2020 RESEARCH TRANSITION REPORT

Transitioning research into practice - crossing boundaries through integrative collaboration

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ABOUT THE SERC

The Systems Engineering Research Center (SERC), a University-Affiliated Research Center (UARC) of the United States Department of Defense, leverages the research and expertise of senior lead researchers from 22 collaborator universities throughout the United States. The SERC is unprecedented in the depth and breadth of its reach, leadership, and citizenship in systems engineering through its conduct of vitally important research and the education of future systems engineering leaders.

Led by Stevens Institute of Technology and principal collaborator the University of Southern California (USC), the SERC launched in 2008 as a national resource providing a critical mass of systems engineering researchers—a community of broad experience, deep knowledge, and diverse interests. SERC researchers have worked across a wide variety of domains and industries and bring that wide-ranging wealth of experience and expertise to their research. Establishing such a community of focused SE researchers, while difficult, delivers impact well beyond what any one university could accomplish.

OBJECTIVE OF THIS RESEARCH TRANSITION REPORT

All research within the SERC is conducted with an objective of transitioning that research into practice, as appropriate. This aspect of the SERC continues to grow in impact through our collaboration with a number of FFRDCs, National Laboratories, and DoD Industry. To support the SERC transition goals, this report highlights research tasks in the government fiscal year 2020 (GFY2020), from 1 October 2019 - 30 September 2020. SERC researchers have published more than 500 technical papers and reports over the past eleven years. Research findings have transitioned into numerous courses across the SERC universities and beyond. We encourage organizations to review the research tasks highlighted in this report, and to contact us if we can assist in the necessary discussion and engagement to support the transition of relevant research into practice at serc@sercuarc.org.

INTRODUCTION AND CONTEXT

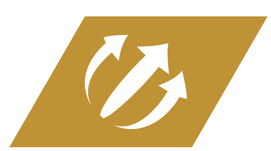
The SERC mission is to enhance and enable the DoD's capability in systems engineering for the successful development, integration, testing, and sustainability of complex defense systems, services, and enterprises. This is done through research leading to the creation, validation, and transition of innovative SE methods, processes, and tools (MPTs) to practice. It responsibly manages impact while evolving and coalescing the number, connectedness, and responsiveness of the SE research community in the United States to the needs of the DoD.

In coordination with its sponsors, the SERC has focused its research portfolio into four thematic areas with associated Grand Challenges, as shown in Figure 1.

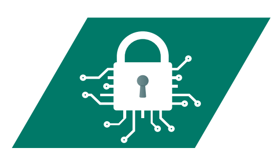
Figure 1. Research Areas Addressed by SERC Research Tasks

Enterprises and Systems of Systems

Human Capital Development



Systems Engineering and Systems Management Transformation



Trusted Systems

ENTERPRISES AND SYSTEMS OF SYSTEMS:

Providing ways to develop, characterize and evolve very large-scale systems composed of smaller systems, which may be technical, socio-technical, or even natural systems. These are complex systems in which the human behavioral aspects are often critical, boundaries are often fuzzy, interdependencies are dynamic, and emergent behavior is the norm. Research must enable prediction, conception, design, integration, verification, evolution, and management of such complex systems.

> ***Grand Challenge:*** *Create the foundational SE principles and develop the associated MPTs that enable the DoD and its partners to model (architect, design, analyze), acquire, evolve (operate, maintain, monitor, adapt) and verify complex enterprises and systems of systems to generate affordable and overwhelming competitive advantage over its current and future adversaries.*

HUMAN CAPITAL DEVELOPMENT:

Providing ways to ensure that the quality and quantity of systems engineers and technical leaders provide a competitive advantage for the DoD and defense industrial base. Research must determine the critical knowledge and skills that the DoD and IC workforce requires as well as determine the best means to continually impart that knowledge and skills.

> ***Grand Challenge***: *Discover how to dramatically accelerate the professional development of highly capable systems engineers and technical leaders in the DoD and defense industrial base and determine how to sustainably implement those discoveries.*

SYSTEMS ENGINEERING AND SYSTEMS MANAGEMENT TRANSFORMATION:

Providing ways to acquire complex systems with rapidly changing requirements and technology, which are being deployed into evolving legacy environments. Decision-making capabilities to manage these systems are critical in order to determine how and when to apply different strategies and approaches, and how enduring architectures may be used to allow an agile response. Research must leverage the capabilities of computation, visualization, and communication so that systems engineering and management can respond quickly and agilely to ensure acquisition of the most effective systems.

> ***Grand Challenge:*** *Move the DoD community's current systems engineering and management MPTs and practices away from sequential, document-driven, hardware-centric, point-solution, acquisition-oriented approaches; toward concurrent, portfolio and enterprise-oriented, hardware-software-human engineered, model-driven, set-based, full life cycle approaches. These will enable much more rapid, flexible, scalable definition, development and deployment of the increasingly complex, cyber-physical-human DoD systems, systems of systems and enterprises.*

TRUSTED SYSTEMS:

Providing ways to conceive, develop, deploy and sustain systems that are safe, secure, dependable, adaptable and survivable. Research must enable prediction, conception, design, integration, verification, evolution and management of these emergent properties of the system as a whole, recognizing these are not just properties of the individual components and that it is essential that the human element be considered.

> ***Grand Challenge:*** *Achieve much higher levels of system trust and assurance by applying the systems approach to the increasingly complex, dynamic, cyber-physical-human net-centric systems and systems of systems.*

TRANSITION APPROACH

The SERC approaches transition in a number of ways, beginning when the research effort is first defined. The goal is to get "useful combinations" of SE MPTs into the hands of SERC sponsors and stakeholders as quickly and efficiently as possible. MPTs are the SERC's technological output. Effective transition into application is key to the SERC providing real systems engineering research value to its sponsors.

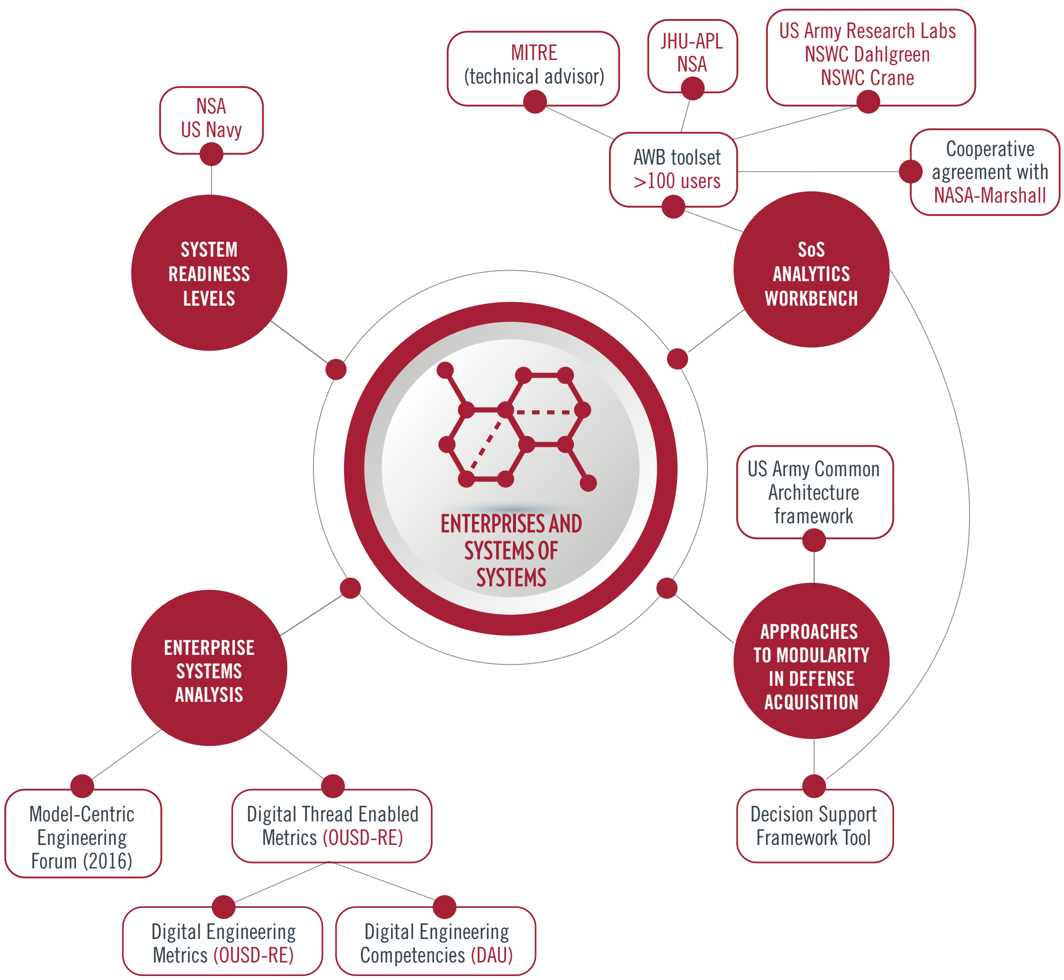
Major impact is realized when the MPTs are transitioned to the early majority. A SERC MPT successfully transitioned to the early majority would be:

- Widely applied within its potential market of practitioners
- Demonstrably and credibly delivering its intended value when applied
- Widely taught in relevant university programs
- Articulated in books, videos, papers, social media, and other knowledge channels
- Sustained and improved largely by resources and infrastructure outside the SERC, including having commercial quality tooling, training, and a cadre of experts that aid in its application

As the SERC has continued to grow and mature, the organization has gained significant experience in the area of transition, learning important lessons on what is and is not effective. In addition, the SERC has proactively formed partnerships to strengthen the transition pipeline, building an active network of systems researchers and practitioners. As the graphics on the following pages depict, strong relationships have been forged with several professional organizations, including INCOSE and the National Defense Industrial Association (NDIA) Systems Engineering Division to name a few.

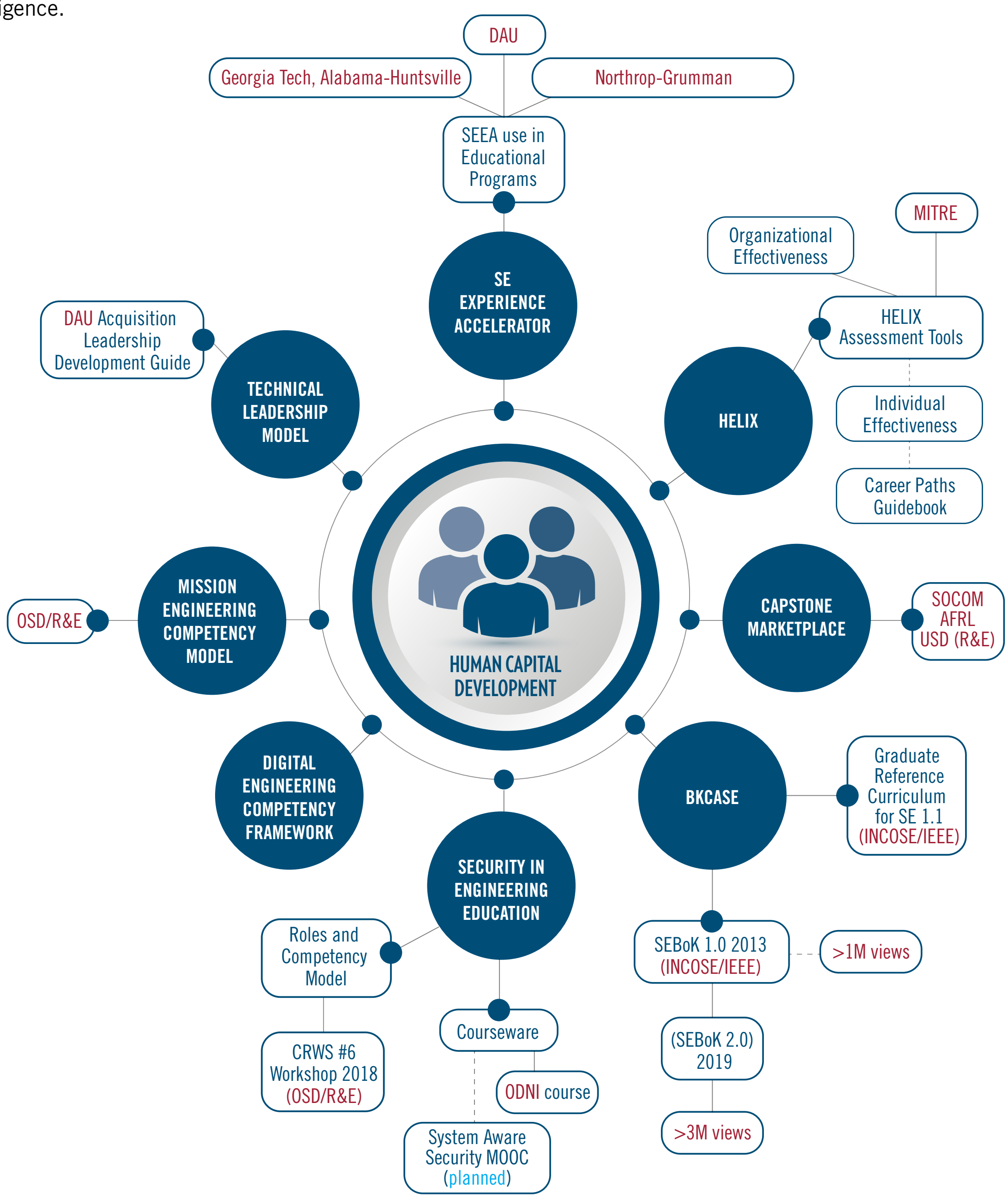
ENTERPRISES AND SYSTEMS OF SYSTEMS:

- With MITRE as a technical advisor, the SoS Analytics Workbench tool set has over 100 users and has collaborated broadly with JHU-APL NSA, US Army Research Labs as well as a Cooperative agreement with NASA-Marshall.
- The concepts and methods for calculating System Readiness Levels were developed along with NSA and US Navy and are now used regularly by those organizations.
- Approaches to plan strategy and assess measures for enterprise transformation developed in the Enterprise Systems Analysis research were first applied to healthcare and then to DoD policy, including DoD acquisition enterprise transformation using Digital Engineering. Current work is being conducted to support OUSD-RE in the areas of Digital Engineering Metrics, Digital Model Curation, and with DAU in Digital Engineering Competencies.



HUMAN CAPITAL DEVELOPMENT:

- The SE Experience Accelerator is being used by several universities in their masters level SE programs. The DAU and Northrop Grumman are also using the game-based simulator in the delivery of their educational programs.
- The Helix study developed the Atlas 1.1 SE career path guide, and Atlas 1.2 organizational proficiency guide. HELIX has been adopted by MITRE as well as several commercial companies. HELIX development is continuing with the development of web-based self-assessment tools.
- The SERC Capstone Marketplace engages with undergraduate students in SE research across the SERC network and beyond. In 2019 the project supported 28 senior design teams across 10 universities, involving ~150 students.
- The BKCASE project developed a body of knowledge for SE. The project developed the SEBoK website which is maintained jointly between the SERC, INCOSE, and IEEE. SEBoK has earned over 10 million views to date. The project also developed the Graduate Reference Curriculum for SE 1.1 used by a number of universities, with version 2.0 anticipated in 2021.
- In 2020 the SERC published the initial Digital Engineering Competency Framework (DECF) and conducted 9 educational webinars reaching more than X thousand people across the domains of Digital Engineering, Data Analytics, and Artificial Intelligence.



