SYSTEMS ENGINEERING
Research Center

2013

ANNUAL REPORT

A US DEPARTMENT OF DEFENSE
UNIVERSITY AFFILIATED RESEARCH CENTER

SYSTEMS ENGINEERING
Research Center

contents

"We choose to go to the moon in this decade and do the other things. Not because they are easy, but because they are hard."

John F. Kennedy

GRAND CHALLENGES

We are often challenged in our everyday life, but we rarely consider these challenges to be insurmountable or to require substantial organization of resources from a wide variety of other people. When challenges do arise, we respond to the best of our ability. In most cases we can find a way to resolve the issue, solve the problem, or at least defer the challenge until we have the time and energy to deal with it. This constant handling of challenges provides most of the intellectual fodder of our lives in a fast-changing and increasingly complex world. However, there are other challenges and problems that require a more unified effort to address.

Grand Challenges are a special type of challenge, where the solution will make a large difference in many lives. Not arising on their own or thrust upon us by circumstance, such challenges are specifically and carefully designed to focus an organization, industry, or political entity on solving an extremely difficult problem. Such challenges demand a collective effort from many, usually in a systematic or strategic manner over a sustained period that could last years or even decades.

The United States has a long history of national Grand Challenges, many of which have been accomplished to a great degree.

- The Continental Congress and Constitutional Convention founding the first constitutional democracy in a world of monarchies
- Lewis and Clark and their Corps of Discovery seeking a "practicable water communication across this continent"
- Lincoln's challenge at Gettysburg to ensure that "government of the people, by the people, for the people shall not perish from the earth"
- Breaking the sound barrier
- Kennedy's challenge to send a man to the moon and return him safely
- Repairing and preventing the pollution of air, water, and land
- Cures for malaria, polio, muscular dystrophy, ALS, Alzheimer's, cancer, and a host of other diseases
- Mapping the human genome

The SERC was created with the mission 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. From this mission, the sponsor and SERC leadership established four Grand Challenges—one for each of the SERC Focus areas. Each of these provides a well-defined target for research strategy, roadmaps and alignment, inspiration for new approaches and concepts, and a mechanism for intentional, integrated, cross-discipline work directed solely toward solving some part of the Grand Challenge.

Because Grand Challenges cannot be met in a research cycle or two, they impel the work to continuously build toward an ultimate solution or a set of evolving solutions to meet the evolving need. While the benefits and value of Grand Challenge research are often directly and immediately applicable, they also accrue fundamental intellectual capital toward removing the challenge. With good strategies and roadmaps, this capital can be compounded over time to hasten that resolution.

This annual report provides the research baseline and describes the strategies and tasks currently planned for addressing four Systems Grand Challenges.

FROM THE EXECUTIVE DIRECTOR

It is with great pride that I commence the 2013 Systems Engineering Research Center (SERC) Annual Report. This was a milestone year for the SERC—we completed the fifth year of our operation and its founding contract from the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)). Over the course of the first five years, SERC received approximately $10 million in core research funding while conducting nearly $30 million in Systems Engineering research tasks. I am extremely pleased to announce that this success has resulted in ASD(R&E) awarding Stevens Institute of Technology a five-year follow-on contract for the SERC with $25 million in core funding and a contract ceiling of $60 million.

In the past year, the SERC has made several membership and operational changes.

- The SERC has grown its operational and leadership staff by appointing a new Director of Program Development and Transition. Dr. Mitchell Kerman joined us in this role in October 2013. He leads the SERC's strategic communications and outreach program, developing and nurturing our sponsorships, collaborative relationships, and key external alliances. Mitchell is also responsible for promoting and expanding the sponsorship base and raising visibility of SERC programs and initiatives across the Department of Defense (DoD) as well as other federal departments and agencies.

- Recognizing the growing strength and diversity of the SERC's research program, we restructured and expanded the Research Council, which is lead by SERC Chief Scientist, Dr. Barry Boehm. Two or three distinguished faculty now represent each of the four research focus areas, providing more effective guidance to the SERC's research portfolio as described more fully on page 2.

Given the SERC's strong growth and significant impact achieved in its first five years, we look forward to continuing to conduct research toward the Grand Challenges...

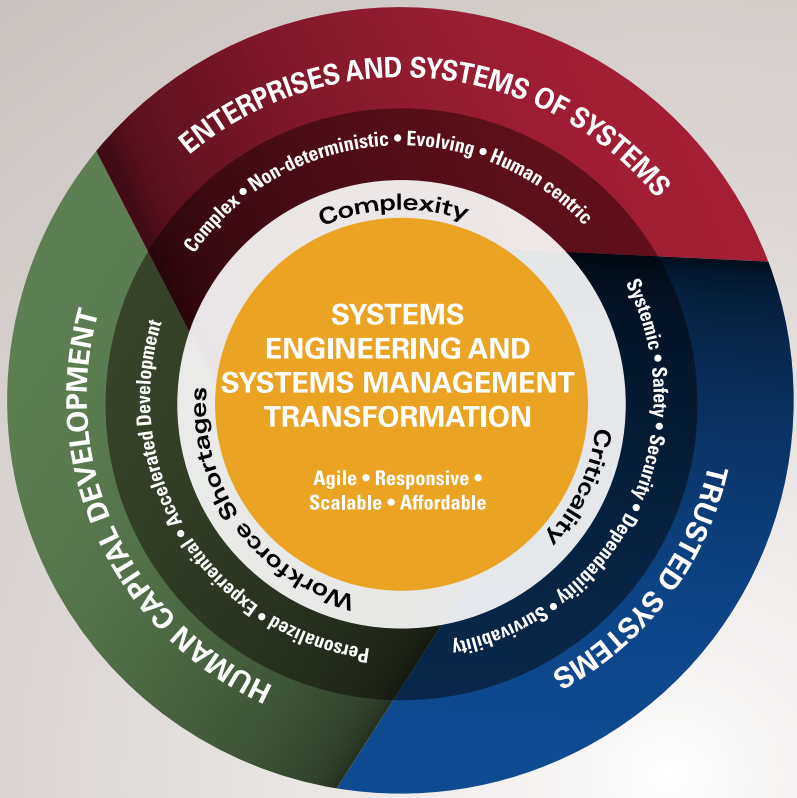
- The SERC Doctoral Fellows Program is now in its second year of operation, and I am excited to announce that there are three inaugural organizations—one from industry, one from government, and a Federally Funded Research and Development Center. I call your attention to a brief description of the program and its current constituency on page 13.

The theme for this year's Annual Report is the DoD Systems Engineering Grand Challenges. In the pages that follow, we introduce the Grand Challenges defined for each of the SERC's core research areas in our recently approved and published SERC 2014-2018 Technical Plan. We also describe our accomplishments in accordance with our operational principles, and highlight the impactful research that we started, conducted, and completed over the past year.

Given the SERC's strong growth and significant impact achieved in its first five years, we look forward to continuing to conduct research toward the Grand Challenges, developing meaningful and impactful results, and expanding the benefits of those results across government, industry, and academia throughout the world.

SERC RESEARCH FOCUS AREAS

In coordination with its sponsors, the SERC has structured its research portfolio into the following four thematic research focus areas:



- **Enterprise Systems and Systems of Systems**—the evolving need of 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.
- **Trusted Systems**—the need for ways to conceive, develop, deploy, and sustain systems that are safe, secure, dependable, 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.
- **Systems Engineering and Systems Management Transformation**—the need for 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 to determine how and when to apply different strategies and approaches. Research must leverage the capabilities of computation, visualization, and communication so that systems engineering and management can respond quickly and agilely to the characteristics of these new systems and their acquisitions.
- **Human Capital Development**—the need to respond to the retirement of the baby boomer generation, the reduced numbers of US citizens entering the technical workforce and the new systems challenges facing technical staff. Research must determine the critical knowledge and skills that the DoD and Intelligence Community (IC) workforce require as well as the best means to continually impart that knowledge and skills.

