999933	✓ 50.000 Real
detectHumanActivityInDaylight	Real	0.0	99.9999999999933	✓ 50.000 Real
detecVehicleActivityAtNight	Real	0.0	100.0	✓ 50.000 Real
detecVehicleActivityInDaylight	Real	0.0	100.0	✓ 50.000 Real
dwellAtAreaOfInterest	Real	0.0	1.39613811661762	✗ 48.604 Real
eoSearchAreaOfInterestQuickly	Real	0.0	1.0	✗ 49.000 Real
irSearchAreaOfInterestQuickly	Real	0.0	1.0	✗ 49.000 Real
reachAreaOfInterestQuickly	Real	0.0	30.5751510595	✗ 19.425 Real

MBSE Pak from within Model Center



Property	Units	Original	New	Margin
avoidBeingSeenByEnemy	Real	0.0	97.45084860...	✓ 47.451 Real
avoidImpedingSoldierMobility	Real	0.0	95.75701149...	✓ 45.757 Real
detectHumanActivityAtNight	Real	0.0	99.99999999...	✓ 50.000 Real
detectHumanActivityInDaylight	Real	0.0	99.99999999...	✓ 50.000 Real
detecVehicleActivityAtNight	Real	0.0	100.0	✓ 50.000 Real
detecVehicleActivityInDaylight	Real	0.0	100.0	✓ 50.000 Real
dwellAtAreaOfInterest	Real	0.0	1.396138116...	✗ 48.604 Real
eoSearchAreaOfInterestQuickly	Real	0.0	1.0	✗ 49.000 Real
irSearchAreaOfInterestQuickly	Real	0.0	1.0	✗ 49.000 Real
reachAreaOfInterestQuickly	Real	0.0	30.5751510595	✗ 19.425 Real



# SysML Model Transformed using MBSE Pak into ModelCenter for MDAO

Independent Variables (are Design Variables)

The screenshot displays the Phoenix Integration ModelCenter 11.2 interface. On the left, a Component Tree shows a hierarchical model structure. The central workspace contains a SysML diagram with various components and relationships. On the right, the Optimization Tool 1.4.4 window is open, showing the following data:

**Objective Definition**

Objective	Value	Weight	Goal
Model Values.Values measures uSystem weight	10.7322	1	minimize

**Constraint**

Constraint	Value	Lower Bound	Upper Bound
Model Values.Values iSearchAreaOfInterestQuickly		1	50
Model Values.Values reachAreaOfInterestQuickly	58.9317	1	50
Model Values.Values eoSearchAreaOfInterestQuickly		1	50
Model Values.Values avoidBeingSeenByEnemy	52.9563	50	1
Model Values.Values detectVehicleActivityAtNight	100	50	1
Model Values.Values detectHumanActivityInDaylight	100	50	1

**Design Variables**

Design Variable	Type	Value	Start Value (Explicit value)	Lower Bound	Upper Bound
Model Values.Values measures uSystem air_Vehicle airtime wingspan	contin	7.15	2.60115		
Model Values.Values measures uSystem payload eoSensor horzSheets	discrete	100	100	2	20
Model Values.Values measures uSystem payload eoSensor vertPneaks	discrete	100	100		

Below the optimization tool, a Data Explorer window shows a plot of various variables over 550 runs. The y-axis represents values for variables like 'enByEnemy', 'detectVehicleActivityAtNight', and 'detectHumanActivityInDaylight'. The x-axis is 'Run Number'.

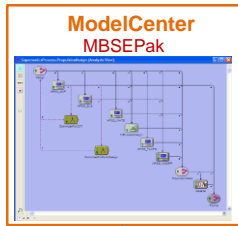
Optimization Tool

Dependent Variables -- Values (are Constraints/Objectives)

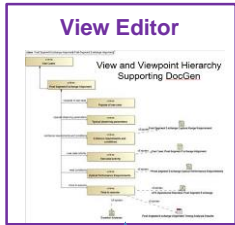
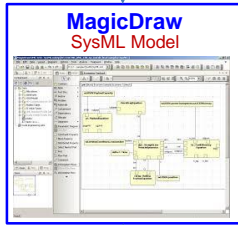
# Interoperability and Integration Framework (IoIF) using Semantic Web Technologies

- Uses OpenMBEE, SysML Models and ModelCenter (MDAO) and a Decision Ontology to support Visualization of Tradespace

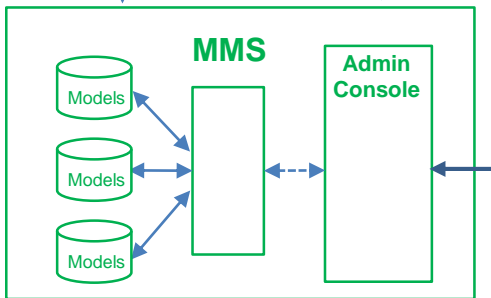
## MDAO



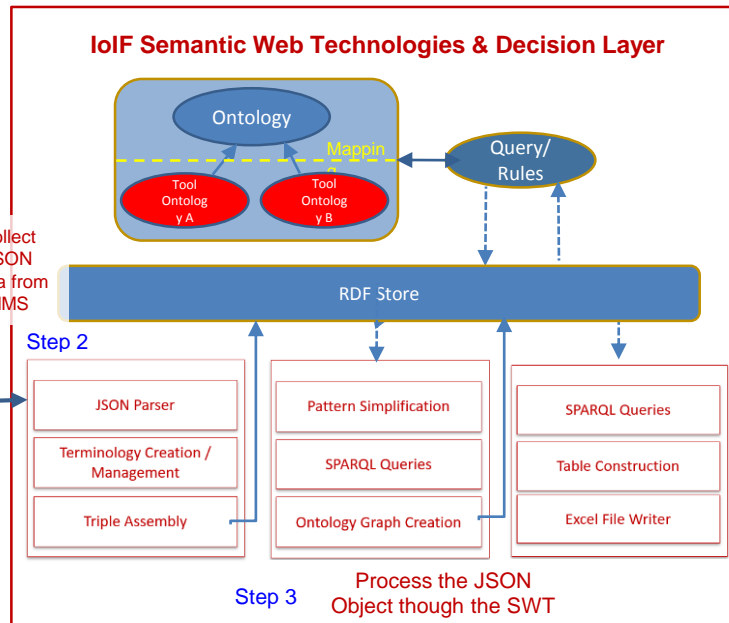
**Docker Installer for OpenMBEE**



Step 1 Store Data into MMS



## Interoperability and Integration Framework (IoIF)



## Alternative Analysis Visualizations Views

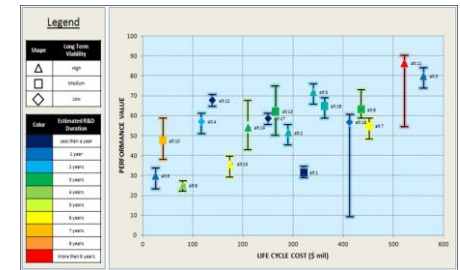
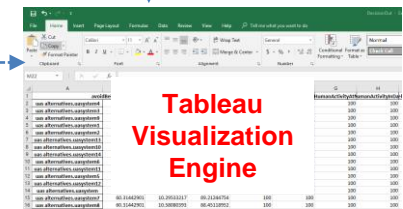


Tableau will auto update the Visualization when the Excel Data Changes  
Step 5

Write Data to Excel File

Step 4



**Tableau Visualization Engine**

OpenMBEE: Model Management System (MMS), View Editor, Model Development Kit (DocGen)

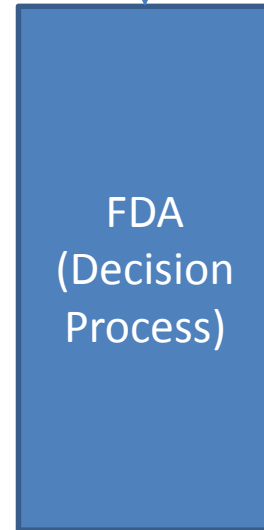
RDF: Resource Description Framework  
SPARQL: Query Language for RDF

- OBO foundational to solving the human genome
- Basic Formal Ontology (BFO) foundational to developing interoperable ontologies

Analogous to Decision Framework

Basic Formal Ontology (BFO)

RELATION TO TIME	CONTINUANT				OCCURRENT
	INDEPENDENT		DEPENDENT		
GRANULARITY					
ORGAN AND ORGANISM	Organism (NCBI Taxonomy)	Anatomical Entity (FMA, CARO)	Organ Function (FMP, CPRO)	Phenotypic Quality (PaTO)	<b>Biological Process (GO)</b>
CELL AND CELLULAR COMPONENT	Cell (CL)	<b>Cellular Component (FMA, GO)</b>	Cellular Function (GO)		
MOLECULE	Molecule (ChEBI, SO, RnaO, PrO)		<b>Molecular Function (GO)</b>	Molecular Process (GO)	



Original OBO (Open Biomedical Ontologies) Foundry  
(Gene Ontology in yellow)



## RT-168: Graphical CONOPS



RT-168: Graphical CONOPS

Navigate with arrow keys

Design

Reset  Graph  Thrust Model  Propulsion/Endurance  Mass Done

Blue UAV Design Parameters: Baseline in ( )

0	N	0	100%	100%
0	N	0	100%	100%
0	N	0	100%	100%
0	N	0	100%	100%
0	N	0	100%	100%
0	N	0	100%	100%
0	N	0	100%	100%
0	N	0	100%	100%
0	N	0	100%	100%
0%	% of ref val	100%	100%	100%
0%	% of ref val	100%	100%	100%

