SYSTEMS ENGINEERING
Research Center

STEVENS
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1870

Stevens Institute of Technology
&
Systems Engineering Research Center (SERC)

Model Centric Engineering Enabling a New Operational Paradigm for Acquisition

Presented by:

Dr. Mark R. Blackburn (PI)

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Dr. Dinesh Verma

With Contributing Sponsors (NAVAIR, ARDEC, DASD(SE))
With Contributing Researchers (RT-48, 118, 141, 157, 168, 170, 176)

October 25, 2017

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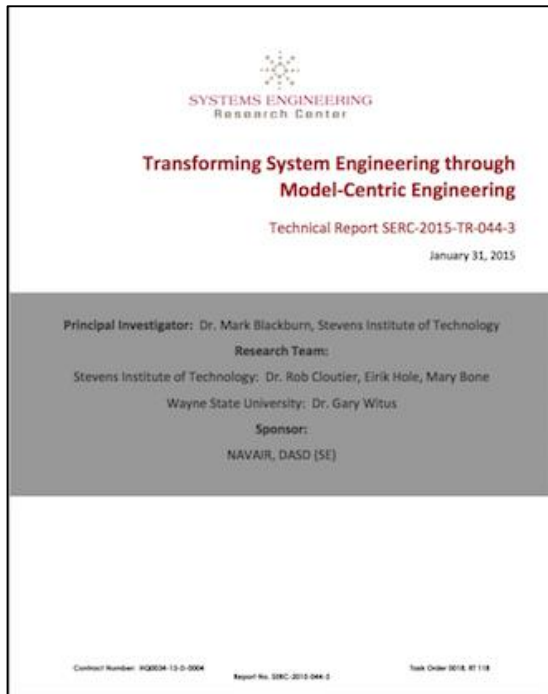
- Historical perspective and resources

- Systems Engineering Transformation (SET) Framework for a new operational paradigm between government and industry

- Surrogate pilot experiment(s) for ***Executing*** the SET Framework
  - —Research emphasis
  - —Methodology for modularizing models
  - —Integrated Modeling Environment and approach to demonstrate Authoritative Source of Truth
  - —"Specification generation" from models

NAVAIR is Interested in Sharing Concept and Getting Feedback

- Resources
  - Technical reports link: http://www.sercuarc.org/researcher-profile/mark-blackburn/
  - Comprehensive briefing: http://www.sercuarc.org/publications-papers/presentation-systems-engineering-transformation-through-model-centric-engineering-past-why-present-what-and-future-how/

NAVAIR: RT-141 Phase I Summary	**NAVAIR: RT-157 Phase II – SET Initiated**	**ARDEC: RT-168 Synergistic**

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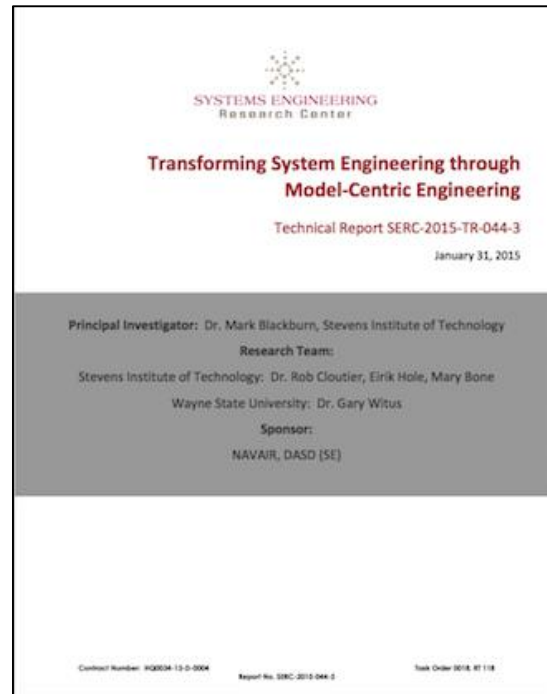
Transforming System Engineering through Model-Centric Engineering

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, Eirik Hole, Mary Bone

Wayne State University: Dr. Gary Witus

Sponsor:

NAVAIR, DASD (SE)

Contract Number: HQ0034-13-D-0004   Report No. SERC-2015-044-0   Task Order 0018, RT 118
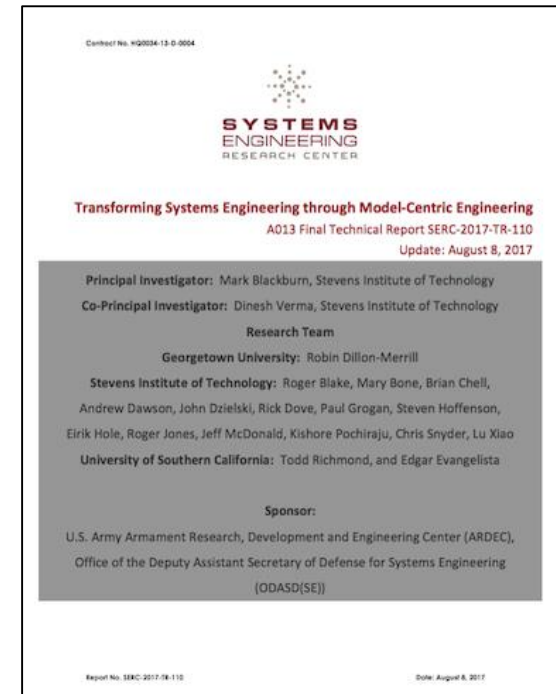