SERC GRAND CHALLENGES

In developing the SERC 2014-2018 Technical Plan, the SERC and sponsors chose to use a Grand Challenges model. Grand Challenge problems were identified in each of the four SERC thematic research areas. The SERC Grand Challenges were formulated to provide:

- A point of integration between existing programs in each research focus area
- Opportunities to generate new, related research areas
- Inspiration and an integration point for non-SERC researchers to perform collaborative research
- Natural transition into use

The following table describes the Grand Challenge identified for each area, as well as the strategies planned to incorporate existing research and determine new research over the next five years.

Research Areas Icons

GRAND CHALLENGES AND STRATEGIES BY RESEARCH FOCUS AREA

ENTERPRISE AND SYSTEMS OF SYSTEMS (ESOS)

Create the foundational SE principles and develop the associated MPTs to enable the DoD and its partners to model (architect, design, analyze), acquire, evolve (operate, maintain, monitor) and verify complex enterprises and systems of systems to provide the DoD with an affordable and overwhelming competitive advantage over its current and future adversaries.

Model: Develop MPTs that allow quick and insightful modeling of enterprises/SoSs so that the effects of changes in policies, practices, components, interfaces, and technologies can be anticipated and understood in advance of their implementation.
Acquire: Develop MPTs that allow insight into enterprise/SoS acquisition approaches in the face of significant uncertainty and change to minimize unintended consequences and unforeseen risks.
Evolve: Develop MPTs that facilitate evolving and growing an enterprise/SoS, including insight into different architectural and integration approaches that facilitate evolution in the face of uncertainty and change in how an enterprise/SoS is employed, the technologies available to realize it, and the environment in which it exists.
Verify: Develop MPTs that allow the properties of an enterprise/SoS to be anticipated, monitored and confirmed during development and evolution, including an enterprise/SoS with legacy systems that are operational while development and evolution are underway.

TRUSTED SYSTEMS (TS)

Achieve much higher levels of system trust by applying the systems approach to achieving system assurance and trust for the increasingly complex, dynamic, cyber-physical-human net-centric systems and systems of systems of the future.

Design for System Assurance and Trust: Develop design patterns and systems architectures, with corresponding systems engineering principles guiding application, and associated design analysis MPTs for early assurance of needed properties.
Understand the Cost of Assurance and Ensure Cost-Effective Assurance: Develop MPTs that enable understanding, predicting, and ensuring the cost-effectiveness of implementing high-assurance policies and requirements, especially on complex systems and systems of systems.
Understand and Ensure Balanced Tradeoffs Between Assurance "-ilities" and Other "-ilities": Develop MPTs that enable understanding, predicting, and ensuring cost-effective relationships among assurance policies/requirements and other "iilities," such as usability, interoperability, and maintainability.
Measure System Assurance: Develop MPTs that allow measuring "how much" assurance of needed properties a system has, and that permit comparison of the relative assurance and trust provided by alternative systems.

SYSTEMS ENGINEERING AND SYSTEMS MANAGEMENT TRANSFORMATION (SEMT)

Move current SE and management away from sequential, single stovepipe, hardware-first, outside-in, document-driven, point-solution, acquisition-oriented approaches toward concurrent, portfolio and enterprise-oriented, HW-SW-human engineered, outside-in and inside-out, model-driven, set-based, full life cycle approaches. This will enable rapid, concurrent, flexible, and scalable evolution of the increasingly complex, dynamic, multi-stakeholder, cyber-physical-human systems and enterprises of the future.

Make Smart Trades Quickly: Develop MPTs to enable stakeholders to understand and visualize the tradespace and make smart decisions quickly taking into account how the many characteristics and functions of systems impact each other.
Rapidly Conceive of Systems: Develop MPTs that allow multi-discipline stakeholders to quickly develop alternative system concepts and evaluate them for their effectiveness and practicality.
Balance Agility and Assurance: Develop SE MPTs that work with high assurance in the face of high uncertainty and rapid change in mission, requirements, technology, and other factors, allowing a system to be rapidly acquired and responsive to both anticipated and unanticipated changes in the field.
Align with Engineered Resilient Systems: Align research to leverage both research and technology results of the Engineered Resilient Systems (ERS) program, and contribute to it; e.g., ERS efforts to define new approaches to tradespace.

HUMAN CAPITAL DEVELOPMENT (HCD)

Discover how to dramatically accelerate the professional development of highly capable systems engineers and technical leaders in DoD and the defense industrial base, and determine how to sustainably implement those findings.

Create and Provide Easy Knowledge Access: Make it easy for systems engineers to understand the SE discipline and to access the information needed to expertly perform SE, ensuring a workforce that can master the most important competencies.
Educate and Train Faster: Develop innovative approaches and technology to educate and train, engineers, systems engineers, and systems teams at all levels, as well as STEM students, much more rapidly, effectively and efficiently than with classical means.
Develop Effective Technical Leaders: Develop innovative approaches to educate DoD technical leaders with the right mix of technical, business, and enterprise skills.
Improve SE and STEM Education: Develop recommendations and curricula for the next generation of systems engineers, engineers and STEM students.
Track Progress: Track the changes in SE workforce demographics and performance over time to understand how the workforce is improving.

SERC OPERATIONAL PRINCIPLES AND ACCOMPLISHMENTS

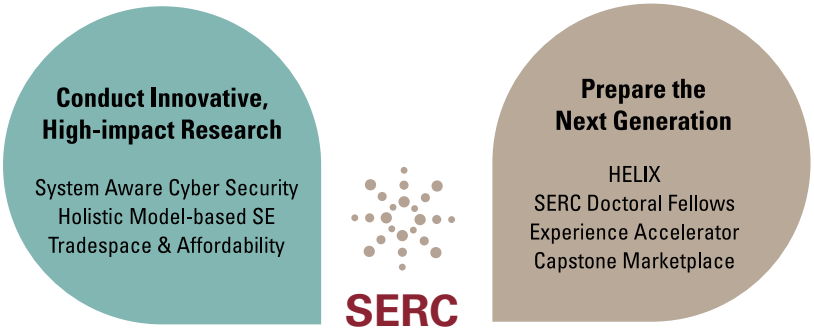
MESSAGE FROM THE DIRECTOR OF BUSINESS OPERATIONS

During 2013, the DoD completed its five-year review of the SERC and awarded a new $60 million 5-year contract that will run from September 2013 through September 2018. In that review, the government concluded that the SERC continues to satisfy an essential DoD need and that the SERC is executing well to deliver against that need.

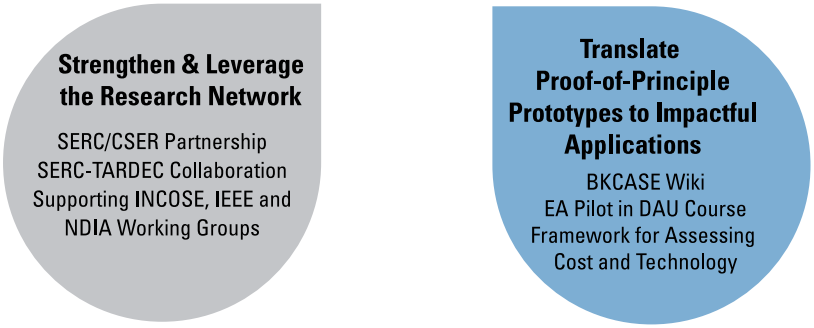
Since 2008, the government awarded the SERC $30.5 million to perform systems research, involving nearly 400 faculty, staff, and students from across the SERC Collaborators. That research spanned 38 projects focused on the SERC's four strategic research areas (see page 2 for more information). Those projects led to more than 100 journal and conference papers plus nearly 70 technical reports.