Dependent Variables

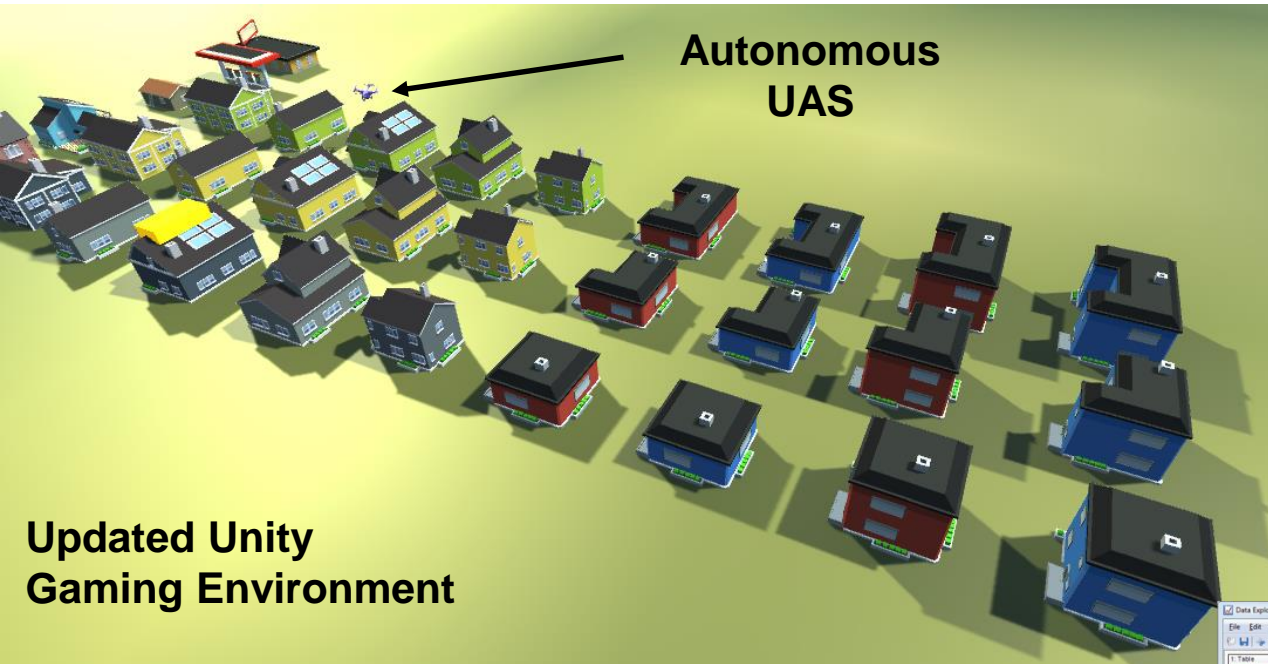
- 0 (mAh)V--- Energy in Battery
- 5 g--- Battery Mass
- 10 g--- UAV Mass
- 314 cm<sup>2</sup>--- Rotor Area
- 0 ma--- Max Current
- 0 W--- Max Power
- Max Thrust to Weight
- Max HorizontalThrust to Weight

Design Parameters

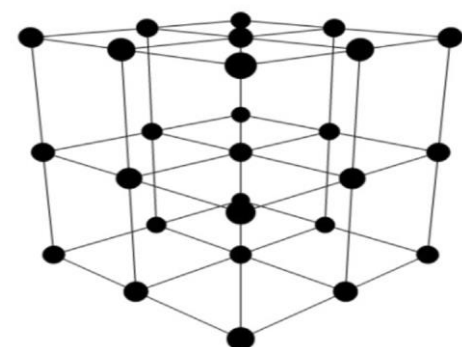
Quit

/Users/blackburnm/Downloads/GraphicalCONOPsv108Mac/GraphicalCONOPsv108Mac.app/Contents

# Graphical CONOPS Simulation with MDAO tools Exercises DoE Space 'Headlessly'

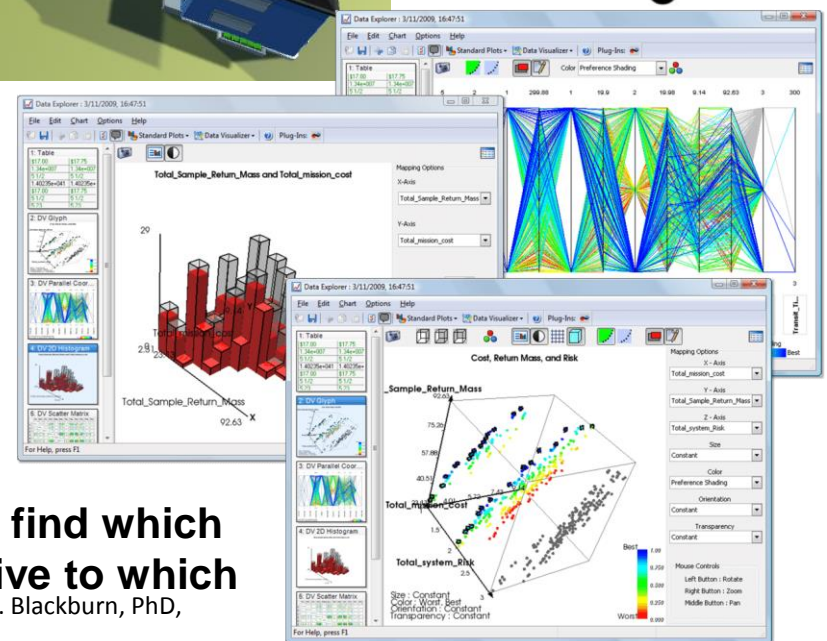
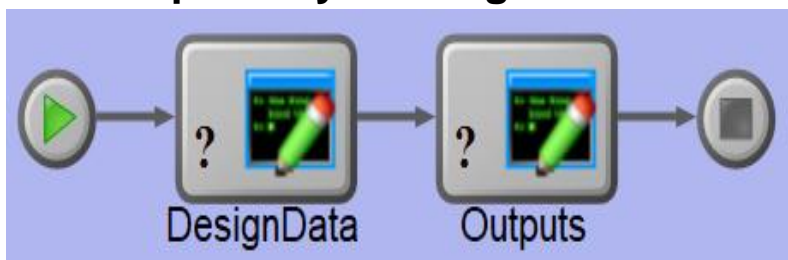


1000s of runs to cover Design of Experiments vs. 10s that could be run manually



Updated Unity Gaming Environment

Headless (no humans in loop) ModelCenter Workflow Wraps Unity Gaming Software



Sensitivity Analysis – to find which outputs are most sensitive to which input variables

Mark R. Blackburn, PhD,

Brian Chell and Roger Jones

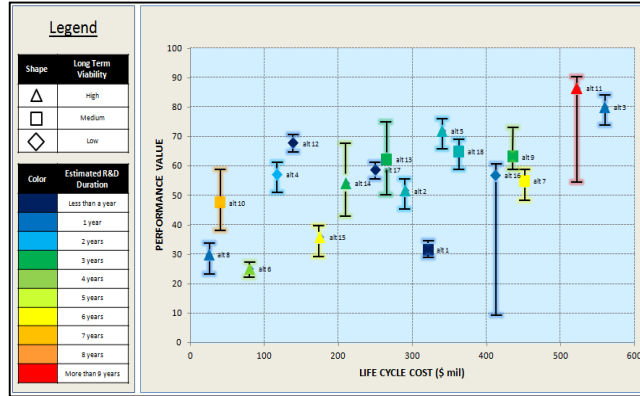
# Future: Mission Capabilities Alternative Analysis of Composable System Alternatives using IoIF

- Ontologies provide representations to enable AI/Machine Learning

Mission/CONOPS

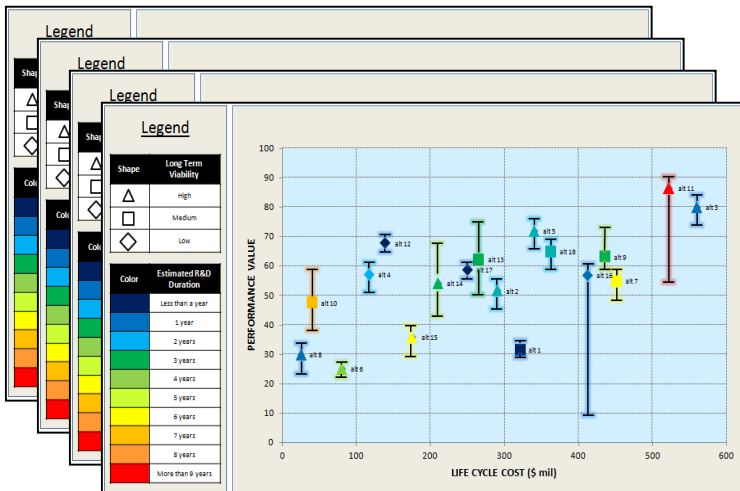
2) Inverse design optimization problem

System Tradespaces of Candidate Solutions that could support Mission Capabilities



Mission Capabilities for Tradespaces incorporating Territory, Tactics and Terrain Scenarios

3) Connection of the forward problem and the inverse problem through feedback control?



4) New: design optimization in a learning system and in multiple learning systems

response to changing aspect of Tactics, Terrain and Territory

response to Red Team

1) Forward design optimization problem



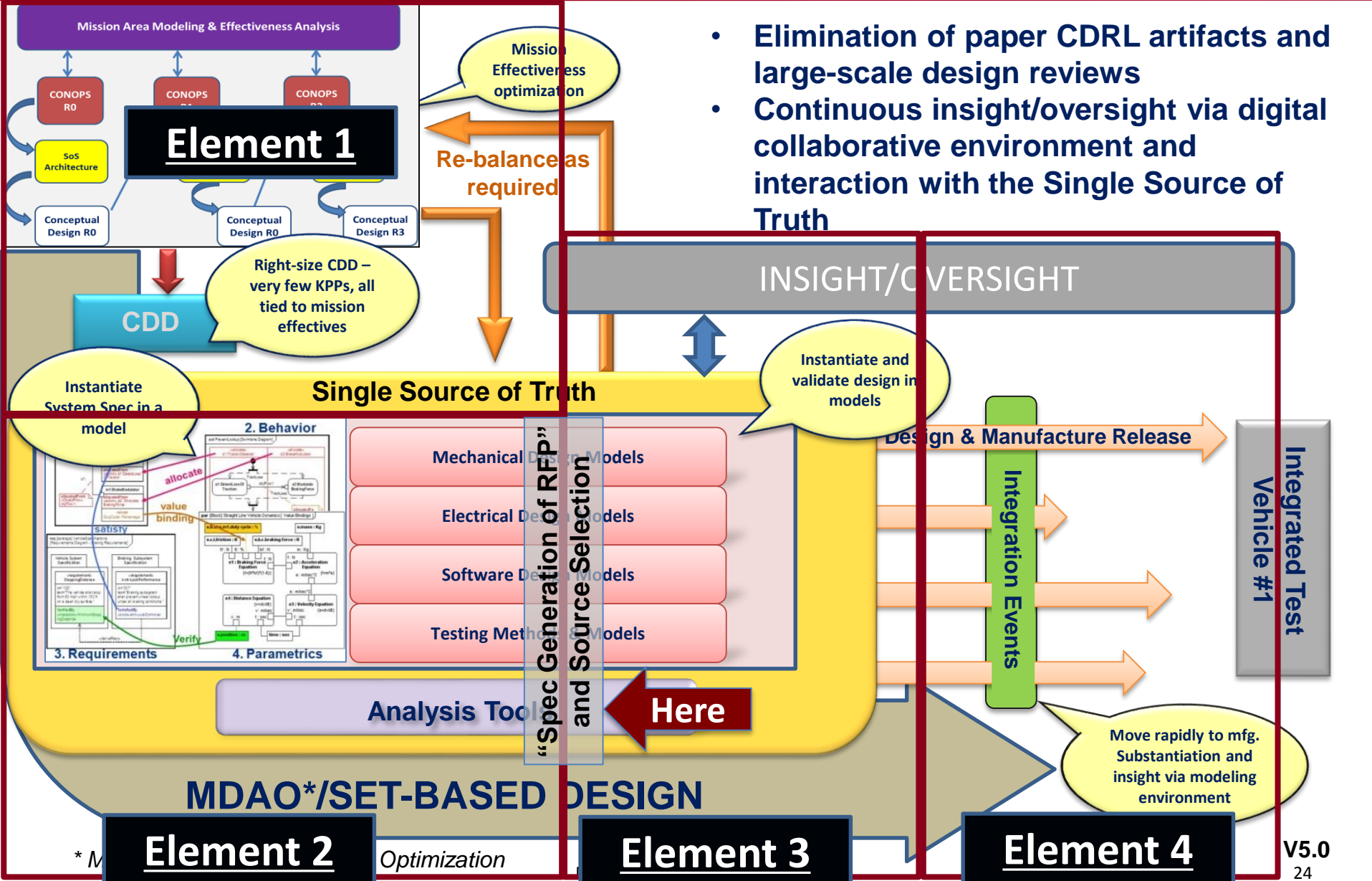
# Surrogate Pilot for NAVAIR SE Transformation Framework Experiments