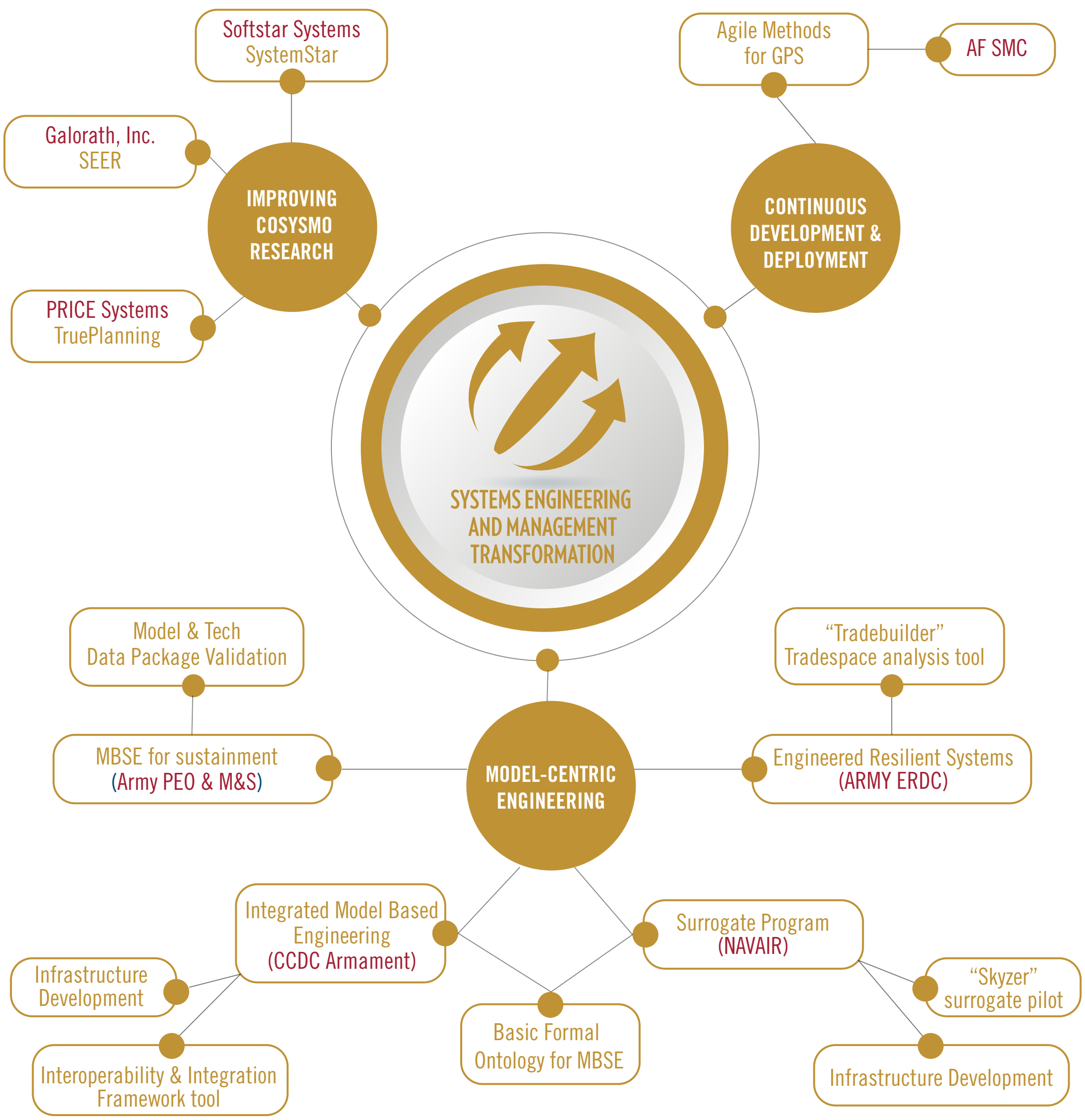
SYSTEMS ENGINEERING AND SYSTEMS MANAGEMENT TRANSFORMATION:

- Extensive transition work is represented in the area of Model-Centric Engineering, specifically a Surrogate Program with NAVAIR, Engineered Resilient Systems with Army ERDC, Integrated Model Based Engineering with CCDC AC, and MBSE for sustainment with Army PEO. Areas of transitioned research include tradespace analysis tools that use Multi-Domain Analysis and Optimization (MDAO), set-based design, basic formal ontology for MBSE, integration of model-management tools, use of MBSE for program source selection and digital sign offs.

- The SERC has supported a number of projects for improving COSYSMO, the standard toolset for estimation of SE effort in large projects. SERC COSYSMO projects are transitioned to several industry partners who provide SE effort estimation tools.

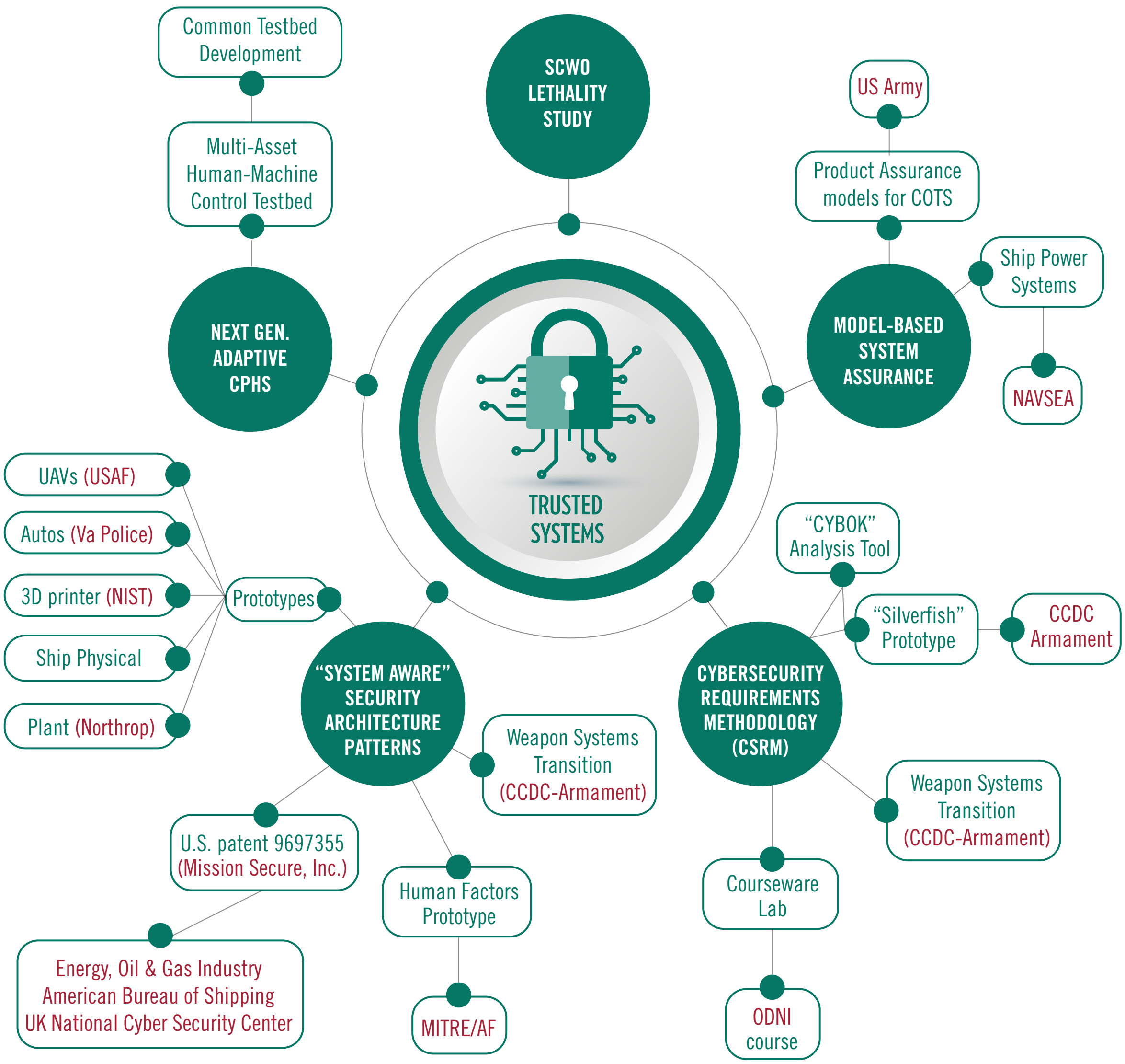
- In the area of Velocity, the SERC hosted a DoD workshop on Continuous Development and Deployment of military capabilities, and is transitioning SE principles for agile methods to the DoD GPS program.

- in 2020 the SERC developed and hosted a series of SERC/Navy transition talks demonstrating innovative approaches to digital engineering for transition to Navy programs. Additional transition talks are being planned for other services and industry.

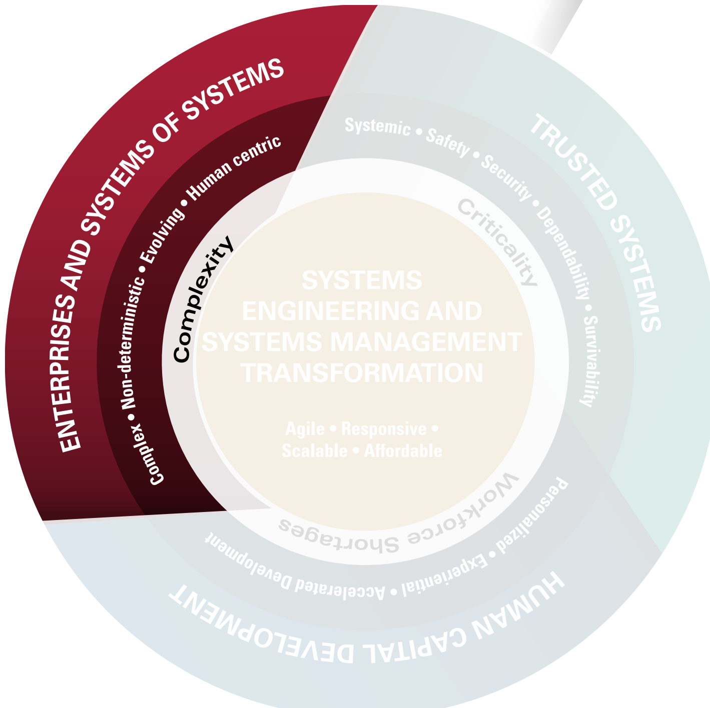


TRUSTED SYSTEMS:

- SERC "System Aware" Security Architecture Patterns, a methodology to design in security for cyber-physical systems, has resulted in various prototypes for the USAF, Virginia police department, NIST, Northrop Grumman and MITRE/AF. A portion of the toolset was patented and transitioned to the Oil and Gas and Shipping domains. in addition, methods are now being employed in a full Weapon System Transition with CCDC AC.
- As part of the System Aware security work, the SERC standardized a Cybersecurity Requirements Methodology. Transition activities include a course developed for the ODNI, a CYBOK analysis tool and "silverfish" prototype for CCDC AC. The methodology is informing future research across the SERC and being extended y teams at Stevens, UVA and Georgia Tech.
- These efforts continue to promote Model-Based System Assurance as a key enabler for future more secure systems. Additional transition has been done through Product Assurance models for the US Army and NAVSEA
- The SERC led a Super Critical Water Oxidation Lethality Study that brought together leading researchers from across the SERC who are renowned for their work in safety and security. *This is an example of SERC thought leadership in an important DoD study.*
- Recently, SERC researchers at USC transitioned a Common Testbed and Development environment for experimentation with Next Generation Adaptive Cyber-Physical-Human Systems to the Aerospace Corp. This simulation environment allows for planning and algorithm development for human-machine teaming.



ENTERPRISES AND SYSTEMS OF SYSTEMS

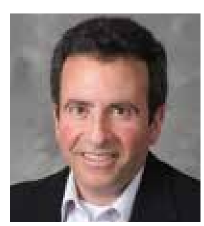


Providing ways to develop, characterize and evolve very large-scale systems composed of smaller systems, which may be technical, socio-technical, or even natural systems. These are complex systems in which the human behavioral aspects are often critical, boundaries are often fuzzy, interdependencies are dynamic, and emergent behavior is the norm. Research must enable prediction, conception, design, integration, verification, evolution, and management of such complex systems.

ESOS Area Goal: *Prototype, demonstrate, and provide MPTs, to transform the development and operational management of end-to-end mission capability (composed of services and platforms with variable autonomy) in complex organizational and mission environments, so those capabilities have fewer unintended negative consequences, quickly recognize and exploit unintended positive consequences, adapt well under changing circumstance, and exhibit greater resilience.*

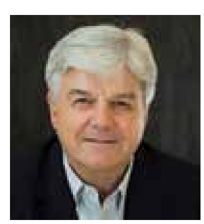
https://sercuarc.org/serc-programs-projects/esos/

RESEARCH COUNCIL MEMBERS FOCUSED ON THIS THEMATIC AREA:



Daniel A. DeLaurentis

Chief Scientist, SERC
Professor, Director, Chief Scientist, Institute for Global Security and Defense Innovation (i-GSDI), Purdue University



William B. Rouse

Senior Fellow, Office of Sr. Vice President for Research, McCourt School of Public Policy, Georgetown University

NEW OBSERVING STRATEGIES TESTBED (NOS-T) DESIGN AND DEVELOPMENT

Principal Investigator: Dr. Paul Grogan
University: Stevens Institute of Technology
Sponsor: NASA
Research Task: ART-015

1. What is the long-term transition goal for the research if continued?

The long-term goal is to establish a computational infrastructure for use by NASA's Earth Science Technology Office (ESTO) that will mature component and system technologies for Earth science space missions. This project designs and develops an initial framework that includes a concept of operations, governance model, and technical architecture for the testbed. These artifacts will be transitioned to government and/or contractor testbed operations staff to further refine and evolve the framework and ultimately manage testbed operations to select, develop, and execute testbed studies in support of ESTO programmatic objectives.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The primary artifacts produced from this project include the concept of operations, governance model, and technical architecture documentation. The concept of operations explains how the testbed environment achieves program objectives as well as how individual studies are to be evaluated using the testbed infrastructure. The governance model explains roles and responsibilities for managing the testbed. Finally, the technical architecture documentation defines the key software interfaces (structural and behavioral) required to participate in a testbed execution. Other artifacts include a test procedure to demonstrate testbed architecture use for a representative Earth-observing mission with multiple constituent models (nodes).

3. Which of these might be or are planned to be incrementally delivered in a future research task?

Future research task deliverables will define the concept of operations, governance model, technical architecture documentation, and demonstration test procedures.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

This project is in communication with several potential transition partners currently engaged in pilot studies and/or research projects with ESTO's Advanced Information System Technology (AIST) program. The potential transition partners represent a broad slice of the Earth science community from multiple NASA centers and universities with representation from both science and engineering disciplines.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

Ongoing and future partnerships with members of the Earth science community through ESTO's AIST research program will help this project's transition outcomes achieve programmatic objectives.

DIGITAL ENGINEERING MEASURES

Principal Investigator: Mr. Tom McDermott
University: Stevens Institute of Technology
Sponsor: OUSD (R&E)
Research Task: WRT-1001

1. What is the long-term transition goal for the research if continued?

DoD program offices and potentially all enterprises are currently struggling to define the value of Digital Engineering (DE) in a measurable way. Because the artifacts of DE are digitally captured in standard sources of truth data, the opportunities to better measure systems development processes with DE should be at hand. However, little progress in this area has been made to date. This is the first research to attempt to classify a set of metrics for DE. As with other digital transformation activities, standard best practice metrics will evolve over time. This research should guide that evolution. Additional efforts should use this research to accelerate program/enterprise DE adoption (see recommended future research).

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The project developed a metrics framework in the final report and the associated survey supplemental report. These together provide organizations undergoing DE transformation an essential resource to start the process of planning an organizational performance measurement strategy. At the completion of this effort, the work is not ready for development of specific tools. However, two tool opportunities were identified: 1. a general organizational performance assessment based on the Baldrige Capability Performance Evaluation framework; and 2. a set of specific measurement models built from causal models linked to data collected in the Digital Engineering process.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

The specific measurements and related causal models will be developed in a follow on research task, WRT-1040. This is expected to start in the fourth quarter of 2020.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The research team worked extensively with the OUSD sponsor, INCOSE, and NDIA on this research, all of which could be considered advocates. A follow on activity, started in October 2020 and that will continue for 2021, has been created as a joint AIA/INCOSE/NDIA project and focuses on specific measures. This will build a set of recommended metrics, potentially to serve as a standard. The follow-on research project will partner with selected projects to build the causal models and measurements when it begins.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

The resources were not available in this task to pilot the research with a transition partner. The follow on task will partner with selected government agencies.

APPROACHES TO ACHIEVE BENEFITS OF MODULARITY IN DEFENSE ACQUISITION

Principal Investigator: Dr. Daniel DeLaurentis
University: Purdue University
Sponsor: OUSD (R&E)
Research Task: WRT-1002

1. What is the long-term transition goal for the research if continued?

WRT-1002 extended prior RT-163 and RT-185 research towards developing useful artifacts to support Program Managers in acquisition problems decision-making, accounting for guidelines suggested from a Modular Open System Approach. This research expanded the engagement with the community, resulting in collaborations that helped to identify important user needs. Since the main tool developed in this research, the Decision Support Framework (DSF), has been built as a problem-agnostic framework, it is open to a variety of applications. Therefore, the primary long-term transition goal for this research is increasing the use and refinement of the DSF, distributing it to groups working with MOSWG (military, industry), to the Defense Acquisition University, and to other users of interest, and soliciting useful feedback. Another long-term transition goal is the production of tailored MOSA decision-support tools through partnership with specific programs.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

Besides conference and journal publications, this research produced two artifacts that can be used by external sponsors:

a. Program Managers (PM) Guidance Document (current version is 2.0). This is a handbook of practical information for PM, including case studies related to early stage acquisition and lessons learned about the application of MOSA principles; and

b. Decision Support Framework (DSF, current version is 2.1). This is a software tool that allows users to input databases of systems and their associated capabilities, System-of-Systems (SoS) level capabilities, mission requirements, cost limits, and stakeholder preferences. The output of the tool is a set of Pareto-optimal portfolios of systems that provide the required SoS capabilities, an evaluation of risk vs. cost, analysis of operational risks and identification of critical systems, and analysis of applicability of MOSA principles.