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Transforming Systems Engineering through Model-Centric Engineering

A013 Final Technical Report SERC-2017-TR-110

Update: August 8, 2017

Principal Investigator: Mark Blackburn, Stevens Institute of Technology

Co-Principal Investigator: Dinesh Verma, Stevens Institute of Technology

Research Team

Georgetown University: Robin Dillon-Merrill

Stevens Institute of Technology: Roger Blake, Mary Bone, Brian Chell, Andrew Dawson, John Dzielski, Rick Dove, Paul Grogan, Steven Hoffenson, Eirik Hole, Roger Jones, Jeff McDonald, Kishore Pochiraju, Chris Snyder, Lu Xiao

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))

Report No. SERC-2017-TR-110   Date: August 8, 2017

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

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

RT-141
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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)
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-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

- Over 30 organizational discussions "**tell us about most advanced and holistic approach**…":
  - Model-Based Engineering (MBE), Integrated Model-Centric Engineering, Interactive Model-Centric Systems Engineering (IMCSE), Model-Driven Development, Model-Driven Engineering (MDE), and even Model-Based Enterprise, which brings in more focus on manufacturability

- **MCE** characterizes the goal of integrating different model types with simulations, surrogates, systems and components at different levels of abstraction and fidelity across discipline throughout the lifecycle with manufacturability constraints

- SERC Research Supports **Digital Engineering** (DE) Thrust by DoD:
  - *An integrated digital approach that uses <u>authoritative sources of systems' data and models</u> as a continuum across disciplines to support lifecycle activities from concept through disposal*

- Organizations (with a few exceptions) were unwilling to share quantitative data, however

- Qualitative data in the aggregate suggests that **MCE technologies and methods are advancing and adoption is accelerating**

NAVAIR Executive Leadership Response:

- NAVAIR must move quickly to keep pace with other organizations that have adopted MCE

- NAVAIR must transform in order to perform effective oversight of primes that are using modern modeling methods for system development

March 2016: Change of Command has Accelerated the Systems Engineering Transformation and Broadened the Scope

Semantic Web Technologies
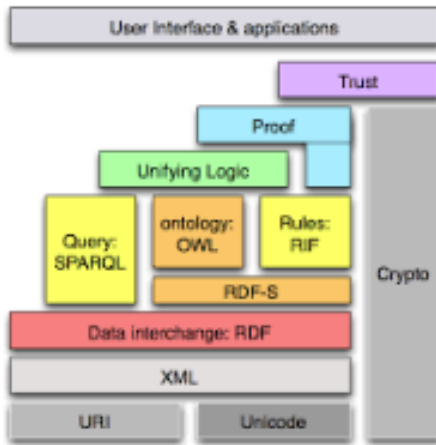
Enforces **Modeling Methods**

Modeling Methodologies

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

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

Multidisciplinary Design, Analysis and Optimization MDAO

Digital System Model: Single Source of Truth (*authoritative source of truth*)

Integrated Modeling Environment

MDAO Workflow

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

SERC 168/170.

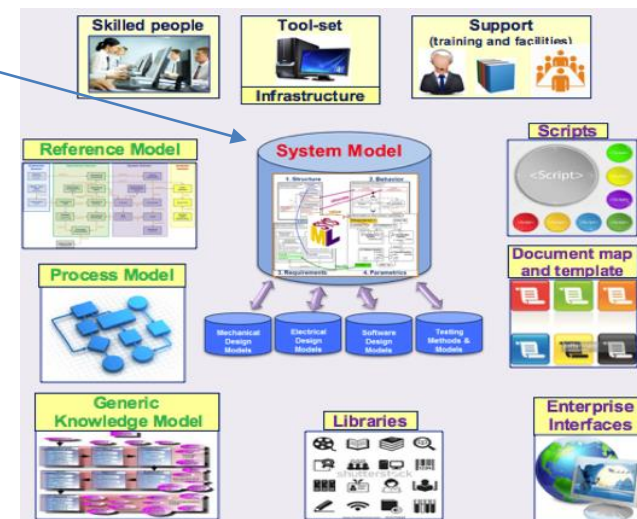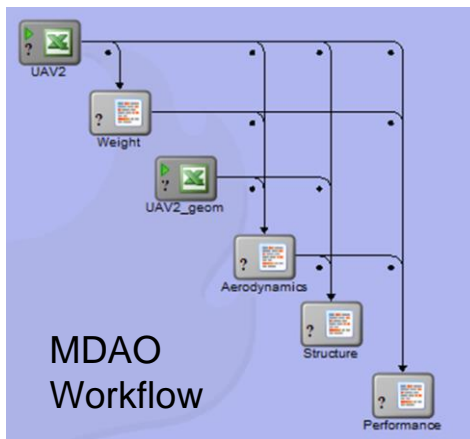# Surrogate Pilot focus is on _Execution_ of SET Framework