The SERC's ability to conduct long-term, impactful research has been greatly enhanced by this year's approval of the SERC's first five-year Strategic Technical Plan, coupled with our sponsor's commitment to provide $5 million annually as the foundation to implement that technical plan. That vote of confidence by Mr. Al Shaffer, the Acting Assistant Secretary of Defense for Research and Engineering, is an important strategic milestone in the SERC's history.

The SERC began performing a small amount of classified work in 2013. At the end of 2013, the SERC became poised to significantly expand its classified work in 2014 based on relationships nurtured with the military Services. The new SERC contract explicitly recognizes the added value that the SERC can deliver to DoD through classified work performed at a number of its university collaborators.



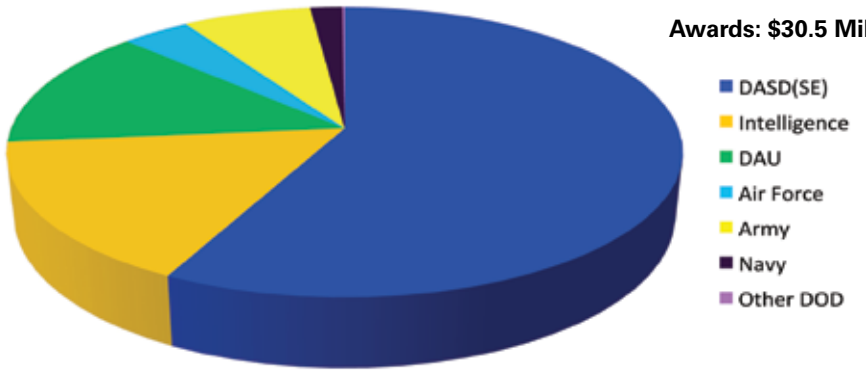
Example Achievements by Operational Principle



SUMMARY OF ACTIVITY BY RESEARCH FOCUS AREA

Focus Area	No. of Projects	Funding		Publications	
		$000's	%	Accepted Papers	Technical Reports
HCD	8	$18.8	42%	45	16
ESOS	5	$3.8	12%	14	12
SEMT	23	$11.5	38%	36	36
TS	2	$2.4	8%	6	5
TOTAL	38	$30.5		101	69

AWARDS 2008-2013



SERC RESEARCH HIGHLIGHTS

BKCASE® PROJECT *Completed Research*

PI: Dr. Art Pyster, Stevens Institute of Technology
Co-PI: Dave Olwell, Naval Postgraduate School
Sponsors: DASD(SE) Collaborators: Naval Postgraduate School

Following successful development and on-time release of the Guide to the Systems Engineering Body of Knowledge (SEBoK) and the Graduate Reference Curriculum for Systems Engineering (GRCSE®) by the end of 2012, the Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE®) project moved to operational and transitional phases in 2013.

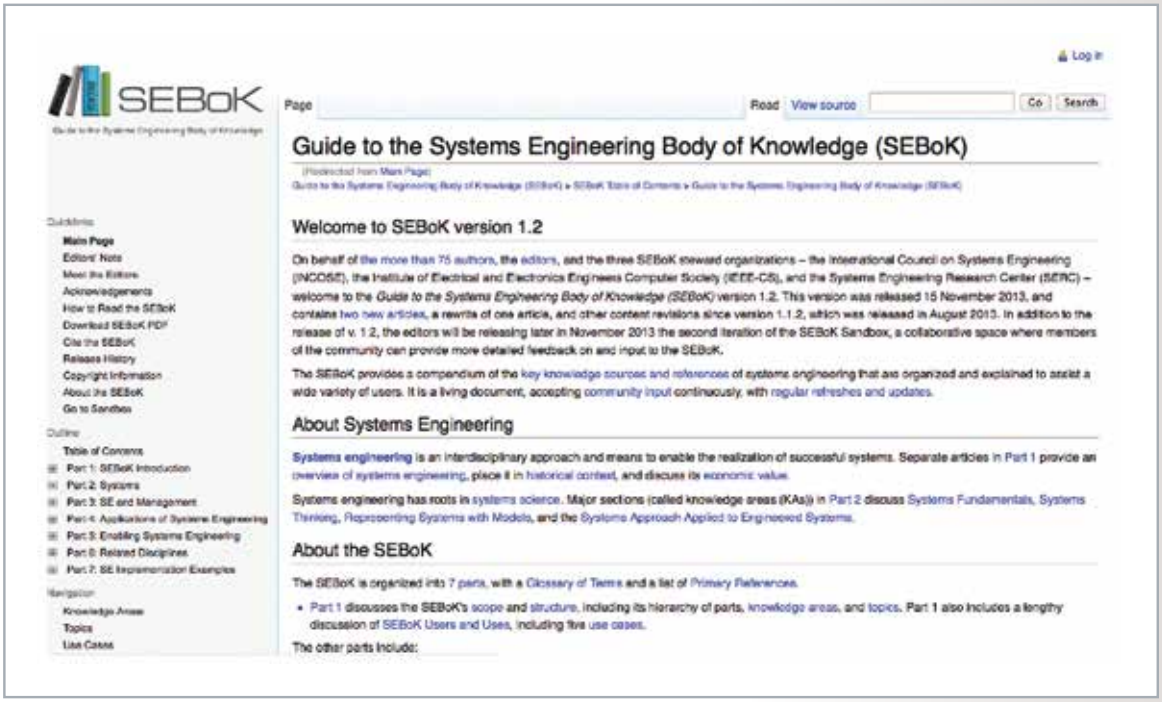
A governing board consisting of representatives from the SERC, INCOSE and IEEE-Computer Society took over joint-stewardship of the BKCASE project and its two products. A Memorandum of Understanding between these organizations marked a formal transition of BKCASE from being a research effort under SERC to a community activity led by the leading professional societies of systems engineering. A new editorial board was set up under the leadership of an Editor-in-Chief and Co-Editor-in-Chief. Associate Editors were recruited to the editorial board from around the world. Some were previously BKCASE authors while many were getting involved with BKCASE for the first time. Under the new governance structure, two minor releases of SEBoK were published in 2013, with updates to many existing articles and the addition of a few new articles.

Tens of thousands of systems engineers worldwide have accessed the SEBoK wiki since its September 2012 launch and many universities have begun looking to GRCSE for recommendations on how to launch a new graduate program or improve existing programs. The companion article "BKCASE Impact" describes more fully how the SEBoK and GRCSE are being applied around the world.

BKCASE® CONTACTS

BKCASE: www.bkcase.org
SEBoK: www.sebokwiki.org
Sandbox: www.sebokwiki.org/sandbox
GRCSE: www.grcse.org
E-mail: bkcase@stevens.edu

In 2014, the transition from SERC leadership to full collaborative leadership among the SERC, INCOSE, and the IEEE-CS will be complete. Stevens' Art Pyster will step down as Editor-in-Chief, the Naval Postgraduate School's Dave Olwell will step down as Co-Editor-in-Chief, and Cranfield University's Rick Adcock will become Editor-in-Chief. IEEE-CS will assume responsibility from the SERC for hosting the SEBoK wiki and INCOSE will take over marketing BKCASE activities and products.



SYSTEM AWARE CYBER SECURITY *Continuing Research*

PI: Dr. Barry Horowitz, University of Virginia
Sponsors: DASD(SE)
Collaborators: Georgia Institute of Technology

When defining new systems, the system engineer is called upon to find the combination of policies, processes (including human factors), and technologies that together create a system that satisfies system stakeholder objectives within the boundaries of real-world constraints. In some cases mathematically derived solutions that find optimum results are possible, but more frequently a mixture of mathematics, experimentation, technology availability, and experience serve to discover the desired solutions. The SERC has been called upon by the DoD to explore the possibilities for developing new systems that are focused on cyber security.