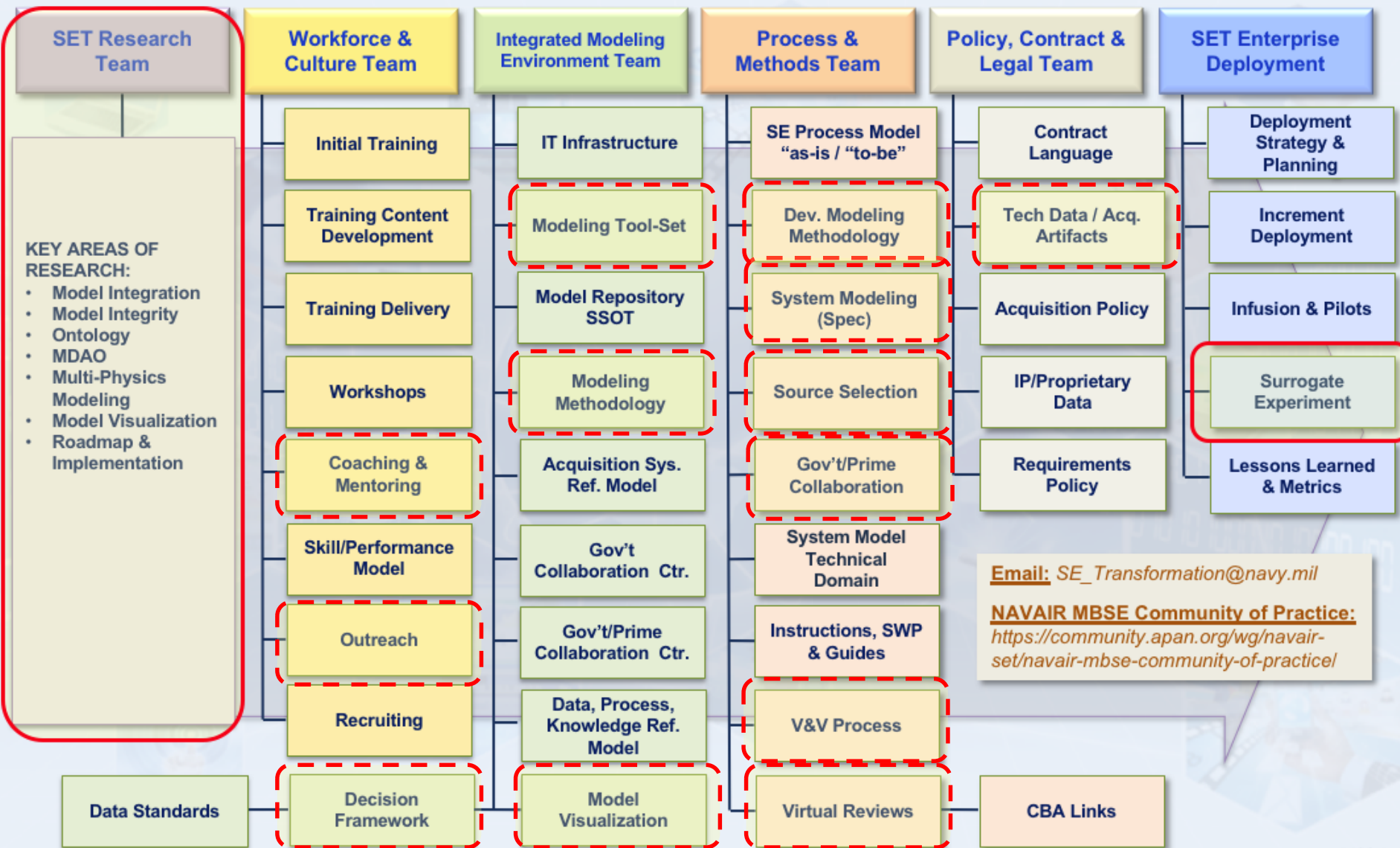
- 2013-2015: Global Scan of Most Holistic approaches to MCE/DE
- 2015: NAVAIR leadership decides they must move quickly to keep pace with other organizations that adopted MCE
- 2016: NAVAIR leadership – Accelerate Systems Engineering Transformation (SET) based on new **SET Framework** Concept
- 2017: Systematic planning of six (6) SET Functional Areas
- 2017 - late: **Surrogate Pilot Experiments kickoff** to Characterize, Assess and Refine SET Framework approach to Model-based Acquisition using new operational paradigm between government and industry
- 2018 – now: Awaiting Request for Proposal (RFP) Response from Surrogate Contractor

# Surrogate Pilot focus is on Characterizing Assessing, and Refining SET Framework



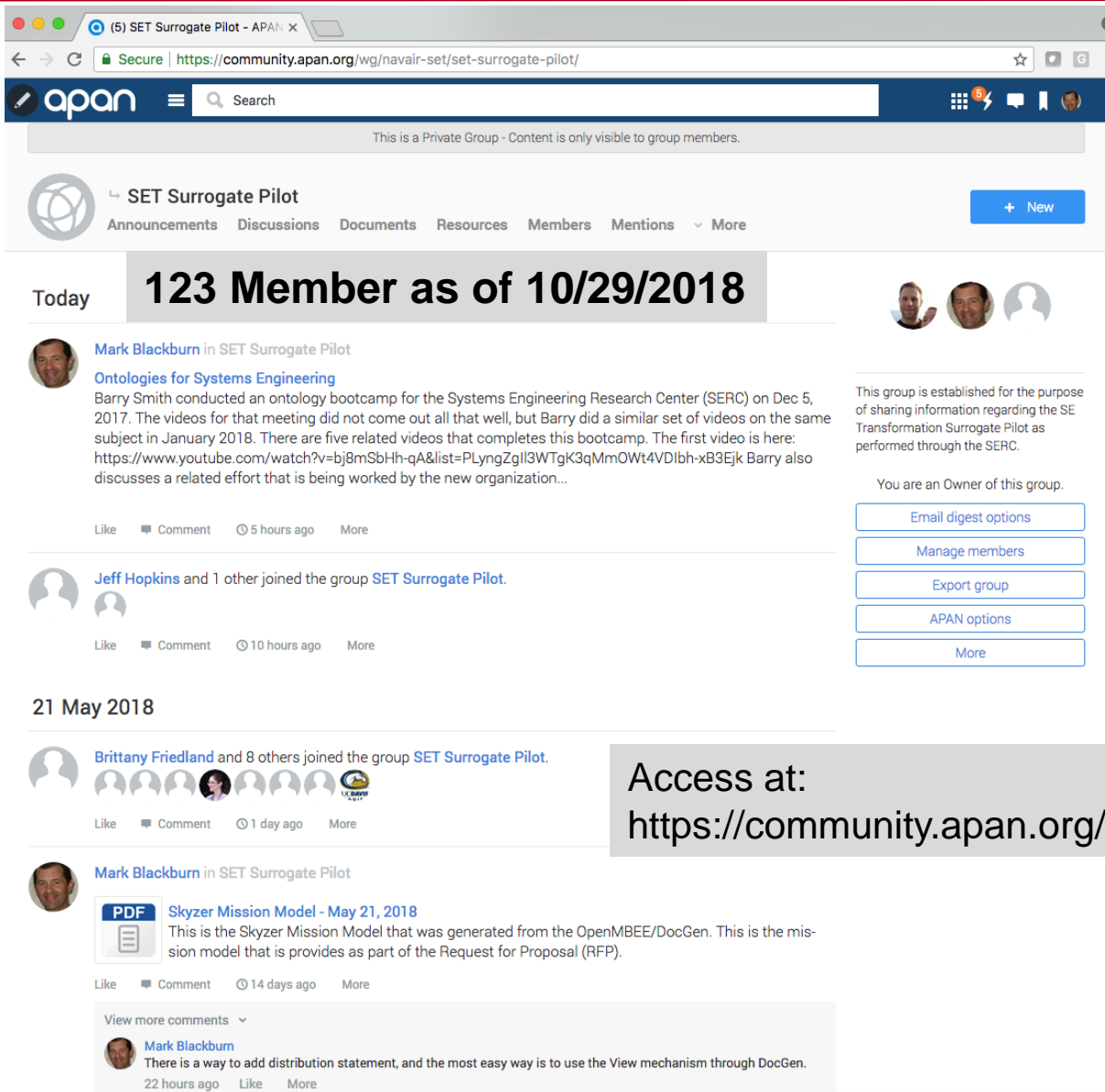


# SET Functional Areas



**Email:** [SE\\_Transformation@navy.mil](mailto:SE_Transformation@navy.mil)  
**NAVAIR MBSE Community of Practice:**  
<https://community.apan.org/wg/navair-set/navair-mbse-community-of-practice/>

# Continuous Updates of Discussion Threads Provided on Public All Partners Network (APAN.org)



(5) SET Surrogate Pilot - APAN x

Secure | <https://community.apan.org/wg/navair-set/set-surrogate-pilot/>

apan Search

This is a Private Group - Content is only visible to group members.

SET Surrogate Pilot

Announcements Discussions Documents Resources Members Mentions More

+ New

Today **123 Member as of 10/29/2018**

Mark Blackburn in SET Surrogate Pilot

**Ontologies for Systems Engineering**

Barry Smith conducted an ontology bootcamp for the Systems Engineering Research Center (SERC) on Dec 5, 2017. The videos for that meeting did not come out all that well, but Barry did a similar set of videos on the same subject in January 2018. There are five related videos that completes this bootcamp. The first video is here: <https://www.youtube.com/watch?v=bj8mSbHh-qA&list=PLyngZgI3WTgK3qMmOWt4VDIbh-xB3Ejk> Barry also discusses a related effort that is being worked by the new organization...