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

Mission Area Modeling & Effectiveness Analysis

CONOPS R0 · CONOPS R1 · CONOPS R2

SoS Architecture

Conceptual Design R0 · Conceptual Design R0 · Conceptual Design R3

Element 1

Mission Effectiveness optimization

Re-balance as required

Right-size CDD – very few KPPs, all tied to mission effectives

CDD

Instantiate System Spec in a model

INSIGHT/OVERSIGHT

Single Source of Truth

Instantiate and validate design in models

2. Behavior
3. Requirements
4. Parametrics
allocate · value binding · satisfy · Verify

Mechanical Design Models

Electrical Design Models

Software Design Models

Testing Methods Models

"Spec Generation of RFP" and Source Selection

Analysis Tools

Design & Manufacture Release

Integration Events

Integrated Test Vehicle #1

Move rapidly to mfg. Substantiation and insight via modeling environment

MDAO*/SET-BASED DESIGN

Element 2 · **Element 3** · **Element 4**

*M... Optimization

V5.0

- <u>Mission:</u> Collaboration between Government and Industry in Model-based Acquisition under SET Framework

- <u>Goal:</u> Execute SET Framework to Assess, Refine, and Understand a New Paradigm for Collaboration in Authoritative Source of Truth (AST)

- <u>Objectives</u> (non exhaustive):
  —Formalize experiment to answer questions about executing SET framework using Surrogate Contractor (SC)

  —"Government team" creates mission, system (& other) models, "generates specification/RFP," & provides acquisition models to SC as Government Furnished Information (GFI)

  —SC refines GFI reflects corrections/innovations with physical allocation views with multi-physics-based Initial Balanced Design

  —Simulate continuous virtual reviews and derive new objective measures for assessing maturing design in AST

  —Demonstrate visualizations for real-time collaboration in AST

  —Demonstrate and document methods applied

  —Investigate challenging areas and research topics in series of pilots

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Element 1

Operational Models

Other Business Models
Personnel, support, training, etc.

Element 2

SoS Level

User Capability Model

System Model is Authoritative Requirements Source (e.g. Gov't Specification)

Acquisition Agreement

Warfighter

System Model | Initial System Model
Final System Model

Main Contract

Acquirer

Element 3

System Level

Functional Baseline

Sub-System 1 Model | Sub-System 2 Model | • • • | Sub-System n Model

Sub Contracts

Prime Contractor

ub-System Level Allocated Baseline

Element 4

Component 1 Model | Component 2 Model | • • • | Component n Model
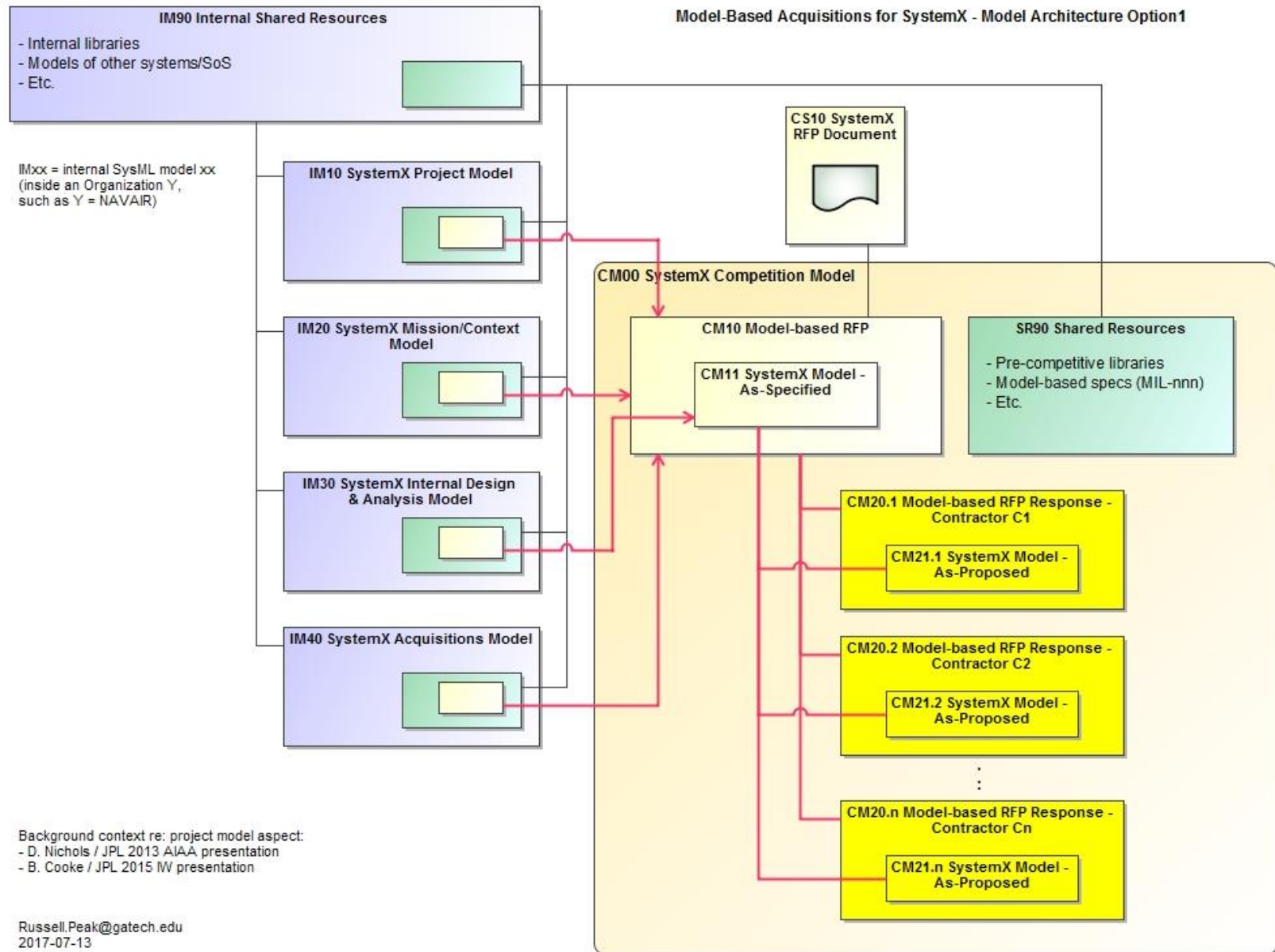
Sub Contractors