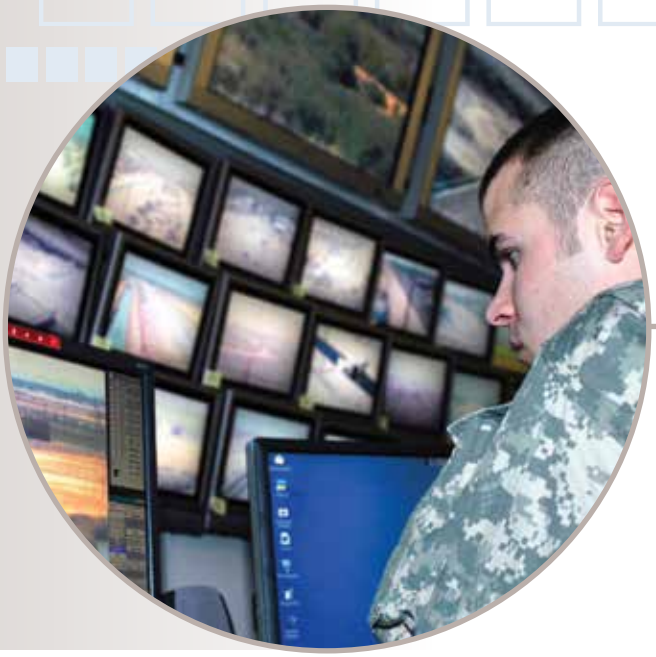
Recognizing that the current state of cyber security has focused on network security and securing the perimeter surrounding systems (e.g., authorizing and controlling user access, encrypting selected information that leaves or enters the system, authenticating users), the SERC response has been to explore the securing of applications (e.g., the combat systems, sensor systems, command and control systems). From a military perspective, securing applications can be looked at as "point defense," whereas network and perimeter security can be considered as "area defense." Adding point defense provides another layer of security to protect the most critical system functions from attackers who have penetrated the area defenses, and also can protect against insider attacks and supply chain attacks that are designed to bypass area defenses by being embedded within the system to be protected.

Led by the University of Virginia with significant support from Georgia Tech, the SERC research efforts regarding new systems for point defense have been called System Aware Cyber Security. This name was selected to recognize that point defense requires detailed understanding of the functions of the system to be protected as well as it's design, so that the most effective point defenses can be added to the already existing and continuously improving area defenses.

The System Aware research effort has focused on a particular mission area—the collection of surveillance information by autonomous surveillance systems on board unmanned aerial vehicles (UAVs) and the ground-based exploitation of that information. Within the constraints of scope surrounding the research, four types of systems have been considered for System Aware protection:

1) Airborne system, including the collection subsystem and the auto-pilot and surveillance control subsystem
2) Ground-based UAV pilot support system
3) A newly defined cyber attack response system, involving a cyber officer and other staff officers representing the mission objectives (e.g., surveillance officer, intelligence officer, UAV mission commander)
4) Data analysis system that supports interpretation of collected surveillance data

Consistent with the system engineering approach of combining policy, process, and technology to achieve a satisfying solution, the research has elements focusing on each of these areas. The integrated effort is approaching its fourth year and has gained interest from the DoD community, including co-funding from the Air Force and interested members of the defense industrial base.



SERC RESEARCH HIGHLIGHTS

SYSTEMS ENGINEERING CAPSTONE MARKETPLACE *Continuing Research*

PI: Mark Ardis, Stevens Institute of Technology
Sponsors: DASD(SE)
Collaborators: Air Force Institute of Technology, Auburn University, Georgia Institute of Technology, Missouri University of Science and Technology, Naval Postgraduate School, Pennsylvania State University, Southern Methodist University, University of Alabama in Huntsville, University of Maryland, University of Virginia, Wayne State University

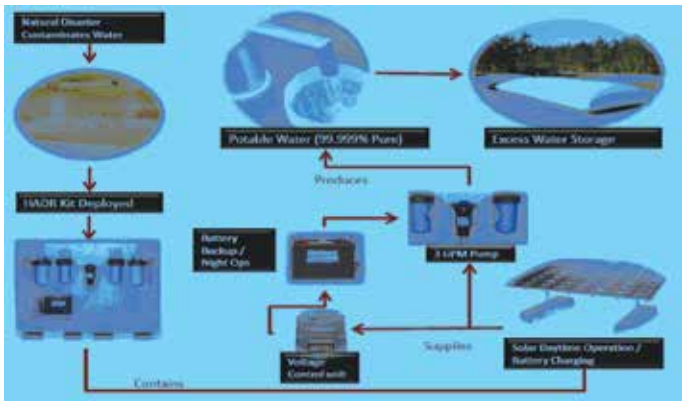
In the pilot year of the Capstone Marketplace, a team of students from the University of Alabama in Huntsville (UAH) worked with students at Stevens Institute of Technology to develop a Humanitarian Aid and Disaster Recovery (HADR) kit that can be deployed by means of a dual-use ferry. The project was targeted towards areas that experience frequent flood related disasters, such as Bangladesh. The ferry would be specifically designed to effectively and efficiently support logistics in a disaster situation while serving as a commercial ferry in normal conditions.

Mechanical and Aerospace Engineering students from UAH worked on the HADR kit, Naval Architecture students from Stevens worked on the ferry design, and Engineering Management (EM) students from Stevens were responsible for developing a Concept of Operations (ConOps) for a Dual-Use Ferry in a flood-induced disaster situation. The EM students also performed overall project management.

While the initial ConOps was useful in developing a strategy for the work of the sub-teams, a more detailed ConOps was created just for the HADR kit. In the event of a natural disaster, basic human requirements such as potable water flow are disrupted. Local water sources become contaminated with bacteria and viruses originating from common refuse and human waste. As conveyed through the ConOps graphic, the HADR kit was designed to be a self-contained, single operator, rapidly deployable unit that filters and purifies water. This detailed ConOps was a useful tool for students in developing their requirements and in testing their designs.

All three teams of students met with the project sponsors and mentors at the Washington, DC office of Stevens Institute at the completion of the project. The students presented their work and gave a demonstration of the HADR kit functional model. The US Navy sponsors were very pleased with the efforts and results put forth by the student teams.

This pilot project demonstrated that useful collaborations between engineering students at different schools can be formed through the Capstone Marketplace. It also provided valuable experience in conducting these types of multi-disciplinary projects. There are now six projects underway in the 2013-2014 academic year.



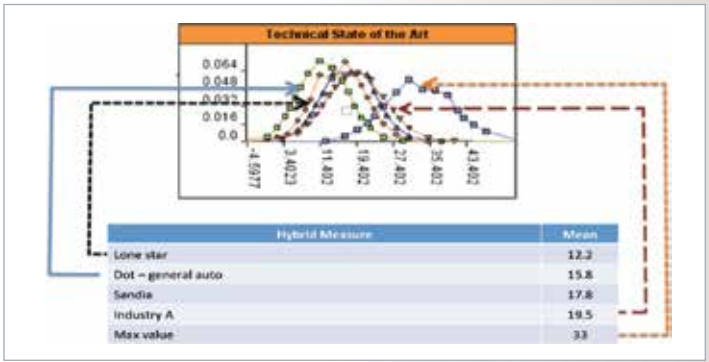
TRANSFORMING SE THROUGH MODEL-BASED SYSTEMS ENGINEERING *New Research*

PI: Mark Blackburn, Stevens Institute of Technology
Sponsors: DASD(SE) and NAVAIR
Collaborators: Wayne State University

The DoD and Naval Air Systems Command (NAVAIR) need to significantly reduce the time it takes to develop and deploy large-scale weapon systems. This research task focuses on a vision held by NAVAIR's leadership to assess the technical feasibility of creating/leveraging a more holistic Model-Based Systems Engineering approach to support this vision of Mission-based Analysis and Engineering in order to achieve a 20 percent reduction in time—reduce 15 years by at least 3 years. The research need includes the evaluation of emerging system design through computer models that can demonstrate system compliance to performance and design integrity requirements. The first phase of the effort should assess the technical feasibility of moving to a "complete" model-driven lifecycle and includes four tasks as shown in Figure 1.

