

A Few Words First

Courtesy – Please mute your phone (*6 toggle).

Upcoming Chapter Meetings:

- Mar 08, Integration of Agile Principles into the Systems Engineering Lifecycle Model, Alan Benson, Caltrans (California Dept. of Transportation)
- Mar 13, Joint Chapter meeting with SOARizona Chapter Enabling and Facilitating Agility in Systems Engineering and Hardware Development, Rick Dove (at SOARizona Chapter), Paradigm Shift International
- Apr 12, **Lunch Time: 11:45am-13:00pm MST**
What the Systems Community Can Learn from ASME Work in Computational Model V&V Standardization, Bill Schindel, ICTT System Sciences

International Systems Safety Conference, **Albuquerque, August 21-25, 2017**
Submissions: **Abstracts March 30**, Draft Paper April 20, Final Paper June 30
<http://issc2017.system-safety.org>

CSEP Courses by *Certification Training International*:

Course details | Course brochure

2017 Course Schedule (close by, but many more locations and dates):

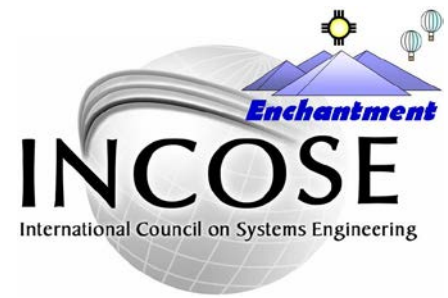
February 27 – March 3 | Las Vegas, NV

April 24-28 | Albuquerque, NM

First slide, not recorded but retained in pdf presentation.

And Now - Introductions

Enchantment Chapter Monthly Meeting



8 February 2017 – 4:45-6:00 pm:

Transforming Systems Engineering through a Holistic Approach to Model-Centric Systems Engineering

Dr. Mark Blackburn, Associate Professor, Stevens Institute of Technology
mblackbu@stevens.edu

Abstract: This presentation discusses perspectives from several Systems Engineering Research Center (SERC) projects addressing research challenges and opportunities for leveraging model-centric engineering (MCE), sponsored by the Naval Air Systems Command (NAVAIR) and the United States Army RDECOM-ARDEC. Model-centric engineering can be characterized as an overarching digital engineering approach that integrates different model types with simulations, surrogates, systems and components at different levels of abstraction and fidelity across disciplines throughout the lifecycle. Industry is trending towards more integration of computational capabilities, models, software, hardware, platforms, and humans-in-the-loop. The integrated perspectives provide cross-domain views for rapid system level analysis allowing engineers from various disciplines using dynamic models and surrogates to support continuous and often virtual verification and validation for tradespace decisions in the face of changing mission needs.

Download slides anytime from the Chapter Library at www.incose.org/enchantment

NOTE: This meeting will be recorded

Today's Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Speaker Bio



Mark R. Blackburn, Ph.D. is a Research Associate Professor with Stevens Institute of Technology and principal at KnowledgeBytes. Dr. Blackburn's research focuses on methods, models, and automated tools for reasoning about complex systems of systems. He is the Principal Investigator (PI) on several System Engineering Research Center research tasks for both NAVAIR and US. Army ARDEC on Systems Engineering Transformation through Model-Centric Engineering.

He has also been Principal on a FAA NextGen project and has received research funding from the National Science Foundation.

He develops and teaches a course on Systems Engineering of Cyber Physical Systems.

Prior to joining Stevens, Dr. Blackburn worked in industry for more than 25 years. He has been the Principal Investigator to the National Institute of Standards and Technology on projects dating back to 2000 involving model-based tools and methods for verification and validation of security-related products and applications.

Dr. Blackburn holds a Ph.D. from George Mason University, a M.S. in Mathematics (emphasis in C.S.) from Florida Atlantic University, and a B.S. in Mathematics (C.S. option) from Arizona State University.

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

Systems Engineering Transformation through Model Centric Engineering

Presented By:

Dr. Mark R. Blackburn

With Contributing Researchers (RT-48, 118, 141, 157, 168, 170):

Dr. Mary Bone

Dr. Dinesh Verma - Stevens Institute of Technology (RT-168)

Dr. Robin Dillon-Merrill - Georgetown University (RT-168)

Dr. Russell Peak - Georgia Tech University (RT-170)

Dr. Mark Austin - University of Maryland (RT-170)

Dr. Todd Richmond - University of Southern California (RT-168)

Research Tasks and Collaborator Network

RT-48

Rob Cloutier
Eirik Hole
Gary Witus – Wayne State

RT-107

Gary Witus – Wayne State

RT-118

Rob Cloutier
Eirik Hole
Gary Witus – Wayne State

RT-141

Mary Bone
Gary Witus – Wayne State

RT-142

Gary Witus – Wayne State

RT-157

Mary Bone
Roger Blake
Mark Austin

RT-168

Dinesh Verma
Roger Blake
Mary Bone
Paul Grogan
Deva Henry
Steven Hoffenson
Eirik Hole
Roger Jones
Jeff McDonald
Kishore Pochiraju
Gregg Vesonder
Lu Xiao
Robin Dillon-Merrill – Georgetown University
Todd Richmond – University of Southern California

RT-170

Mary Bone
Roger Blake
Deva Henry
Paul Grogan
Steven Hoffenson
Mark Austin – University of Maryland
Leonard Petnga – University of Maryland
Russell Peak – Georgia Tech
Stephen Edwards – Georgia Tech

- Problem, Objectives and Terminology (Phase I)
- Bottom Line (Up Front)
- Current research thrusts
- Perspectives and status RT-157/RT-170 (Phase II)
- Perspectives and status RT-168 (Phase 1)
- Conclusions and Impacts
- Acknowledgments
- Acronyms and Image credits

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Problem statement (Phase I):

It takes too long to bring large-scale air vehicle systems from concept to operation

Primary question:

Is it **Technically Feasible** to have a **Radical Transformation** through Model Based Systems Engineering (MBSE) and achieve a **25 percent reduction** in the **time** to develop large-scale air vehicle system (using computer/digital models)?

Corollary:

How do we know that models/simulations used to assess **Performance** have the needed **Integrity** to ensure predictions are accurate (i.e., that we can trust the models)?



Sponsor's Vision at Kickoff Meeting: Cross-Domain, Multi-Physics, Models Integration

Continuous refinement of models through cross-domain & multidisciplinary analysis supporting virtual V&V from CONOPS to manufacturing (and training systems)



Integrated Environment to Produce Digital System Model:
Single Source of Technical Truth

Model Based System Engineering (MBSE) versus Model-Centric Engineering (MCE)

- Over 30 organizational discussions “most 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
 - Digital Thread envisions frameworks that merges physics-based models generated by (cross)discipline engineers during detailed design process with MBSE’s conceptual and top-level architectural models, resulting in a single authoritative representation of the system [West, Pyster, INCOSE 2015]
- **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
- We could have used the words **Digital Engineering**, which we do

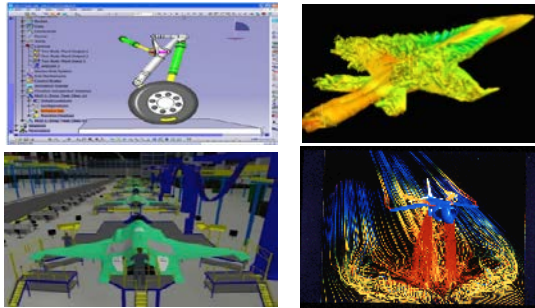


Scope of Data Collection for Task 1 Traced to Evidence (not exhaustive)