Like Comment 5 hours ago More

Jeff Hopkins and 1 other joined the group SET Surrogate Pilot.

Like Comment 10 hours ago More

21 May 2018

Brittany Friedland and 8 others joined the group SET Surrogate Pilot.

Like Comment 1 day ago More

Mark Blackburn in SET Surrogate Pilot

**PDF Skyzer Mission Model - May 21, 2018**

This is the Skyzer Mission Model that was generated from the OpenMBEE/DocGen. This is the mission model that is provides as part of the Request for Proposal (RFP).

Like Comment 14 days ago More

View more comments

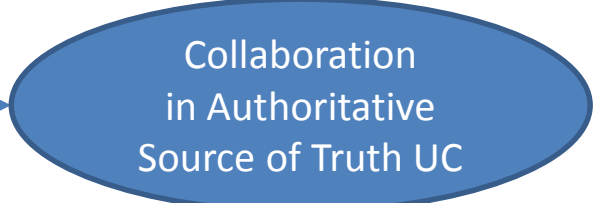
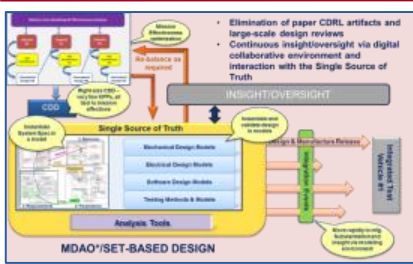
Mark Blackburn

There is a way to add distribution statement, and the most easy way is to use the View mechanism through DocGen.

22 hours ago Like More

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

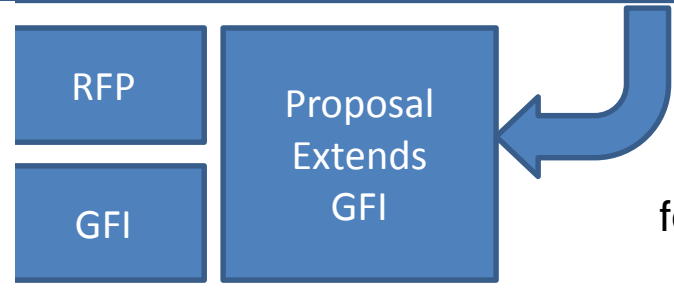
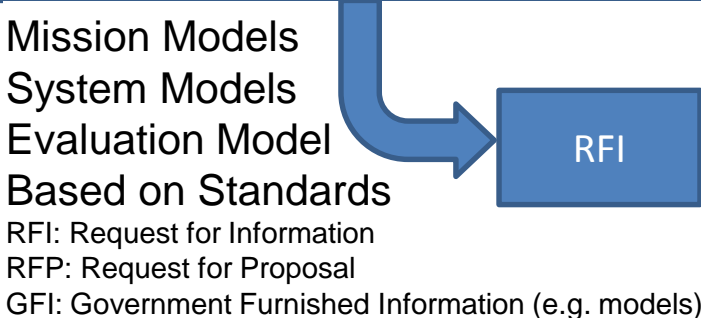
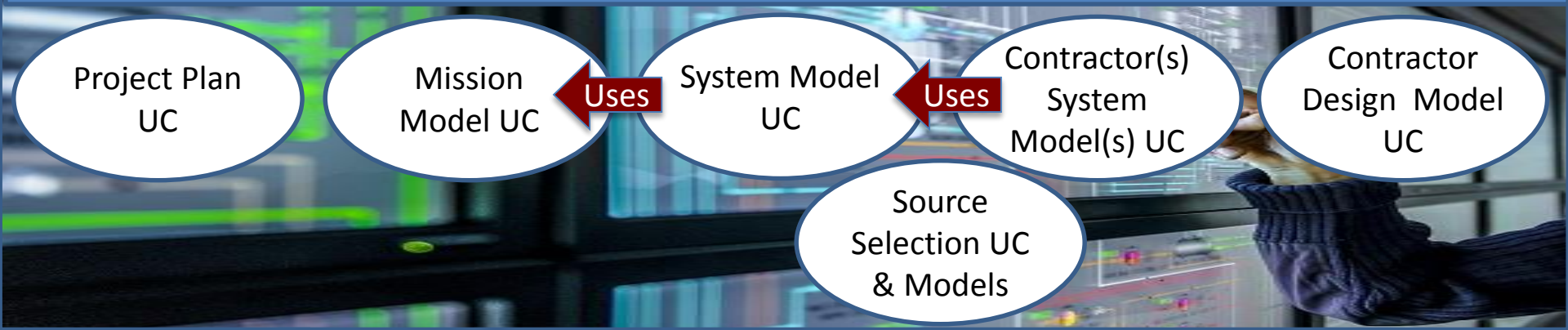
# Use Cases for Surrogate Pilot and Experimental System (Skyzer)



Objectives to Assess SE Framework

How we Collaborate in AST

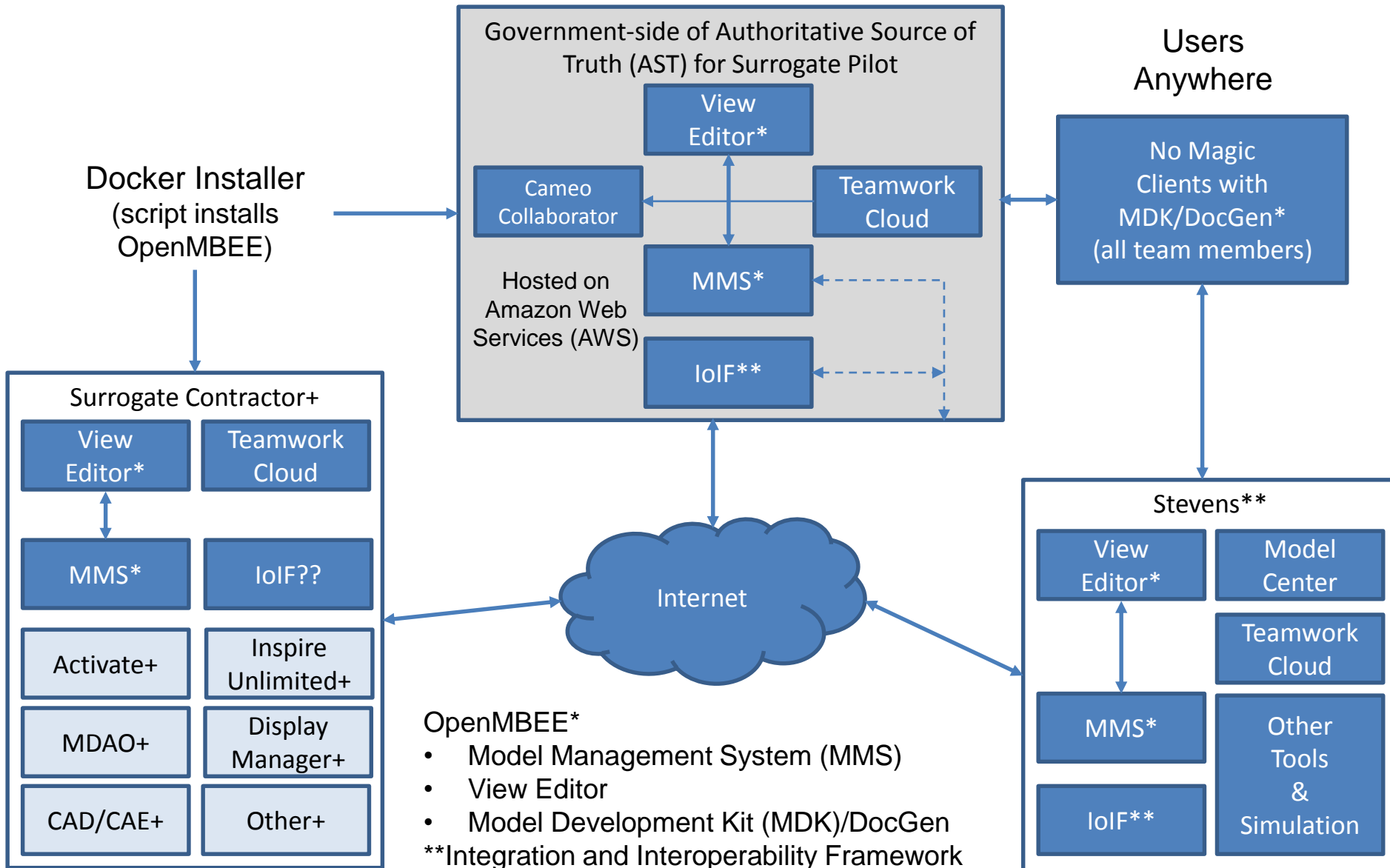
## Skyzer is Experimental System using Authoritative Source of Truth (AST)



