2014 ANNUAL REPORT

SYSTEMS ENGINEERING
Research Center

A U.S. DEPARTMENT OF DEFENSE
UNIVERSITY AFFILIATED RESEARCH CENTER

SYSTEMS ENGINEERING
Research Center

"Invention consists in avoiding the constructing of useless contraptions and in constructing the useful combinations which are in infinite minority."

Henri Poincare, French Mathematician, 1854-1912

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MULTIPLYING VALUE: TRANSITIONING SYSTEMS ENGINEERING RESEARCH

Systems engineering research succeeds when systems engineers create more value for their stakeholders. No matter what insights we achieve through our research, until they are implemented and validated by practicing engineers—actively improving the development and evolution of safe, reliable, useful systems—they are merely, per M. Poincare, "useless contraptions." It is understandable then, how transition from research to practice is integral to most SERC projects. There are many interwoven dynamics to transition. Rarely is transition easy, with clear applicability, rapid adoption, and impact both high and obvious.

Sometimes, in spite of the fuzziness of the issues or the intransigence of the problem, researchers develop impactful solutions to hard problems and deploy those solutions rapidly, incrementally, and neatly. Early success is both surprising and enjoyable. More often, though, research progress is halting, with premature enthusiasm for what becomes a dead end. Immature or too rapid deployment usually leads to disappointment and failure. Sarah Sheard's classic essay[1] describes this situation well, where "silver bullets", if fired by irrational adopters, can go astray and cause significant harm.

In most cases, research transitions slowly at the beginning, with a handful of early adopters taking a chance on unvalidated techniques and tools. Even if those early trials are successful, the research still must overcome social, economic, and technical barriers before it can become widely adopted. Challenges are even greater when the research runs counter to past practice and established mental models.

Conscious of these many challenges and with a goal to get combinations of useful research into the hands of practitioners and educators as rapidly as possible, the SERC approaches transition by applying these six principles:

1. Plan early, making successful transition an explicit goal from the outset.
2. Balance long-term high impact with short-term utility, incrementally delivering results.
3. Continuously engage users to improve utility and confirm validity.
4. Engage the community to create advocates and adopters.
5. Leverage partners to mature research into high-quality products and services.
6. Use SERC infrastructure and incentives to help projects transition.

This report presents a variety of ongoing and completed research work. Five projects are called out for significant progress in transitioning to the community and as examples of the transition principles: The SE Experience Accelerator, Technical Leadership, BKCASE, Next Generation Cost Estimation and Measurement, and –ilities Tradespace and Affordability programs.

[1] *Sheard, S., "Life Cycle of A Silver Bullet," CrossTalk, July, 2003. http://seir.sei.cmu.edu/sheard/Life%20Cycle%20Silver%20Bullet.pdf*

FROM THE EXECUTIVE DIRECTOR

It is with immense pride that I introduce the 2014 SERC Annual Report, which marks the conclusion of our sixth year of operation. This year's Annual Report focuses on the critical theme of "Research Transition." This perspective is consistently applied to all ongoing research within the SERC —given our ultimate objective to evolve and enhance the practice of systems engineering on projects and programs of critical importance to society in general, and national security in specific. As you read through this report, you will see clear examples of the pragmatic impact of SERC research.

This year, we have had some significant changes to the SERC Advisory Board. The Honorable Michael Wynne, our founding SERC Advisory Board Chairman, has stepped down and now serves as Emeritus Member of the board. Dr. Michael Griffin has joined our board and serves as Chairman, succeeding Mr. Wynne. We welcomed several members to our board this year: Major General Curtis Bedke, USAF (Ret.), Ms. Victoria Cox, Mr. David Long, and Dr. Stephen Rottler. We extend our deep gratitude to Mr. John Grimes, who has stepped down from the board at the conclusion of his term.

Our SERC Research Council has also expanded. Dr. Paul Collopy, currently Professor and Department Chair of Industrial and Systems Engineering and Engineering Management at the University of Alabama in Huntsville, becomes the 10th member of the Research Council, joining Dr. Barry Boehm and Mr. Tom McDermott as a Research Council member in the Systems Engineering and Systems Management Transformation focus area.