Discussion Topics (not exhaustive)	Instances where discussed (not exhaustive)											Characteristics					From Kickoff Briefing								
	NASA/JPL	A	B	C	Altair	GE	Sandia	DARPA META (VB)	DARPA META (BAE)	Model Center	Automotive	CREATE	Performance	Integrity	Affordability	Risk	Methodology	Single Source of Tech Truth	Prioritization & Tradeoff Analysis	Concept Engineering	Architecture & Design Analysis	Design & Test Reuse & Synthesis	Active System Characterization	Human-System Integration	
Modeling CONOPS	x															x	x	x		x	x			x	
Modeling Patterns	x								x					x		x	x	x		x	x	x	x		
Multi-Physics Modeling and Simulation		x	x	x	x			x	x		x	x	x	x					x	x	x	x	x	x	
Multi-Discipline/Domain Analysis and Optimization	x	x	x	x	x	x	x	x	x	x								x							
Mission-to-System-level Simulation Integration	x	x	x													x				x	x	x	x	x	x
Affordability Analysis			x				x									x	x			x		x	x	x	
Quantification of Margins			x				x									x	x			x		x	x	x	
Requirement Generation (from Models)	x		x				x										x	x		x		x	x		
Tool agnostic digital representation	x	x			x				x								x	x		x		x	x	x	x
Model measures (thru formal checks)	x		x			x		x	x							x	x	x				x	x		
Modeling and Sim for Manufacturability			x			x		x								x	x	x		x	x	x	x	x	
Process Automation (workflows)	x				x				x	x							x	x				x			
Iterative/Agile use of MCE	x	x	x														x					x	x		
High Performance Computing	x	x	x		x		x	x					x	x						x	x	x		x	
Platform-based and Surrogates	x	x	x																	x	x	x	x	x	
3D Environments and Visualization	x	x	x	x	x	x	x	x												x	x		x	x	x
Immersive Environments		x	x																	x				x	x
Domain-specific modeling languages	x	x	x	x	x	x	x	x	x							x				x	x	x			
Set-based design		x				x														x	x	x			
Model validation/qualification/trust							x													x		x	x		
Modeling Environment and Infrastructure	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x

Conceptual Reference Model: Integrated Environment for Iterative Tradespace Analysis of Problem and Design Space

Appropriate Views for Stakeholders



Rich Modeling Interfaces

“Web” Interface integrated with Rich Visualizations

Multidiscipline Design, Analysis and Optimization (MDAO)

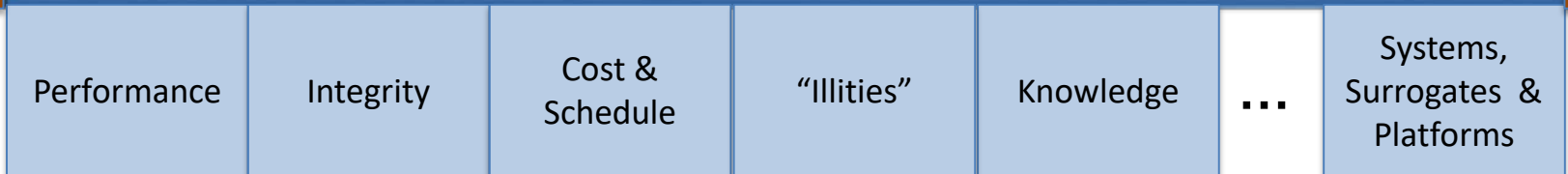
Computer Augmentation & Training Continuous Workflow Orchestration DocGen

Single Source of Technical Truth:
Tool Agnostic, Semantically Precise Cross Domain Integration & Interoperability enabled by HPC



Secure Plugin

PLM



1) Model Cross-Domain Integration

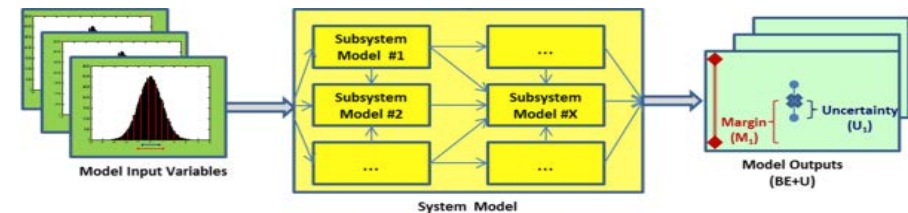
Targeted discussions with Government, Industry & Academia on developing and operating in modeling framework enabling cross-domain model integration & Single Source of Technical Truth (SSTT) methodology



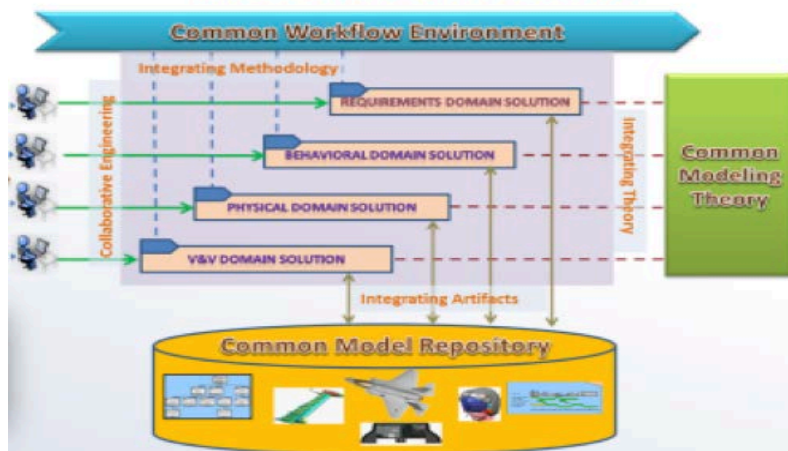
2) Model Integrity

Define Methodologies for Model Integrity and Uncertainty Quantification:

- Provide trust in model-based predictions, with Quantification of Margins & Uncertainties
- Framework for integrating risk and understanding uncertainty in the data

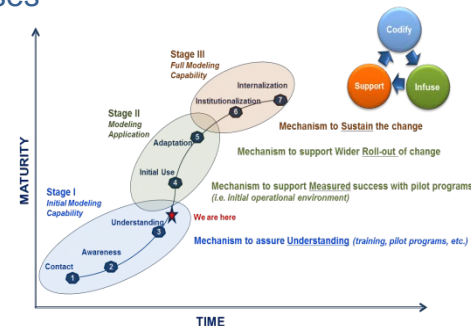


Model-Centric Methodology



Develop a roadmap to rollout capabilities addressing all five perspectives in parallel:

1. Technologies and infrastructure for SSTT
2. Methodologies and processes
3. People, competencies and SSTT interfaces
4. Operational & contractual paradigms for transformed interactions with industry
5. Governance