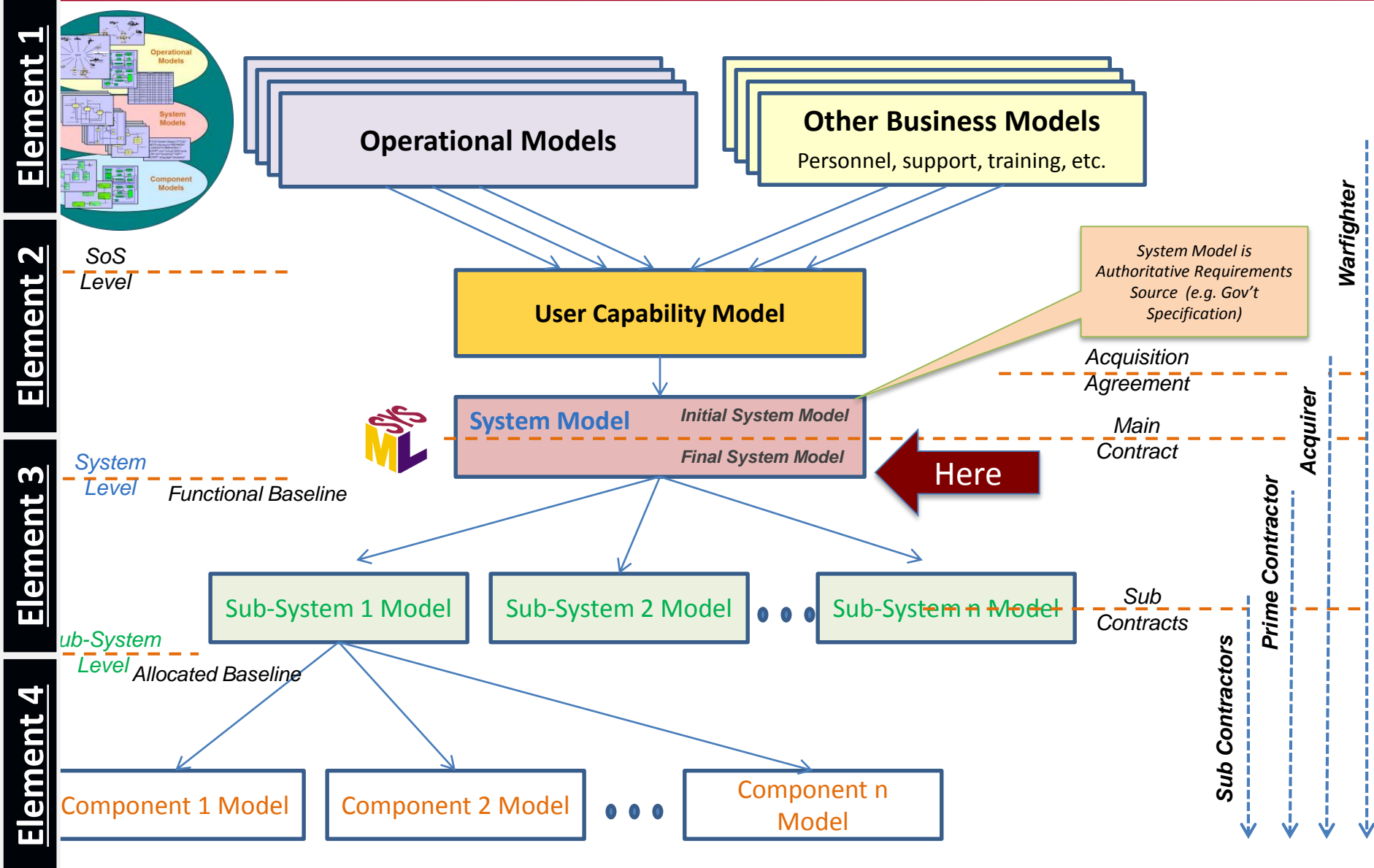
Proposal for Design Models must be able to demonstrate aspects for Producability Decisions involving **Multi-physics**



# Elements of Authoritative Source of Truth for Government/Industry Collaboration



# Skyzer Demonstrates Formalizing the Use of Models for the SET Framework Elements

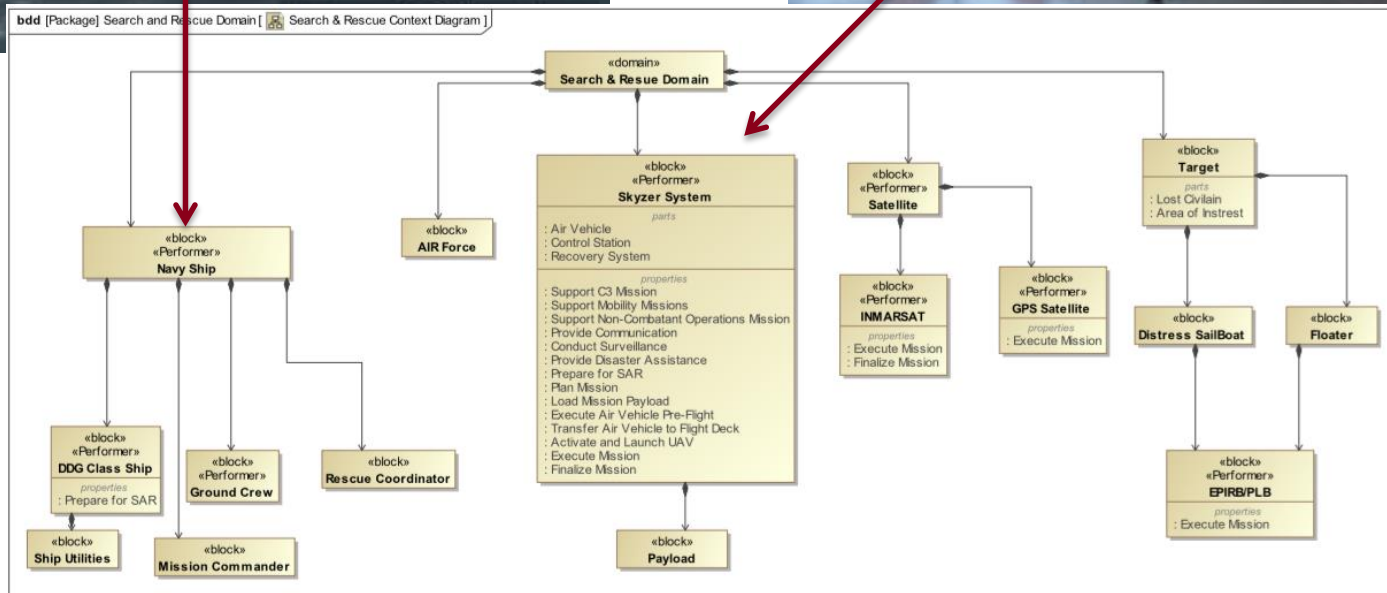




## Graphical CONOPS Scenario: Search & Rescue



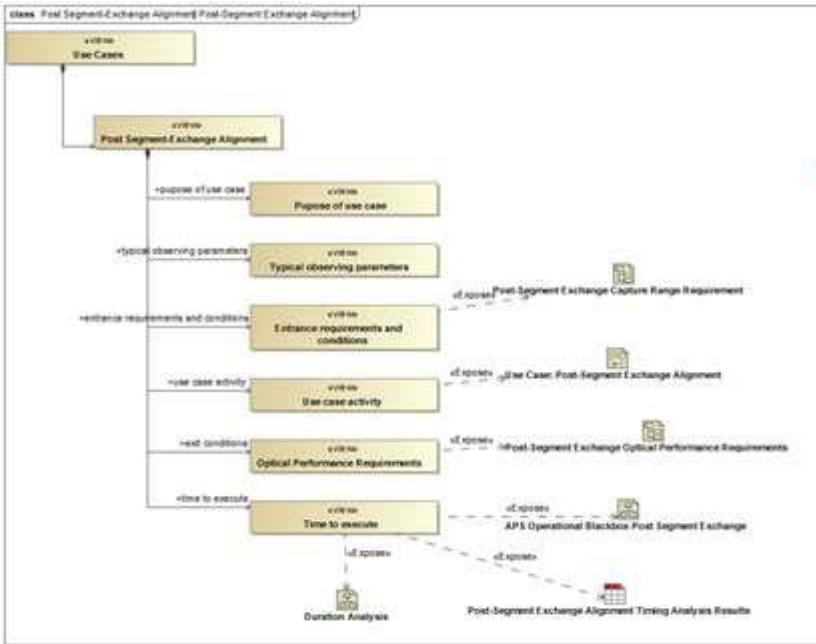
## Airfoil designation for a similar Bell tilt-rotor



Skyzer System & Mission Models developed using SysML

Mark R. Blackburn, PhD,

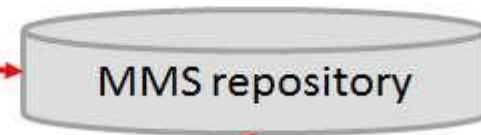
## Model Development Kit/DocGen View and Viewpoint Hierarchy



