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

Systems Engineering Transformation through Model Centric Engineering
Presented by:
Dr. Mark R. Blackburn (PI)

With Contributing Sponsors (NAVAIR, ARDEC, DASD(SE))
With Contributing Researchers (RT-48, 118, 141, 157, 168, 170, 176)
November 8, 2017
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• Historical perspective and resources

• Perspectives and status RT-170 - NAVAIR
  — Systems Engineering Transformation (SET) Framework for a new operational paradigm between government and industry
  — Surrogate pilot experiment(s) for Executing the SET Framework that provides an experimentation environment for our research

• Perspectives and status RT-168 – ARDEC
  — Sponsor’s vision for integrated Model-Based Engineering (iMBE) environment
  — Research uses cases and a few examples of deliverables and demonstrations
Historical Perspectives and Resources

- Resources
  - Technical reports link: http://www.sercuarc.org/researcher-profile/mark-blackburn/

**NAVAIR: RT-141**
Phase I Summary

**NAVAIR: RT-157**
Phase II – SET Initiated

**ARDEC: RT-168**
Synergistic
# Research Tasks and Collaborator Network

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<thead>
<tr>
<th>RT</th>
<th>Research Task</th>
<th>Collaborators</th>
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<td>RT-48</td>
<td>Mark Blackburn (PI), Stevens, Rob Cloutier (Co-PI) - Stevens, Eirik Hole - Stevens, Gary Witus – Wayne State</td>
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<td>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., Rob Cloutier (Visiting Professor)</td>
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<td>RT-168</td>
<td>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</td>
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<td>RT-176</td>
<td>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</td>
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• 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 authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal*
Phase II: Systems Engineering Transformation
Initiated at NAVAIR

- 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
Current Research Trusts Investigated in Evolving Pilots

Semantic Web Technologies

Enforces **Modeling Methods**

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

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

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

Modeling Methodologies

Integrated Modeling Environment

Multidisciplinary Design, Analysis and Optimization

**MDAO**

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

MDAO Workflow

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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

**CDD**
- Right-size CDD – very few KPPs, all tied to mission effectives
- Instantiate and validate design in models

**Integrated Test Vehicle #1**
- Move rapidly to mfg. Substantiation and insight via modeling environment

**MDAO*/SET-BASED DESIGN**

**Element 1**
- Instantiate System Spec in a model

**Element 2**
- Spec Generation of RFP

**Element 3**
- “Spec Generation of RFP” and Source Selection

**Element 4**
- Integration Events

**INSIGHT/OVERSIGHT**
- Re-balance as required
- Design & Manufacture Release

**Mission Area Modeling & Effectiveness Analysis**
- Mechanical Design Models
- Electrical Design Models
- Software Design Models
- Testing Methods & Models

**V5.0**

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

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Surrogate Pilot Overview

• **Mission:** Collaboration between Government and Industry in Model-based Acquisition under SET Framework

• **Goal:** Execute SET Framework to Assess, Refine, and Understand a New Paradigm for Collaboration in Authoritative Source of Truth (AST)

• **Objectives** (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
Formalizing the Use of Models...
Creating a Digital Thread...

Operational Models

Other Business Models
Personnel, support, training, etc.

User Capability Model

System Model
Initial System Model
Final System Model

Sub-System 1 Model
Sub-System 2 Model
Sub-System n Model

Component 1 Model
Component 2 Model
Component n Model

SoS Level
System Level
Sub-System Level
Component Level

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Example of Surrogate Questions (not exhaustive)

- Learning about new operational paradigm between government and industry in the execution of 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)
  - 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”
  - Objective measures for evaluating evolving design maturity, with the reduction of risk
  - 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)
Formalize and Refine SET Framework

SysML Activity Diagram is draft
Process Model for SET Framework

1 Mission Engineering and Analysis

2 Manage KPPs that are Critical to Mission Capabilities

3 Develop and Refine Specification

4 Perform MDAO

5 Create Balance Optimized Design

6 Perform Continuous Model-Centric Asynchronous Integration Analysis and Optimization

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

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

Use View and Viewpoint Hierarchy to Validate models and generate specification - such "specification" can then be "pushed" to server.
Methods for Partitioning of Work and Modularization of Models

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

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

IM40 SystemX Project Model

IM20 SystemX Mission/Context Model

IM30 SystemX Internal Design & Analysis Model

IM40 SystemX Acquisitions Model

Model-Based Acquisitions for SystemX - Model Architecture Option1

CS10 SystemX RFP Document

CM00 SystemX Competition Model

CM10 Model-based RFP

CM11 SystemX Model - As-Specified

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

SR90 Shared Resources
- Pre-competitive libraries
- Model-based specs (ML-wnn)
- Etc.
Using OpenMBEE Model Development Kit/DocGen for Generating Specification from Modularized Model
Open Model Based Engineering Environment (OpenMBEE)

Model Development Kit/DocGen
View and Viewpoint Hierarchy

Model Management System

Visualization in View Editor

http://www.openmbee.org
Surrogate Pilot Using OpenMBEE as Basis for Demonstrating Authoritative Source of Truth