3) Modeling Methodology Implementation at NAVAIR

4) SE Transformation Roadmap

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



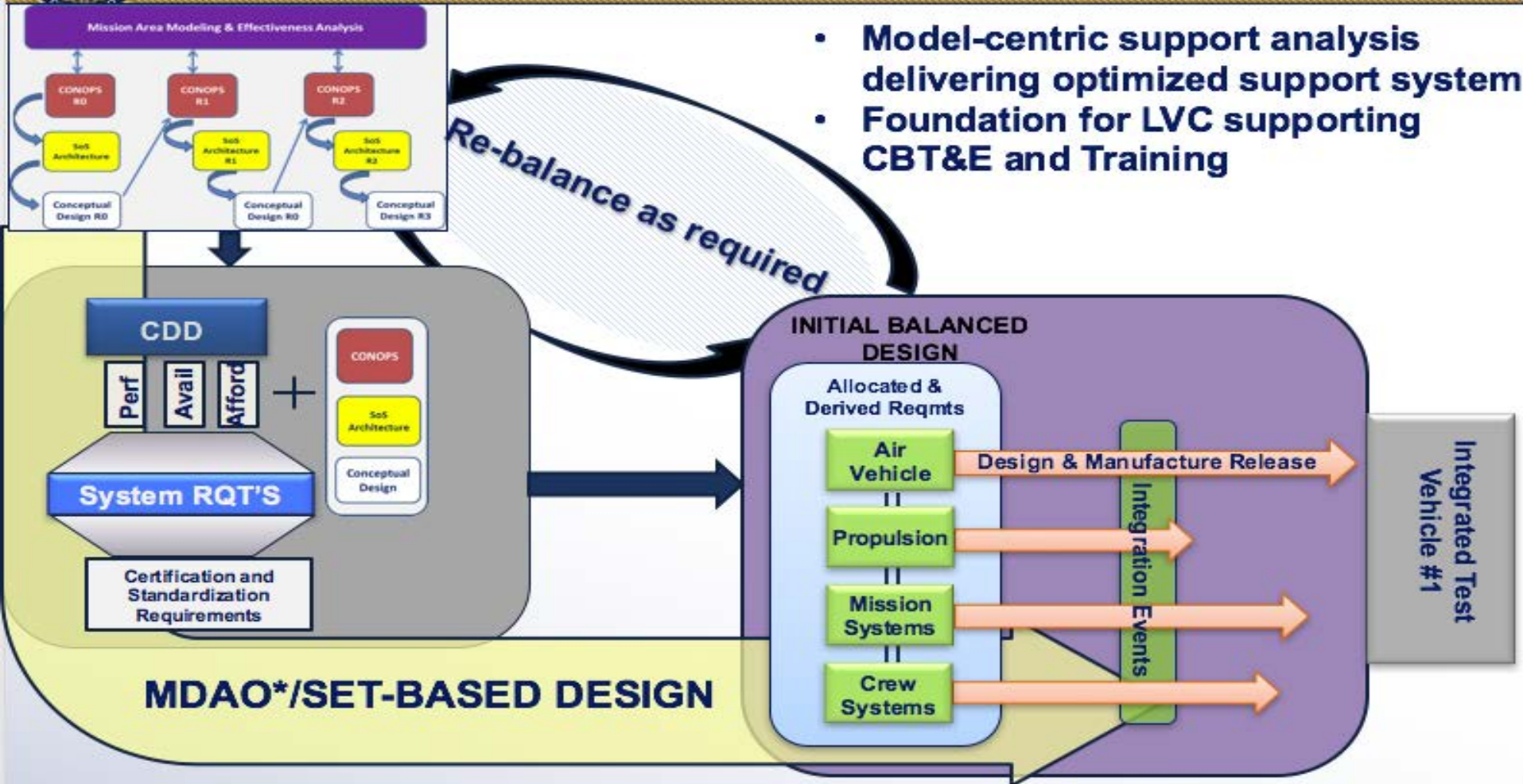
Model-Centric Engineering Can Enable New Types of Coordination

- In a “Digital Engineering” environment, government and industry need to work in a different way



Framework for New Operational Paradigm Between Government and Industry

SET Framework



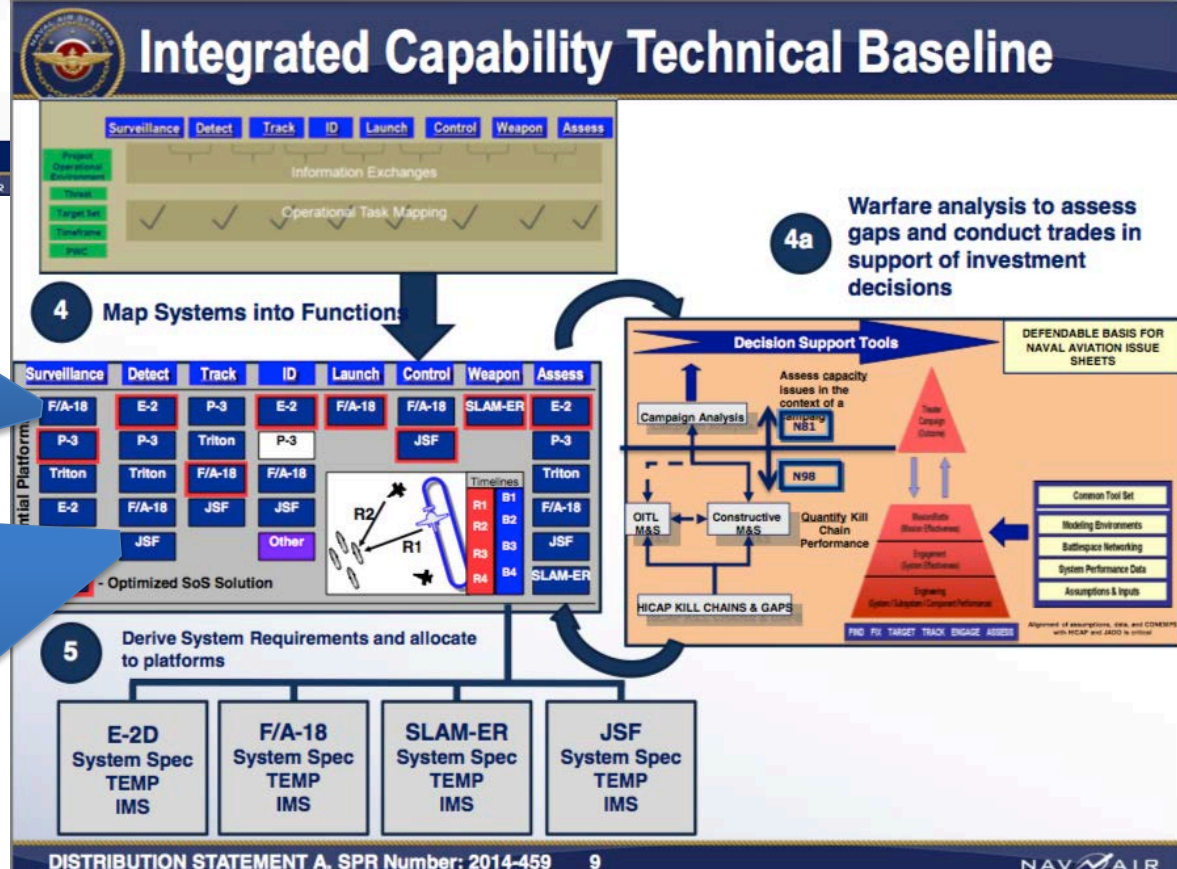
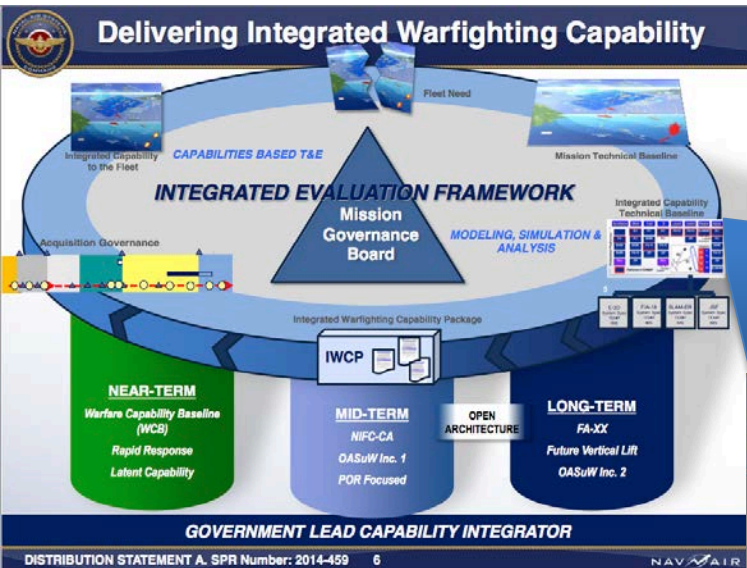
- Model-centric support analysis delivering optimized support system
- Foundation for LVC supporting CBT&E and Training