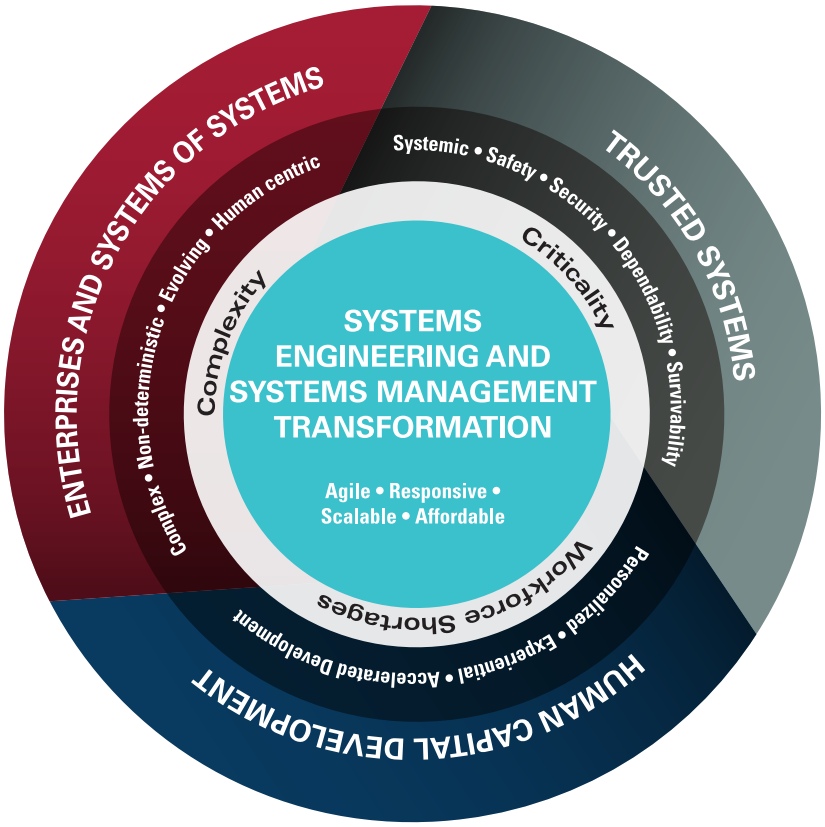
This perspective is consistently applied to all ongoing research within the SERC—given our ultimate objective to evolve and enhance the practice of systems engineering on projects and programs of critical importance to society in general, and national security in specific.

Collaboration and outreach are deeply ingrained in the SERC's 'DNA'. We continually form new relationships and strengthen existing ones to enrich our role as a networked national resource. Two of the most important relationships are with the International Council on Systems Engineering (INCOSE) and the National Defense Industries Association (NDIA). Many SERC researchers, both faculty and students, belong to INCOSE and contribute to its working groups, conferences, and workshops. SERC research has transitioned to many INCOSE corporate members. A dozen faculty from SERC Collaborating universities are INCOSE fellows. Additionally, SERC researchers routinely present much of their research at the annual NDIA Systems Engineering Division conference. Of equal importance, the SERC Capstone Research Project and Doctoral Fellows Program aid in the education of our country's next generation of systems leaders.

Dinesh Verma, Ph.D.
Executive Director

SERC RESEARCH FOCUS AREAS

The SERC research portfolio is structured into four thematic focus areas:



Research Areas Icons

Enterprises and Systems of Systems

Trusted Systems

Systems Engineering and Systems Management Transformation

Human Capital Development

Enterprises 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 that 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 Department of Defense (DoD) and Intelligence Community (IC) workforce require as well as the best means to continually impart that knowledge and skills.

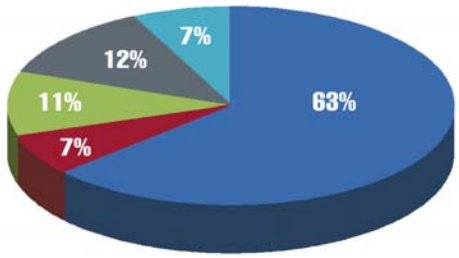
OVERVIEW

Since 2008, the SERC has received over $42.3 million in research awards ($12.8 million in 2014) involving nearly 500 faculty, staff and students from across the SERC Collaborators. That research spanned 48 projects and focused on the SERC's four strategic research areas. Those projects produced 140 journal and conference papers and 88 technical reports.