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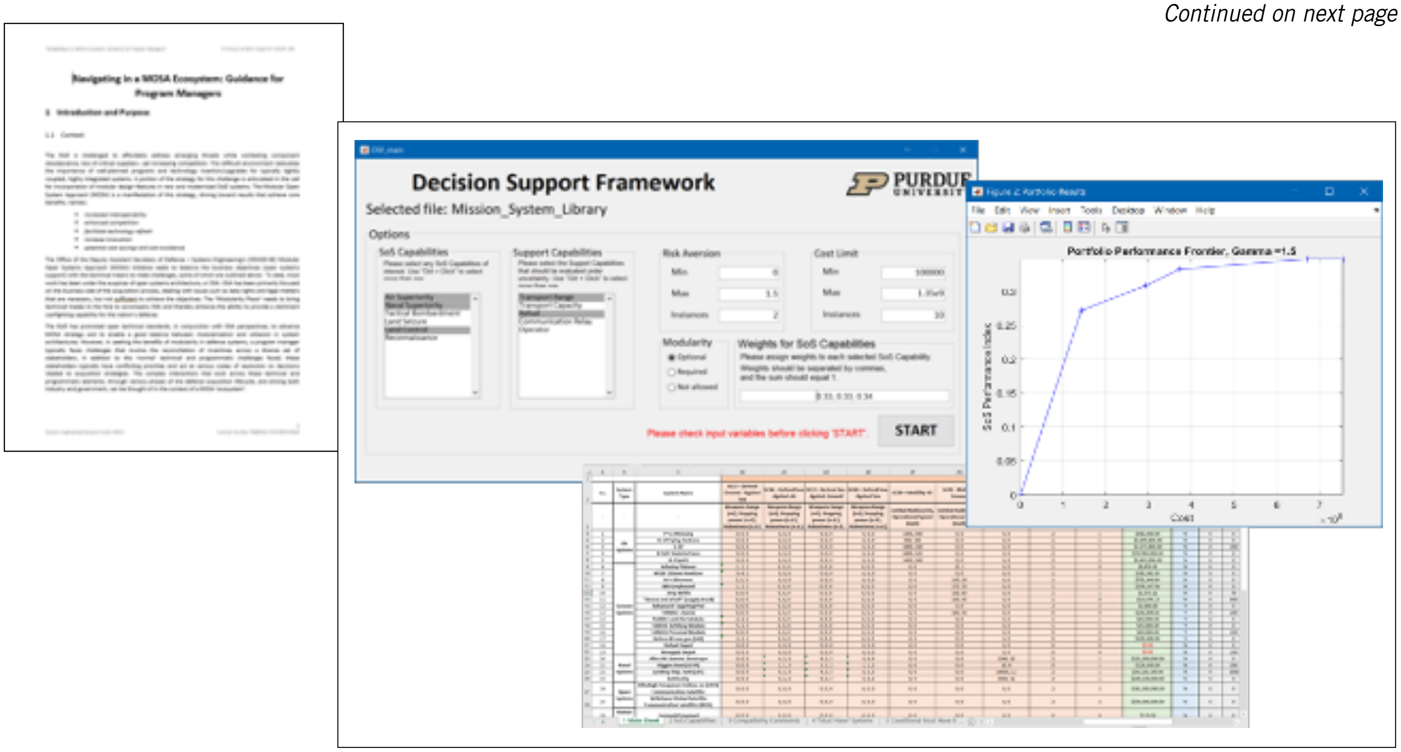


3. Which of these might be or are planned to be incrementally delivered in a future research task?

While there is no plan to extend research in Modularity in Defense Acquisition, the DSF is still being developed and refined in different research projects. In particular, research teams are working on the integration of the DSF with tools from Purdue's Analytic Workbench (AWB, RT-155) and on the development of databases of systems for specific applications in Mission Engineering.

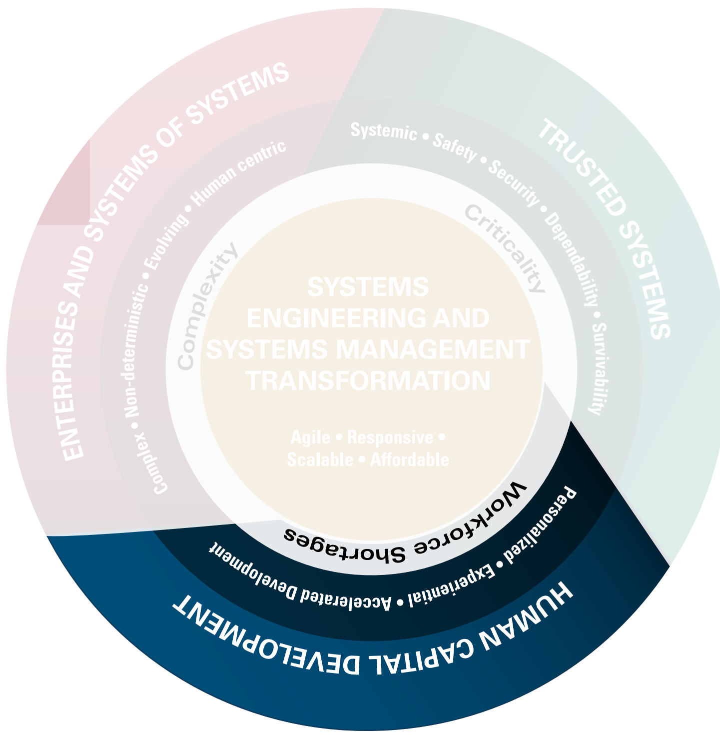
4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

Specific transition partners have not been identified, but participation in MOSWG meetings raised interest in this research. Further dissemination of the work through presentation at the Conference on Systems Engineering Research and use of the artifacts in other research projects may identify interested transition partners.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

The research products have been used and improved in a research project sponsored by JPEO-CBRND (WRT-1014), which overlapped with the end of WRT-1002. The sponsor is interested in this research, and some of the groups in JPEO-CBRND could serve as a pilot.

HUMAN CAPITAL DEVELOPMENT

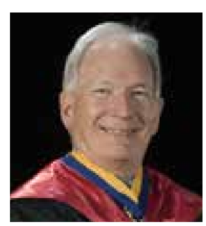


Providing ways to ensure that the quality and quantity of systems engineers and technical leaders provide a competitive advantage for the DoD and defense industrial base. Research must determine the critical knowledge and skills that the DoD and IC workforce require as well as determine the best means to continually impart that knowledge and skills.

HCD Area Goal: *Ensure a competitive advantage for the DoD and the defense industrial base through the availability of highly capable systems engineers and technical leaders. Aggressively encourage the investigation and use of emerging digital technologies as both a central competency of the future SE and an evolution of SE education.*

https://sercuarc.org/serc-programs-projects/hcd/

RESEARCH COUNCIL MEMBERS FOCUSED ON THIS THEMATIC AREA:



Dr. Cliff Whitcomb

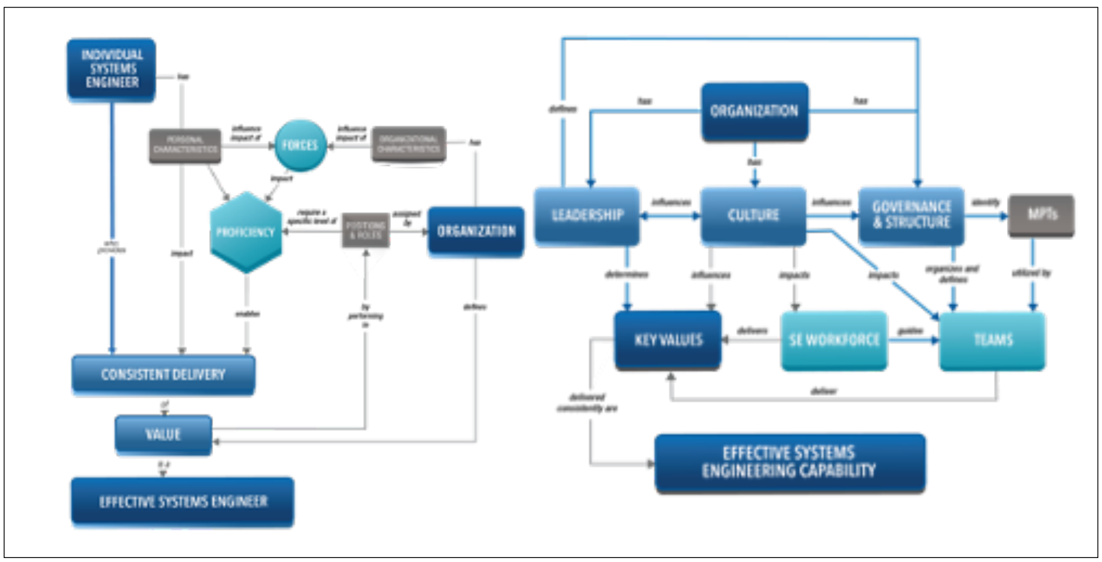
Distinguished Professor, Systems Engineering, Graduate School of Engineering and Applied Sciences, Naval Postgraduate School

HELIX - ORGANIZATIONAL SYSTEMS ENGINEERING EFFECTIVENESS 2019

Principal Investigator: Dr. Nicole Hutchison
University: Stevens Institute of Technology
Sponsor: OUSD (R&E)
Research Task: WRT-1004

1. What is the long-term transition goal for the research if continued?

The research phase of the Helix project has been completed. Over the eight years of the project, many findings have been generated and the team developed tools to help individuals and organizations take advantage of these findings. Findings and tools are publicly available at **https://helix-se.org/**. The research effort is complete and the SERC is currently investigating options to commercialize the tools and associated data sets so they can be sustained and used in the future. The Helix team also investigated in this process the generalization of the tools into a wider set of organizational disciplines. The two different lenses of the Helix findings are reflected below.



2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

Helix spent eight years investigating what makes systems engineers effective and why, and what makes organizations effective at systems engineering. The findings are detailed in Atlas, a guide that provides information for individuals, about their skills and how to grow these throughout their career paths, and for organizations to build self-awareness of their systems engineering capabilities. The Helix team developed web-based tools to enable individuals and organizations to self-assess based on Atlas and track their progress over time.

Over the course of the pilot, the Helix team helped several organizations pilot programs to implement Atlas and captured lessons learned from these experiences in the Atlas Implementation Guide. A detailed assessment of the career paths of systems engineers – and the skillsets developed during those careers – is also captured in the Career Path Guidebook. All of these resources are freely available at **https://helix-se.org/**. The tools, guides and other artifacts that resulted from the Helix project are represented in the visual below.

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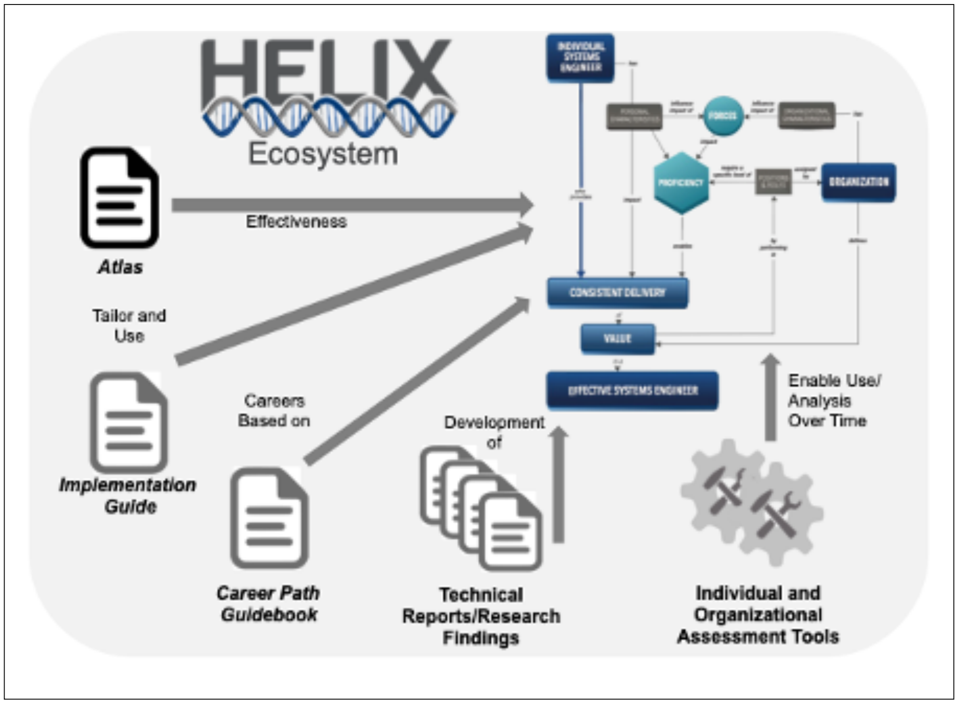


3. Which of these might be or are planned to be incrementally delivered in a future research task?

The planned commercialization effort will continue to iterate on the tools and add capabilities, such as individual coaching sessions or organizational support for implementing findings. This effort is investigating integration with other organizational employee development and skill assessment tools. At this point, the work has transitioned out of research, and a transition approach is being developed to place it into practice.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

Several organizations in the US, UK, and the Netherlands have improved their self-awareness of their systems engineering capabilities and implemented changes based on their findings using the Helix research. The ESI Group (Netherlands) has incorporated Helix findings into their training of systems architects. The Helix team's work in the Netherlands led a group of multiple organizations to create a periodic working group to collaborate and learn from each other's systems engineering experiences and specifically to explore issues of systems engineering implementation and culture that impact their effectiveness.

The commercialization effort is currently working with an existing commercial platform, Jearni.co, to define an enduring business model. The Jearni.co toolset brings additional capabilities to the HELIX toolset to evaluate individual learning capacity, a key aspect of SE capacity, as well as an effective coaching/mentoring process.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

Participants in Helix were promised anonymity: the team never announced organizations or individuals who were participating. However, some organizations found such value in participating that they publicly shared their participation in the project. Pilot organizations included: MITRE, CCDC/AC SED, Rockwell-Collins, and Rolls-Royce, as well as five technology organizations in the Netherlands. There are many other organizations both within the DoD and in the defense industrial base that are likely to use Helix. Transition partners to this point have been focused on evaluating Helix use in organizations. The commercialization effort is evaluating transition options for the tools and data.

PREPARING THE ACQUISITION WORKFORCE FOR DIGITAL ENGINEERING - DEVELOPING A DIGITAL ENGINEERING COMPETENCY FRAMEWORK (DECF)

Principal Investigator:	Dr. Nicole Hutchison
University:	Stevens Institute of Technology
Sponsor:	OUSD (R&E)
Research Task:	WRT-1006

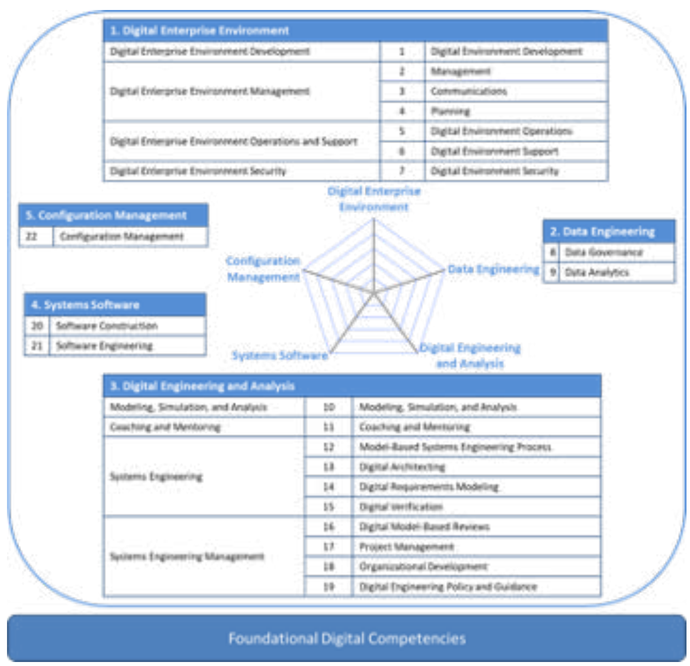
1. What is the long-term transition goal for the research if continued?

Ideally, the Digital Engineering Competency Framework (DECF) will be widely adopted and implemented within the Department of Defense (DoD). The DECF will also provide a useful reference for private organizations trying to improve their workforce proficiencies in digital engineering.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The primary result from this research is the Digital Engineering Competency Framework (DECF) itself. The DECF v. 1.0 contains 22 competencies across the five competency groups comprising nearly 700 individual knowledge, skills, abilities, and behaviors (KSAB) descriptions.

By the end of the current research task, the team will also have generated clear recommendations for the Defense Acquisition University (DAU) on improvements to the existing digital engineering curriculum as well as possible new training courses. These recommendations will be available for anyone working on developing training for digital engineering and will be linked to the DECF.



3. Which of these might be or are planned to be incrementally delivered in a future research task?

Currently, the task is slated to end in January 2021 and no follow-on research is currently planned. Both the DECF and recommendations for training will be delivered at this time.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The team will provide the DECF and recommendations to the OUSD (R&E) and to DAU. In addition, the team will brief the DoD Digital Engineering Working Group (DEWG) on the findings of the research. There is, in particular, a subgroup of individuals focused on developing training in DE. The team will also reach out to provide the materials and brief this group. Finally, the US Navy currently has a group working to create a Naval Digital Engineering Book of Knowledge (NDEBoK). The research team has begun collaborating with this group and will continue to do so, ensuring that they have a chance to review the DECF and that they receive the final version of the DECF. It is possible that the DECF and recommendations on training for digital engineering may be incorporated into the NDEBOK.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

The OUSD (R&E) is currently using the DECF as part of its work toward Goal 5 of the DoD Digital Engineering Strategy, which is to "transform the culture and workforce to adopt and support digital engineering across the life cycle". No formal partners beyond those listed above have been identified at this time.