* Multi-Disciplinary Analysis & Optimization



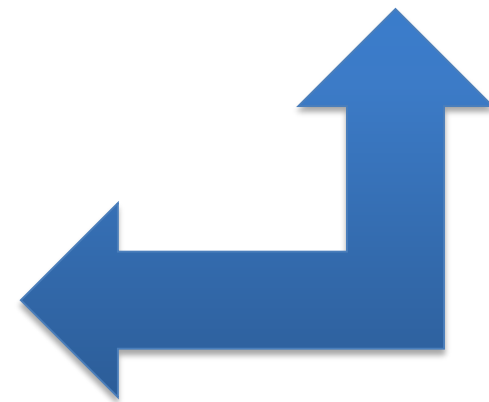
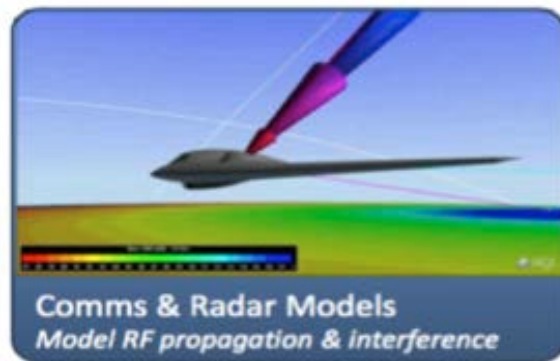
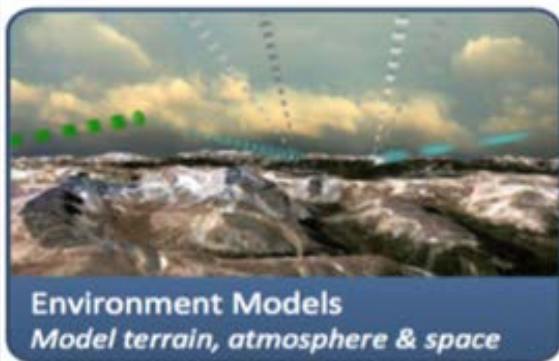
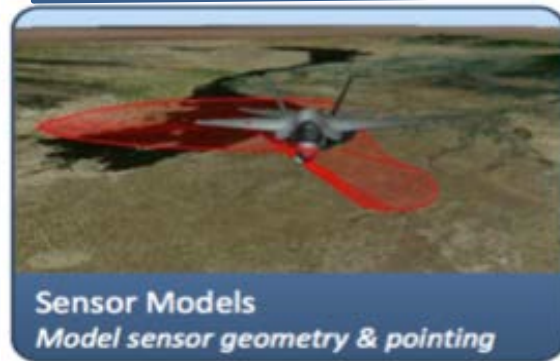
RT-157/170 Perspectives (NAVAIR)

Tracing the Campaign and Mission Analysis to System Capabilities of Evolving Platforms



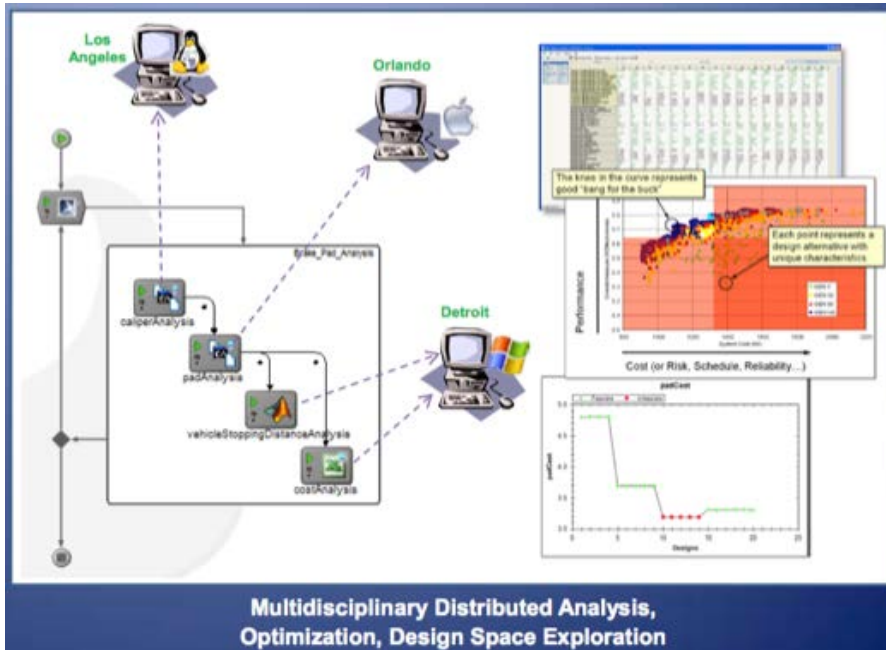
Dynamic CONOPS Integrated with Mission Simulations to Better Understand Needed System Capabilities

Simulated-based
Study Views Method
Structures and Formalizes
the JCIDS* Concepts prior
to DoDAF Modeling

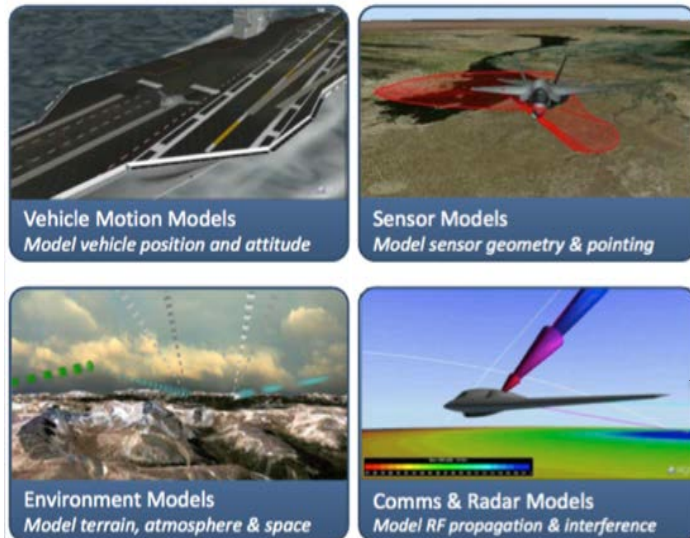
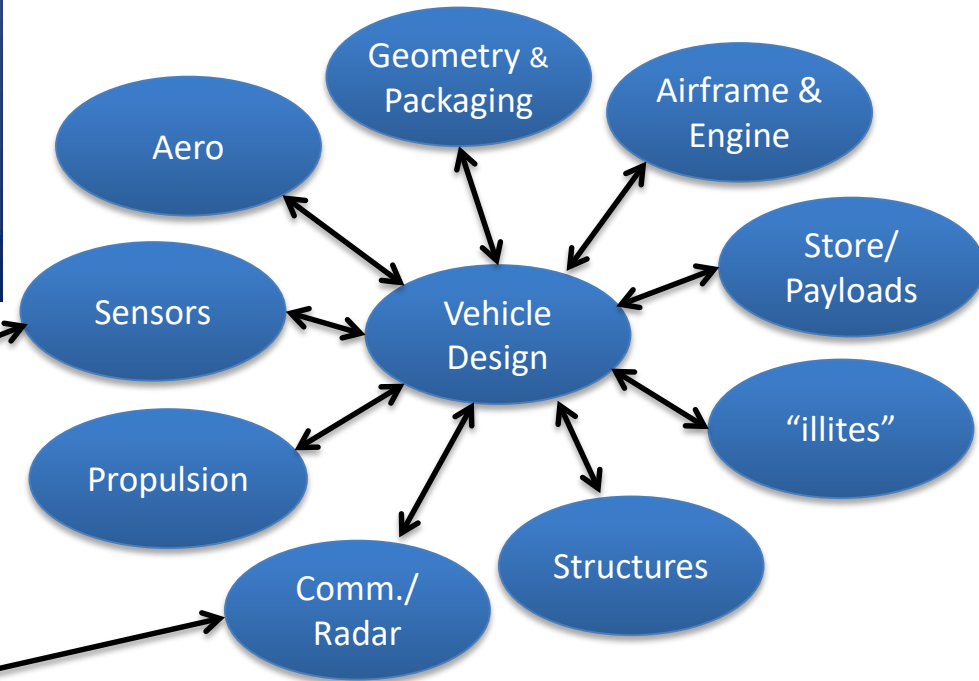


*Joint Capabilities Integration and Development System (JCIDS)