Research Category	Projects	Conference & Journal Papers	Technical Reports
Human Capital Development	11	48	25
Enterprises and Systems of Systems	5	39	14
Systems Engineering and Management Transformation	29	47	43
Trusted Systems	3	6	6
TOTAL	**48**	**140**	**88**

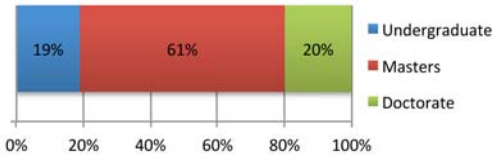
The SERC's ability to conduct long-term, impactful research has been greatly enhanced by the development of the SERC's first 5-year Strategic Technical Plan, approved in October 2013, together with our sponsor's commitment to provide $5 million annually as the foundation to implement it. The inclusion of the SERC funding in the National Defense Authorization Act, approved by Congress and signed by the President, is an important strategic milestone in the SERC's history.

2014 SPONSOR AWARDS



SPONSOR	2014
DASD(SE)	63%
DAU	7%
Army	11%
Navy	12%
Other DoD	7%

STUDENTS - 206 since the SERC began operation



SERC PROJECT INCUBATOR

In 2014, the SERC initiated the Project Incubator—a new method for identifying the best and brightest ideas emerging from our collaborators. While our DoD sponsors remain the SERC's primary "voice of the customer," exploiting innovative ideas from a wide range of sources is key to maintaining leading-edge capability. Support for new ideas in their infancy may create knowledge that proves critical to successfully responding to emergent challenges.

As described in the 5-year Strategic Technical Plan, each year, the SERC will issue an open call to its Collaborators to propose early stage research that can be nurtured by relatively small levels of seed funding. Preference will be given to proposals that either address issues not currently included in SERC research, or present novel approaches for current SERC research. The research should show strong potential for funding beyond the SERC core allocation. The most promising research topics will be selected for seed funding and those producing the best results will be considered for longer-term funding.

In 2014, 29 proposals were received and reviewed by the SERC Research Council using the selection criteria of Intellectual Merit, Clarity of Vision, Past Performance, and Potential Strategic Impact. The following lists the six projects selected for 2015; their results will influence the annual revisions to the SERC 5-year Strategic Technical Plan.

A Multilevel Framework of System Safety: Technical Failures, Human Factors, Organizational Culture, and Societal Influence
Mark Avnet, Texas A&M (PI), Tonya L. Smith-Jackson, North Carolina A&T (Collaborator)

Transitioning Systems Thinking to Model-Based Systems Engineering
Rob Cloutier, Stevens Institute (PI)

Detecting and Evaluating Technical Debt of Software Systems
LiGuo Huang, Southern Methodist University, (PI), JoAnn Lane, University of Southern California (Collaborator)

Formal Methods in Resilient Systems Design using a Flexible Contract Approach
Azad Madni, University of Southern California, (PI)

Foundations of Systems Engineering
Kevin Sullivan, University of Virginia, (PI), John Baras, University of Maryland (Collaborator)

Policies and Practices for Model-Centric Government-Industry Collaborative Environments for Systems Engineering and Development
Gary Witus, Wayne State University (PI), Mark Blackburn, Stevens Institute (Collaborator)

The SERC in Action

As discussed in the research overview, the SERC has grown steadily since its inception. In this section, we spotlight several research projects from each of the focus areas that were underway in 2014, and that illustrate the diversity of approaches, strategies, and outcomes of the SERC as a whole.