THE CAPSTONE MARKETPLACE

Principal Investigator: *CAPT William Shepherd*
University: *Stevens Institute of Technology*
Sponsor: *OUSD (R&E) & SOCOM*
Research Task: *WRT-1007*

https://capstonemarketplace.org/

VISION

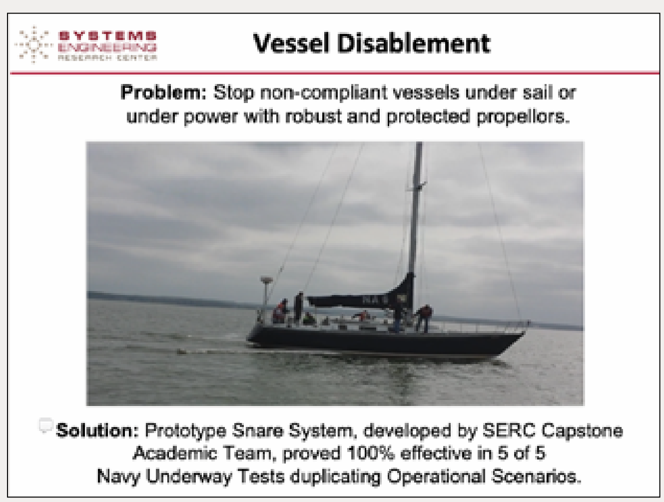
The Capstone Marketplace's vision is a self-sustaining forum connecting government users, undergraduate students, and industry, capturing innovation, developing useful hardware and software prototypes, providing academic enrichment, and meeting important customer needs.

BACKGROUND

The Capstone Marketplace was established as a SERC Human Capital Development research thrust in 2013, introducing basic system engineering methodologies and R&D management techniques to undergraduates. The Capstone Marketplace connects undergraduate engineering students with military and government customers to address needs and solve small-scale problems that are largely unaddressed by traditional acquisition systems. The Marketplace solicits military organizations for topics of interest and presents these to university students, who create applied engineering solutions in their senior design courses. During the 2019-2020 academic year, Capstone Marketplace personnel engaged 24 teams who developed hardware and software prototypes at 11 universities.

HISTORICAL TRANSITIONS

Since the start of the Capstone Marketplace, SERC has collaborated with the Naval Special Warfare Development Group (NSWDG) to address their special equipment needs. Students in a Stevens Institute Capstone project prototyped a personal flotation device (lifejacket) for the Navy with a computer-controlled inflation actuator. The success of their concept was recognized by the U.S. Special Operations Command, who engaged industry to produce an operational version of the lifejacket for special operations and other government personnel, including US Coast Guard sailors. In another recent year, students at University of Alabama Birmingham and Stevens Institute prototyped capture and restraint systems for Navy customers to safely entrap and stop small boats out in open water. A prototype design was selected and proved highly successful in operational testing. A follow-on device based on students' design is now a Navy operational capability.



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OBSTACLES TO TRANSITION

Transition of Capstone Marketplace projects to "programs of record", engineering/manufacturing development, and production has been extremely difficult. Several obstacles must be overcome for effective transition of Capstone projects. These include: the low technical maturity of most student projects; existing disconnects between DoD operational and acquisition organizations; and the need for effective management of intellectual property.

Maturity. A principal aim of the Marketplace is to provide educational enrichment for Capstone students. Students are allowed to make mistakes in building their solutions. Although Military and government user groups want (and expect) well-matured prototypes, students' prototypes are often low maturity items because of their limited time, money, expertise, etc. Technology Readiness Levels (TRL) of 4 or 5 are typical for Capstone prototypes.

To increase the maturity of selected research topics, Capstone Marketplace occasionally assigns follow-on student teams to continue work on a project topic over more than one academic year. This approach has proven successful in maturing final project prototypes.

Organizational Disconnects. Capstone Marketplace's strategy is to engage operational military personnel and organizations at low levels—individuals and operational organizations not usually doing development, acquisition, or administrative work. This approach often harvests very innovative ideas from these military "customers"—users who are at the "point of need". Often, traditional R&D organizations have great difficulty implementing good ideas from the "bottom up": by organizational doctrine, "operators" don't do R&D. Some DoD organizations regard Capstone activity as an "out-of-process" activity. Despite this, Capstone students continue to produce valuable, "out-of-the-box" solutions. Perceptions are slowly changing.

Intellectual Property. Creation and assignment of Intellectual Property (IP) generated during Capstones remain a challenge. The Federal Acquisition Regulations (FAR) regarding intellectual property rights are addressed in Capstone Marketplace's administrative and contractual documents. These FAR requirements are flowed down to each participating university in SERC's subcontract awards. Each university has their own IP protocols that address relationships among institution, faculty, employees, and students. To illustrate the complexity of IP assignment, in a hypothetical project example, the government, military or government civilian employees, students, faculty advisors, the university, and perhaps one or more industrial collaborators can all generate rights to IP that would need to be assigned and protected. To date, no Capstone Marketplace projects have reached a maturity where IP disclosures or patent applications have been filed. IP generation is expected in Capstones for the 2020-2021 academic year.

FUTURE STEPS

The Capstone Marketplace continues to pursue means to implement transitions of students' projects. USSOCOM, the key government research partner, has committed to follow-on research and development funding for the most relevant and attractive Capstone project efforts. A dedicated budget line item for Capstone transition funding is being coordinated with USSOCOM's Science and Technology Directorate. USSOCOM has frequently used Other Transaction Agreements that can facilitate rapid transitions and development. In Spring 2019, USSOCOM invited SERC's Capstone teams to make student presentations at their annual industry conference (SOFIC) in Tampa. This forum was intended to showcase promising projects and attract academic and defense industry interests in follow-on work. Unfortunately, the global pandemic in Spring 2020 forced cancellation of the conference. Plans are in work to return to the conference in 2021.

HUMAN CAPITAL DEVELOPMENT

DAU CREDENTIAL DEVELOPMENT

Principal Investigator: Mr. Ralph Giffin
University: Stevens Institute of Technology
Sponsor: DAU
Research Task: WRT-1018

1. What is the long-term transition goal for the research if continued?

The research deliverables are intended to aid in curriculum development and execution. The Defense Acquisition University (DAU) will implement transition by folding the research results into their micro-credentialing programs for digital engineering, artificial intelligence/machine learning, and data analytics. The research findings are also available online to support other curriculum development activities in the DoD.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The work has resulted in a competency framework for the three areas of strategic importance (ASIs) addressed in the research. The framework, shown below, includes subtopics for each ASI and was developed in conjunction with and as an extension to the Digital Engineering Competency research conducted by WRT-1006.

Digital Eng	AI/ML	Data Analytics
Eng Processes	Digital Engineering	Digital Engineering
Decision Making	Social & ethical issues and implications	Diagnostic, Predictive and Prescriptive analytics
	Human-computer interaction	Exploration, mining and visualization
	Action execution patterns	Data driven systems: Bottom-up machine learning
Modeling	Natural Text Processing - NLP	
	Algorithm and modeling for Knowledge representation	
	Learning patterns	
Data Engineering	Data engineering: collecting, transmitting, preparing & organizing data	
SW Literacy	Computer Science	
Digital Literacy	prerequisite	prerequisite

In addition, comprehensive sets of practitioner and manager KSABs (knowledge, skills, abilities, and behaviors) were developed for each of the associated ASIs by subtopic.

Next, the research team conducted a search for available and relevant education and training material and courses specific to each ASI from across a various set of sources (MOOCs, universities, books, podcasts, and videos). This data will be made available online as a reference for anyone developing curriculum in these areas.

Finally, the research team developed nine webinars (three per ASI) and partnered with DAU in their delivery as the DAUs ***Digital Readiness Webinar Series***. These webinars are available at **https://www.dau.edu/dau-webcasts/p/Explore-Webcast-Series** and can be incorporated into training in the ASIs as appropriate.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

These research deliverables were fulfilled on the current RT.

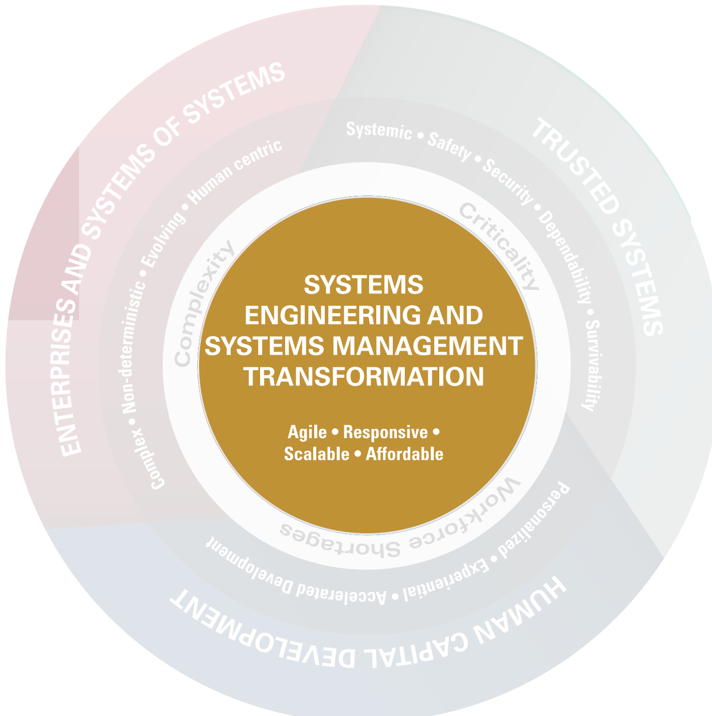
4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

In addition to DAU, there may be others within the DoD who are focused on enhancing their Digital Engineering capabilities and would benefit from the deliverables developed as part of this research.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

The framework and KSABs have been delivered and are currently being utilized by DAU in the creation of their micro-credentials and associated curriculum for each ASI. This work is ongoing and is in addition to mentoring between the research team and DAU curriculum developers and faculty. As previously mentioned, there may be others within the DoD who are focused on enhancing their Digital Engineering capabilities that would benefit from the deliverables developed as part of this research.

SYSTEMS ENGINEERING AND SYSTEMS MANAGEMENT TRANSFORMATION

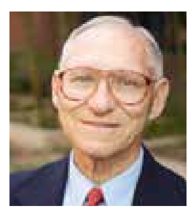


Providing ways to acquire complex systems with rapidly changing requirements and technology, which are being deployed into evolving legacy environments. Decision-making capabilities to manage these systems are critical in order to determine how and when to apply different strategies and approaches, and how enduring architectures may be used to allow an agile response. Research must leverage the capabilities of computation, visualization, and communication so that systems engineering and management can respond quickly and agilely to ensure acquisition of the most effective systems.

Goal: *Prototype, demonstrate, and provide methods to continuously advance the transformation of systems engineering to dynamic processes that leverage rapidly evolving computational technologies enabled by computational intelligence. Develop dynamic approaches for iterative procurement cycles that rapidly and concurrently develop cost-effective, flexible, agile systems to respond to evolving threats and mission needs.*

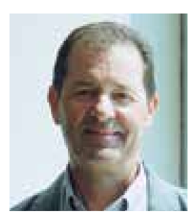
https://sercuarc.org/serc-programs-projects/semt/

RESEARCH COUNCIL MEMBERS FOCUSED ON THIS THEMATIC AREA:



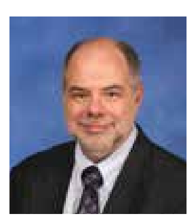
Barry Boehm

Research Council Chair and Chief Scientist Emeritus, SERC; TRW Professor of Software Engineering, Computer Science Department, University of Southern California; Director, USC Center for Systems and Software Engineering



Mark R. Blackburn

Senior Research Scientist, Stevens Institute of Technology



Paul Collopy

Professor, Industrial and Systems Engineering and Engineering Management, University of Alabama in Huntsville

METHODS TO EVALUATE COST/TECHNICAL RISK AND OPPORTUNITY DECISIONS FOR SECURITY ASSURANCE IN DESIGN

Principal Investigator:	Mr. Tom McDermott
University:	Stevens Institute of Technology
Sponsor:	OUSD (R&E)
Research Task:	ART-004

1. What is the long-term transition goal for the research if continued?

This project was conducted as Phase I of an envisioned multi-year research program aiming to produce systems engineering MPTs that enable evaluation of cost and technical risks and opportunity decisions for combined safety and security assurance in design. The project showed success in feasibility for methods. Processes and tools were developed that can be used broadly by the community to improve safety and security assurance case analysis and decision making in system development. The project has documented the recommended combined safety/security assurance methodology and will continue in a second phase to expand the framework and address mission engineering, formal modeling, and dynamic simulations. SERC Research Task WRT-1033 has been awarded to drive this transition.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

This project and related SERC Research Task WRT-1013 developed a process and metamodel for capturing system safety and security requirements and functions into a standard "Mission-Aware" (MA) metamodel implemented in a model-based systems engineering (MBSE) tool. The metamodel captures the results of a standard Cyber Security Requirements Methodology (CSRM) intended to be conducted through the early stages of system definition and development. The metamodel was fully implemented and demonstrated in this project in an example application (oil-pipelines). A public executable version of the model was created and is openly available to explore at **https://coordinated-systems-lab.github.io/pipeline-cps/index.html**. A demonstration of the approach was provided at a SERC Talks event and is recorded for further use at **https://sercuarc.org/event/serc-talks-can-we-assure-resilience-of-cyber-physical-systems-using-model-based-systems-engineering/**.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

SERC Research Task WRT-1033 was awarded September 30, 2020. Although an initial standard process and MA metamodel were created, the full link from mission engineering to system requirements to design using formal modeling and dynamic simulations of the system is today not well integrated. Transition to common standards, methods and processes, and tools and techniques are needed. As the CSRM and MA metamodel have matured, an opportunity exists to unify and standardize approaches to model-based systems assurance and mission engineering through informal modeling and dynamic simulations. Three transitional tasks are being explored in this research to answer questions needed to complete full transition: 1. mission engineering; 2. formal modeling; and 3. dynamic simulation. Mission analysis methods are needed that trade requirements and design decisions based on evaluation of hazard/risk, cost, and threat adversary properties. Formal modeling processes that address concerns in verification and validation throughout the lifecycle, specifically in the early phases, remain deficient. Further research should connect the MA metamodel from mission engineering and system definition phases to lower-tier system requirements and design processes. Finally, approaches will be investigated to formally integrate the MA metamodel with dynamic simulation capabilities and tools in order to standardize full-lifecycle assurance analysis and evaluation activities, linking mission-level simulation to appropriate system-level functional simulation methods and tools. These will be addressed in part as a tool interoperability problem, which will be a barrier to transition if not resolved.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

Existing CSRM and MA metamodel results have been transitioned to the Army Combat Capability Development Command-Armament Center (CCDC-AC). The follow-on task is also working with John Hopkins Applied Physics Lab (JHU-APL) and is exploring transition into the Army Aviation programs. A relationship with Thales and their Arcadia-Capella MBSE toolkit is also in discussion to demonstrate multi-platform integration.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

This project was not piloted with a transition partner. However, Research Task WRT-1013 performed a transition pilot with CCDC-AC. WRT-1033 will be focused on partner transitions.

METHODS FOR INTEGRATING DYNAMIC REQUIREMENTS

Principal Investigator: Dr. William Rouse
University: Georgetown University
Sponsor: OUSD (R&E)
Research Task: ART-005

1. What is the long-term transition goal for the research if continued?

The research team developed a methodology for strategic decision making in situations where there are substantial uncertainties about mission or market needs and the technologies that can best meet these needs. Working with General Motors, the first application focused on enabling automotive OEMs to address market opportunities for autonomous vehicles. This application focused on alternative technology platforms. The next application is addressing the design of policy portfolios, likely for defense acquisition.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The research team drafted a development plan for the ***Uncertainty Management Advisor***, a software tool based on the methodology reported in the first article. Actual development will be conducted in conjunction with the second application on the design of policy portfolios.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

The team expects that the ***Uncertainty Management Advisor*** will evolve through a series of releases, with updates driven by each new application. There will be a series of journal articles associated with each application. The team may eventually publish a book suitable for a graduate course.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

General Motors contributed to the first application and was a coauthor of the associated article. They are interested in using the planned ***Uncertainty Management Advisor***. The OUSD will be asked to identify potential users for the application to the design of policy portfolios.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

General Motors was recruited for the first application based upon long-term relationships with the company that provided access to expertise and relevant data. This enabled rapid progress for this application.

COGNITIVE BIAS IN INTELLIGENT SYSTEMS

Principal Investigator: Dr. Laura Freeman
University: Virginia Tech
Sponsor: US Army
Research Task: ART-007

1. What is the long-term transition goal for the research if continued?

This research developed a framework for testing Multi-Agent Systems of Autonomous Intelligent Agents. Another aspect of the research included a deep dive into performance measures, environments, actuators, and sensors for specific systems and scenarios. The research team quickly identified that the key to success was having an actual system to test the framework. Therefore, the research team plans to integrate with a system developer to pilot performance measures and iterate on the test framework as the actual system development progresses.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

This research developed two separate frameworks,: one for an overarching test and evaluation process, another for developing performance measures based on the knowledge available ("onion model"). These frameworks could be used by a variety of sponsors to develop test and evaluation processes and procedures for artificial intelligence algorithms and systems incorporating these algorithms.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

The research team plans to integrate the performance measures framework in a future research task that implements the recommendations and updates using a design-test-evaluate-design loop. This will be conducted using agile development processes.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

Research transition partners identified by the sponsor and researchers include IDA, MITRE, and Penn State University Applied Research Laboratory.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

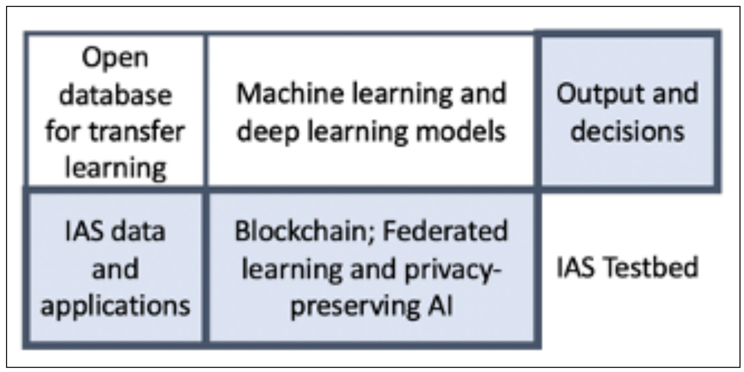
The sponsor is currently considering piloting the research with the above transition partners. Numerous other organizations, including the Joint AI Center (JAIC), may benefit from a systematic framework process for testing autonomous intelligent agents.