A key goal is to leverage virtual designs that integrate with existing system data and simulations, as well as surrogates to support a more continuous approach to systems and systems of systems analysis of alternatives. Tradeoffs in this context will consider potentially non-optimal solutions that can close the gaps much more rapidly to support the warfighter's efforts in averting new or emerging threats. This should allow for proposing and rapidly evaluating solutions to the mission/capability gaps, significantly faster than in the current process, considering cost and time constraints and satisfying safety and airworthiness requirements.

A successful Phase 1 will likely result in a Phase 2 that would work towards an initial demonstration. The research will support SERC's Systems Engineering (SE) Transformation thrust and expand SE knowledge, document lessons learned in transitioning engineering organizations from document-based to model-based practices.



HELIX PROJECT *New Research*

PI: Dr. Art Pyster, Stevens Institute of Technology
Sponsors: DASD(SE), NDIA Systems Engineering Division

SERC initiated the Helix project in 2012, a multi-year longitudinal study designed to build an understanding of the landscape of the systems engineering workforce supporting the US Department of Defense (DoD). Helix is not focused on 'systems engineering' per se, but instead on the people who perform systems engineering. This distinction is important and permeates how the research is being conducted.

Helix focuses on three main research questions:

1. What are the characteristics of systems engineers?
2. How effective are systems engineers, and why?
3. What are employers doing to improve the effectiveness of their systems engineers?

In 2013, the Helix research team interviewed over 100 systems engineers from 7 organizations, both DoD and defense contractors. Interviews were semi-structured, engaging participants in a conversation for deeper exploration and understanding of their responses.

Interview data was analyzed qualitatively and quantitatively, using a grounded-theory based approach to find patterns and themes. Initial findings have been reported (see SERC Technical Report 2013-TR-038-2) on the following:

1. The most important traits and competencies of effective systems engineers
2. The greatest contributions of systems engineers
3. What makes systems engineers most effective
4. What makes systems engineers least effective
5. Potential risks to the systems engineering workforce

In 2014, the Helix team will return for follow-up interviews with previous participants, conduct interviews with a number of additional organizations that have shown interest, and continue to analyze the large volumes of data that are being collected. In 2014, Helix also expects to access and analyze two large data sets about systems engineers that have been separately developed over the past few years, and to position itself to begin to collect interview data in 2015 outside the US and outside the defense related community.

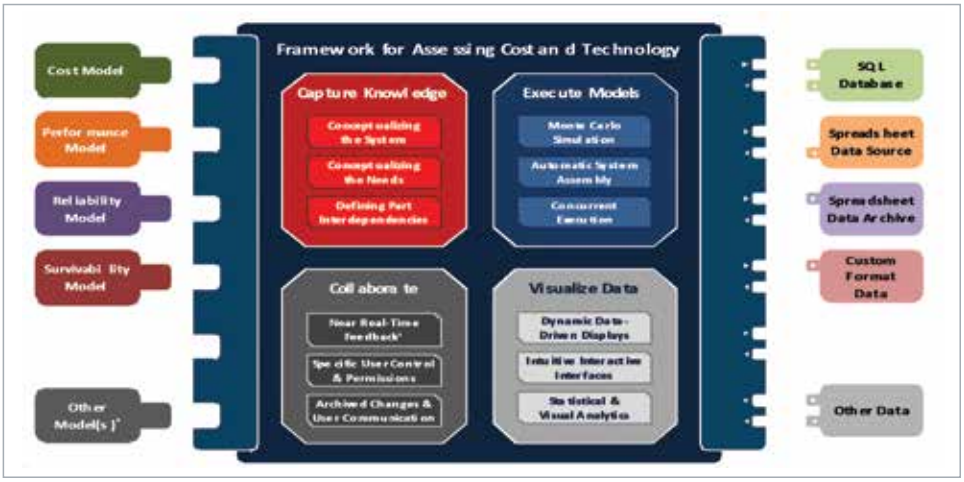
SYSTEMS ENGINEERING METHODOLOGY AND TOOL SUPPORT FOR MARCORSYSCOM *New Research*

PI: Daniel Browne, Georgia Institute of Technology
Sponsors: Marine Corps Systems Command

Beginning in early 2014, the SERC will support the Marine Corps Systems Command (MARCORSYSCOM) with the development of systems engineering methods and their instantiation within web-based tools to support active programs. The efforts will build on the existing Framework for Assessing Cost and Technology (FACT), which has been under continuous development since Spring 2011. FACT is a web-based, collaborative, systems engineering toolset designed to support Department of Defense acquisition and platform upgrade/retrofit programs. FACT enables users to integrate disparate models through a process of defining the system and needs via SysML. Users can then execute the models and conduct analysis using data visualization techniques.

SERC will work with MARCORSYSCOM to further develop FACT, exploring means to integrate FACT with execution of test scenarios via the Virtual World developed by the Naval Undersea Warfare Center. MARCORSYSCOM envisions an integrated chain of modeling and simulation tools to assist engineers in the design process from conception to fielding to eventual disposal. Integrating FACT with testing capabilities works toward the vision of an integrated suite of tools for supporting systems engineers. Additionally, SERC will be working with specific Marine Corps program offices to improve FACT capabilities for executing higher-fidelity models and to automate some of the proposal review process.

Finally, SERC will be exploring techniques for portfolio optimization. Decision makers need assistance in determining what set of off-the-shelf or existing technologies best meets the defined requirements within cost, schedule and/or other constraints. Portfolio management capabilities will be developed for the FACT suite of tools to enable tradespace analyses at the system level that feed into portfolio-level analysis.



SERC RESEARCH IMPACT

EXPERIENCE ACCELERATOR PILOT RESULTS

PI: Jon Wade, Stevens Institute of Technology
Sponsors: DASD(SE), DAU
Collaborators: Georgia Institute of Technology, Purdue University

An ongoing project, the Experience Accelerator (EA) capped its third year with a pilot use within a systems engineering class at the Defense Acquisition University. Five teams in the Systems Engineering 302 course used the Lead Systems Engineer experience software to guide an unmanned air vehicle program from Preliminary Design Review (PDR) to Critical Design Review (CDR). As shown in the flow graph, the students interacted with various non-player characters, made recommendations, and received information on the program progress based on those recommendations. Four six-month cycles were simulated in this manner. Then students used the results to recommend whether to go forward with CDR or slip the schedule. The student and instructor feedback emphatically validated the potential of the EA.

A number of the targeted lessons were clearly represented in the team presentations, an indication of the effectiveness of the EA in promoting its targeted learning outcomes. More importantly, the learners gained this understanding after only fully completing the first two phases of the experience. The EA was designed to be played multiple times by learners, so these results are truly impressive given the limited implementation of the experience.

Students liked the case-based format of the EA, noting its representation of real-life issues and modeling of real work interactions, and were enthusiastic about the user interface, identifying a number of additional features to extend the usability. Students also noted the importance of immediate feedback on the decisions and the interactive nature of the simulation—accelerating learning by simulating a project lifecycle in a short amount of time. The challenging aspect of the simulation was also highlighted as it was noted that failure kept the experience more interesting, a possible reference to the EA's intent to develop virtual "scar tissue"—an emotional connection in order to promote learning. Recommendations also provided insights on how to improve the EA, including a greater focus on performance and technical aspects as opposed to cost and schedule concerns.