ENTERPRISES AND SYSTEMS OF SYSTEMS

ANALYTIC WORKBENCH: Assessing the Impact of Development Disruptions and Dependencies in Analysis of Alternative of System of Systems

ENTERPRISES AND SYSTEMS OF SYSTEMS

PI: Daniel DeLaurentis (Purdue University)

Sponsor: DASD(SE)

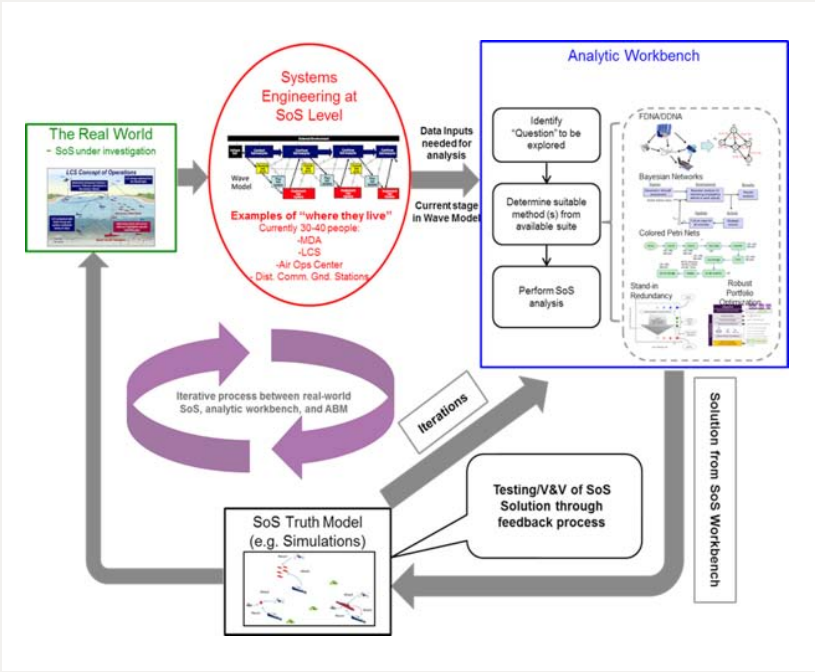
Partners: MITRE Corporation, Army Research Laboratory, Naval Surface Warfare Center Dahlgren Division (NSWCDD)

The development of a large group of interacting (but otherwise independent) systems, or System of Systems (SoS), presents significant challenges across technical, operational and programmatic dimensions. Trades between cost, schedule, performance, and consideration of various risks are essential during analysis of alternatives for evolving a SoS architecture (including selection of the systems that comprise it). Further, decisions are often made at the level of participating systems with insufficient consideration for cascading effects on the SoS. The large number of decision variables involved, variety of uncertainty sources, and complex interactions between systems create analysis problems that go well beyond the immediate mental faculties of decision-makers and necessitate the development and employment of new tools.

This project addresses the need for designing and evolving SoS architectures through tools that provide the SoS practitioner with meaningful analytical products related to these tradespaces. In the defense arena, guidance for such trades has been generally provided through handbooks such as the System Engineering Guide for System of Systems (SoS-SE). However, such documents fail to provide an analytic perspective or a set of tools for evaluating decisions.

Building on previous research, we seek to establish an analytic workbench—an organized set of computational tools that can aid practitioners in making decisions on evolving SoS architectures. Typical questions asked by SoS practitioners have been collected and mapped to methods/formulations appropriate to produce the desired analytical outputs. A key emphasis in the workbench approach is to relegate the difficult complexities in dealing with highly interconnected systems within an SoS to the methods, while empowering the decision-maker with the products expressed in understandable tradespace visualizations.

Efforts thus far have resulted in the generation of an initial prototype SoS Analytic Workbench that has been shared with our research partners for pilot study experimentation. Our continued efforts with collaborators will be critical to refine these tools, extending their use over a wide range of practitioners, while retaining their domain independence.



FILA-SoS: Flexible and Intelligent Learning Architectures for SoS

ENTERPRISES AND SYSTEMS OF SYSTEMS

PI: Cihan Dagli (Missouri University of Science and Technology)
Sponsor: DASD(SE)
Collaborator: Pennsylvania State University