INTELLIGENT DEFENSE SYSTEMS

Principal Investigator:	Dr. Victor Lawrence
University:	Stevens Institute of Technology
Sponsor:	US Army
Research Task:	ART-009

1. What is the long-term transition goal for the research if continued?

ART-009 IDS research aims to develop a national center in Intelligent Armament Systems (IAS) that provides technological, educational, and experimentational resources for Picatinny Arsenal (including CCDC) and the defense industry. In particular, an Intelligent Armament Systems Testbed will be implemented. The IAS Testbed architecture, which highlights its security and privacy-preserving features, is shown in the following diagram.



2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The principal tools and artifacts are as follows:

- AI, machine learning, and deep learning study modules
- Machine learning software toolbox
- Deep learning software toolbox
- Multimodal machine learning software toolbox
- Multimodal deep learning software toolbox
- Unsupervised object discovery and description toolbox
- An integrated IAS Testbed

3. Which of these might be or are planned to be incrementally delivered in a future research task?

- AI, machine learning, and deep learning study modules
- Machine learning software toolbox
- Deep learning software toolbox
- Multimodal machine learning software toolbox
- Multimodal deep learning software toolbox
- Unsupervised object discovery and description toolbox
- An integrated IAS Testbed

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

Discussions and laboratory demonstrations have been conducted for Army Futures Command, Combat Capability Development Command (CCDC) Armament Center

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

Pilot uses will be conducted by CCDC and defense industry partners.

INTEGRATED MISSION EQUIPMENT (IME) ARCHITECTURE PROCESS FOR VERTICAL LIFT SYSTEMS

Principal Investigator:	Dr. Bryan Mesmer
University:	The University of Alabama in Huntsville (UAH)
Sponsor:	CCDC / AvMC
Research Task:	ART-016

1. What is the long-term transition goal for the research if continued?

The long-term transition goal for this research is to provide a validated and rigorous systems architecture process based on evidence and theory from a broad collection of disciplines and applied to a system of systems context. This architecture process will elicit, represent, and communicate holistic high-level stakeholder preferences that enable the execution of consistent design decision-making, both within an organizational hierarchy and externally within contracted firms. This system architecture process will result in: informed trade-off analyses that span systems that incorporate complex interface and operability concerns; increased exploration of the design space; rapid delivery of technologically enabled capabilities to the end-user; improved agility to adjust for uncertainty in system use environments; and early identification of conflicts between stakeholders to reduce cost and schedule overruns.

The current research project's goal is to enable rapid integration of flight-capable technology in a manner that is sustainable over the lifecycle of a platform, system, or component for the Combat Capabilities Development Command – Aviation and Missile Center (CCDC AvMC). To accomplish this goal, UAH is assisting in maturing the existing Comprehensive Architecture Strategy (CAS) approach by developing methods for consistent application across multiple programs. CAS provides a holistic and strategic architecture decision-making approach to satisfy the technical and business requirements at all levels of an organization responsible for developing and fielding a system. Included in CAS is the selection of mechanisms (tactics, patterns, or methods) to guide and inform design solutions that align with stakeholder technical objectives and key business drivers.

UAH is verifying that the intent of CAS, which should produce a well-defined, rigorous, and easily followed process for architecture development to ensure consistency, will achieve the intended results in actual product development in heterogeneous systems development programs. UAH is analyzing CAS as a transformational system in a complex environment and making recommendations for improving the effectiveness of CAS itself, better integrating CAS with the acquisition and engineering environment, and improving the transition of CAS into wider usage. Four key topics concerning preferences are investigated: Elicitation, Representation, Communication, and Execution. The research is identifying current capabilities of a broad collection of fields including engineering, psychology, business, and marketing for implementation into CAS. Approaches based on evidence and that have been rigorously validated in their previous contexts will be implemented in CAS, with the approaches' theoretical and validation limitations characterized within this new context.

If funded, the research team will expand in three areas: depth, couplings, and validation. The team will relax assumptions and analyze additional important areas of concern identified in collaboration with the sponsor. The team will examine the couplings among the four preference topics to enable a more holistic analysis. The team will validate adopted approaches in the new CAS context to ensure rigor is present in the new use. This work will examine the key topics concerning preferences at a higher fidelity in order to provide holistic, validated approaches that represent critical elements of a comprehensive architecture strategy.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The primary artifact produced in the research will be an approach that transitions systems engineering and architecting from its current ad-hoc state to a state built on rigor and theory, encapsulated in tools and training products.

The current research will produce a technical report characterizing the Architecture Body of Knowledge in the form of a wiki that will be accessible online at the UAH website. Reports primarily in the form of conference and journal articles will detail the processes and methods adopted from other disciplines applied to CAS. Recommendations for training will be made in the form of training course outlines and through coordination with the Defense Acquisition University to prepare a plan for putting the training into practice.

Continued on next page

A workshop at CCDC AvMC will be conducted to train a group of engineers and acquisition professionals in order to validate the transition plan.

When the long-term transition goals are met, the methods researched will be encapsulated in tools and training products. The primary product will be the evolved CAS approach based on evidence and validations. This will become an essential tool for organizations dealing with highly coupled and complex systems of systems. The evolved CAS approach will span the elicitation, representation, communication, and execution of high-level stakeholder preferences to enable consistent decision making throughout the organization and by contractors. To ensure proper use of the approach, workshops and courses for training will be formed and conducted for the multiple CAS tiered levels and for the many roles employed in CAS. Digital engineering / MBSE tools will be formed, as has begun in current research, to enhance the effectiveness of the CAS approach and enable architects to understand the impacts of their decisions early in the process.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

The current research has been designed to focus on four topic areas concerning the elicitation, representation, communication, and execution of stakeholder preferences. While these areas are coupled, they are currently being researched in parallel, and it is planned to continue to do so in future research. Currently, the topics being investigated most in depth were identified by the sponsor as most critical. The project's ability to investigate topics in parallel and adjust the research fidelity by the criticality of each topic enables a high amount of agility and adaptability in delivering needed resources incrementally.

In future research, it is planned to continue this parallel and collaboratively determined work, enabling incremental continuous improvement to and refinement of the CAS approach, systems engineering, and architecting knowledge.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

This research develops a meta tool that is organization agnostic by leveraging knowledge from engineering and non-engineering fields to fundamentally improve the rigor and validity of systems engineering and architecting, thus enabling complex trades beyond that of current methods. Organizations that benefit the most from this research are large hierarchical organizations that develop highly coupled and complex systems of systems. The tools developed provide justification for tradeoff decisions at all levels of the organization. For example, for an organization engineering a helicopter, the tool developed in this research will inform the decision maker of the impact of a design decision on: traditional performance concerns (i.e., weight, speed, latency, etc.), organizational business concerns (i.e. interoperability, acquisition agreements, operations, sustainment, etc.), and the combined effects on the organization's valuation of a helicopter.

The organizations that UAH has identified as likely transition partners are DoD, specifically Army CCDC, Army FVL, and NASA, and large military contractors such as Northrop Grumman and Lockheed Martin. NASA is an advocate for and has shown a significant interest in the application of this type of research. This interest is evident by synergistic research funded by NASA and conducted within the NASA Systems Engineering Research Consortium, led on the academic side by UAH.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

Research findings are being immediately incorporated into the CAS approach, which in turn is being immediately implemented in vertical lift systems as part of the Army's FVL program. These research-informed adjustments can immediately be assessed for improvements, thus enabling a continuous piloting of and feedback on the research. Transition research will follow a similar continuous piloting construct to enable immediate impacts in the field but allow for adjustments to incrementally improve rigor and validity. If fully funded, it is anticipated that NASA would be an organization interested in piloting the research findings, as evident by their synergistic NASA Systems Engineering Research Consortium work.

TRANSFORMING SYSTEMS ENGINEERING THROUGH MODEL-CENTRIC ENGINEERING

Principal Investigator: Dr. Mark Blackburn
University: Stevens Institute of Technology
Sponsor: NAVAIR, DASD (SE)
Research Task: WRT-1008 & ART-002

1. What is the long-term transition goal for the research if continued?

In 2013, the Naval Air Systems Command (NAVAIR) sponsored Systems Engineering Research Center (SERC) research to investigate the technical feasibility of a radical transformation through advanced and holistic approaches to Model-Based Systems Engineering (MBSE). This transformation was re-framed as Model Centric Engineering (MCE) and is now more broadly characterized as Digital Engineering (DE), as part of the DoD Digital Engineering Strategy. The challenge mandated an expected capability of MCE, and more broadly of DE, that can enable mission and system-based analyses and engineering that reduce the typical time by at least 25 percent for large-scale air vehicle systems. This issue is not limited to NAVAIR; it also impacts the DoD, resulting in schedule delays and large cost overruns. The complexity of the DoD systems demands the use of enabling technologies, methods, tools and workforce transition to practices that are used by leading industry organizations.

The initial objectives evolved in 2016 with a new concept and plan for an SE Transformation involving broad adoption that aligns the DoD DE Strategic Goals. There are several parallel use cases, but as discussed in the SERC 2019-2023 Technical Plan (2018), this transition plan will focus on the following longer-term objective:

To use Artificial Intelligence, Augmented Intelligence and Machine Learning to automate the systems engineering practices supported by underlying ontologies for knowledge representation and use the SET Surrogate Pilot (referred to as Skyzer) to demonstrate these capabilities and advances.

This transition plan uses the Digital Engineering for Systems Engineering Roadmap construct (shown in Figure 1) to provide both contextual background and to identify the enabling technologies for longer-term transition plans. The order of the numbers is not arbitrary. With the exception of #1 (a “goal”), the order reflects how it is expected that the research will move the team to the right and up towards the goal. The numbered sequence in Figure 1 highlights enabling technologies that have been demonstrated, as well as some that will be expanded on as part of the transition plan, including:

1. The transition research is working toward increased Semantic Integration to leverage Augmented Intelligence as capabilities to support Augmented Engineering are advanced;
2. MBSE has been maturing for a number of years and helps refactor and Strengthen implementation of Systems Engineering principles (Goal 3) by moving beyond Requirements to formalize Structural, Behavioral and Interface analyses at different levels of abstraction--Mission, System, Subsystem--where different types of methods are needed;
3. The OpenMBEE environment provides a means to instantiate and demonstrate a Collaboration Environment (Goal 4) for the Skyzer Surrogate pilot;
4. OpenMBEE also provides an underlying infrastructure for a computational Collaboration Framework where the Skyzer Surrogate Pilot produced tangible examples to assist understanding of the enabling technologies using an instantiation of an Authoritative Source of Truth (Goal 2);
5. The Collaboration Framework with Authoritative Source of Truth and OpenMBEE provide a means to exchange modeling data across domains using Semantic Web Technologies (SWT) and Ontologies (Goal 3), and provides computational automation to reason about information across those domains at different levels of abstraction;
6. Research created the Interoperability and Integration Framework (IoIF), a platform for using ontologies and SWT to integrate model information across domains and disciplines; a publicly available demonstration was created using a Cyber Ontology Vulnerability Analysis use case (more use cases are needed);
7. The evolving NAVAIR Systems Engineering Method (NAVSEM) goes beyond processes to characterize MBSE artifacts at different levels of abstraction; the Skyzer models demonstrate the use of NAVSEM in modeling unclassified examples that are being transformed into training material to support Workforce Development (Goal 5);

Continued on next page

8. The NAVSEM artifacts provide for the demonstration of Digital Signoffs directly within the collaborative environment and demonstrate an approach to move beyond traditional Contract Data Requirement List (CDRLs), the traditional document-based deliverables to Digital Signoff of modeling artifacts in the Authoritative Source of Truth;

9. A key transition plan objective is to formalize the ontologies for NAVSEM using Artificial Intelligence to be able to computationally reason the completeness and consistency of the modeled information, establishing the basis for Augmented Engineering to enable the modeling community with digital assistants; and

10. Some preliminary results demonstrate the combination of ontologies for semantic representation of domain information, with Artificial Intelligence and Machine Learning as a means of defining an architecture pattern to support Digital Twin Automation; this also builds on an ever-evolving set of Semantic Rules to support automation for Decision Making (Goal 1).

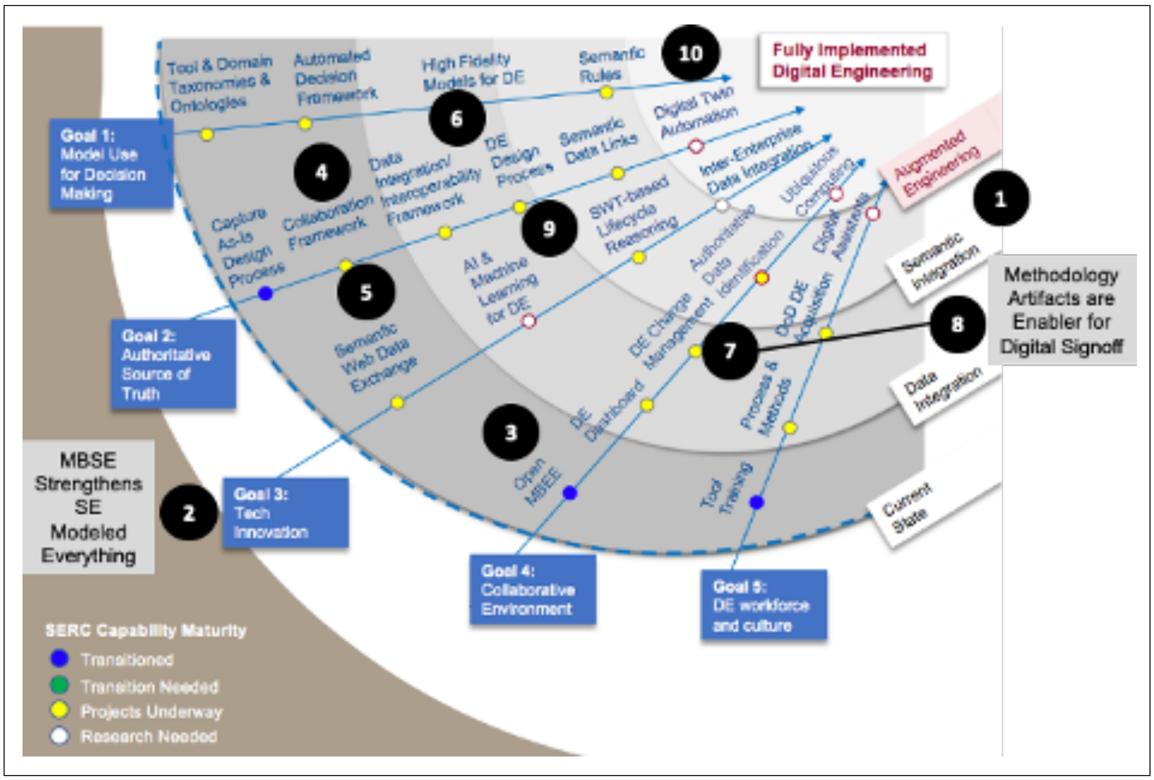


Figure 1. Digital Engineering for Systems Engineering Roadmap

The Skyzer case studies continue to evolve and demonstrate the art-of-the-possible that has resulted in over 60 products (see Section 2) focused on developing models, examples, reports, and videos to help support Workforce Development (Goal 5). Some reference models, referred to as Stakeholder Analysis Model by NAVAIR, are being developed for the areas of Airworthiness (i.e., for getting flight clearances). Teaming with NAVAIR Subject Matter Experts supports development of a MBSE Cost Modeling example for Skyzer, which is in the initial stages of research. Similar types of Stakeholder Analysis Model models for other life cycle phases and competencies such as Logistics, Dependability, Mission Systems and Cyber Security are being developed or planned for development.

There is still a need for more adoption by programs enabled by Digital Signoffs to leverage new concepts being developed for use in the Skyzer pilots. These provide a means for transforming away from traditional monolithic design reviews such as Systems Requirement

Continued on next page

Review 1 [SRR1] (prior to RFP release), SRR2 (after RFP response), Preliminary Design Review [PDR], etc. using a concept named the Baseline Progress Measures. This concept provides a means for transforming traditional document-based CDRLs using Digital Signoffs for source selection technical evaluation directly in the RFP response model.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

More than 60 technical products have been produced (shown in Figure 2), including:

- Reports, journal and conference papers;
- Models as examples and for Workforce Development including: Mission, System, Subsystem, and Discipline Specific models for analysis and design; and specialty models for Cyber, Airworthiness, Statement of Work (SOW), Capability-Based Test and Evaluation with others in development to support Cost Modeling;
- Additional tools to leverage model-based, document-based generated using DocGen, which have also been used to support Digital Signoffs;
- Videos demonstrating modeling; and
- Ontologies and the Interoperability and Integration Framework used to demonstrate Cyber ontologies, including SysML modeling profiles that map SysML models to ontologies. Note: The Interoperability and Integration Framework is a potential candidate to be transitioned in the longer-term, but is only being considered for some DoD case studies.