- Learning about new operational paradigm between government and industry in the **Execution** the SET Framework (NOT an air vehicle design)
- We are concerned with interactions (non-exhaustive):
  —Simulating prior to contract award (now)
  —Formalization of a "specification" for "Request for Proposal (RFP)" and methods for providing models to contractor
  —Simulating "Execution" of Oversight / Insight in AST per SET Framework for real-time collaboration in heterogeneous environments
  —**Simulating feedback back to mission engineering caused by specified objectives for unachievable Key Performance Parameters (KPP)**
  —Objective measures for evaluating evolving design maturity, with the reduction of risk
  —Simulating approach for "faults in specification/model" detected after contract award
  —Simulating source selection – desirably as a dynamic simulations and V&V
  —Working with contracts/legal to get agreement on what a "specification" would be
  —Methods for modularizing model used to "generate specification"
  —How will we use the Systems Engineering Technical Review (SETR) guide and checklist that NAVAIR uses? And, how will we make recommendations for its evolution
  —Use of Multidisciplinary Design, Analysis and Optimization (MDAO) at mission, systems, and subsystems (by surrogate contractor)
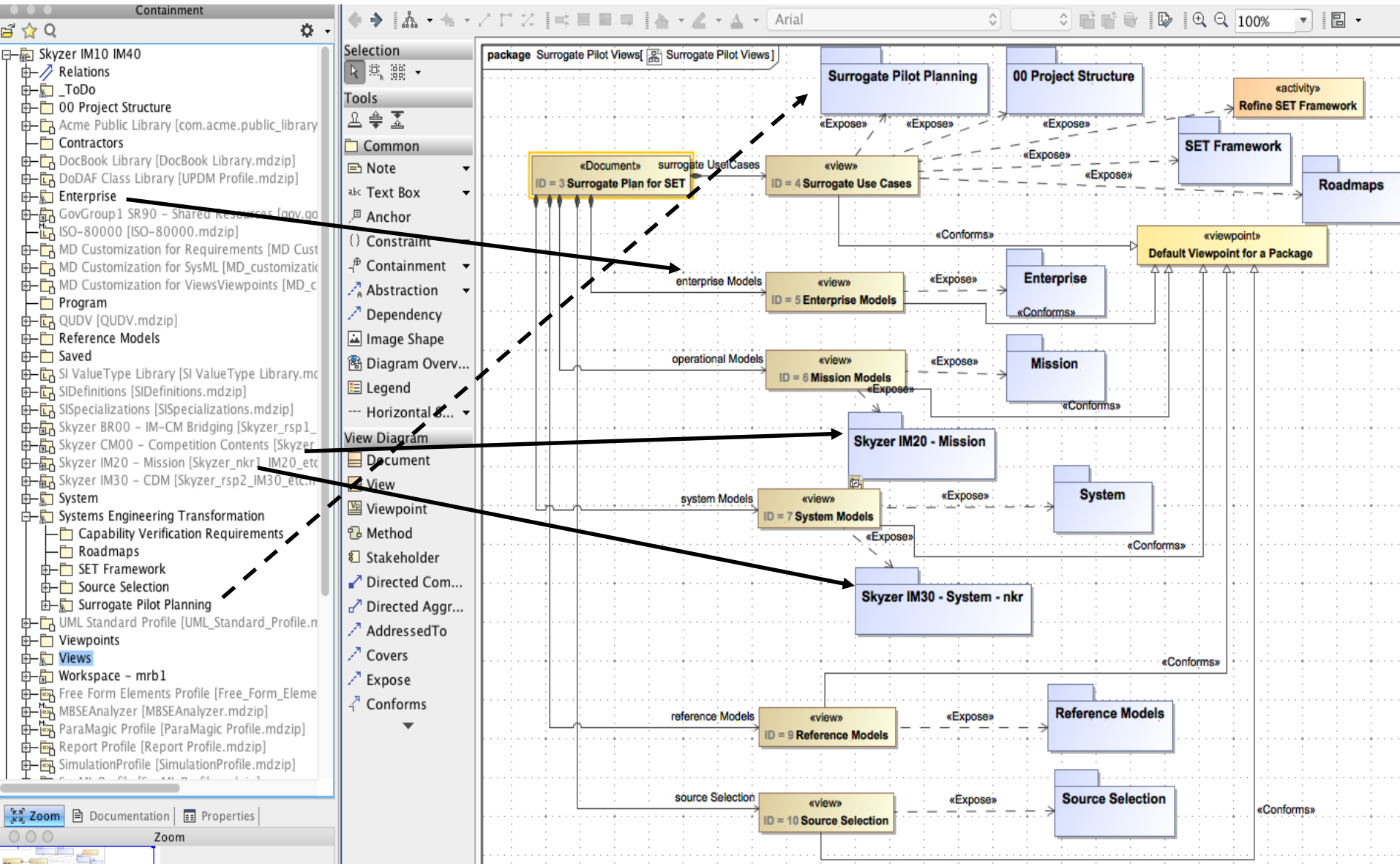
**SysML Activity Diagram is draft
Process Model for SET Framework**