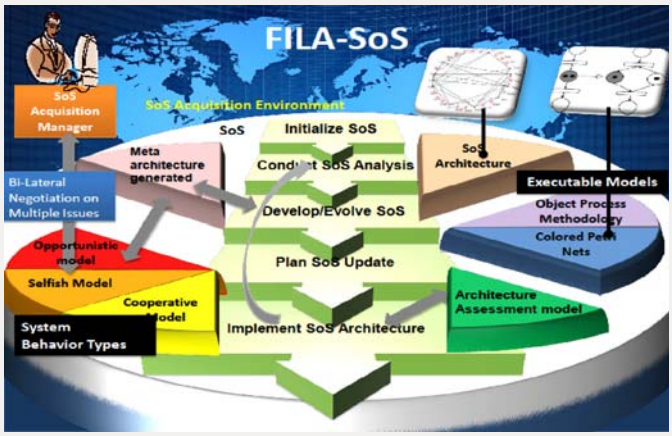
This project models the operation of Acknowledged Systems of Systems (ASoS). ASoS retain their own management, funding, and authority in parallel, and voluntarily work together to address shared or common interests. An integrated model is being developed as a decision making aid for ASoS managers. FILA-SoS, based on the wave model, uses a straightforward system definitions methodology and an efficient analysis framework to support speedy exploration and understanding of key trade-offs and requirements by a wide range of ASoS stakeholders and decision makers.

The FILA-SoS integrated model structure addresses four challenging aspects of SoS architecting:

1. Uncertainty and variability of the capabilities and availability of potential component systems
2. Evolution of the SoS needs, resources and environment over time
3. Differing approaches and motivations of autonomous component system managers
4. Optimizing SoS characteristics in an uncertain, dynamic environment with fixed resources

FILA-SoS also provides insight into the key questions associated with operating an ASoS.

- "What are effective collaboration patterns in systems of systems?" Since persuasion is key in managing ASoS, systems are allowed to negotiate with the SoS manager. Issues of concern include deadlines for preparation, funding, and performance required to complete the mission. Different combinations of behavior types assigned to the systems can help gauge the most effective collaboration patterns in systems of systems after the end of negotiations.
- "What are the roles and characteristics of effective SoS leadership?" This is addressed by incorporating views from multiple stakeholders while assessing the architecture's quality. Characteristics similar to those of an ASoS manager distributing funds and resources among systems for a joint operation are maintained in the integrated model. The ASoS manager also can consider likely future scenarios. This will improve the process of acquisition in terms of overall effectiveness, cycle time, and integrating legacy systems.
- "What are effective approaches to integrating constituent systems into a SoS?" The model addresses this by balancing the resources used and the degree of control exercised by the SoS manager on the constituent systems. The meta-architecture generation is approached as a multi-objective optimization problem and based on views of multiple stakeholders integrated together using a fuzzy inference engine. The constituent systems and the interfaces between them are selected while optimizing resources such as operations cost, interfacing cost, and performance levels.
- "How can SE address capabilities and requirements?" Organizations that acquire large-scale systems have transformed their attitude to acquisition, and want solutions to provide a set of capabilities, rather than a single specific system that meets an exact set of specifications. The systems selection process now ensures that each capability is provided by more than one system.
- "How can SE provide methods and tools for addressing the complexities of SoS interdependencies and emergent behaviors?" Autonomous behavior for each system is maintained through pre-assigned negotiation behaviors, operations costs, interfacing costs, and performance levels. Net-centric architecture is encouraged and several communication infrastructures are supported.



FILA-SoS is an integrated model for addressing the complexities of SoS interdependencies and emergent behaviors. Potential applications include modeling a wide variety of complex systems models such as logistics and cyber-physical systems. Examples include transportation, health, energy, economic institutions, and communication infrastructures. It also provides a test-bed for decision makers to evaluate operational guidelines and principles for managing various acquisition environment scenarios. These complex entities comprise socio-economic and physical systems undergoing rapid, dynamic change. Capabilities currently in progress are extending the model to include multiple interface alternatives among systems and incorporation of risk models into environmental scenarios. The 17 volumes of FILA-SoS project reports span the various aspects of the integrated model.