POC: Mark Blackburn
Usage - Primary Role: Provide unclassified examples for workforce development demonstrate modeling methods and associated technologies (e.g.,
Usage - Restrictions: Mostly None, or Distro A., but some unmarked should be considered Distro D until we get a Distro A marking

Name of Product	Type	Brief Description	Status	Location
SERC Technical Reports (RT-48/118/157/170/195/1008)	Report	SERC Research Technical Reports - See Reports Tab (also on AR&M, Research | Documents | Research Folders | SERC Technical Reports)	See Report Tab	https://sercuarc.org/project/?id=26&project=Transforming+Systems+Engi[illegible]
Digital Engineering Success Measure vs SET Lessons Learned	Report	New		
Surrogate Pilot Project Model	Model	Surrogate Pilot Project Model Created for Phase 1 - defined objective of the phase 1 surrogate pilot effort	Done	On AR&M, Research | Documents | Surrogate Pilot | MagicDraw Models
Skyzer Mission Model (NAVSEM 1 & 2)	Model	SysML of Skyzer Mission Model evolved through Surrogate Pilot	Evolving	On AR&M, Research | Documents | Surrogate Pilot | MagicDraw Models
Skyzer System Model (NAVSEM 3 & 4)	Model	SysML versions of Skyzer System Model for Phase 1	Evolving	On AR&M, Research | Documents | Surrogate Pilot | MagicDraw Models
Skyzer System Model Document	Model	Provides the View and Viewpoints, Digital Signoffs for System Model	Evolving	
Skyzer Surrogate Contractor Model (NAVSEM 5)	Model	Surrogate Contractor Model for both Phase 1 and Phase 2, which is now compliant with NAVSEM Step 5	Evolving	On AR&M, Research | Documents | Surrogate Pilot | MagicDraw Models
Skyzer CBTE&E/MBTD	Model	Provides modeling representation for information to support Capability-Based Test and Evaluation based on a Mission-Based Test Design Process	Evolving	On AR&M, Research | Documents | Surrogate Pilot | MagicDraw Models
Cyber Ontology Pilot Model	Model	SysML Model for a cyber computer system example that is seeded for vulnerability, with Stereotype that maps to Cyber Ontology	To be Evolved	On AR&M, Research | Documents | Surrogate Pilot | MagicDraw Models
Cyber Ontology Pilot Ontology	Ontology	Cyber Ontology that aligns with Stereotype from Cyber Ontology Pilot Model	To be Evolved	
Cyber Ontology Pilot Demonstration	Video	Video of the Cyber Ontology Demonstration	Done	http://www.markblackburn.com/MBSE/Navy_Cyber_Ontology_Pilot_Dem[illegible]
Skyzer Mission Model NAVSEM Steps 1 & 2	Generated Spec	NAVSEM 1.0 Data Collection, 2.0 Operational Stakeholder Needs generated by DocGen and saved from View Editor	Evolving	On AR&M, Research | Documents | Generated Model Views
Skyzer System Model NAVSEM Step 3	Generated Spec	Skyzer System Requirements Analysis (Step 3) generated by DocGen and saved from View Editor	Evolving	On AR&M, Research | Documents | Generated Model Views
Skyzer System Model NAVSEM Step 4	Generated Spec	Skyzer Logical Architecture Definition (Step 4) generated by DocGen and saved from View Editor	Evolving	On AR&M, Research | Documents | Generated Model Views
Skyzer Contractor System RFP Response NAVSEM Step 5	Generated Spec	Skyzer_RFP_Response v2 (Step 5) generated by DocGen and saved from View Editor	Evolving	On AR&M, Research | Documents | Generated Model Views
Skyzer Mission Model Document	View Editor	Includes Skyzer Mission Model NAVSEM Steps 1 & 2	Evolving	https://mms.sercuarc.org/alfresco/mmsapp/mms.html#/login
Skyzer System Model Document	View Editor	Includes Skyzer System Model NAVSEM Step 3 & 4	Evolving	https://mms.sercuarc.org/alfresco/mmsapp/mms.html#/login
Digital Signoff Video	Video	Provides an overview of Digital Signoffs and provides a demonstration showing how to do a Digital Signoff for different types of model artifacts, and also shows Digital Signoff Metrics	Done	http://www.markblackburn.com/MBSE/WRT_1006_Digital_Signoff_Video_[illegible]
Cyber Ontology Demonstration Video	Video	Long and short versions of Cyber Ontology Pilot Demonstration	Evolving	CCyber Ontology Pilot
Interoperability and Integration Framework Video	Video	Platform for using Ontologies - used in Cyber Ontology Pilot	Done	On AR&M, Research | Documents | Videos | Interoperability and Integratio[illegible]

Figure 2. SERC Systems Engineering Transformation Technical Products Delivered to NAVAIR

DE methods and enabling technologies such as DocGen have been integrated into the Stevens Institute of Technology course SYS-673, Implementing Cyber Physical System. More than five cohorts, primarily DoD industry contractors, have completely modeled and generated their final course reports directly from models using the OpenMBEE DocGen capability.

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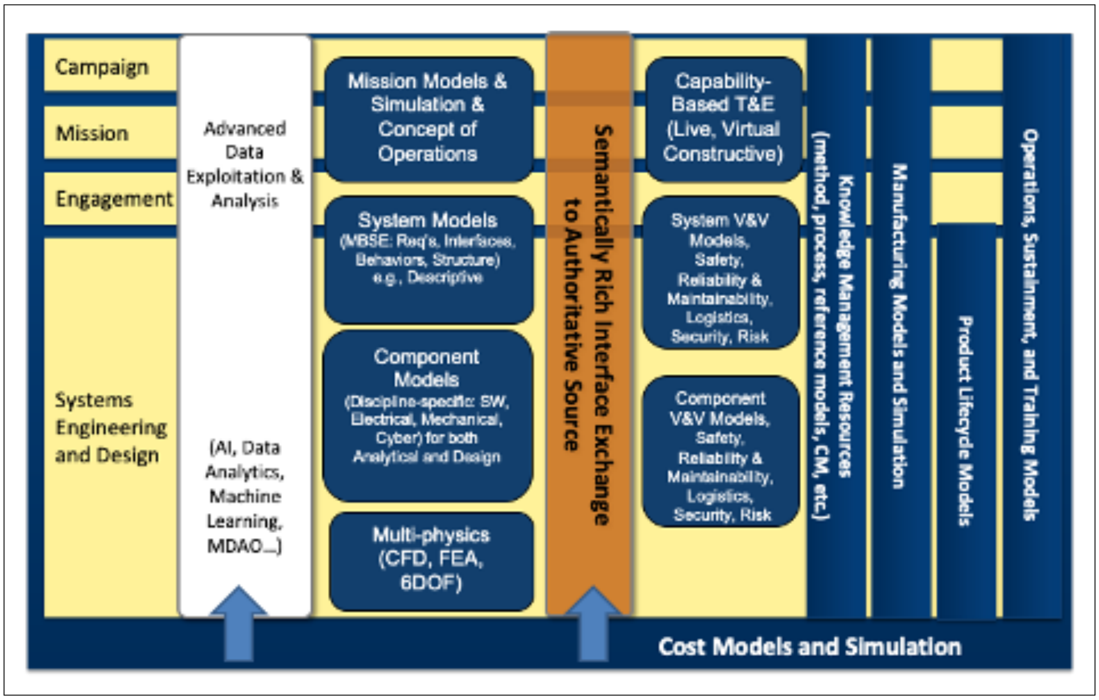

Figure 3. Reference Architecture for Integrated Modeling Environment in Support of DE

Another research concept underway is formalization of the NAVSEM method as an ontology to enable specifications modeling that uses semantic technology tools to confirm consistency and completeness. This is just one of many methods that fits into a broader reference architecture as shown in Figure 3.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

All of the tools, models, reports, videos reflected in Figure 2 are being incrementally delivered and refined or refactored to align with ever-evolving methods such as NAVSEM. A key takeaway is that many more "digital" artifacts (models, tools, enabling technologies) are being delivered, in addition to the traditional technical reports, than ever were over the first five years of research, which started in 2013.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The research team is actively involved as a member of the NAVAIR outreach team and consistently provides meetings/webinars as recommended by NAVAIR to communicate efforts. Like the 60 products identified above, most products reside on the All Partners Network (APAN.org), where the team has more than 300 people who are members of the APAN Research and Surrogate Pilot Groups.

NAVAIR government employees and contractors are considered transfer partners. While most people supporting the efforts are not directly funded to do the transfer, they have seen the possible benefits and want to participate in the effort as part of the extended team. Other potential transition partners include:

- Attendees of the NAVAIR Working Sessions, now totaling 51 since 2013;
- Attendees of the Navy Cross SYSCOM events;
- The Airworthiness team, which is transitioning the research;
- Cyber teams, including NAVAIR, NAVSEA, and CUBRC;
- NASA JPL, which asked for the technologies to be open-sourced (this was not permitted);
- MITRE, which has been informed;

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- The Aerospace Corporation;
- INCOSE, specifically the Pattern Working Group that has an interest in ontologies;
- The OpenMBEE Group, however the government in general does not want to use open source software (with a few exceptions); and
- Five cohorts (Stevens SYS-673) that developed their entire projects using these models and used DocGen to automatically generate their final technical reports (including requirement, designs, implementation, testing and safety analyses) for a Cyber Physical System using a telepresence robot.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

The Navy teams and their contractors are considered to be transition partners. Subject matter experts, including NAVAIR contractors, continue to engage with and understand the technologies on their own time. The US Air Force participates regularly, as does the US Army, who already shares in some of the research advances.

MODEL CURATION INNOVATION & IMPLEMENTATION

Principal Investigator: Dr. Donna H. Rhodes
University: Massachusetts Institute of Technology
Sponsor: OUSD (R&E)
Research Task: WRT-1009

Model Curation can be defined as the lifecycle management, control, preservation and active enhancement of models and associated information to ensure value for current and future use, as well as for repurposing beyond initial purpose and context. Curation practices promote formalism and provide for the strategic management and control of models and associated digital artifacts, particularly when managed as a collection at the enterprise level. Curation activities include model governance, accession, acquisition, valuation, preservation, active enhancement, model discovery, deaccessioning, and archiving.

Not all models are suitable for enterprise-level curation. Curation applies to longer duration models, rather than those developed for a quick study or to simply work out a problem. A first category of models suitable for curation includes models that will be used throughout the lifespan of a major program, for example models comprising a digital twin. A second category includes models designed (or enhanced) to be intentionally reused for a new purpose and/or within a new context. Examples are reference architectures and models, and "platform" models that enable the enterprise to effectively re-purpose and reuse models.

Model curation requires supporting infrastructure to enable an enterprise to establish and actively enhance a collection of models of value to the larger enterprise. As evidenced by curation practice in institutional collections (e.g., museums, historical societies, libraries), dedicated leadership, governance and support functions are essential. An enterprise model collection could include models for programs under development, models used by active programs in operations phase, models archived for historical or objective evidence purposes, reference models, surrogate models, demonstration models, and others.

Model curation is a broad topic that spans: implementation of model curation practice; the roles and responsibilities of involved individuals and organizations; approaches to curate models for intended purpose and model consumer preference; and options for new technologies that enable curation and curating. Prior phase investigation of model curation, especially on organizational aspects, was accomplished in SERC RT-199 (2019). Building on prior efforts, this research further explored implementation practice and the relationship of model curation to authoritative source of truth. A preliminary set of guiding principles for governance and implementation practices was derived from research findings, along with precursors to credibility in the model curation context. Several areas of innovation are summarized as a look ahead to potential use of newer technologies to advance curation beyond a largely manual endeavor.

1. What is the long-term transition goal for the research if continued?

The long-term transition goal for model curation research is to accelerate the implementation of effective model curation practice in the government. This will be accomplished through continued active technical exchanges and collaboration with research stakeholders as new knowledge is generated. Activities to enable transition include journal articles, workshops; development of reference practices and useful guidance material; and generation of knowledge on enabling technologies for the government, as well as the broader DoD systems community. Exploration into innovation through newer technologies will inform the development of model environments and enabling infrastructure, such as augmented decision support for discovery of models and visualization of model-generated information suited to the needs and preferences of model consumers.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

Ongoing work on guiding principles for model curation implementation and governance might be used for external sponsors to develop policies, practices, and operating procedures. Precursors to authoritative source of truth resulting from investigation of model credibility in the model curation context have potential to be used in education and training. Cross-project collaboration between WRT-1009 and WRT-1008 provided the opportunity for illustrative application of research outcomes, with potential for future use in education and training. An initial set of criteria for accepting a model into an enterprise collection resulted from the work and was used to generate an illustrative example for a hypothetical case for the Skyzer Surrogate Systems Model.

Continued on next page

3. Which of these might be or are planned to be incrementally delivered in a future research task?

Trial application of the criteria for accepting a model into an enterprise collection would be matured through further research, ultimately leading to a published guidance document and/or embedding criteria into a decision tool. Continued research, empirical investigation, and observational studies are needed as parallels to early adopter implementation. Results of a well-designed empirical research study could inform the formulation of implementation policies and practices, reveal barriers and enablers for curation, and provide better understanding to inform curation-related innovation. A planned future research task will investigate curating for model consumers, through developing use cases and understanding of needs and preferences respective to roles. An exploration of model credibility and data credibility is expected to clarify the dependencies and interrelationships, and further elaborate required metadata. Planned further research will investigate the valuation of enterprise-level models and model collections. The results will be used to inform business cases for investment in model collections, and for model acquisition and shared model agreements. A related task is to better understand accreditation practices and enterprise model collections. Model discovery and model composition are planned areas of future research, ultimately leading to the potential for producing "digital demonstrators" from model repositories. Future research also aims to investigate collaborative model collections and features of such model repositories.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The research team interacted with many interested stakeholders and potential adopters of model curation, including through technical exchange meetings, workshops/forums, and interaction through working groups in several organizations, especially Army CCDC-Armaments Center, NAVAIR, SPAWAR Atlantic, Sandia National Laboratories, and SAF CMSO.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

The SERC WRT-1009 project has included technical exchanges and interactions with government agencies that have been exploring and piloting model curation-related approaches and practices. Early research findings were shared in support of government partners' efforts to define and implement model curation related activities. It is expected that early government adopters of the research will be DoD agencies with active digital engineering transformation initiatives. Several publications and webinars have resulted from the research that have raised awareness in this topic and resulted in useful feedback to further research goals.

MESHING CAPABILITY AND THREAT-BASED SCIENCE AND TECHNOLOGY (S&T) RESOURCE ALLOCATION - PART 2

Principal Investigator: Dr. Carlo Lipizzi
University: Stevens Institute of Technology
Sponsor: US Army
Research Task: WRT-1010

1. What is the long-term transition goal for the research if continued?

The minimum viable product realized during Phase I and Phase II of the project (Threat Based Decision System - TBDS) is available for installation in the Picatinny environment, but it will not be ready for use in cases of core relevance for CCDC-AC. A potential Phase III is intended to accomplish a seamless transition to CCDC-AC and encompasses two main tasks:

Task 1: Supporting the adaptation of TBDS to CCDC-AC/Picatinny mission.

The research team wishes for TBDS to become a key part of the CCDC-AC/Picatinny information systems, keeping the focus on decisions made from multiple, integrated sources. To better achieve this goal, the team will leverage the members able to handle CUI work and the PI's secret-level clearance.

In order to make the systems fully operational at the Army Mission Based environment, TBDS needs to be tuned both at the theoretical and coding levels.

While all the code has been released during Phase II and may be modified by Picatinny personnel, some changes will require more in-depth knowledge of the systems and the theoretical assumptions that are essential components of the systems and their code. The actual users of the systems in Picatinny will also require additional metrics of presentations that would make the system more functional for their operations. This will require adjustments such as:

- development of plug-ins for specific streams of data sources;
- integration of the additional informational content from the new sources;
- redefinition of the competitive scenario;
- adjustment/redefinition of the metrics to better serve the goals of CCDC-AC;
- adjustment to the way Room Theory works on the actual CCDC-AC data;
- adjustment and customization of the visualizations; and
- development of additional user interfaces for possible uses of a subset of TBDS functionalities.

The Risk DSS component of TBDS is calculating the different aspects of the risk based on metrics extracted from past and present documents. At the same time, during Phase II, the research team developed two prototypes, interpolating the past evolution of technology up to the present in order to determine: (1) what possible technologies may become available in the future; and (2) what are the possible future contexts of application of current technologies.

Integrating the Risk DSS and the Technology Forecasting modules would place the risk evaluation in a predictive mode, giving the decision-makers more elements on which to work in a critical area such as investments in technologies of military relevance.

The integration between the Risk DSS and the Technology Forecasting modules would additionally address the use case of evaluating the impact of technology horizon scanning on the current and future operations. This includes the questions:

- How might the competitive scenario change based on the evolution of the current key technologies?
- What are the opponents that can benefit most from future technology scenarios?
- What are the technologies that can have a higher strategic value in the coming competitive scenario?