NOTE: KPPs are planned to be removed from the JCIDS and we should be using KSAs

Need to Simulate
Acquisition-related feedback paths
(not exhaustive)

1 Mission Engineering and Analysis

2 Manage KPPs that are Critical to Mission Capabilities : 2 Manage KPPs that are Critical to Mission Capabilities

3 Develop and Refine Specification

4 Perform MDAO

result

[No]

specifications

All operational scenarios covered

Synthesize Contract

Use View and Viewpoint Hierarchy to Validate models and generate specification - such "specification" can then be "pushed" to server.

Are KPP Relevant
[Yes] [No]

Perform Source Selection

5 Create Balance Optimized Design

Are KPP Achievable
[No] [Yes] [No]

6 Perform Continuous Model-Centric Asynchronous Integration Analysis and Optimization

Are KPP Achieved
[Yes]

7 Continuous System Integration, Reconciliation, & Optimization Configuration & Performance

«centralBuffer» Integrated Test Vehicle

Model-Based Acquisitions for SystemX - Model Architecture Option1

IM90 Internal Shared Resources
- Internal libraries
- Models of other systems/SoS
- Etc.

IMxx = internal SysML model xx
(inside an Organization Y,
such as Y = NAVAIR)

IM10 SystemX Project Model

IM20 SystemX Mission/Context Model

IM30 SystemX Internal Design & Analysis Model

IM40 SystemX Acquisitions Model

CS10 SystemX RFP Document

CM00 SystemX Competition Model

CM10 Model-based RFP

CM11 SystemX Model - As-Specified

SR90 Shared Resources
- Pre-competitive libraries
- Model-based specs (MIL-nnn)
- Etc.

CM20.1 Model-based RFP Response - Contractor C1

CM21.1 SystemX Model - As-Proposed

CM20.2 Model-based RFP Response - Contractor C2

CM21.2 SystemX Model - As-Proposed

CM20.n Model-based RFP Response - Contractor Cn

CM21.n SystemX Model - As-Proposed

Background context re: project model aspect:
- D. Nichols / JPL 2013 AIAA presentation
- B. Cooke / JPL 2015 IW presentation

Russell.Peak@gatech.edu
2017-07-13

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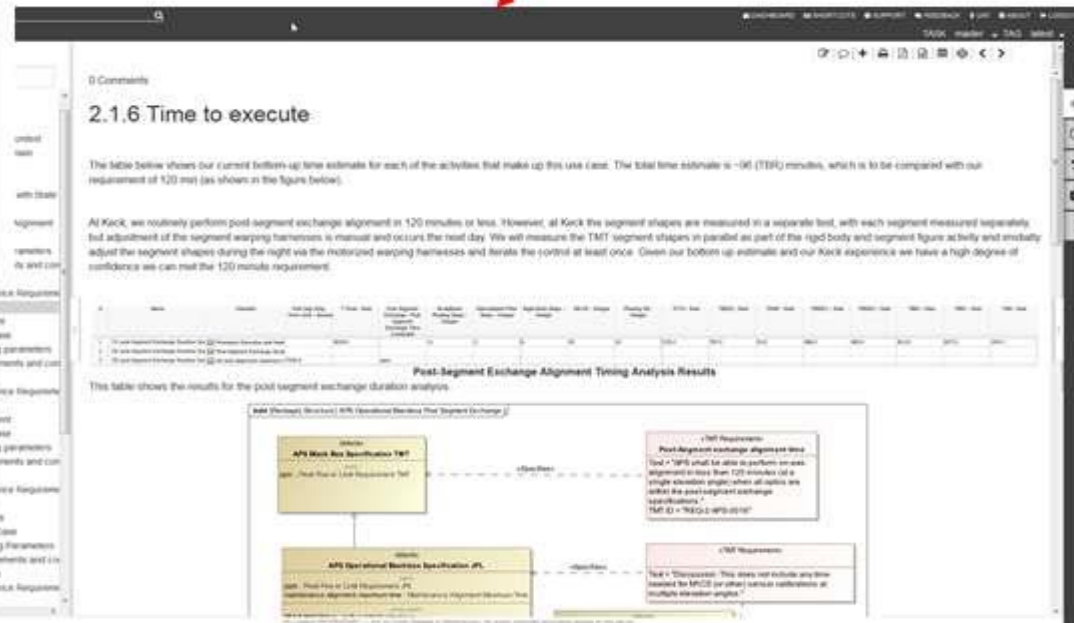Model Development Kit/DocGen
View and Viewpoint Hierarchy