TRADESPACE AND AFFORDABILITY

PI: Dr. Barry Boehm, University of Southern California
Sponsors: DASD(SE), USAF/SMC
Collaborators: Air Force Institute of Technology, Georgia Institute of Technology, Massachusetts Institute of Technology, Naval Postgraduate School, Stevens Institute of Technology, University of Virginia, Wayne State University

Several elements of the -ilities Tradespace and Affordability Project (iTAP) have resulted in funded requests from DoD organizations to SERC for further research in their areas of interest. The Air Force Space and Missile Systems Center has added funding and sources of data for extending USC cost models to address space systems operations and support cost estimation modeling. The Army Engineer Research and Development Center has provided DoD Engineered Resilient Systems funding to MIT for research in systems engineering knowledge management, and to Georgia Tech for extensions of its FACT tradespace analysis capability. The US Marine Corps has also added funding to Georgia Tech for additional extensions to the USMC version of the FACT system. Another round of exploratory discussions with the US Army Tank-Automotive Research and Development Command and Naval Sea Systems Command (NAVSEA) for joint research on set-based tradespace analysis and design ground vehicles and ships is underway, led by Wayne State and involving Georgia Tech, the Naval Postgraduate School, Penn State, and USC.

The INCOSE Affordability Working Group has expressed significant interest in the Georgia Tech-USC work on SysML Building Blocks for Cost Modeling. This research enables better knowledge capture, through modular, reusable, precise, maintainable, and complete units of SysML, that provides acausal modeling and is a key step towards affordability trade studies involving diverse -ilities.

PROGRAM-WIDE MULTI-DIMENSIONAL MODELING

PI: Mark Blackburn, Stevens Institute of Technology
Sponsors: FAA
Collaborators: Georgetown University

SERC research in modeling to support governance, analysis of alternatives, change impact, risk management, and performance in complex systems of systems is spawning applications in other systems engineering projects, including the FAA NextGen Air Traffic Control system. Based on previous work, the SERC will investigate, develop and refine a mixed-methodology that attempts to address System of System (SoS) challenges for a loosely coupled and continuously adapting SoS. This includes work to:

- Identify and model the factors associated with adaptive governance and adaptive management
- Identify and model the factors to increase understanding for more predictable schedule and cost for the Extended Enterprise
- Investigate and track benefit metrics—this can start with the metrics currently in place
- Model how changes to Governance and/or the Extended Enterprise impact Benefits
- Create multi-dimensional model(s) of the cross-cutting cause-and-effects relationships to support dynamic "what if" analysis

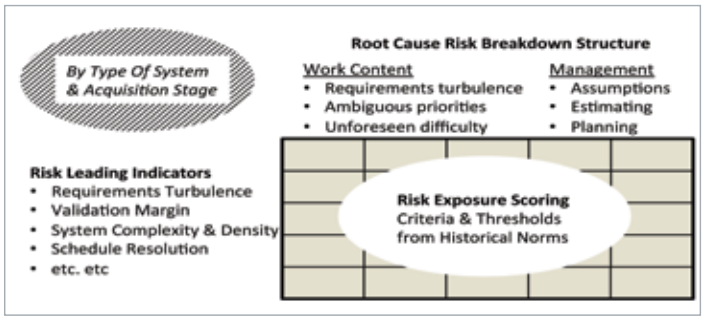
SERC-TARDEC COLLABORATION

PI: Walter Bryzik, Wayne State University
Sponsors: Army TARDEC

The US Army Tank-Automotive Research and Development Command (TARDEC) is a DoD leader in developing and applying Systems Engineering (SE) methods, procedures and tools (MPT) for Major Defense Acquisition Programs (MDAPs). TARDEC's Advanced Systems Engineering Capability (ASEC) is a web-enabled, life-cycle SE software framework designed around program decisions and informed by cumulative historical program experience. ASEC is being evaluated for use across the Army Research, Development, and Engineering Command and the other Armed Services.

The TARDEC-SERC collaboration, led by Wayne State University (WSU), is providing an unparalleled opportunity to demonstrate practicality, relevance, effectiveness, and suitability of SERC MPT for DoD MDAPs and integration into standard DoD acquisition practice. Since 2008, TARDEC and WSU/SERC have collaborated on multiple research tasks addressing current system acquisition issues, e.g. acquiring adaptable and extensible vehicles and families-of-vehicles, capability-suitability-affordability tradeoffs, and proactive risk management. TARDEC funds SERC research and matches with "in kind" resources. TARDEC personnel have received or are completing advanced SE degrees at SERC collaborator universities, including WSU and the Naval Postgraduate School.

A case-in-point is the research to enhance and complement traditional DoD risk management. This task studies early warning assessment of "conditions conducive to adverse outcomes" to inform decision makers of the risk-exposure impacts of alternative choices, and alert them to adverse



developments. The approach provides risk exposure estimates at the decision point, enabling decision makers to make risk-informed choices and proactively avoid unnecessary risk exposure.

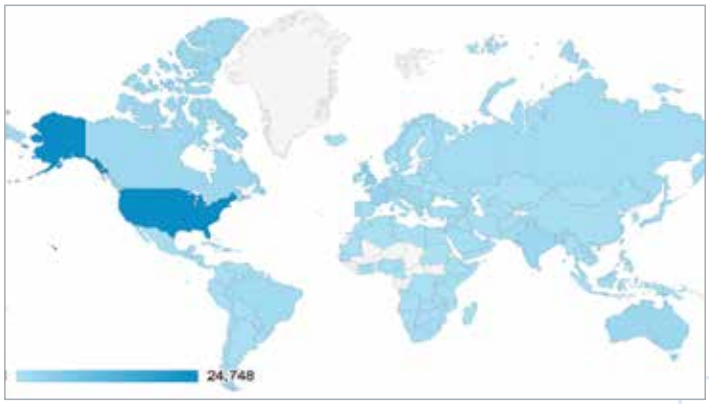
This complementary approach assesses the "risk health" of the program, adapting risk exposure assessment principles developed in commercial product development and engineering program management, financial and insurance underwriting, and medical care. TARDEC and WSU are actively collaborating to develop sets of "risk leading indicators" and evidence-based risk exposure scoring (analogous to credit scoring), linked back to major root cause concerns from the Performance of the Defense Acquisition System, 2013 Annual Report, DUOSD-ATL. Working with the Armored Multi-Purpose Vehicle (AMPV) Program Management Office and Risk Team, TARDEC-WSU/SERC has begun a pilot application of this risk management enhancement. The pilot will provide evidence of the relevance, practicality, and benefits to the program of early risk exposure scoring of alternative choices, as well as feedback to refine and enhance the MPT. At the same time, WSU/SERC is working with TARDEC to define functional and technical interface standards to integrate SERC SE tools into TARDEC's ASEC system.

IMPACT OF BKCASE® ON SE COMMUNITY

PI: Dr. Art Pyster, Stevens Institute of Technology
Co-PI: Dave Olwell, Naval Postgraduate School
Sponsors: DASD(SE) Collaborators: Naval Postgraduate School

The Guide to the Systems Engineering Body of Knowledge (SEBoK) is one of the most popular resources for the systems engineering community. Available at www.sebokwiki.org, in 2013 alone there were more than 60,000 visits to SEBoK with over 200,000 page views. As shown in the map, users have accessed the SEBoK from over 160 countries in 6 continents. In addition to individual users, organizations have begun to incorporate SEBoK into their in-house systems engineering training modules, and university faculty include SEBoK articles in their classroom readings.

INCOSE's next version of the Systems Engineering Handbook version 4.0, slated for mid-2014 release, will draw much of its new content from the SEBoK. Similarly, the next version of the ISO/IEC/IEEE 15288 standard is also expected to draw content from the SEBoK. The IEEE-Computer Society's draft competency model for software systems engineers draws material from the SEBoK to explain what software engineers should know about systems engineering. More than a dozen of INCOSE's technical working groups will regularly contribute to SEBoK updates, writing new articles and updating existing articles, and make ready reference to the SEBoK in their other activities and products. Overlapping authors and



editors among these significant community efforts provide for natural integration between these products.