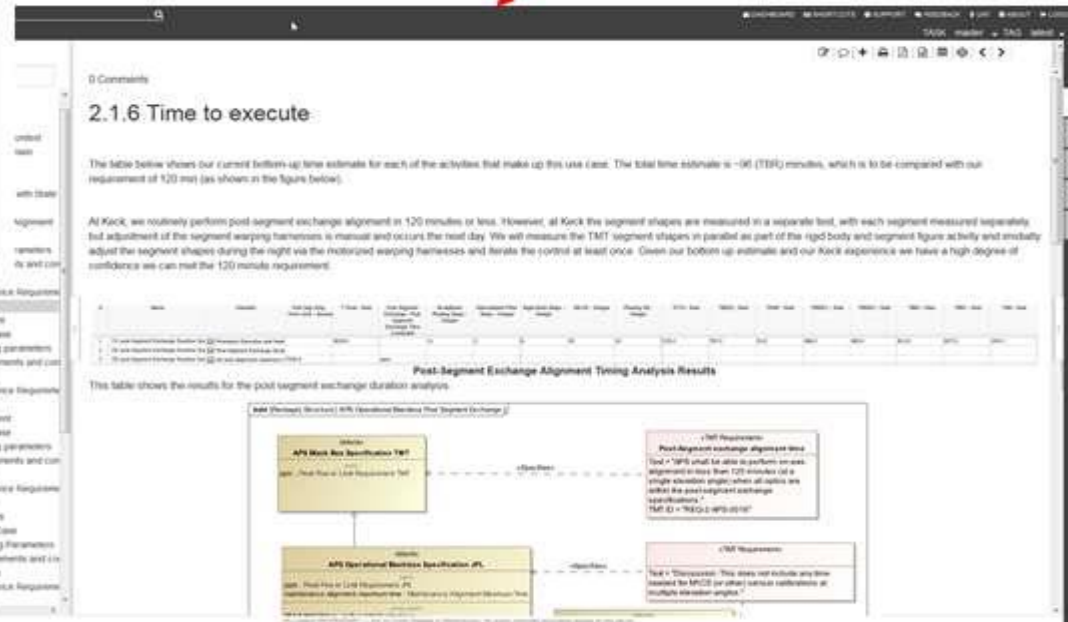
Visualization in View Editor



## Model Management System



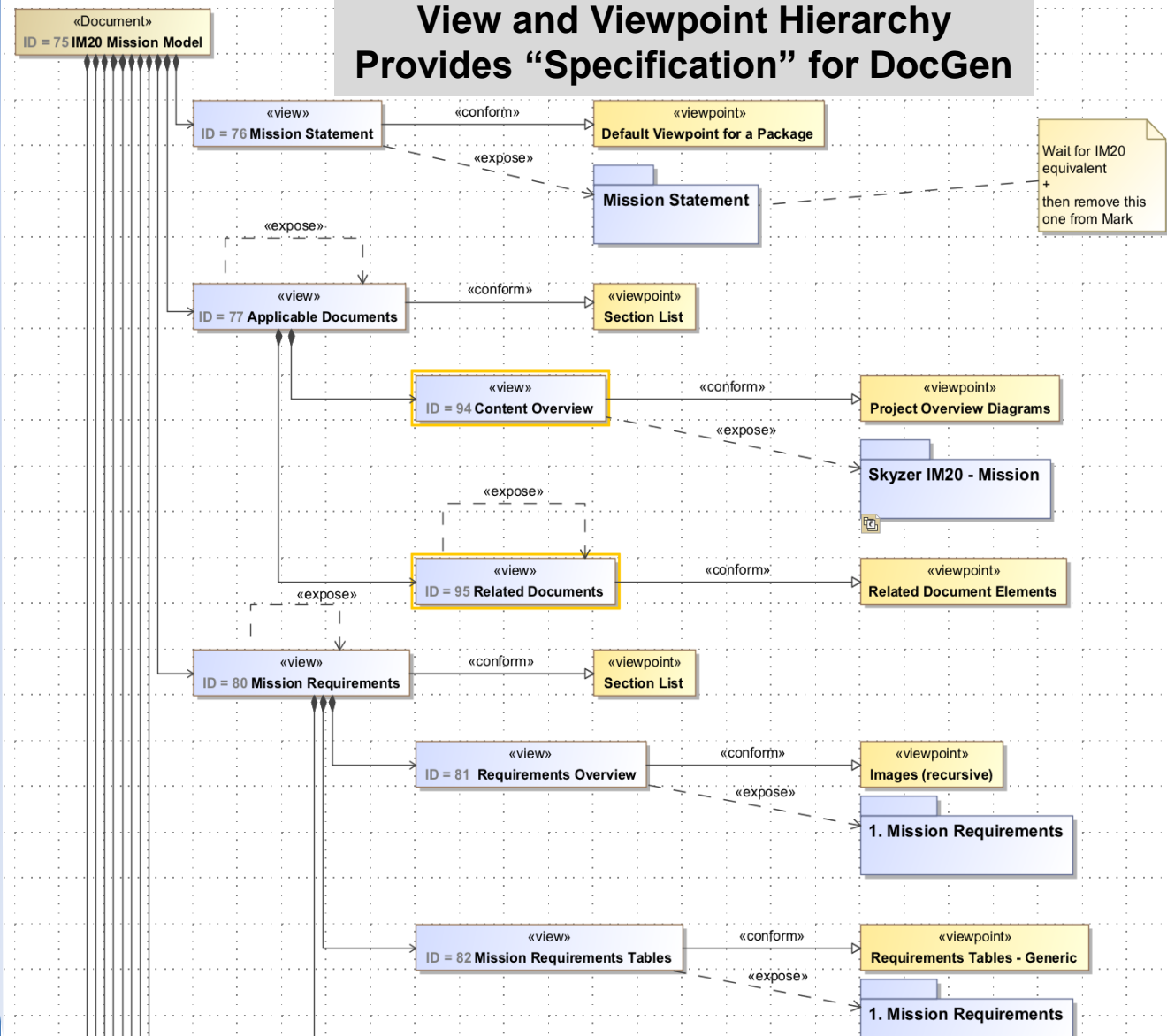
## View Editor



# Mission Model Generated View Aligned with Integrated Capability Framework

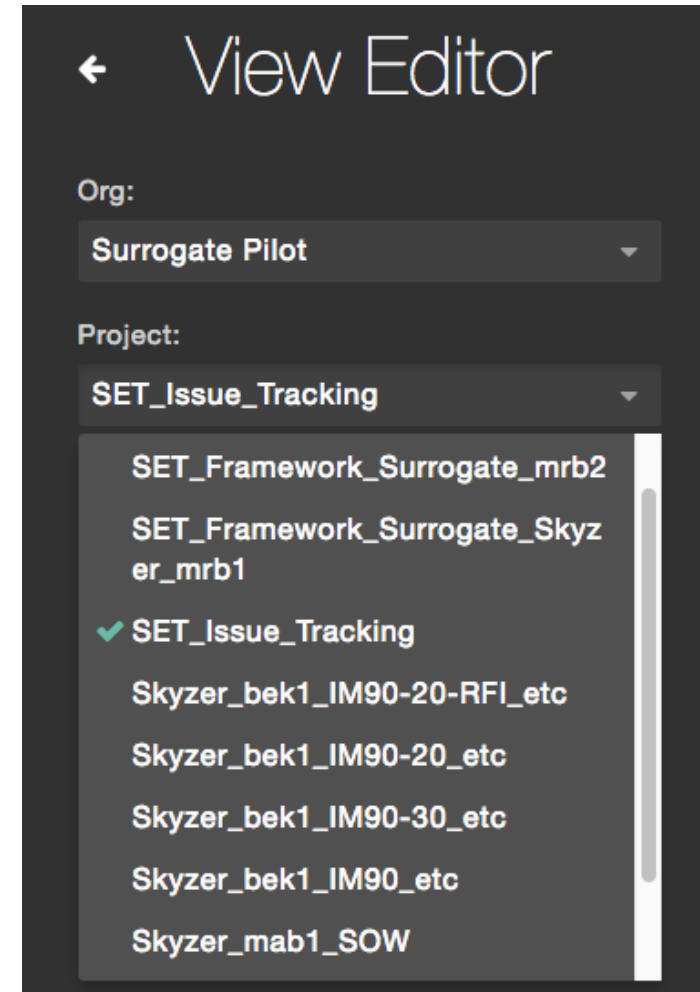
Navy Integration and Interoperability  
 Integrated Capability Framework  
 Operational Concept Document

## View and Viewpoint Hierarchy Provides "Specification" for DocGen

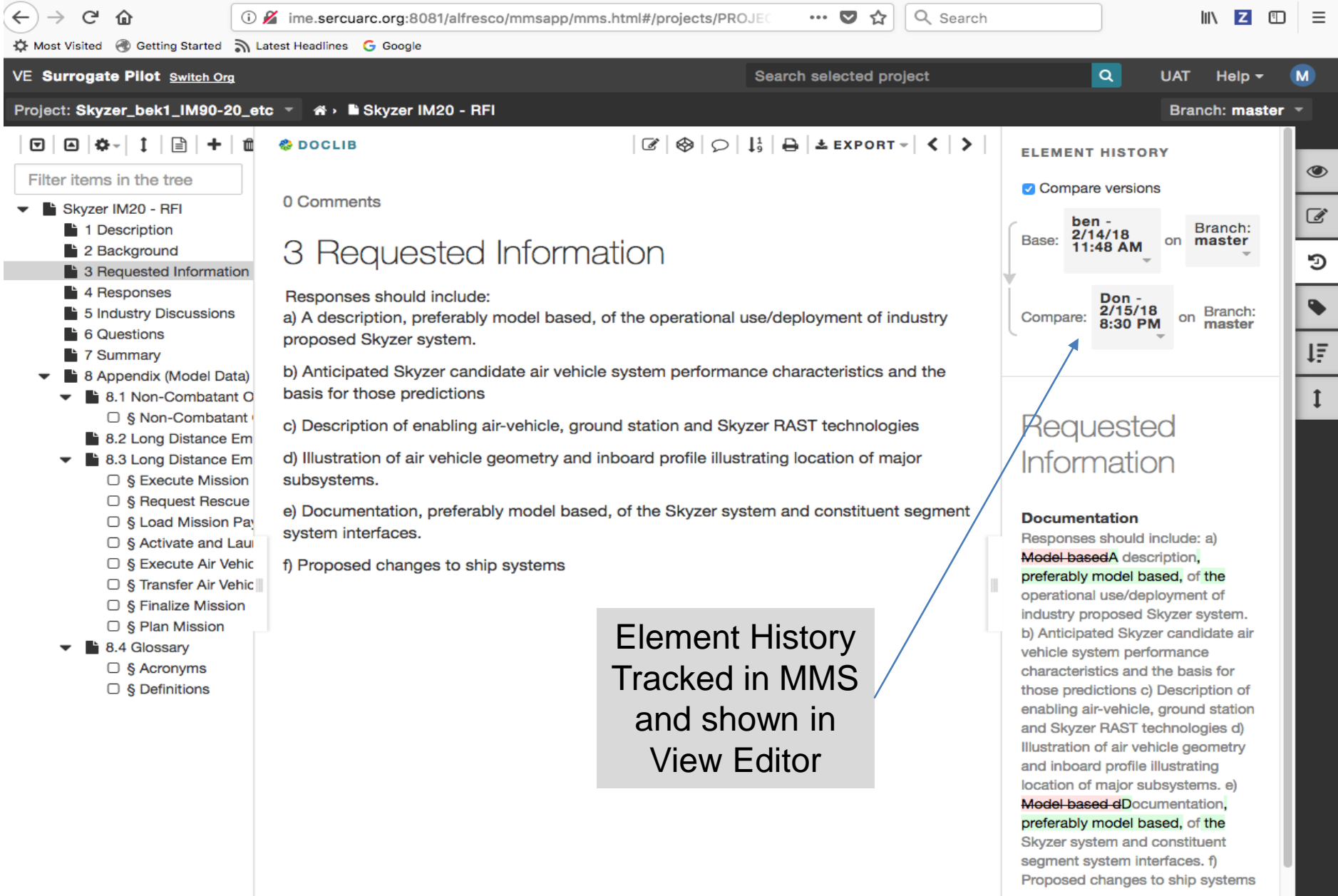


Wait for IM20 equivalent + then remove this one from Mark

- Skyzer Mission Model & View (IM90-20 on AWS, pdf in APAN)
- Skyzer System Model & View (IM90-30 on AWS, pdf in APAN)
- Skyzer System Model as Government Furnished Information (GFI) (on APAN)
- Statement of Work (SOW) Model and View
- Section L & M Model and Views
  - Technical evaluation
- Evaluation Model (GFI) and View
  - Computes Margins for KPPs
- Issue tracking in View Editor on AWS
- Official Release: July 9th, 2018 tagged in MMS and Teamwork Cloud
  
- Log in instructions to examine the models are available on APAN



# View Editor Allows Updates to Skyzer Mission Model in Web Browser



The screenshot displays a web browser interface for the Skyzer Mission Model. The browser address bar shows the URL: `ime.sercuarc.org:8081/alfresco/mmsapp/mms.html#/projects/PROJEC`. The page title is "VE Surrogate Pilot" with a "Switch Org" link. The project path is "Project: Skyzer\_bek1\_IM90-20\_etc" and "Skyzer IM20 - RFI". The branch is set to "master".

The main content area shows "0 Comments" and a section titled "3 Requested Information". The text under this section reads: "Responses should include:" followed by a list of six items (a-f) detailing requirements for the Skyzer system, such as "A description, preferably model based, of the operational use/deployment of industry proposed Skyzer system."

On the right side, the "ELEMENT HISTORY" panel is visible. It includes a "Compare versions" checkbox and a comparison table:

Base:	Compare:	Branch:
ben - 2/14/18 11:48 AM	Don - 2/15/18 8:30 PM	master

Below the history table, the "Requested Information" section is shown, containing a "Documentation" subsection that repeats the list of requirements (a-f) from the main content area. A blue arrow points from a text box to the "Compare" entry in the Element History table.