Model Management System
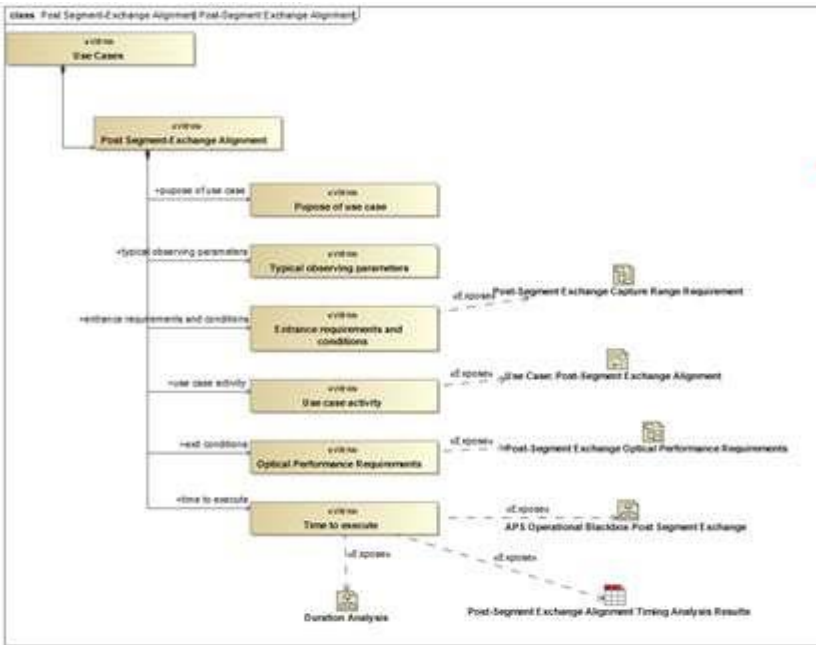
Visualization in
View Editor
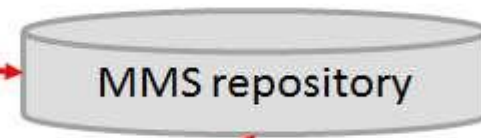
View Editor

Surrogate Pilot Using OpenMBEE as Basis for Demonstrating Authoritative Source of Truth
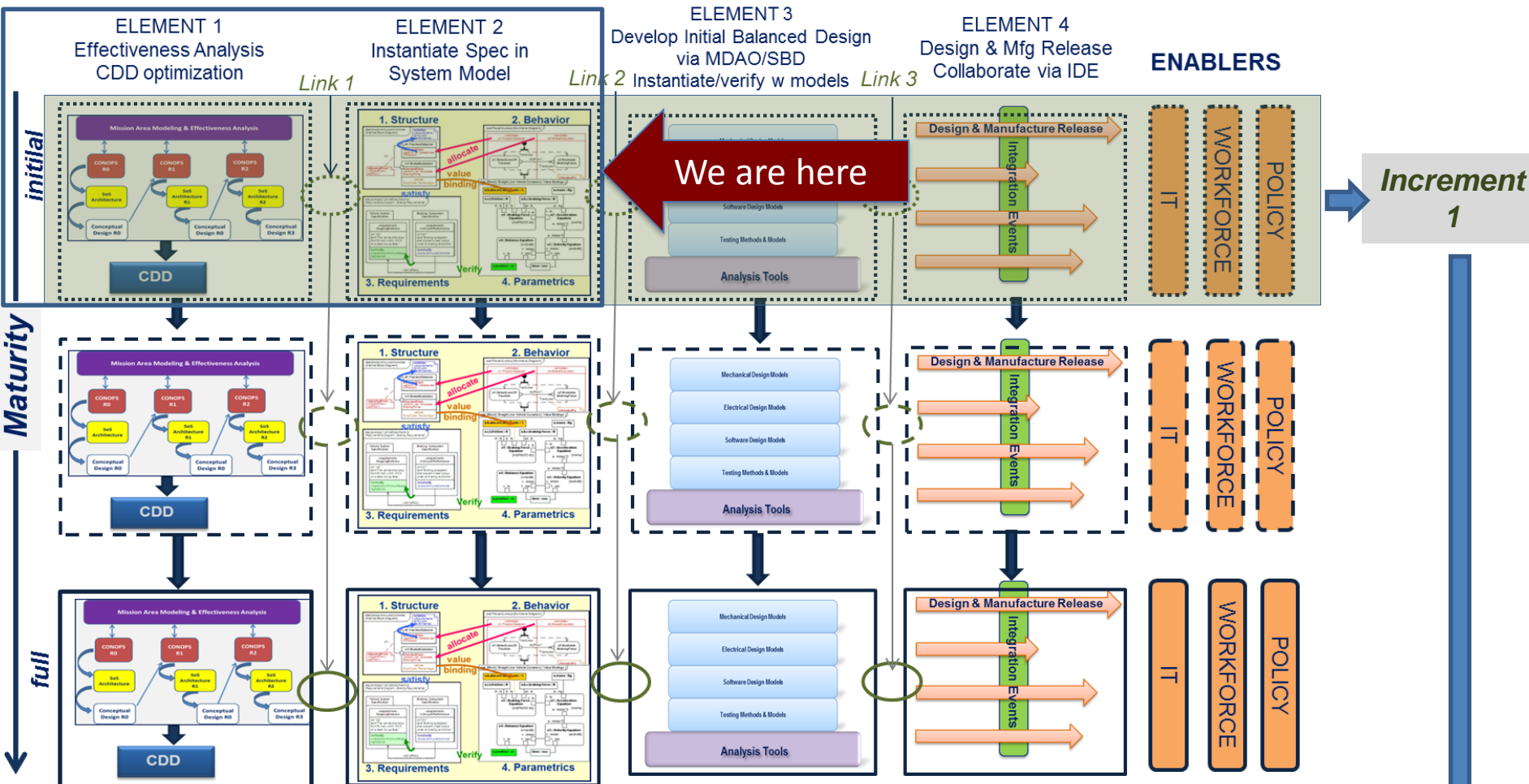
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Multidisciplinary Design, Analysis, and Optimization (MDAO) platform