Multidisciplinary Design, Analysis and Optimization Supports Tradespace Analysis Across Disciplines



MDAO Implements Workflow with Solvers to Evaluate Trades Systematically Driven by Design of Experiment



Detailed Design from Associated Disciplines and Competencies

Need to Better Integrate Multiple Levels of System Models with Discipline-Specific Designs

Architecture Models

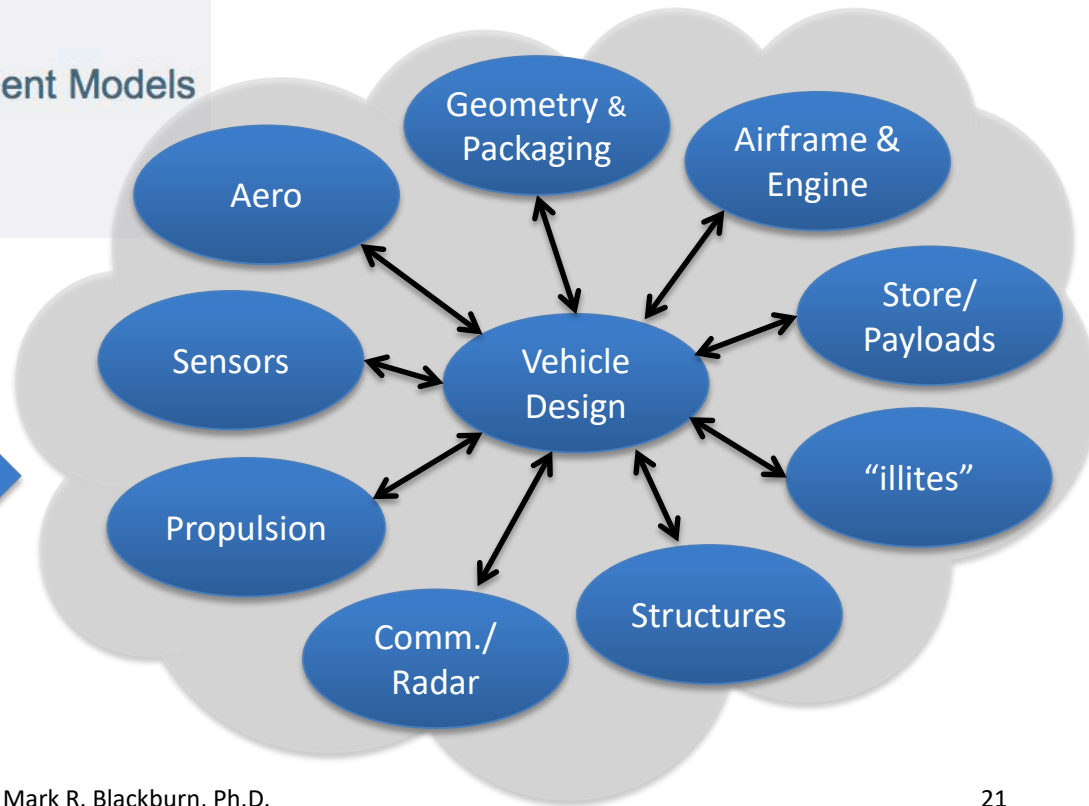
Systems Models

Component Models

Architectural, System and Component Models Define the Cross-Domain Integration and Bring in Detailed Behaviors

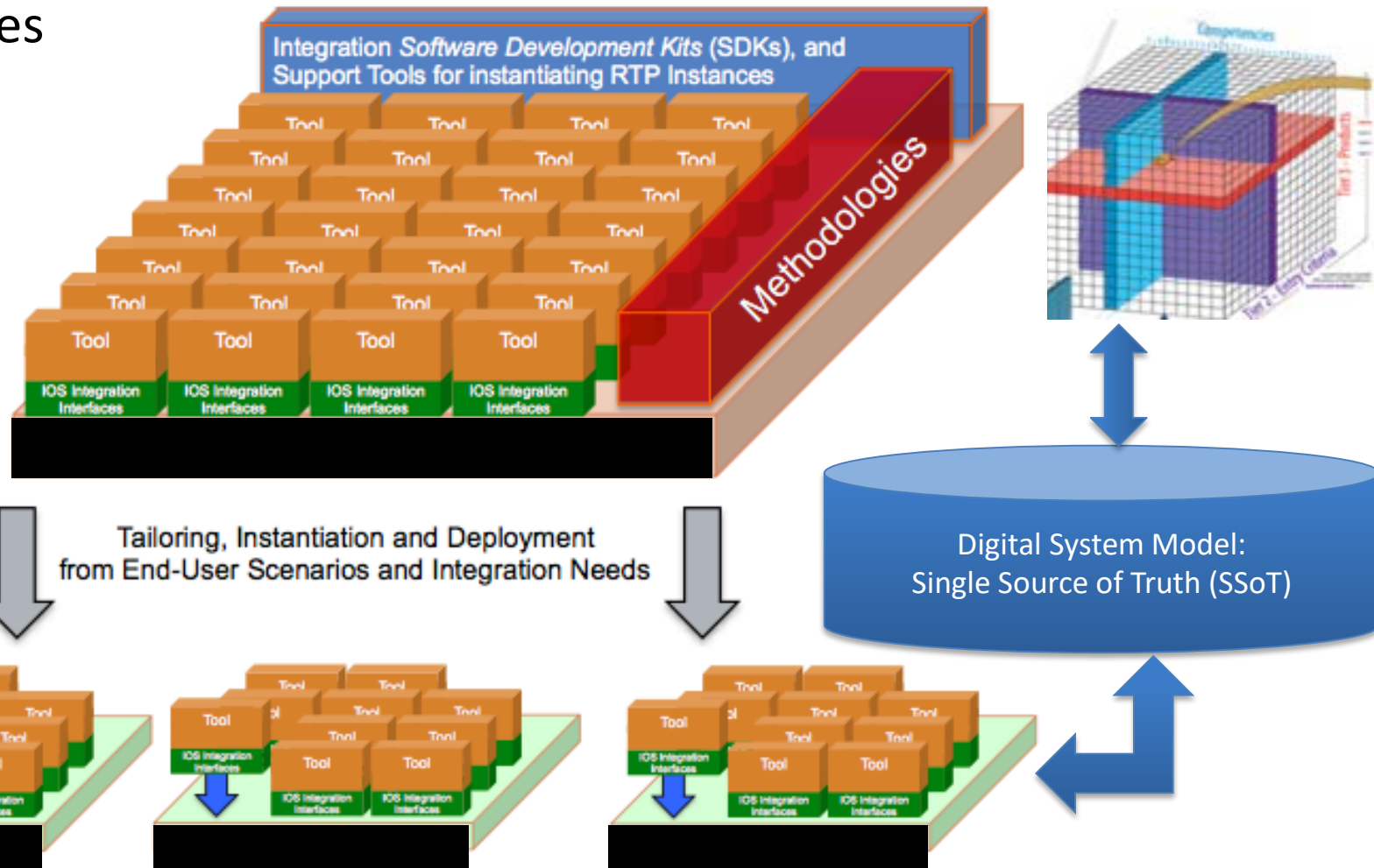


Iterative Process



Methodologies are Critical Because Commercial Tools are Method Agnostic

Cross-domain methodologies ensure tool usage produces complete and consistent information compliant with ontologies of SSTT