Element History Tracked in MMS and shown in View Editor



# View Editor Can Display Model Elements Such as Skyzer RFI Mission Model Use Cases

- ▼ Skyzer IM20 - RFI
  - 1 Description
  - 2 Background
  - 3 Requested Information
  - 4 Responses
  - 5 Industry Discussions
  - 6 Questions
  - 7 Summary
  - ▼ 8 Appendix (Model Data)
    - ▼ 8.1 Non-Combatant Operations
      - § Non-Combatant Operations
    - 8.2 Long Distance Emergency Delivery
    - ▼ 8.3 Long Distance Emergency Delivery
      - § Execute Mission
      - § Request Rescue
      - § Load Mission Payload
      - § Activate and Launch
      - § Execute Air Vehicle Flight
      - § Transfer Air Vehicle to Flight Deck
      - § Finalize Mission
      - § Plan Mission
    - ▼ 8.4 Glossary
      - § Acronyms
      - § Definitions

0 Comments

## 8.2 Long Distance Emergency Delivery

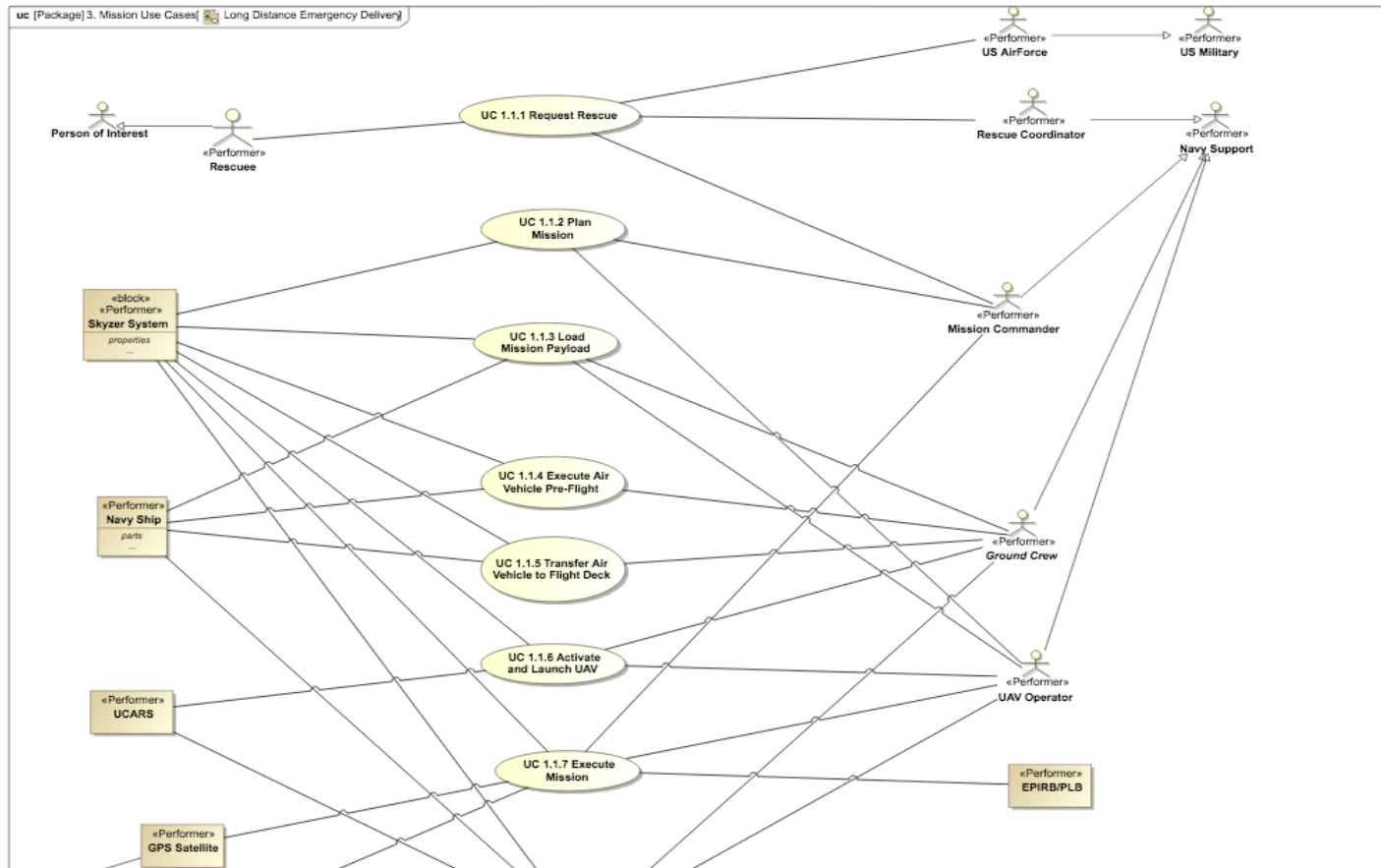


Figure 6.1. Requirements Satisfiability

Legend	System Model																								
↗ Satisfied By	Skyzer UAV System										Subsystems														
	airframe : Airfr	avionics : Avio	communicatio	cruiseSpeed :	Emergency Sh	endurance : hr	FlyMissionPlan	maxSpeed : kt	operationalAlt	operationalRac	payload : Paylc	PowerDown0	PowerUp0	Process Comm	propulsion : Pr	recoveryWeigh	sensor : Senso	takeOffGrossW	rast coupler	Hover()	Loiter()	Lost Link Rr	Navigate/ Pr	Received Be	disperse/ Tr
1. Mission Requirements [Skyzer IM20:Skyzer IM20 - Mission]	1	3	8	1	1	1	1	1	1	4	1	1	2	1	1	1	1		2	1	1	1	2	1	1
1.2 Functional Requirements			3	8	1	1					1	1	2		1				2	1	1	1	2	1	1
1.2.1 Skyzer System Functional Requirements																									
1.2.1.5 Midflight Payload Dispersal	1																		1						1
1.2.2 UAV Functional Requirement						1															1	1	1	2	1
1.2.2.2 Autonomously navigate to search area specified in miss	1																		1		1				1
1.2.2.3 Autonomously navigate to ship recovery hold position	1																		1		1				1
1.2.2.4 Autonomously execute lost link flight plan if ground sta	1																		1		1				1
1.2.2.5 Autonomously loiter at commanded position	1																		1		1				1
1.2.2.6 Autonomously home on 406 mgz beacon to locate distr	1																		1		1				1
1.2.2.7 Autonomously hover at cmdnged position	1																		1		1				1
1.2.2.8 UAV Fly Patterns	1	1																							
1.2.3 Launch/Recovery System Functional Interface																									
1.2.3.1 Disengage RAST restraint	1																			1	1				1
1.2.3.2 Engage RAST restraint	1																			1	1				1
1.2.4 Ground Station Functional Interface			3	8	1						1	1	2		1										
1.2.4.1 Receive ground station commands	1	1																							
1.2.4.2 Image Resolution	1	1																							
1.2.4.3 Communication Range	1	1																							
1.2.4.4 Transmission Quality	1	1																							
1.2.4.5 UAV Transmission Bandwidth	1	1																							
1.2.4.6 Execute ground station commands	1	1																							
1.2.4.7 Store ground station mission plan	1	1																							
1.2.4.8 Receive ground station mission plan	1	1																							
1.2.4.9 Power up on command of ground station	1	1																							
1.2.4.10 Power down on command of ground station	1	1																							
1.2.4.11 Report execution of ground station commands	1	1																							
1.2.4.12 Transmit current position to ground station	1	1																							
1.2.4.13 Power down on ground crew emergency shut off	1	1																							
1.2.4.14 Acknowledge receipt of ground station commands	1	1																							
1.2.4.15 Transmit video or still images to ground station	1	1																							
1.2.4.16 Relay distressed vessel/ individual VHF communicatio	1	1																							
1.2.4.17 Communicate via LOS or BLOS depending on the distar	1	1																							
1.3 Performance Requirements																									
1.3.1 Max Speed	1	1																							
1.3.2 Cruise Speed	1	1																							
1.3.3 Max Payload Weight	1	1																							
1.3.4 Operational Radius	1	1																							
1.3.5 Recovery Condition	1	1																							
1.3.6 Operational Altitude	1	1																							
1.3.7 UAV Operation Period	1	1																							
1.4 Design Constraints			1								3			1											
1.4.2 Fuel Type	1	1																							
1.4.3 Weight	1	1																							
1.4.6 Operational Bounding Box	1	1																							
1.4.10 Payload	1	1																							
1.4.10.1 Long Range Mission	1	1																							

System Requirements

Mission Requirements

Traceability



<b>Future Research Areas</b>	<b>G1.</b> Formalize the development, integration and use of models to inform enterprise and program decision making.	<b>G2.</b> Provide an enduring authoritative source of truth.	<b>G3.</b> Incorporate technological innovation to link digital models of the actual system with the physical system in the real world.	<b>G4.</b> Establish a supporting infrastructure and environment to perform activities, collaborate and communicate across stakeholders.	<b>G5.</b> Transform a culture and workforce that adopts and supports DE across the lifecycle.
<b>Cross-discipline integration of models</b> to address the heterogeneity of the various tools and environments using semantic technology	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>
<b>High Performance Computing (HPC)</b> advancements such as; 1) supporting organizing and analyzing “Big Data” and 2) being able to program in parallel to take advantage of HPC capabilities, are needed to support the DE effort	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	
<b>Model integrity</b> to ensure trust in the model predictions by understanding and quantifying margins and uncertainty	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>	<b>X</b>
<b>Modeling methodologies</b> that can embed demonstrated best practices and provide computational technologies for real-time training within digital engineering environments	<b>X</b>		<b>X</b>	<b>X</b>	<b>X</b>
<b>Model composability</b> to understand the possibilities, constraints and rulesets for composition of multiple models	<b>X</b>		<b>X</b>		
<b>Human-model task allocation</b> to understand what activities are best performed by human decision makers and what can effectively be automated or augmented with model intelligence					<b>X</b>
<b>Workforce development</b> to understand what is needed to educate model developers, users and decision makers to work in a DE environment					<b>X</b>
<b>MCE acquisition</b> to understand the needed changes to acquisition and security when developing in the new DE environment	<b>X</b>	<b>X</b>		<b>X</b>	<b>X</b>