SE Modeling Patterns formalized as Ontologies

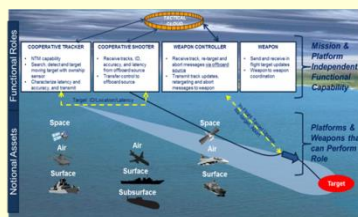Semantic Web Technologies support Continuous Checks and Model Measures
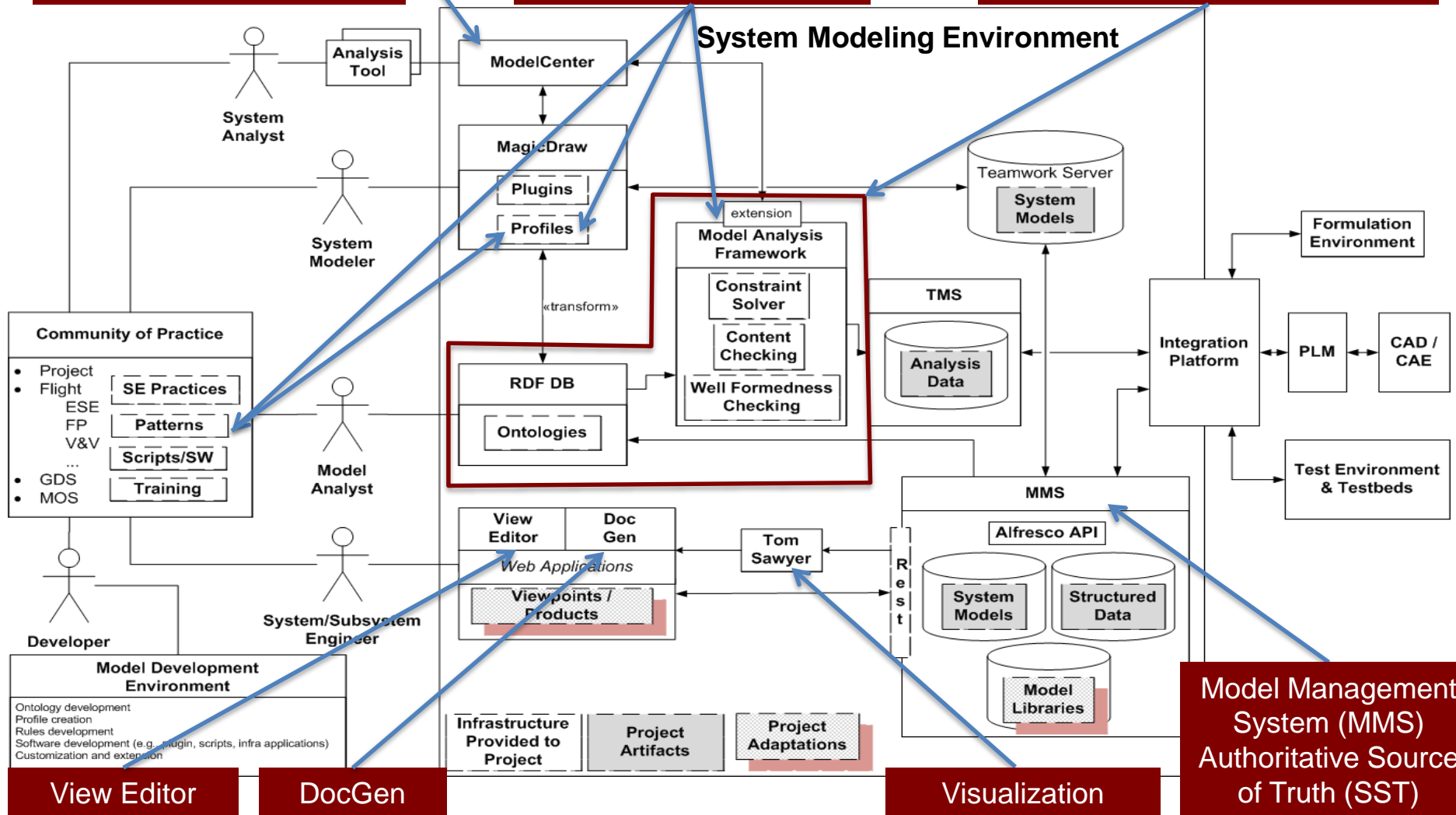
System Modeling Environment