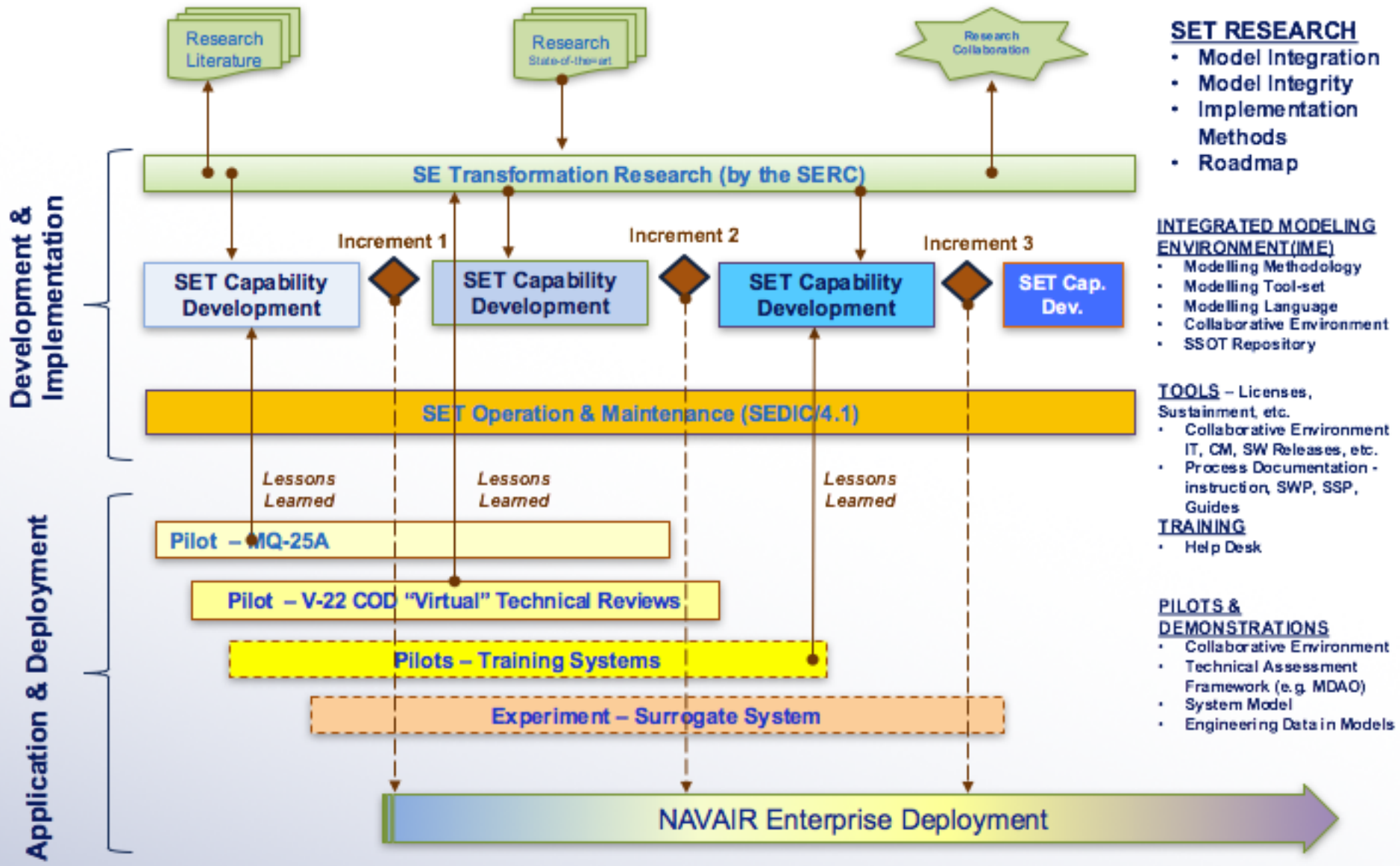


Organizations are Modeling and Simulating Manufacturing Before Tooling

- Set-based delays design selection and increasingly factors in manufacturability



SE Transformation “Role-out” Strategy

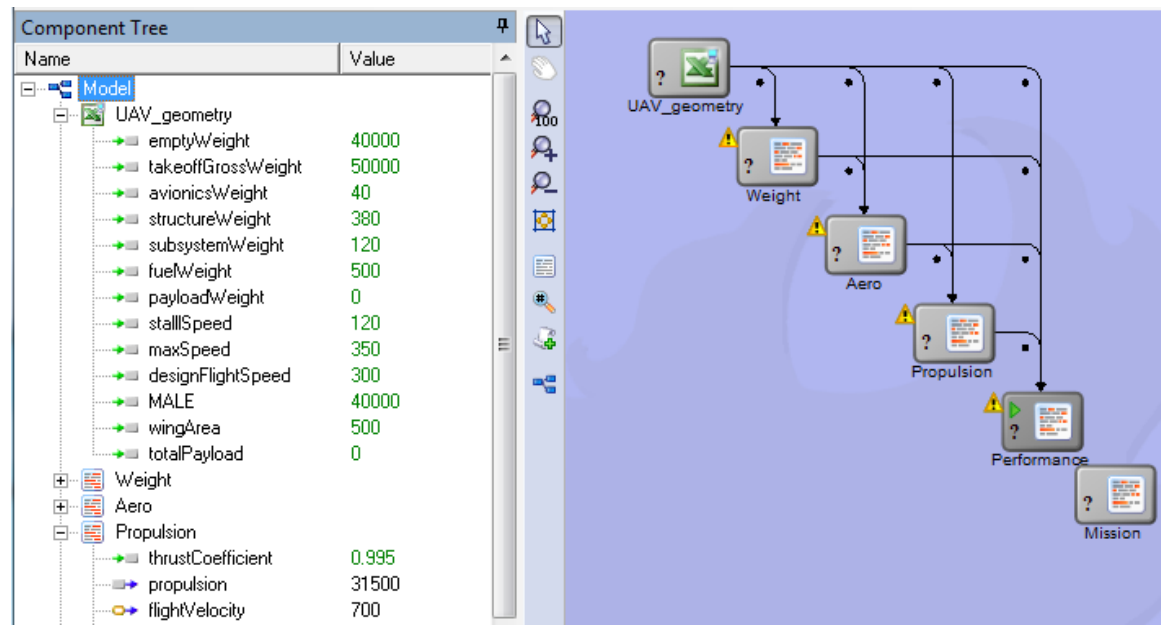


Status Against Framework Research (1/3) – Contracting through Digital Engineering

- Developing surrogate UAV to demonstrate how models represent requirement at logical and functional levels
 - Concept can be part of a SOW and RFP for new contractual vehicle based on Digital Engineering for competitive down select (NDIA involved in this effort)
 - Illustrate links from system models to MDAO and other types of models
 - Illustrating what needs to be modeled beyond DoDAF focused on net-ready views
- UAV example started by Stevens, now being extended by new team collaborator Georgia Tech
- Developing models of methods and processes to illustrate linkage between mission, system, reference and MDAO, etc. model

Status Against Framework Research (2/3) – MDAO Example Relevant to UAV

- Developed MDAO workflow for example of KPP (range) using UAV Weight, Aero, Propulsion, Performance, which links back to system model to illustrate method:
 - Defining sequence of workflows (scenarios)
 - Identifying a set of inputs and outputs (parameters)
 - Define a Design of Experiments (DoE) and use analyses such as sensitivity analysis and visualizations to understand the key parameter to scope
 - Use Optimization using solvers with key parameters and define different (key objective functions – on outputs) to determine set of solutions (results often provided as a table of possible solutions)
 - Use visualizations to understand relationships of different solutions
 - Concept applicable at mission, system and subsystems



Status Against Framework Research (3/3) – Model Integrity

- Steven's PhD candidate Col. Timothy West (advisor Mark Blackburn) runs wind tunnels at Arnold Engineering Development Complex
- Research involves a proposed methodology to use Sandia National Laboratory (SNL) DAKOTA Toolkit with DoD Computational Research and Engineering Acquisition Tools and Environments (CREATE) Air Vehicle (AV) family of computational tools (e.g., CFD, FEA), in order to develop an optimized wind tunnel campaign for two different aerodynamic shapes to assess the process



Aeropropulsion

F136 in J2



Aerodynamics

B-52 in 16T



Hypersonics

HTV at Tunnel 9

RT-170 Task - Mission Engineering and Analysis using MDAO Methods

SERC RT170 MCE Project for NAVAIR
ASDL Contact: Russell.Peak@gatech.edu (PI)