Multidisciplinary Design, Analysis, and Optimization (MDAO) platform

SE Modeling Patterns formalized as Ontologies

Semantic Web Technologies support Continuous Checks and Model Measures

System Modeler

System Analyst

Model Analyst

Community of Practice

- Project
- Flight
- ESE
- FP
- V&V
- GDS
- MOS

SE Practices
Patterns
Scripts/SW
Training

Model Development Environment

- Circuity development
- Profile creation
- Rules development
- Software development (e.g., python, scripts, mka applications)
- Customization and adaptation

Modeling Environment

Analysis Tool

ModelCenter

MagicDraw

Plugins
Profiles

Model Analysis Framework

Constraint Solver
Content Checking
Well Formedness Checking

RDF DB

Ontologies

TMS

Teamwork Server

System Models

Formulation Environment

Integration Platform

PLM

CAD/CAE

Test Environment & Testbeds

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

View Editor

DocGen

Visualization

Where Are We:
Increment 1 and Elements 1 & 2
Our Research Efforts are Synergistic With Our ARDEC Sponsor and Other Collaborators
Perspectives on Characterizing Challenges of Research Space

Concept of Operation (CONOPS)

Trade Space of mission alternatives

What

Mission Effectiveness
Optimization to right-size Mission & System Capabilities for the critical Key Performance Parameters (KPPs)
("All requirements are tradeable")

Methods for Identifying KPPs

Decision Framework (Performance vs. Cost vs. Time vs. Risk)

Trade Space of system & subsystem alternatives

How

Information Model Capturing Cross-Domain Relationships

How well

Reasoning about completeness and consistency of information across domains

Methods for
Identifying
KPPs
Key Performance Parameter (KPP)

• Performance attributes of a system considered critical to the development of an effective military capability.

• Example:
  — Predator shall have an endurance of 40 hours
  — Possibly with other constraint:
    o And carry 340kg of multiple payloads including video cameras, laser designators, communications
  — Meet some availability and cost objectives

Example: Cross Domain Relationships Needed for System Trades, Analysis and Design

- Scenario Refueling UAV
- Valve – Cross-domain **Object**
- Mechanical **Domain**
  - Valve connects to Pipe
- Electrical **Domain**
  - Switch opens/closes Value
  - Maybe software
- Operator **Domain**
  - Pilot remotely send message to control value
- Communication **Domain**
  - Message sent through network
- Fire control **Domain**
  - Independent detection to shut off valve
- Safety **Domain**
RT-168 Use Case Perspective and Team

07 Research V&V

08 Assess as Chief Engineer Role

05 Use Model Based Engineering

06 Research Decision Framework

01 Research Graphical Conops

02 Research Mission and System Operational Capabilities

03 Research MDAO

04 Create System Models

09 Tradeoff Analysis of Technologies for Integration or Interoperability

11 Assess AVCE iMBE

04.1 MDK/DocGen

09.1 OpenMBEE & Docker

00 Develop Information Model

08 Assess as Chief Engineer Role

Physical Realization

LuigiB

Kishore

JohnD

RobC

PaulG

RogerB

StevenH

BrianC

Mary

BenK

Mark

ChrisS

Ian

TomH

Robin

MattC

Eirik

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Decision Framework – Value Scatterplot of Trades with Assessing Impact of Uncertainty*


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Using MDAO for Assessment Flow Diagram of Decision Framework (AAMODAT)

- Can MDAO represent Assessment Flow Diagram?
- Does AFD characterize needed MDAO workflows?
Understanding Analysis Workflows and Methods for any Configured Workflows

Notional Example

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<td>CFD Muzzle Analysis</td>
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CASRED ← Terminal/Systems Effects
Cross-domain methodologies ensure tool usage produces complete and consistent information compliant with ontologies of AST to ensure model integrity.
IoIF Uses SWT for Interoperability Among “Any” Type of MCE Capability

RT168 – High Level Integrating and Interoperability Framework (IoIF) Design

IoIF – Demo – Pub-Sub, Dual Model & SWT Integration

Example Demonstration

IoIF: Integration and Interoperability Framework
SWT: Semantic Web Technology
Planned CONCEPT for Integrating Technologies into OpenMBEE through IoIF

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

Multidisciplinary Design, Analysis, and Optimization (MDAO) platform

SE Modeling Patterns formalized as Ontologies

Visualization

DocGen

View Editor

Viewpoints / Products

Model Development Environment

Explore Integration of Graphical CONOPS Simulation with MDAO tools

Fully interactive simulation of a blue UAS on a mission to located a treasure with an intelligent (AI) red UAS counterparty disrupting mission

MDAO Methods
- Design of Experiments (DOE)
- Sensitivity Analysis
- Optimize desired objectives

Re-designed to run 1000 scenarios (instead of 10) driven by MDAO to fully cover DOEs
Collaborations

• 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/
Thank You

• 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/
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<td>CDD</td>
<td>Capability Description Document</td>
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