POLICY FLIGHT SIMULATOR: Methods and Tools for Dynamic Enterprise Systems Analysis

ENTERPRISES AND SYSTEMS OF SYSTEMS

PI: Michael Pennock (Stevens Institute of Technology)
Sponsor: DASD(SE)
Collaborator: Georgia Institute of Technology

Many of the challenges that confront the DoD today are characterized by the intersection of complex social, political, economic, and technical phenomena. Examples include:

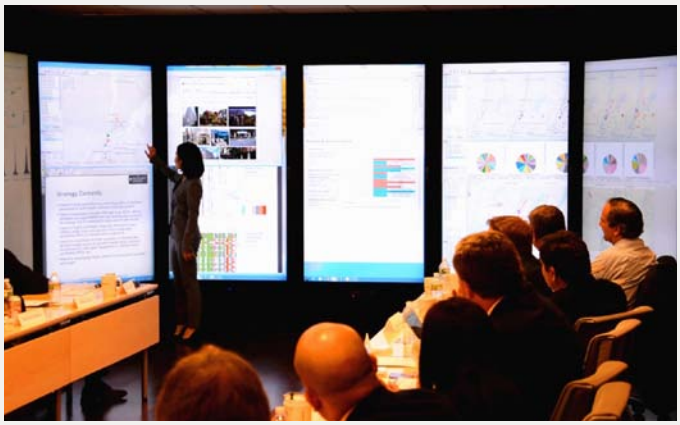
- Managing joint and international acquisition programs
- Coordinating disaster and humanitarian responses involving governments, NGOs, and US agencies
- Sustaining the defense supplier base in the face of declining acquisition quantities

Each of these situations involves the interaction of independent organizations with differing objectives with direct impacts on the performance, operation, and sustainment of technical systems. In other words, one cannot consider the problem of interest without considering the enterprise as a whole. When dealing with such situations, policy makers and decision makers would like to have a policy "flight simulator" that would allow them to:

- Explore the salient features of the enterprise
- Identify the key drivers of system behavior and resulting outcomes
- Perform "what if" analyses
- Evaluate the efficacy of policy options to alter system behavior and outcomes
- "Test drive" the future
- Allow key stakeholders to experience the behavior of the "to be" system

The impediment to building such a policy flight simulator is that simulating the implications of a policy choice cannot be accomplished via physics-based models as one would use to simulate flight. Instead, a policy flight simulator requires consideration of multiple problem layers including organizational, economic, and political. These areas are notoriously resistant to accurate simulation. Consequently, the objective of the Policy Flight Simulator is to develop methods and tools to allow policy makers, decision makers, and analysts to employ a policy flight simulator while acknowledging and actively managing the associated limitations.

During a previous research task, a 10-step methodology was developed to selectively model a complex enterprise problem. For this research task, that methodology was applied to a case study of interest to DoD, the intrusion of counterfeit parts into the defense supply chain. The result was a simulation that integrated multiple views of the defense supply enterprise, including the structure of the defense supply chain; the capabilities and behaviors of enterprise actors such as prime contractors, suppliers, and counterfeiters; DoD and law enforcement policies; as well as macro-economic and geopolitical factors. The simulation allows policy makers to perform "what if" analyses regarding the consequences of various anti-counterfeiting policies. The simulation was developed based on multiple roundtable discussions with stakeholders and experts in counterfeit parts from both government and industry.



The counterfeit parts case study serves as a test case to develop more general enterprise modeling methodologies that explicitly consider the limitations intrinsic to modeling enterprise systems. Specific methods under development include:

- Approaches to visualize enterprise problems that allow decision makers to consider multiple perspectives simultaneously
- Methods and guidelines for drawing inferences from multiple models and simulations that capture different aspects of the same enterprise (e.g., physical, organizational, economic, etc.)
- An enterprise strategy framework that allows decision makers to optimize, adapt, or hedge a policy option based on the level of knowledge available to them

It is anticipated that follow-on work will involve applying the enterprise strategy framework to the counterfeit parts case study and transitioning it to use within the DoD, refining visualization approaches, developing methods for managing enterprise model risk, and expanding the enterprise strategy framework.