GT-ASDL Subtask:

Model-Centric Engineering (MCE) Techniques & Demos

POC: Russell.Peak@gatech.edu

SE Transformation Working Session #26

Wed Nov 9, 2016 • Lexington Park MD

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Semantic-driven Modeling and Reasoning for Systems Engineering Transformation

Mark Austin

University of Maryland

austin@isr.umd.edu NAVAIR Presentation

November 8, 2016

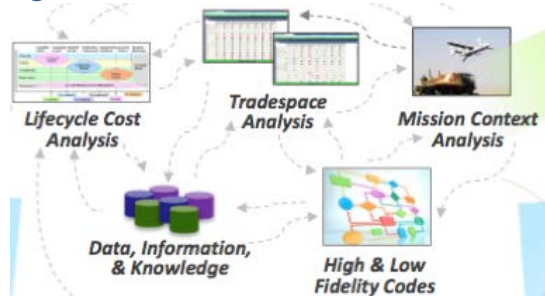


RT-168 Perspectives (US Army - ARDEC)

Systems Engineering Transformation through Model-Centric Engineering (MCE)

1) MCE Framework

Modeling framework enabling mission/system problem and design-space, multi-model and cross-domain model integration with enabling methodologies



2) Formalization of Information Model for ARDEC-relevant Domains

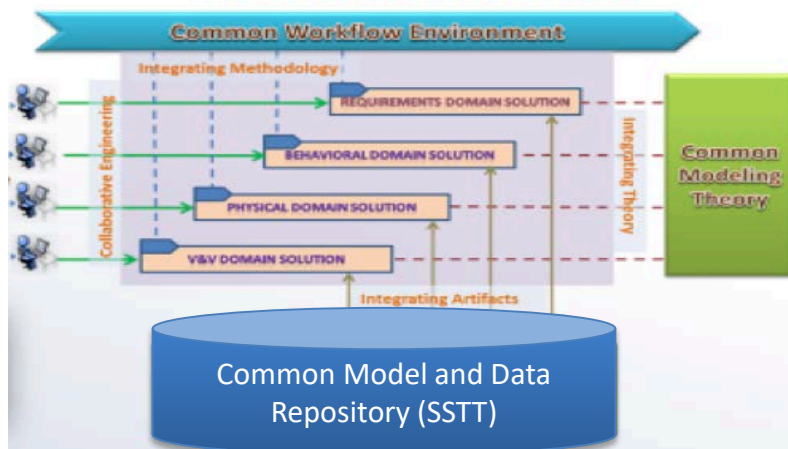
Support capturing and sharing of data and information as a conceptual System Model (or Digital System Model), or “Single Source of Technical Truth”:

- Domain information models can be informed by Army and ARDEC Taxonomy
- Ensure the domains are evolvable to address continual evolution in technologies

Digital System Model:
Single Source of Technical Truth (SSTT)

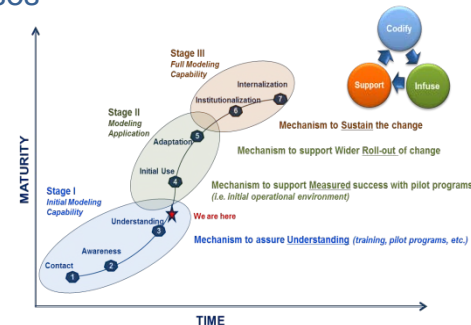
4) Challenge Areas

Model-Centric Methodology



Develop a roadmap to rollout capabilities addressing all five perspectives in parallel:

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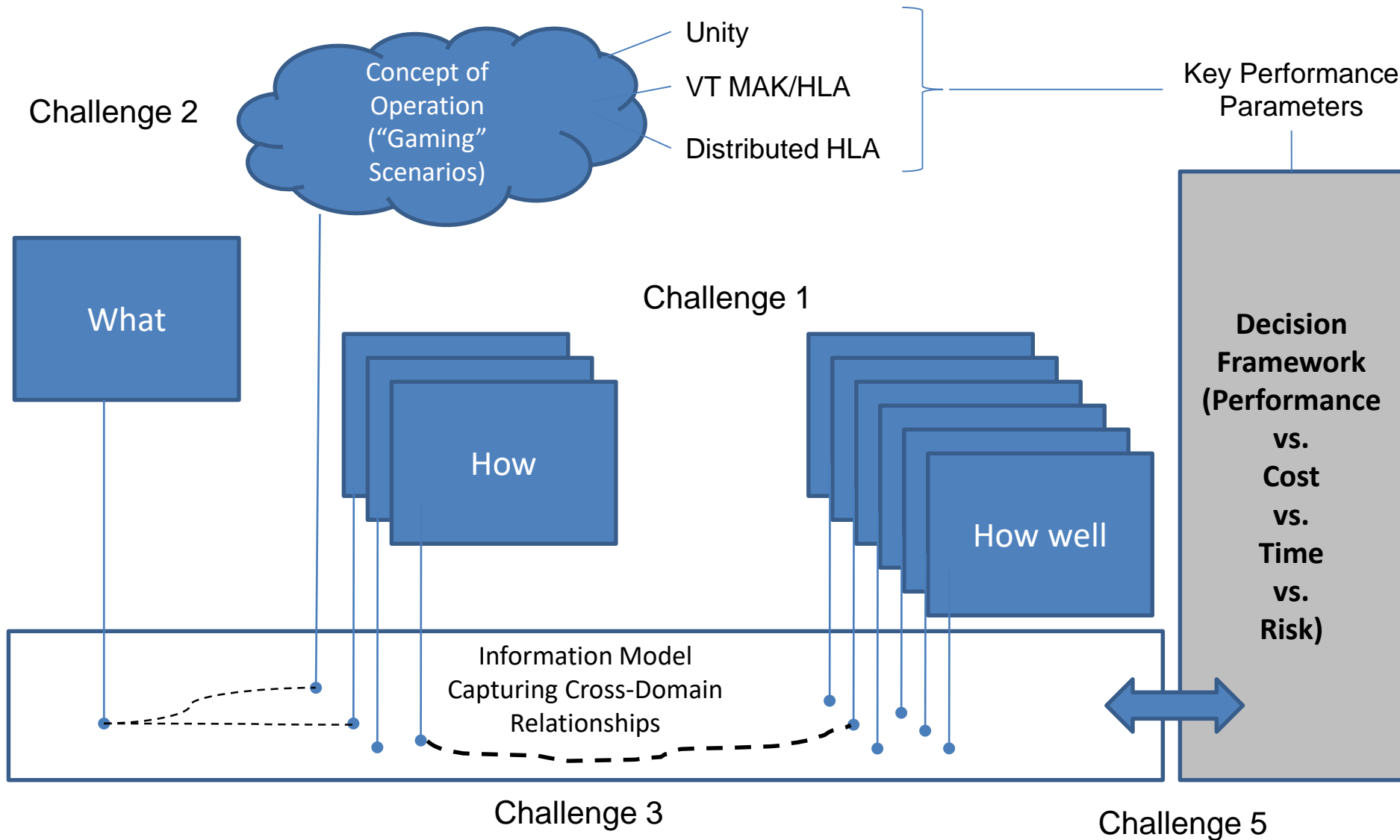