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Task 2: Enhancing the TBDS capabilities.

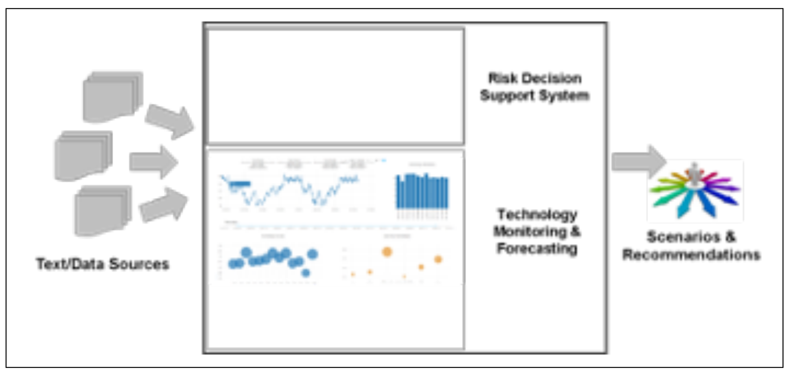
TDBS capabilities would be expanded with the following additions:

- Opponent behavior modeling, a complex task that aims to dynamically position opponents in the range from supportive to non-hostile to hostile.
- Develop a dynamic opponent "technology footprint", representing strengths, weaknesses, and the related evolution in time. Footprints would be represented as kill chain equivalent.
- Introduction of a time-based view to most of the metrics with additional derived metrics on the trends.
- Improvement of the quality of the deployed Room Theory and development of a Room Theory-based triage system to dispatch the incoming document to the most appropriate Room.

The new capabilities would not create answers to new questions/cases but would enhance the accuracy and the ability of TDBS to support the decision process.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The main outcome of this project is a framework that has been implemented into a prototypal data/text-driven computing system able to support capabilities-based planning activities with an on-demand approach. The system, called Threat Based Decision System (TBDS), would provide CCDC-AC with scenario planning support. The following chart is a representation of the system.



While the system as whole has been tailored for specific needs, several of its components can be (and have been) reused in different contexts. Below is a brief recap:

- TBDS has been developed as an assembly of logical components that are pieces of code. Those components can be reused as building blocks for a different system. They cover primarily the area of Natural Language Processing.
- TBDS is centered on an original logical framework and related code to analyze text based on a given point of view. This methodology (the "room theory") can be applied elsewhere and it has been applied already in another SERC project, WRT-1023, to classify acquisition requests by contract type, using a representation of a contracting officer's knowledge base.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

The "room theory" has been used on WRT-1023, which ended on Sep. 26, 2020 with a possible upcoming Phase II.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

A Phase III was proposed to the Sponsor for the medium term. For the longer term, nothing has been decided yet.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

CCDC-AC will use their own team and HW resources to run the system. Future developments beyond a possible Phase III have not been discussed yet.

GLOBAL POSITIONING SYSTEMS - MISSION ENGINEERING AND INTEGRATION OF EMERGING TECHNOLOGIES

Principal Investigator: Dr. Michael Orosz
University: University of Southern California
Sponsor: Air Force
Research Task: WRT-1012

1. What is the long-term transition goal for the research if continued?

The long-term goal is to enable SMC and partner organizations to transition from the existing DoD 5000 Waterfall system development framework to the more flexible Agile/DevSecOps approach. This goal includes documentation and implementation of the necessary platform, tools, and workflow approaches.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

One of the goals of this project is the development of performance measurement tools that track Agile/DevSecOps performance but meet the reporting needs of the US Government. Some of the tools developed to date and that are in use include:

a. Excel-based Kanban viewer: MS Excel-based tool that enables viewing Jira issue exports in a Kanban format;

b. Excel-based Jira issue viewer: MS Excel-based tool for off-line viewing of Jira issues;

c. Excel-based Jira visualization tool: MS Excel-based tool that provides a dashboard view of Feature Team progress status based on data from periodic Jira issue exports; and

d. Software Problem Analysis Tool: MS Excel-based tool used to track problem reports (PRs) created during integration and testing of system components.

Another artifact planned for transition is a guide/process – including training materials -- that can be used by the US Government to transition other traditional waterfall development/acquisition environments to an Agile/DevSecOps process. Included in this guide are lessons learned and recommendations/metrics that indicate when Agile/DevSecOps is not the appropriate approach to take for a specific program.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

The research team plans to incrementally deliver various versions of the performance measurement tools. For example, the tools are currently being used for a new project underway at SMC/PC.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The SMC/PC team will be the primary benefactors of these deliverables and will be involved in using/testing various releases of the technology. In addition, these tools will be introduced to the prime contractors developing technology for SMC/PC. The tools and processes developed will also be introduced to other US Government agencies that have similar systems acquisitions challenges.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

SMC/PC is currently using the performance monitoring tools. In addition, training materials have been developed and used to introduce how Agile/DevSecOps is implemented in a newly started project.

REDUCING TOTAL OWNERSHIP COST (TOC) AND SCHEDULE

Principal Investigator: Dr. Barry Boehm
University: University of Southern California
Sponsor: OUSD (R&E)
Research Task: WRT-1016

1. What is the long-term transition goal for the research if continued?

The long-term transition goal for the project is to enable complex system projects to reduce total ownership costs by using better methods, processes, and tools for satisfying their non-functional (quality) requirements (NFRs). Compared to functional requirements, the NFRs are more difficult to specify and are given lower priority during system definition than the FRs. They are often in conflict with each other. As one example of a major DoD project, the Security team proposed to minimize their vulnerability profile by having a single copy of the database and a single-agent key distribution system, only to have the Reliability team point out that this would create two serious points of failure.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

Among the potential tools and guides resulting from the research are major extensions of the tools developed in the previous SERC System Qualities Ontology, Tradespace, and Affordability (SQOTA) project. For example, the System Qualities Understanding by Analysis of Abundant Data (SQUAAD) tool for large-scale life-cycle analysis of software technical debt was successfully used on a Navy application, and scaled up to analyze the technical debt histories of 1.3 billion lines of code across three large companies and 15 years. The project is currently responding to a MITRE Corp. request to rehost SQUAAD on a private cloud for use in classified technical debt analyses.

The research team is also developing an extension of the COCOMO cost model for estimating the cost of security-critical software. Its current definition was presented at the recent annual COCOMO Forum, at which attendees from the Navy, NASA-JPL, Aerospace Corp., the SEI, and several aerospace companies were interested in participating in its definition and calibration. USC-CSSE and the CAST organization are co-sponsors of the Consortium for Information System Quality, which has strong support from DHS, DoD, and other federal organizations, and the team participates in CISQ events involving information system security cost estimation.

The team has used its Systems and Software Qualities Ontology as a basis for reorganizing the Qualities section of the Specialty Engineering Part 6 of the Systems Engineering Body of Knowledge, and is working on an update of the System Qualities Synergies and Conflicts matrix for industry and government organizations to evaluate side effects of system qualities changes.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

The research team is incorporating its cost impact research results in the next-generation COCOMO III cost estimation model, with participation from NPS, DHS, and Aerospace Corp., and expects to have a preliminary version by the end of Year 2, and a definitive version by the end of Year 3.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

Besides the transition partners identified above, the team will also be collaborating with MITRE on the private-cloud version of SQUAAD, and the US Army CCDC AC on software maintenance cost estimation.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

All of the above mentioned entities are interested in helping the development of the capabilities above, and in conducting pilot applications of them.

ADAPTIVE CYBER-PHYSICAL-HUMAN SYSTEMS TESTBED

Principal Investigator: Dr. Azad Madni
University: University of Southern California
Sponsor: OUSD (R&E)
Research Task: WRT-1019

1. What is the long-term transition goal for the research if continued?

The results of this research will be transitioned to two SERC universities, i.e., University of Virginia and University of Alabama, Huntsville. Researchers will be able to add new models and algorithms to and experiment with the testbed repository, and thereby enable growth and increase utility of the testbed. The long-term transition goal for this research is to make this testbed available to all SERC universities working on MBSE and autonomous systems research and The Aerospace Corporation for use on DoD, NASA, SMC projects.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

Potential tools, guides, educational units, and other artifacts that result from this research and that might be used by external sponsors include: a “starter kit” of scenario and model fragments; scenario authoring tool; dashboard tool; MBSE repository; models of physical systems; and interfaces to virtual and physical systems (used for experimentation). The models and findings will be taught in SAE 547, Model Based Systems Engineering, a graduate course in USC’s Systems Architecting and Education Program. The testbed will allow participating research teams to rapidly and cost-effectively initiate MBSE research on the engineering of autonomous systems, an area of shared interest among several SERC researchers.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

A “starter kit” of models, scenario creation tool, predefined scenarios, library of models, dashboard tool, and hardware specifications will be incrementally delivered in a future research task after appropriate testing.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The transition partners are two SERC universities, University of Virginia and University of Alabama, Huntsville. Eventually, the testbed will be made available to all SERC universities working on MBSE and autonomous systems. The team successfully transitioned a rudimentary testbed prototype from previous RT efforts to The Aerospace Corporation. Potential adopters include a subset of SERC universities and The Aerospace Corporation.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

An early version of the testbed was piloted with The Aerospace Corporation. University of Virginia and University of Alabama, Huntsville are the transition partners for the current version of the testbed. The research team will work with these transition sites before the end of the current contract to successfully transition the testbed prototype.

ANALYZING AND ASSESSING CONTRACTS FOR EMBEDDED RISK

Principal Investigator: Dr. Carlo Lipizzi
University: Stevens Institute of Technology
Sponsor: OUSD (R&E)
Research Task: WRT-1023

1. What is the long-term transition goal for the research if continued?

The research effort has been divided into several phases, and it is logically distributable in multiple years. As stated in the WRT-1023 contract, during the first year duration of the contract, the research team developed an early prototype of the system to prove the validity of the approach. The prototype covered the basic functionalities defined by the Sponsor but with limited robustness, interactivity, proactivity, and reusability.

In particular, during the first year (hereafter named "Phase I"), the research team demonstrated that the prototype can determine the most appropriate contract structure, i.e., contract type, for the contracting officer to use in response to a specific set of requirements. The prototype includes an early version of a user interface that facilitates the interaction between the system and users in a user-friendly and efficient manner.

The following are the tasks that would be performed during a possible Phase II:

Task 1: Supporting the incorporation of the system into the Sponsor's mission

The research team aims to have the system become a key part of the DAU information systems and working process.

In order to make the system fully operational, it needs to be fine-tuned both at the theoretical and coding levels.

While all the code has been released during Phase I, and DAU personnel may modify it, some changes will require a more in-depth knowledge of the system and the theoretical assumptions that are essential components of the system and its code.

A user interface developed by the research team allows users to interact with the prototype at its current level of development, with no flexibility in terms of possible changes that may be required for improper functioning due to either functional or technical reasons. Improper functioning can occur in prototypes due to their nature (from Wikipedia: "a prototype is an early sample or model built to test a concept or process or to act as a thing to be replicated or learned from").

The goals for this task are to:

- conduct a full test on the field to eliminate possible bugs (common in prototypes) and incorporate feedback;
- benchmark the results on a larger scale, using selected existing cases;
- test the newly introduced multi-document analysis to ensure it behaves as consistently as for single documents. Some adjustments may be needed, such as providing different weights to the different single documents that are part of the multi-document;
- provide technical and operational support to users during the introduction of the system; and
- expand the user interface by providing more interactive functionalities and visualizations.

Task 2: Expanding the system's accuracy

The current prototype classifies the requests using a computational version of a corpus representing the knowledge of a contracting officer.

Even if - with the help of the Sponsor - the research team made their best effort to have a comprehensive representation of that knowledge, the level of coverage and consequently the accuracy of the classification are at the prototype level and may not be adequate for the use of the system in the field.

The goals for this task to increase the accuracy are to:

- extend the knowledge base, as needed, to improve the quality of the results;
- introduce an after-processing component to refine the results, which takes into account case-specific classifications; and
- take into account external factors, such as critical relevance of the request, previous agreements with preferred providers, and competitiveness of the market segments (e.g., fewer competitors, more risk).

Continued on next page

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The main outcome of this project is a framework that has been implemented into a prototypal data/text-driven computing system able to support contracting officers.

While the system as whole has been tailored for the specific needs, several of its components can be reused in different contexts, as summarized below:

- The framework and the related prototype have been developed as an assembly of logical components that are pieces of code. Those components can be reused as building blocks for a different system. They cover primarily the area of Natural Language Processing.
- The framework and the related prototype are centered on an original logical framework and related code to analyze text based on a given point of view. This methodology (the "room theory") - originally developed for another SERC project, WRT-1010 - has been adapted to the needs of this project, creating a more generalized solution to evaluate semantic meanings in text by defining a point of view of the recipient/reader of the text. This would extract semantic metrics from a given text, based on a representation of the knowledge of the recipient, such as a contracting officer in the case of WRT-1023.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

There could be a crossbreeding between the possible Phase II of this project and the possible Phase III of WRT-1010.

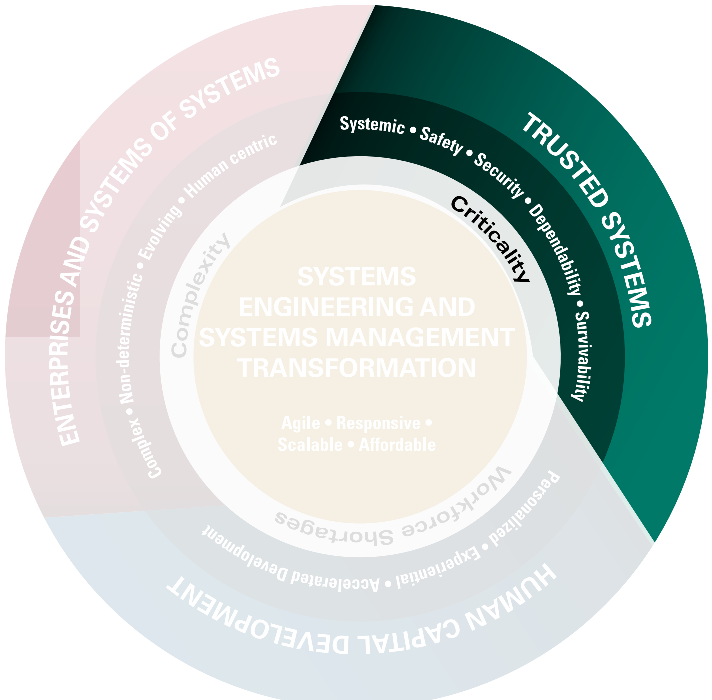
4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

A Phase II was proposed to the Sponsor for the medium term. In the longer term, nothing has been decided yet.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

DAU will use the prototype on online/AWS resources via a user interface developed by the research team. In Phase II, the team would continue providing the needed support. Future developments beyond a possible Phase II have not been discussed yet.

TRUSTED SYSTEMS



Providing ways to conceive, develop, deploy and sustain systems that are safe, secure, dependable, adaptable and survivable. Research must enable prediction, conception, design, integration, verification, evolution and management of these emergent properties of the system as a whole, recognizing these are not just properties of the individual components and that it is essential that the human element be considered.

TS Area Goal: *Develop, evaluate, and catalyze the transitioning of integrated concepts, methods, processes, and tools for providing cost-effective, evidence-based, argument-supported assurance that defense systems and projects provide all critical properties on which diverse stakeholders may legitimately rely for mission success with acceptable levels of residual risk.*

https://sercuarc.org/serc-programs-projects/ts/

RESEARCH COUNCIL MEMBERS FOCUSED ON THIS THEMATIC AREA:

John M. Colombi

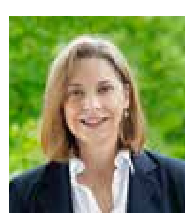
Associate Professor and Systems Engineering Program Chair, Air Force Institute of Technology (AFIT), Lt Col, USAF (Retired)

Peter Beling

UVA Site Director, Center for Visual and Decision Informatics, NSF, Professor and Associate Chair for Research Department of Engineering Systems and Environment, University of Virginia

Laura Freeman

Director, Hume Center's Intelligent Systems Lab, Research Associate Professor, Department of Statistics, Assistant Dean for Research at the National Capital Region, Virginia Tech



Valerie Sitterle

Principal Research Engineer and Chief Scientist, Systems Engineering Research Division, Electronic Systems Laboratory, Georgia Tech Research Institute (GTRI)

CHARACTERIZATION OF EMERGING TECHNOLOGIES IN MILITARY ENVIRONMENT

Principal Investigator: Dr. Pradeep Lall
University: Auburn University
Sponsor: US Army
Research Task: ART-001

1. What is the long-term transition goal for the research if continued?

The long-term transition goals will include:

a. Development of predictive tools for the use of components with new doped-solder alloys and copper-interconnects in high strain-rate environments at very-high and very-low temperatures;
b. Use of the predictive tools by the DoD for the risk assessment with use of the new packaging architectures and design of next-generation electronics; and
c. Identification of feature vectors for early-detection of impending failure and RUL.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The output from the program will be:

a. Foundational data for constitutive behavior;
b. Damage relationships for life-prediction of interconnects;
c. Data on evolution of properties of doped-solder interconnects under prolonged storage;
d. Effect of high strain rates; and
e. Material constants for implementation in FE.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

a. High strain-rate properties of SAC-305, SAC-Q and SAC-R are planned in this program.
b. A follow-on program is needed to study the damage relationships for life prediction with a number of commonly used surface finishes.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The proposed research will be of interest to the DoD in general, owing to the high degree of relevance to the operating environment and the reliance on new commercial-part architectures in defense systems.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

None are identified.