Educational institutions in the US and Europe are using the Graduate Reference Curriculum for Systems Engineering (GRCSE®) to support their efforts in creating new graduate systems engineering programs or updating existing ones. Notably, one US university recently used GRCSE to help it prepare for an ABET accreditation visit for its master's systems engineering program.

SEBoK and GRCSE are playing a key role in harmonizing the efforts and resources of the community, towards building the discipline of systems engineering.

RESEARCH COUNCIL

ENTERPRISE & SYSTEM OF SYSTEMS

Dr. William Rouse
Director of the Center for Complex Systems and Enterprises, Stevens Institute of Technology

Dr. Dan DeLaurentis
Director of the Center for Integrated Systems in Aerospace, Purdue University

Dr. Jo Ann Lane
Co-director of the Center for Systems and Software Engineering, University of Southern California

HUMAN CAPITAL DEVELOPMENT

Dr. Dave Olwell
Chair of Faculty, Naval Postgraduate School

Dr. Jon Wade
Chief Technology Officer, SERC
Associate Dean for Research, School of Systems and Enterprises, Stevens Institute of Technology

TRUSTED SYSTEMS

Dr. Barry Horowitz
Munster Professor of Systems and Information Engineering and Chair, University of Virginia

Dr. Bill Scherlis
Director of the Institute for Software Research, Carnegie Mellon University

SYSTEMS ENGINEERING & SYSTEMS MANAGEMENT TRANSFORMATION

Dr. Barry W. Boehm
Chairman of SERC Research Council; Director of the Center for Systems and Software Engineering and TRW Professor of Computer Science, University of Southern California

Mr. Thomas A. McDermott, Jr.
Deputy Director and Director of Research, Georgia Tech Research Institute

PROJECTS WORKED IN 2013

PROGRAM	PROJECT
Research Category: Human Capital Development (HCD)	
Evolving Body of Knowledge	Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE®)
	The Helix Project (Workforce Evolution)
SE Technical Leadership Education	Developing SE Technical Leadership
	Capstone Research to Grow SE Workforce Capacity
	Army Systems Engineering Career Development Model
Experience Acceleration	SE Experience Accelerator
Research Category: Enterprise and Systems of Systems (ESOS)	
System of Systems Modeling and Analysis	Assessing Impact of Development Disruptions and Dependencies in Analysis of Alternative SoS
	An Advanced Computational Approach to SoS Analysis and Architecting using Agent-based Behavioral Modeling
	Multi-Level Socio-Technical Modeling
Enterprise SE and Modeling	Enterprise Systems Value-Based R&D Portfolio Analytics: Methods, Processes, and Tools
Research Category: SE and Systems Management Transformation (SEMT)	
Affordability and Value in Systems	Next-Generation Cost Estimation and Metrics for Software-Intensive Systems
	Tradespace and Affordability
	Engineering Resilient Systems
	Enterprise Architecture Tradespace Analysis
Quantitative Risk	Quantitative Technical Risk
Interactive Model-Centric Systems Engineering (IMCSE)	Graphical Concept of Operations
	Introducing Model Based Systems Engineering
Agile Systems Engineering	Agile-Lean Systems Engineering: Kanban in SE
Research Category: Trusted Systems (TS)	
Systemic Security	System Aware Cyber Security

SERC ADVISORY BOARD

The Honorable Michael Wynne, *Chair*
Mr. Wynne is a senior advisor to Stevens Institute of Technology and serves as the Chair of the Advisory Board for the Systems Engineering Research Center. He was the 21st Secretary of the Air Force, and before that the Undersecretary for Acquisition, Technology and Logistics in the office of the Secretary of Defense, both spanning 2001 to 2008. He served in the Air Force for seven years, finishing as assistant professor of Astronautics at the Air Force Academy. He spent three years with Lockheed Martin Corp as the general manager for Space Launch, and 23 years with General Dynamics working in aircraft, armored vehicles, and the space division. He retired as senior vice president from General Dynamics.

Lieutenant General Ted Bowlds
Lieutenant General Bowlds, US Air Force (Retired) was Commander of the Electronic System Center and Program Executive Office for Command and Control at Hanscom AFB, managing more than $3 billion in programs annually. The organization comprises more than 12,000 people located at six sites throughout the United States. Throughout his military career, General Bowlds has served in a variety of weapons system acquisition leadership positions to include flight test engineer on the F-117, director of avionics development for the B-2, program director of the C-17, and commander of the AF Research Laboratory. He is currently a member of the Mississippi State University Research and Technology Advisory Council and serves on Battelle's Air Force Market Sector (AFMS) Senior Advisory Group.

Dr. Ruth David
Dr. David is president and CEO of Analytic Services Inc. Prior to joining ANSER, she was Deputy Director for Science and Technology at the Central Intelligence Agency and was awarded the CIA's Distinguished Intelligence Medal, the CIA Director's Award, the Director of NSA Distinguished Service Medal, the NRO's Award for Distinguished Service, and the Defense Intelligence Director's Award. Dr. David is a senior fellow of the Defense Science Board, a member of the Department of Homeland Security Advisory Council, the National Security Agency Advisory Board, the Corporation for the Charles Stark Draper Laboratory, Inc., and the Hertz Foundation Board. She was elected into the National Academy of Engineering in 2002 and currently serves as a councilor of the NAE, chairs the National Research Council (NRC) Board on Global Science and Technology, chairs the NRC Standing Committee on Technology Insight–Gauge, Evaluate, and Review (TIGER), and is a member of the Standing Committee on Science, Engineering, and Public Policy (COSEPUP).

Mr. Alfred Grasso
Mr. Alfred Grasso is president and chief executive officer of The MITRE Corporation. He is responsible for developing and leading the corporation's overall strategic and business operations and cultivating key sponsor and customer partnerships. Mr. Grasso is also a member of MITRE's Board of Trustees. Mr. Grasso is a member of the Defense Science Board, vice chair of the Armed Forces Communications and Electronics Association (AFCEA) International Board of Directors. He is a special advisor to the STRATCOM CYBER Strategic Advisory Group.Mr. Grasso is the president of the Board of Directors of the National GEM Consortium, a nonprofit that works to promote the participation of under-represented groups in science, technology, engineering, and mathematics (STEM) careers.

Mr. John G. Grimes
Mr. Grimes served as the Assistant Secretary of Defense for Networks and Information Integration / Department of Defense Chief Information Officer from 2005 until 2009. Prior to that, he served on the White House National Security Council Staff as Director for National Security Telecommunications Policy; Director of Defense Command, Control and Communications Programs; and Senior Director White House Situation Support Staff. Mr. Grimes has served as Deputy Assistant Secretary of Defense for Defense-wide Command, Control and Communications and was the Deputy Assistant Secretary of Defense for Counterintelligence and Security Countermeasures. He is the recipient of the AIAA Command, Control, Communications and Intelligence Award, the 2010 AFCEA SARNOFF Award, and two U.S. Presidential Rank awards.

Major General Nick Justice
Major General Justice retired from the United States Army after serving over 42 years as an American soldier. He began his Army career as an enlisted soldier. His experiences opened new doors in high performance computing, electronic warfare, telemetry analysis, telecommunications, as well as experiences in legal and leadership in the infantry. Highlights of his career include assignments with NATO during Dessert Storm where he built command and control systems; Project Manager for Force XXI Battle Command Brigade and Below, fielding systems during Operation Iraqi Freedom; Program Executive Officer for Tactical Command and Control Systems; and the Commanding General of the Army Research, Development, & Engineering Command and the Aberdeen Proving Ground.