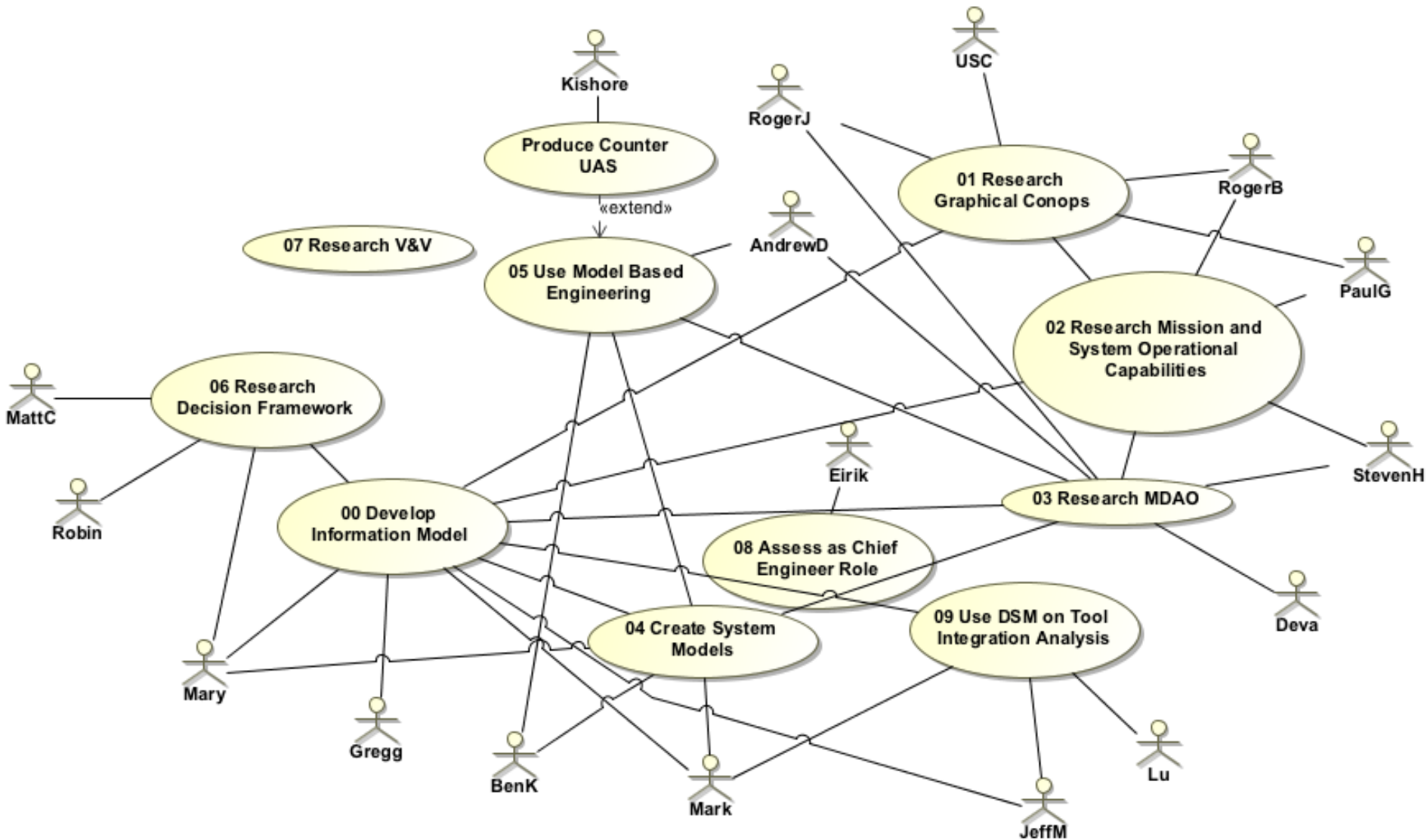
3) Modeling Methodology Implementation at ARDEC

5) SE Transformation Roadmap

- Case study – “Counter UAS”
- Challenge #1 – Development of Dynamic Modeling (system-level)
 - System + Performance + CAD (physics) [could be underperforming surrogate]
 - Multidisciplinary Design, Analysis and Optimization (MDAO)
- Challenge #2 – Concept Generation Capabilities (mission-level)
 - Operational scenarios (graphical CONOPS), mission trades (MDAO)
 - What tools, gaming, how to model early concepts, map to system (e.g., Challenge #1)
 - End state – “Concept” goes to Science and Technology
- Challenge #3 – Information Model/Big Data
 - Single Source of Truth (SST) (linking of cross domain ontologies)
 - Current thinking is based on commercial technologies (e.g., Windchill)
 - What in SST at Milestone A, Engineering & Manufacturing Development (EMD – Milestone B)

Perspectives on the Challenge Areas





Conclusions and Impacts

- NAVAIR is evolving a framework for a new collaborative operational paradigm with industry for **Systems Engineering Transformation**
 - Conducting meetings with industry to “validate” concept and solicit recommendations for improvement and evolution
 - Pilot planning and workforce development initiated
 - New contracting model/approach needed
 - New criteria for assessing “maturity” vice “milestones”
- Policy – can the current policy still work?
- Collaboration:
 - US Army ARDEC targeting their needs for MCE in collaboration with NAVAIR
 - New Naval Postgraduate School collaboration in process
- Government and Industry Forum on MCE
- Digital Engineering Strategy Initiative (coordinated through DASD)
- Airspace Industry Association: CONOPS for Industry/Government Collaborative Framework
- NDIA Working Group– Using Digital Engineering for Competitive Down Select

- We wish to acknowledge the great support of the NAVAIR sponsors and stakeholders, including stakeholders from other industry partners that have been very helpful and open about the challenges and opportunities of this promising approach to transform systems engineering.
- We want to specifically thank Dave Cohen who established the vision for this project, and our NAVAIR team, led by Jaime Guerrero, with latest team: David Meiser, Jason Thomas, Chris Owen, Jeff Smallwood, Michael Gaydar, Ron Carlson, Brandi Gertsner, Gary Strauss and James Light.
- We have had over 40 discussions with organizations from Industry, Government, and Academia, and we want to thank all of those stakeholders (over 200 people), including some from industry that will remain anonymous in recognition of our need to comply with proprietary and confidentiality agreements associated with Task 1.
- We want to thank the ARDEC leadership of Jeff Dyer and the key leads for an evolving team Eddie Bauer, Christina Jauregui, Cliff Marini and Matt Cilli.

CDD	Capability Description Document	MCSE	Model-Centric System Engineering
CONOPS	Concept of Operations	MDAO	Multidisciplinary Design Analysis and Optimization
CDR	Critical Design Review	MDE	Model-Driven Engineering
CDRL	Contract Data Requirements List	NAVAIR	Naval Air Systems Command
CFD	Computational Fluid Dynamics	OV	Operational View
DARPA	Defense Advanced Research Project Agency	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
IoT	Internet of Things	SETR	Systems Engineering Technical Review
JCIDS	Joint Capabilities Integration and Development System	SFR	System Functional Review
KPP	Key Performance Parameter	SRR	System Requirements Review
MBSE	Model-based System Engineering	SoS	System of Systems
MBE	Model-Based Engineering	SOW	Statement of Work
MCE	Model-Centric Engineering	SSTT	Single Source of Technical Truth
		SV	System View
		UAV	Unmanned Air Vehicle
		V&V	Verification and Validation

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Slide #11: <http://www.eonreality.com/hardware/>

Slide #14: www.defenseindustrydaily.com, www.darkgovernment.com, NAVAIR

Slide #12: www.fightercontrol.co.uk, en.wikipedia.org, en.wikipedia.org

Slide #15: Image credit: AGI, NAVAIR Study Views

Slide #16: Image credit: AGI, Phoenix Integration

Slide #17: mosimte.com

Slide #20: CRITICAL SYSTEM Engineering Acceleration, Interoperability Specification (IOS) – V1 D601.021, ARTEMIS-2012-1-332830, 2014.

Slide #21: Slide #18: m.plm.automation.siemens.com, mosimte.com, www.defenseindustrydaily.com, www.darkgovernment.com

Slide #25: Arnold Engineering Development Complex

- For more information contact:
 - Mark R. Blackburn, Ph.D.
 - Mark.Blackburn@stevens.edu
 - Stevens Institute of Technology

Today's Presentation

Things to Think About

How can this be applied in your work environment?

What did you hear that will influence your thinking?

What is your take away from this presentation?

Please

The link for the online survey for this meeting is

www.surveymonkey.com/r/2017_02_MeetingEval

www.surveymonkey.com/r/2017_02_MeetingEval

Look in GlobalMeet chat box for cut & paste link.

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