RISK-BASED APPROACH TO CYBER VULNERABILITY ASSESSMENT USING STATIC ANALYSIS

Principal Investigator:	Dr. Peter Beling
University:	University of Virginia
Sponsor:	ARDEC & OUSD (R&E)
Research Task:	ART-006

1. What is the long-term transition goal for the research if continued?

A number of commercial and research tools are available for static analysis of software systems. These tools produce alert lists of potential implementation vulnerabilities based on analysis of a system's software, without the need to execute the code. The current state of the art for separating true positive from false positive alerts relies on review by human experts. For weapons control and other complex software systems, however, a single static vulnerability-analysis tool might produce vulnerability alerts that number in the thousands, making manual review of all vulnerabilities very expensive. This research addresses that issue through the creation of methods for filtering and ranking the outputs of static analysis tools, either individually or in collection. The overall transition goal is to create tools and methods that improve the productivity of vulnerability analyses and consequent software revisions.

This research project is an integral part of SERC's research strategy for Trusted Systems, which aims to transform system assurance from a late, reactive activity to an early and continuous, pro-active orchestration of advanced assurance methods, processes, and tools. The goal is to balance the simultaneous achievement of cybersecurity trust and assurance with complementary MPTs for assuring safe, reliable, available, usable, interoperable, and resilient mission cost-effectiveness. This research task is anchored on work from several previous SERC research tasks (RTs), including, RT-191, RT-196, and WRT-1013 that aim to develop safe, secure, dependable defense systems, resilient to cyber and other threats through systemic security approaches that complement current, incomplete perimeter/network methods.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The principal tools and artifacts are as follows:

1. The Risk-based Software Cyber Vulnerability Assessment Methodology (RSVAM): Under RSVAM, functional risk filters for static analysis alerts are constructed through the association of mission priority test cases with the software code files to be analyzed. RSVAM was demonstrated on an autopilot system and the RSVAM software was integrated into an existing and widely used toolset, the Source Code Analysis Laboratory (SCALe) from the Software Engineering Institute.
2. The Collect-Assess-Prioritize (CAP) methodology: CAP aims to balance the trade-off between the cost and the value of resolving static analysis alerts. CAP relies heavily on machine learning approaches for the identification of true alerts. The effectiveness of these and other machine learning techniques depends on access to a training data set with a large number of labeled alerts. To address this issue, an active learning methodology was developed for selectively labeling examples to reduce the number of labeled alerts needed for training.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

A future effort would involve a study of the time-to-resolve for static analysis alerts, including the development of refined machine learning models to estimate resolution times without human intervention. Previous studies have focused on the life cycle of alerts from creation to resolution, a process that takes place on the order of days. The new effort would focus on a different time frame–that is, how long does it take a developer to investigate, address, and resolve an alert? This time would be on the order of hours rather than days. This data would be collected and fitted to statistical models. Similar efforts have been performed in the past, but with a focus on issues and bug reports rather than static analysis alerts. Access to better information or models will improve the ability to find efficient alerts. The anticipated result would be further reduction in the levels of human effort to determine which parts of the software system to recommend for improvement. In addition to increasing the productivity in selecting candidates for improved quality, an important second benefit would be related to providing more involvement and buy-in to quality enhancement decisions by the ultimate users who contribute to the functional risk analysis of the system.

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4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

This work was co-sponsored by OUSD(RE) and the United States Army CCDC Armaments Center (CCDC AC), now DEVCOM Armaments Center. The DEVCOM group is currently engaged in applying the tools and methods from the work in the context of their ongoing programs. To support transition to use by programs, the tools and methods from this project have been integrated in the Source Code Analysis Laboratory (SCALe), a product from the Software Engineering Institute that is used by the Army and other organizations to manage outputs from static analysis tools.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

The use of static analysis tools to analyze software is mandated for many DoD programs. This research would provide transition partners with efficient pathways to use static analysis results to improve program software by reducing vulnerabilities.

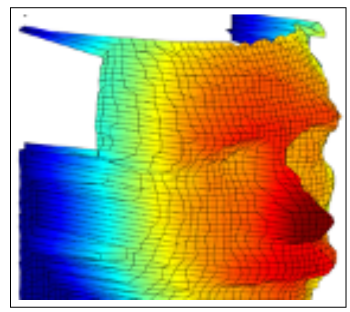
QUANTUM PHOTONICS TASKS FOR RESEARCH

Principal Investigator: Dr. Yuping Huang
University: Stevens Institute of Technology
Sponsor: ARDEC
Research Task: ART-014

The importance of Quantum Science is well recognized by both military and civilian leadership and has been specifically identified as a Modernization Priority in the National Defense Strategy as dictated by the Office of the Secretary of Defense. It addresses all four Strategic Product Areas outlined by Army Futures Command: 1) Quantum Edge Technology; 2) Artificial Intelligence Training and Assessment Technologies; 3) Persistent Tactical ISTAR (Intelligence, Surveillance, Target Acquisitions and Reconnaissance) in Contested Environments; and 4) Tactical Networking and Communications in Contested Environments.

This project explores the boundary between quantum science and system engineering to create revolutionary advancement in defense technology. It harvests the latest advancements made in quantum science and engineering and applies these to system engineering studies to develop integrated nanophotonic circuits, quantum enhanced communication systems, photonic detection technologies, and remote sensing systems. All will lead to substantial reduction in the Size, Weight, Power, and Cost (SWAP-c) of existing devices and systems, while realizing new defense capabilities unmatched by competitors.

1. What is the long-term transition goal for the research if continued?



The long-term goals of the project include:

- Develop and deploy impactful quantum systems by adopting the best system engineering approaches for reduced development cycles and seamless integration with non-quantum systems;
- Create new paradigms for system engineering studies, where quantum information technologies boost information sharing, data processing and decision making capabilities; and
- Facilitate interdisciplinary education and workforce development in quantum and system engineering.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The list of artifacts produced by this project include:

- Quantum encrypted communication systems, where information sharing is protected by the fundamental laws of quantum physics;
- Quantum authentication, where security is uncompromised by all possible attacks;
- Quantum decision making, where rapid optimization and predictive analyses can be carried over extremely large parameter spaces with more than 1 million variables;
- Quantum remote sensing under zero visibility, where precise 3D scene can be constructed remotely despite strong losses and obscuring; and
- System simulators using quantum reservoir computing.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

All are planned to be delivered incrementally with rapid technology transition.

4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The current transition partner is Combat Capabilities Development Command Armaments Center. Potential adopters of this research include all defense departments and NASA.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

No.

SECURITY ENGINEERING 2019: MISSION AWARE CYBER RESILIENCE

Principal Investigator: Dr. Peter Beling
University: University of Virginia
Sponsor: OUSD (R&E)
Research Task: WRT-1013

1. What is the long-term transition goal for the research if continued?

For several years, a principal focus of the Trusted Systems thrust within SERC has been the development of methods and tools that support system design for cyber resilience in cyber-physical systems. This body of work features the development of the Mission Aware (MA) framework for integration and alignment of cyber engineering requirements with the system development lifecycle and systems engineering processes. Mission Aware includes techniques for evaluating cyber-physical system threats and attacks, a framework for formulating requirements and design concepts for cyber resiliency, and model-based tools for the selection of resilient architectures. The centerpiece of the Mission Aware framework is a risk analysis that integrates the perspectives of mission owners, systems engineers, and red teams into a common model-based form.

2. List the potential tools, guides, educational units, or other artifacts that resulted from this research that might be used by external sponsors if the long-term transition goals are met?

The principal tools and artifacts are as follows:

1. The Cyber Security Requirements Methodology (CSRM) supports the design of cyber-resilient systems under the MA framework.
2. The Mission Aware MBSE Metamodel can be used to derive model-based systems engineering (MBSE) representations of systems. The metamodel captures the results of the CSRM and other elements of the MA framework.
3. The Mission Aware Metamodel, which was developed using Genesys, a second-generation MBSE tool from Vitech Corporation that incorporates many of the constructs expected to be present in the yet-to-be-released SysML V2 standard for MBSE. As a result, adopters should find it straightforward to port the Mission Aware Metamodel to the next-generation standard tool environments for MBSE.
4. The Cyber Body of Knowledge (CYBOK) and Security Analysts Dashboard (SD) support red team and vulnerability assessment functions. CYBOK is a multi-view search engine that matches system descriptions to threats from CAPEC, CWE, and CVE, publicly available sources of information about system threats. The Security Dashboard (SD) is the graphical user interface that facilitates the interactions between the system model and the threat analysis results curated from CYBOK. CYBOK takes as input a graph system model and identifies known attack patterns, weaknesses, and vulnerabilities pertaining to the system.

3. Which of these might be or are planned to be incrementally delivered in a future research task?

As the Mission Aware MBSE metamodel has matured, an opportunity exists to unify and standardize approaches to model-based systems assurance and mission engineering through formal modeling and dynamic simulations. Three future tasks are proposed to support this evolution:

- Mission engineering–Development of methods to link the MA process to DoD mission engineering activities and standardize a model-based approach to capture both mission resilience analyses and resulting system resilience mode requirements in the mission engineering process.
- Formal modeling–Define and demonstrate standard methods and tools to specify and assess the quality of assurance arguments linking mission capabilities to system resilience modes. This would include demonstrating methods and tools to link high-level functional mission activity models to lower-level software execution models based on previous SERC and Army/DARPA research.
- Dynamic simulation–Develop and demonstrate approaches to formally integrate the Mission Aware MBSE metamodel with dynamic simulation capabilities and tools in order to standardize full-lifecycle assurance analysis and evaluation activities linking mission-level simulation to appropriate system-level functional simulation methods and tools.

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4. Did you identify any transition partners? Are there other advocates or potential adopters of this research?

The tools and methods developed in this project have reached a level of maturity that would support the transition to broad application in weapons and other systems. Additionally, in future work, these research outcomes could provide the basis for unifying and standardizing approaches to model-based systems assurance and mission engineering through formal modeling and dynamic simulations.

5. Was the research piloted with a potential transition partner? Are there others who would conduct pilot use of the research if fully funded?

Mission Aware was developed through a series of SERC research efforts, including RT-156, RT-172, RT-191, RT-196, and ART-004. Collectively, the prior SERC Mission Aware projects provide a foundational methodology and supporting tools for cyber-resilient design.

The United States Army CCDC Armaments Center (CCDC AC), now DEVCOM Armaments Center, sponsored some of this work and worked closely with the research team in the application of the tools and methods to a hypothetical, design-stage weapons system. The DEVCOM group is currently engaged in applying the methods in the context of their ongoing programs.

DEVELOPMENTAL TEST AND EVALUATION (DT&E) FRAMEWORK FOR CYBERATTACK RESILIENT SYSTEMS

Principal Investigators: *Dr. Peter Beling, Dr. Barry Horowitz, Dr. Cody Fleming*
University: *University of Virginia*
Sponsor: *OUSD (R&E)*
Research Task: *WRT-1022*

This University of Virginia (UVA) research project is a one-year effort sponsored by Developmental Test Evaluation & Assessment (DTE&A), the DoD organization responsible for developmental test and evaluation. The sponsored effort started in early October 2020, building upon prior UVA/System Engineering Research Center (SERC) research efforts sponsored by OSD, the US Army and industry. The project is focused on exploring possible new engineering tools and processes related to enhancing cyber resilience testing and evaluation for cyber physical systems. The project involves developing prototype tools and processes that will be evaluated in experiments alongside other, existing resilience-related toolsets (e.g., STPA-Sec, MBSE). In collaboration with the US Army Combat Capabilities Development Command Armaments Center, UVA previously developed emulations and systems models of a hypothetical weapon system referred to as Silverfish, which will be the basis for experiments.

The long-term transition plan is to accomplish the effort with partners who can: 1. help assure that the value added of the developed concepts for tools and process design is likely to be significant; and 2. can introduce the developed concepts to their own communities of interest. In addition, the DTE&A sponsor for the project intends to introduce early project results to interested government offices, looking to bring about the partnerships that would be necessary for transition.

The two areas for tool and process development will partition elements of system design and development into segments that relate to areas of testing and evaluation. For example, design of a cyber resilient subsystem would include functions such as Attack Sensing, Isolation of attack location, Reconfiguration to alternate diverse system configurations, etc. Anticipation of these lower-level design elements can be used to better prepare for test planning and for development of metrics to be used for evaluation. The sub-elements will provide support that enhances the results and efficiencies associated with the contributions of different contributors and users of the tools and processes, all within a compatible framework.

The results of this effort will be organized to permit ready development of education curriculum. UVA has already packaged results from earlier cyber resilience research efforts into courses provided to Defense Intelligence Agency (DIA) and Operational Test & Evaluation (OT&E) organizations and is currently planning efforts for broader use.

If successful, early adoption of results would be emphasized to enable a “learn through use” strategy for continuous improvement. Note that adversaries potentially can rapidly modify their attack strategies in response to cyber resilience solutions, requiring a rapid enhancement strategy for cyber resilience.

This DT&E research effort and the Army research effort referred to earlier are part of the transition of UVA’s earlier work, and the DT&E effort is an important next step. In addition, UVA has been engaged with the Air Force Institute of Technology in addressing the human performance aspects of cyber resilience solutions and is considering next steps to address that issue, ultimately leading to a potential relationship with the Operational Test organization as a next step.

APPENDIX

RESEARCH TASKS INCLUDED IN THIS REPORT

Research Area	No.	Title	Principal Investigator
TS	ART-001	Characterization of Emerging Technologies in Military Environment	Dr. Pradeep Lall
SEMT	ART-002	Transforming Systems Engineering through Model-Centric Engineering	Dr. Mark Blackburn
SEMT	ART-004	Methods to Evaluate Cost/Technical Risk and Opportunity Decisions for Security Assurance in Design	Mr. Tom McDermott
SEMT	ART-005	Methods for Integrating Dynamic Requirements	Dr. William Rouse
TS	ART-006	Risk-Based Approach to Cyber Vulnerability Assessment using Static Analysis	Dr. Peter Beling
SEMT	ART-007	Cognitive Bias in Intelligent Systems	Dr. Laura Freeman
SEMT	ART-009	Intelligent Defense Systems	Dr. Victor Lawrence
TS	ART-014	Quantum Photonics Tasks for Research	Dr. Yuping Huang
ESOS	ART-015	New Observing Strategies Testbed (NOS-T) Design and Development	Dr. Paul Grogan
SEMT	ART-016	Integrated Mission Equipment (IME) Architecture Process for Vertical Lift Systems	Dr. Bryan Mesmer
ESOS	WRT-1001	Digital Engineering Measures	Mr. Tom McDermott
ESOS	WRT-1002	Approaches to Achieve Benefits of Modularity in Defense Acquisition	Dr. Daniel DeLaurentis
HCD	WRT-1004	Helix - Organizational Systems Engineering Effectiveness 2019	Dr. Nicole Hutchison
HCD	WRT-1006	Preparing the Acquisition Workforce for Digital Engineering - Developing a Digital Engineering Competency Framework (DECF)	Dr. Nicole Hutchison
HCD	WRT-1007	The Capstone Marketplace	CAPT William Shepherd
SEMT	WRT-1008	Transforming Systems Engineering through Model-Centric Engineering	Dr. Mark Blackburn
SEMT	WRT-1009	Model Curation Innovation & Implementation	Dr. Donna H. Rhodes
SEMT	WRT-1010	Meshing Capability and Threat-based Science and Technology (S&T) Resource Allocation - Part 2	Dr. Carlo Lipizzi
SEMT	WRT-1012	Global Positioning Systems - Mission Engineering and Integration of Emerging Technologies	Dr. Michael Orosz
TS	WRT-1013	Security Engineering 2019: Mission Aware Cyber Resilience	Dr. Peter Beling
SEMT	WRT-1016	Reducing Total Ownership Cost (TOC) and Schedule	Dr. Barry Boehm
HCD	WRT-1018	DAU Credential Development	Mr. Ralph Giffin
SEMT	WRT-1019	Adaptive Cyber-Physical-Human Systems Testbed	Dr. Azad Madni
TS	WRT-1022	Developmental Test and Evaluation (DT&E) Framework for Cyberattack Resilient Systems	Dr. Peter Beling
SEMT	WRT-1023	Analyzing and Assessing Contracts for Embedded Risk	Dr. Carlo Lipizzi

SYSTEMS ENGINEERING
RESEARCH CENTER

University or Research Organization

1. Stevens Institute of Technology
2. University of Southern California
3. Air Force Institute of Technology
4. Auburn University
5. Carnegie Mellon University
6. Georgetown University
7. Georgia Institute of Technology
8. Massachusetts Institute of Technology
9. Missouri University of Science and Technology
10. Naval Postgraduate School
11. North Carolina Agricultural & Technical State University
12. Old Dominion University
13. Pennsylvania State University
14. Purdue University
15. Texas A&M University
16. University of Alabama in Huntsville
17. University of Maryland
18. University of Massachusetts Amherst
19. University of Virginia
20. University of South Florida
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