Model Management System (MMS) Authoritative Source of Truth (SST)

View Editor

DocGen

Visualization

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ELEMENT 1
Effectiveness Analysis
CDD optimization

ELEMENT 2
Instantiate Spec in
System Model

Link 1

ELEMENT 3
Develop Initial Balanced Design
via MDAO/SBD
Instantiate/verify w models

Link 2   *Link 3*

ELEMENT 4
Design & Mfg Release
Collaborate via IDE

ENABLERS

initial

Maturity

full

We are here

Increment 1

PILOTS

Our Research Efforts are Synergistic With Our ARDEC Sponsor and Other Collaborators
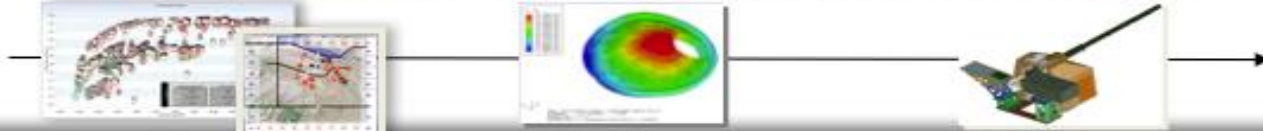
- SERC Collaborator: Georgia Tech, Georgetown, Naval Postgraduate School, Univ. of Maryland, Univ. of Massachusetts, Univ. of Southern Cal., Wayne State

- Digital Engineering Working Group

- Airspace Industry Association: CONOPS for Industry/Government Collaborative Framework

- Semantic Technologies for Systems Engineering Foundation

- NDIA Working Group – Using Digital Engineering for Competitive Down Select

- NASA/JPL

- OpenMBEE Collaborator Group
  - https://groups.google.com/d/forum/openmbee/

- For more information contact:
  —Mark R. Blackburn, Ph.D.
  —Mark.Blackburn@stevens.edu
  —Stevens Institute of Technology
  —Links to technical reports: http://www.sercuarc.org/researcher-profile/mark-blackburn/
  —Overview briefing of both projects from SERC Sponsor Review 2016: http://www.sercuarc.org/wp-content/uploads/2014/05/05B_SSRR-2016_RT157_Blackburn_v2.pdf
  —Historical perspective with a long briefing: http://www.sercuarc.org/publications-papers/presentation-systems-engineering-transformation-through-model-centric-engineering-past-why-present-what-and-future-how/

CDD	Capability Description Document		MCSE	Model-Centric System Engineering
CONOPS	Concept of Operations		MDAO	Multidisciplinary Design Analysis and Optimization
CDR	Critical Design Review			
CDRL	Contract Data Requirements List		MDE	Model-Driven Engineering
CFD	Computational Fluid Dynamics		NAVAIR	Naval Air Systems Command
DARPA	Defense Advanced Research Project Agency		OV	Operational View
			P&FQ	Performance and Flight Quality
DASD	Deputy Assistant Secretary of Defense		PDR	Preliminary Design Review
DoD	Department of Defense		PLM	Product Lifecycle Management
DoE	Design of Experiments		RT	Research Task
FEA	Finite Element Analysis		SLOC	Software Lines Of Code
HPC	High Performance Computing		SE	Systems Engineering
IMCE	Integrated Model-Centric Engineering		SET	Systems Engineering Transformation
IMCSE	Interactive Model-centric Systems Engineering		SERC	System Engineering Research Center
			SETR	Systems Engineering Technical Review
IoT	Internet of Things		SFR	System Functional Review
JCIDS	Joint Capabilities Integration and Development System		SRR	System Requirements Review
			SoS	System of Systems
KPP	Key Performance Parameter		SOW	Statement of Work
MBSE	Model-based System Engineering		SSTT	Single Source of Technical Truth
MBE	Model-Based Engineering		SV	System View
MCE	Model-Centric Engineering		UAV	Unmanned Air Vehicle
			V&V	Verification and Validation