**Decision Making**

**Authoritative Source of Truth**

**Technological Innovation Link Digital Models to Physical systems**

**Collaborative Infrastructure and Environment**

**Transform Culture and Workforce in DE lifecycle**

- Resources

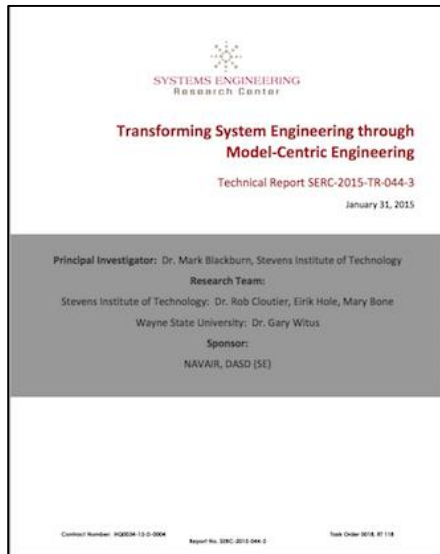
- Technical reports link: <https://sercuarc.org/researcher/?id=121&Mark-Blackburn>
- Comprehensive briefing:  
[http://www.markblackburn.com/MBSE/SERC\\_SE\\_Transformation\\_Big\\_Picture\\_7\\_31\\_2017\\_v8.pdf](http://www.markblackburn.com/MBSE/SERC_SE_Transformation_Big_Picture_7_31_2017_v8.pdf)


**NAVAIR: RT-141  
Phase I & II – Global  
Scan Advanced  
Approaches**


**NAVAIR: RT-157  
Phase III –  
SE Transformation  
(SET) Initiated**


**ARDEC: RT-168  
Phase I & II -  
Synergistic  
Research**

**NAVAIR: RT-170  
Phase IV -  
SET Planned  
and in Execution**



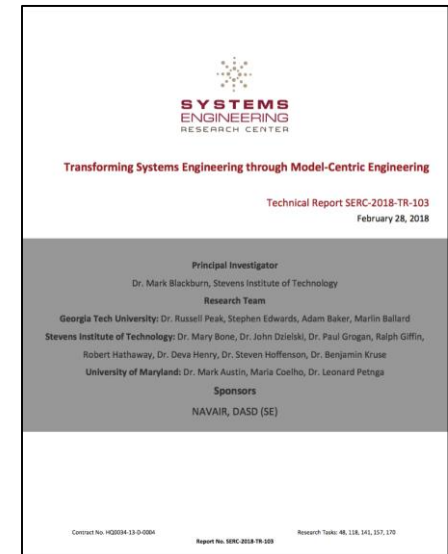
  
**Transforming System Engineering through Model-Centric Engineering**  
 Technical Report SERC-2015-TR-044-3  
 January 31, 2015  
**Principal Investigator:** Dr. Mark Blackburn, Stevens Institute of Technology  
**Research Team:**  
 Stevens Institute of Technology: Dr. Rob Cloutier, Erik Hole, Mary Bone  
 Wayne State University: Dr. Gary Witus  
**Sponsor:**  
 NAVAIR, DASD (SE)




  
**Transforming Systems Engineering through Model-Centric Engineering**  
 Technical Report SERC-2017-TR-101  
 January 18, 2017  
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**Transforming Systems Engineering through Model-Centric Engineering**  
 A013 Final Technical Report SERC-2017-TR-110  
 Update: August 8, 2017  
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**University of Southern California:** Todd Richmond, and Edgar Evangelista  
**Sponsor:**  
 U.S. Army Armament Research, Development and Engineering Center (ARDEC), Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD(SE))



  
**Transforming Systems Engineering through Model-Centric Engineering**  
 Technical Report SERC-2018-TR-103  
 February 28, 2018  
**Principal Investigator**  
 Dr. Mark Blackburn, Stevens Institute of Technology  
**Research Team**  
 Georgia Tech University: Dr. Russell Peak, Stephen Edwards, Adam Baker, Marlin Ballard  
**Stevens Institute of Technology:** Dr. Mary Bone, Dr. John Dzieleksi, Dr. Paul Grogan, Ralph Griffin, Robert Hathaway, Dr. Deva Henry, Dr. Steven Hoffenson, Dr. Benjamin Kruse  
**University of Maryland:** Dr. Mark Austin, Maria Coelho, Dr. Leonard Petnga  
**Sponsors**  
 NAVAIR, DASD (SE)

# Thank you!

Dr. Mark Blackburn

Senior Research Scientist

Member of SERC Research Council

Member of Leadership Team for OpenMBEE Collaboration Group

Member of Semantic Technologies for Systems Engineering Initiative

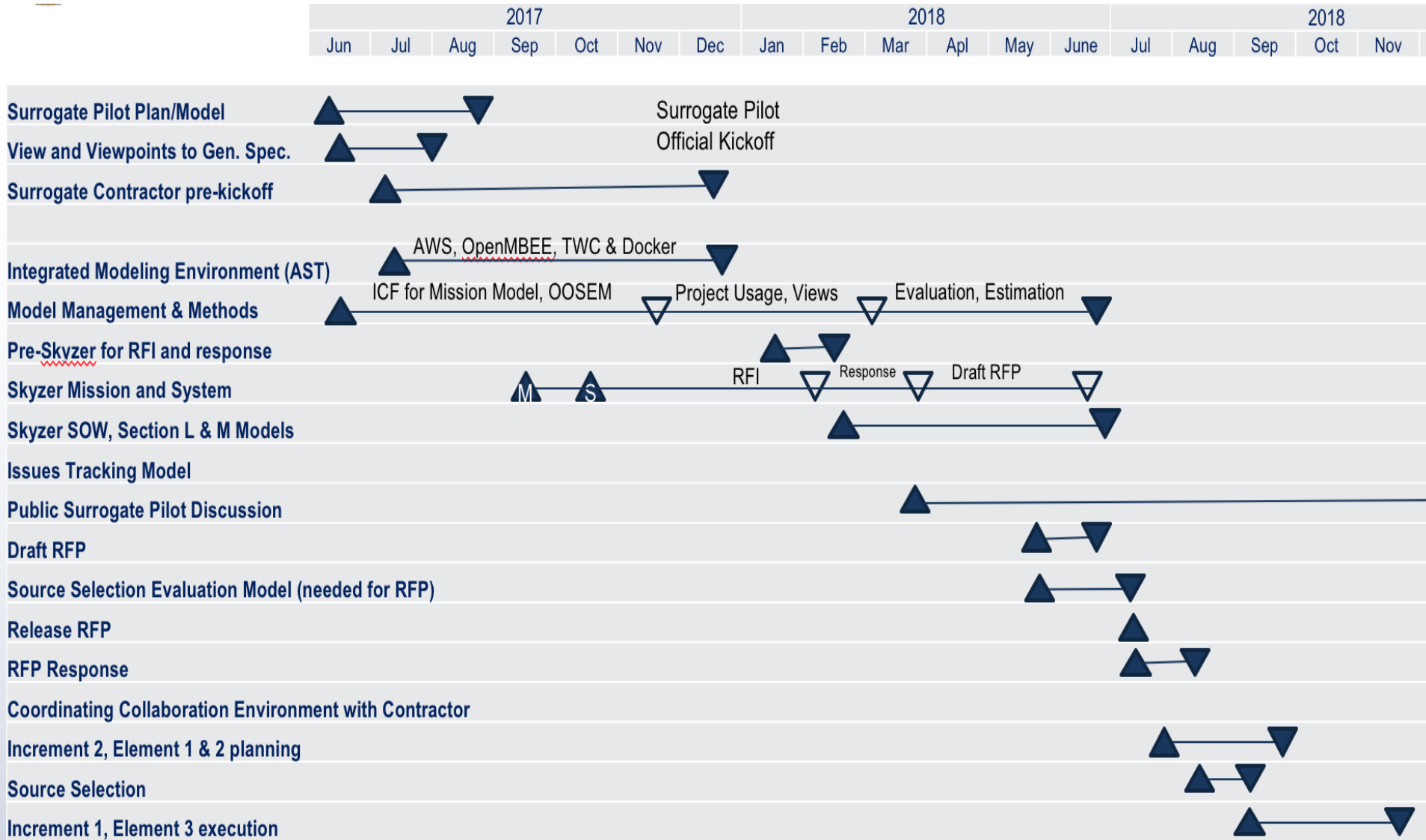
School of Systems & Enterprises

Systems Engineering Research Center

Stevens Institute of Technology



# Time Line of Surrogate Pilot Experiments



- Project Usages of Skyzer Mission Model in the Skyzer System Model to trace mission requirements to system requirements
  - Skyzer System Model has several Project Usages, such as the Project Usage of the Mission Model (IM20)
  - Allows System model to create traceability linkages from system information (e.g., behavior in state machine and activity diagrams) in the Skyzer System model to the Skyzer Mission requirements
  - Requirements table is automatically generated
  - Provides significantly more rationale through analysis for requirements
    - Some behaviors have simulations that allow reviewers to understand broader implications through these dynamic views of a simulated model
  - If Mission requirements are updated, this will be immediately visible in the System model, which may then need to be modified to address those changes in the mission model.
- Reuse Model Libraries of DocGen Viewpoints
  - Collected and developed a number of Viewpoints (mechanism for extracting information from models to produce documents)
  - Standardizing on Viewpoints adds uniformity to the generated specification. In addition, this means that very few modelers need to create or know how to create viewpoints.
  - As part of the OpenMBEE, NASA/JPL developed an implementation for View and Viewpoints are part of the Model Development Kit/DocGen [59], which is extensively used to generate stakeholder-relevant views from all of the models used in the surrogate pilot
- Project Usages of Evaluation Model and Estimation Model
  - Our team is also working on an Evaluation Model to be used for Source Selection



- We have had to take “short-cuts” to get through experimental process
- Establish infrastructures for IME tools and AST as early as possible
- Technically feasible to develop everything as a model
- Establish model management practices early
- Project Usages Technologies valuable for Model Modularization, Reuse, partitioning work, linking GFI to RFP responder models, etc.
  - Uses cases and benefits on APAN
- Requirement management can be done directly in models
- Don’t provide mission model for RFI – too confusing
  - Do use Views of mission model for appropriate context
  - Need some type of evaluation criteria for a model-based RFI
- Simulating Virtual Industry Days was useful
- Modeling provided a means to simplify SOW with emphasis in providing tool agnostic modeling information
- Iterations (agile-esk) very useful – is there anything “illegal” with doing this
  - How would it work in a competition?

- Standardize on DocGen Viewpoints to makes Views look consistent
  - We have a library of Viewpoints
- Use Glossary Capability in modeling clients to fully define terms
- Issue tracking necessary and formalized as a model
- Agreed on using a stereotype (or Tag) for identifying Key Performance Parameters (KPP)
- Industry MBSE RFI suggested use of parametrics, which has been developed into an Evaluation Model (part of Section L)
  - Can be distributed as GFI for Section L to ensure contractor model characterizes performance for KPPs
- Team SME with modelers: SME may supply mission scenario and constraints in non-modeling representations
- Use SME Stakeholders to define relevant Views
  - Provides a means from transitioning from Doc-based to Model-based
  - Program leadership will make an approval decision based on model generated report
  - Only modeler will likely know/understand what is in entire model
  - Need to address potential of unintentional data leak can enable a protest