CAPT William M. Shepherd
CAPT Shepherd is a retired Navy SEAL and United States Astronaut. He was a SEAL platoon commander and operations officer. Shepherd was selected for the NASA astronaut corps in 1984. He completed three flights as a mission specialist on STS-27 Atlantis, STS-41 Discovery, and STS-52 Columbia, and was the commander of the Expedition-1 crew on the International Space Station. In 1993, CAPT Shepherd was assigned as the Program Manager for the International Space Station. He retired from active duty in 2002, and served at USSOCOM from 2008 to 2011 as Science Advisor, where he managed the Special Operations Forces' science and technology portfolio. Capt. Shepherd's awards include the National Intelligence Medal, NASA's "Steve Thorne" Airmanship Award, the Komarov Diploma, the Spirit of St. Louis Medal, the Gagarin Gold Medal, the Robert H. Goddard Trophy, and the Congressional Space Medal of Honor. Capt. Shepherd was recently designated "Honorary Naval Aviator Number 30" by the Chief of Naval Air Warfare.

ABOUT THE SERC

The Systems Engineering Research Center (SERC), a University-Affiliated Research Center of the US 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, including through the SERC Doctoral Fellows Program (see below).

Begun in 2008 and led by Stevens Institute of Technology and principal collaborator, the University of Southern California (USC), the SERC is 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.

BECOMING A SPONSOR

Since 2008 SERC research sponsors have benefited from research performed by nearly 400 faculty, staff, and students across the SERC Collaborator universities. Any US Government organization can benefit from the SERC by sponsoring systems research or by adopting the results of research sponsored by others.

Interested government organizations should contact the SERC's primary sponsor, the Deputy Assistant Secretary of Defense for Systems Engineering, to discuss their needs and determine if addressing them is within the scope of the SERC's mission. If it is, then the organization will refine those needs and the SERC will respond with its technical approach, cost estimate, and deliverables. The SERC will then select a principal investigator and a team of researchers to perform the work and deliver results and value to the funding organization. Unless specifically limited, results are published and available for inclusion in education and transition activities across the systems engineering community.

CONDUCTING RESEARCH WITH THE SERC

While the existing SERC collaborators already represent a significant portion of the systems and software engineering research talent in the United States, there are opportunities for other academic institutions to participate in SERC activities. To discuss this possibility, please contact a member of the SERC Leadership Team.

LEADERSHIP

Executive Director
Dr. Dinesh Verma,
Dean and Professor,
School of Systems and Enterprises,
Stevens Institute of Technology

Chief Operating Officer
Dr. Arthur Pyster,
Distinguished Research Professor,
School of Systems and Enterprises,
Stevens Institute of Technology

Chief Scientist
Dr. Barry Boehm,
Director of the Center for Systems and Software Engineering,
University of Southern California

Chief Technology Officer
Dr. Jon Wade,
School of Systems and Enterprises,
Stevens Institute of Technology

Director of Program Development and Transition
Dr. Mitchell Kerman,
Stevens Institute of Technology

Director of Business Operations
Ms. Doris Schultz,
Stevens Institute of Technology

SERC DOCTORAL FELLOWS PROGRAM

Built on a foundation of education and training, the SERC Doctoral Fellows Program consists of selected SERC Collaborator Universities and participating US based organizations that nominate and select employees to become PhD Students with a focus on systems-related research that is consistent with the SERC's vision. Based on their size and revenue, participating organizations sponsor a specific number of Doctoral Fellows each year. Fellows receive tuition reimbursement from their participating organizations and are allocated one work day per week to dedicate toward their doctoral studies and research.

The Program is now in its second year of operation and currently has three participating organizations—The Boeing Company; the US Army Armament Research, Development and Engineering Center (ARDEC) at Picatinny Arsenal; and the MITRE Corporation.

CONTACT

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Director of Program Development and Transition
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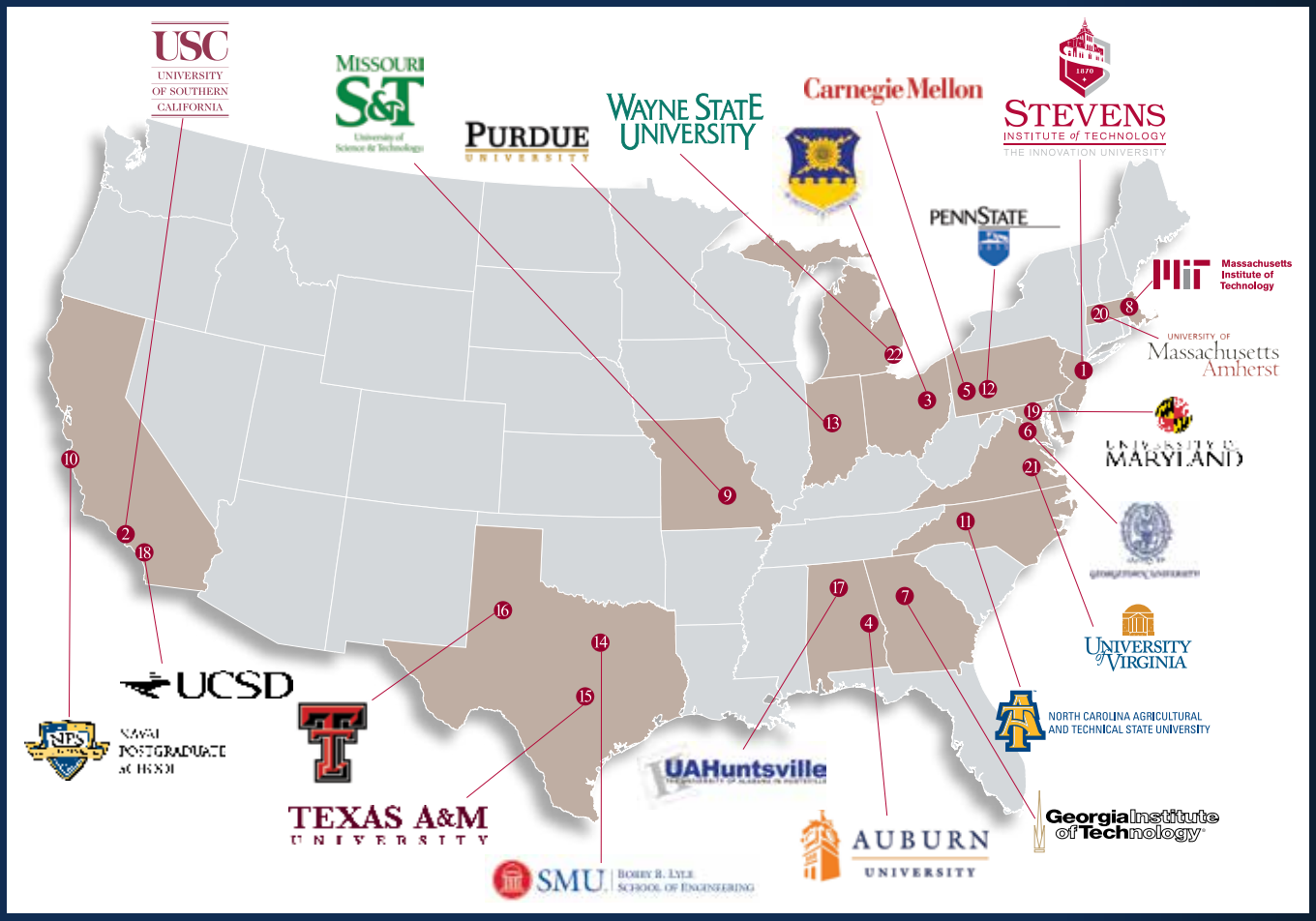
E-mail: mitchell.kerman@stevens.edu

BOEING MITRE



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. Pennsylvania State University
13. Purdue University
14. Southern Methodist University
15. Texas A&M University
16. Texas Tech University
17. University of Alabama in Huntsville
18. University of California - San Diego
19. University of Maryland
20. University of Massachusetts Amherst
21. University of Virginia
22. Wayne State University

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SYSTEMS ENGINEERING
Research Center

For more information about the SERC, please visit the SERC website at
www.SERCuarc.org