TRUSTED SYSTEMS

SYSTEM-AWARE SECURITY: A Cybersecurity Prototype for a Cyber-Physical System

TRUSTED SYSTEMS

PI: Barry Horowitz (University of Virginia)

Sponsor: DASD(SE)

Collaborators: Georgia Institute of Technology, Air Force Institute of Technology

Partners: The MITRE Corporation, Virginia Commonwealth University

The current state of cybersecurity practice emphasizes securing systems through protection techniques deployed around their perimeters (firewalls, access control via authorization and authentication techniques, encryption, network security techniques, etc.). However, over the past several years, new types of cyber attacks that were embedded inside of systems emerged as important risks that perimeter protection solutions were not addressing; in addition, there have been a number of important successful cyber attacks against systems that managed to evade the in-place perimeter protection mechanisms. As a result, four years ago the University of Virginia started the System-aware Security project to explore security measures that would be embedded within systems.

The System-Aware Security project is based on real-time monitoring of systems by a highly secured Sentinel integrated into the protected system—a Sentinel that detects attacks, deflects attacks, rapidly restores a system after a successful attack, and all before significant harm is done. The Sentinel is designed to recognize illogical system activities based on the intended design and configuration of the protected system and to determine if these behaviors are the result of a cyber attack. The research focuses on developing new approaches that could protect software-controlled physical systems as well as information systems.

By the fall of 2013, the project had advanced to the point where the DoD sponsors were interested in developing a rapid prototype Sentinel-based protection system for an autonomous video surveillance system on board an unmanned air vehicle (UAV). In collaboration with the Georgia Institute of Technology, with Mike Heiges as lead investigator, and with support from an emerging cybersecurity-focused electronics company (SiCore), a prototype Sentinel-based cybersecurity system was designed, developed, and evaluated in flight.

A set of cyber attacks were designed, developed and deployed for use in the flight tests, enabling disruption of the UAV's intended surveillance mission. Specific attacks were designed and implemented so that surveillance of sensitive areas would be negated. The implemented cyber attacks ranged from taking control of the UAV through attacks on the navigation subsystems (GPS, autopilot control system), to taking control of the camera-pointing subsystem for control of the video cameras on the UAV. Using a number of reusable designs for providing cybersecurity via a secure Sentinel, the flight evaluations showed that highly disruptive attacks could both be detected and avoided through use of the Sentinel-based solutions. These results led to an effort to look at issues related to coordination of individual Sentinels that are protecting cooperating systems and to explore techniques for decision support regarding prioritization of system functions to be protected. In addition, a radar system cybersecurity prototyping effort employing the System-Aware concept is in the planning stages, with a goal of gaining a better understanding of the value of designing new systems accounting for considerations of how they would be monitored and protected from cyber attacks.

(http://www.uasmagazine.com/articles/891/university-of-virginia-research-protects-uas-from-cyber-attackers)

SYSTEMIC ASSURANCE: Achieving More Assurance Cost-Effectively

TRUSTED SYSTEMS

PI: William Scherlis (Carnegie Mellon University)
Sponsor: DASD(SE)
Collaborator: None

Systems cannot be deployed until customer organizations judge them fit for use in the mission environment. These assurance judgments must be based on evidence that a system manifests the necessary functionality and does so at a level of quality and security appropriate to the operating environment.

The Systemic Assurance project, now in its initial phases, focuses on improving both the level of assurance obtainable and the cost-effectiveness of assurance-related effort, with a goal of rapid recertification to support evolving components and systems. The project combines technical analysis of system artifacts and requirements with architecture techniques to promote assurance and resiliency. The team includes eight faculty leaders and several graduate students.

The extent of the assurance challenge is growing rapidly:

- More systems involve complex integrations of hardware, software, and human operators. Reliability is influenced by how software responds to hardware faults and human errors.
- Systems should degrade gracefully when under attack rather than fail outright.
- The operating environment involves interlinking with other systems, working in coalitions, relying on civil infrastructure, and use of personal devices.
- Modern systems, such as mobile and big-data, rely on extensive libraries and frameworks with rich supply chains. These architectures expose attack surfaces within systems.
- Systems are more autonomous, with some rules of engagement embodied in the system and evaluators taking more responsibility for assuring rule compliance.

There are four technical themes for our work in advancing assurance capability.

- **Evidence and traceability:** Facilitate early validation by accumulating assurance-related evidence and creating traceability structures during development.
- **Requirements, architecture, composition, variabilities:** Address assurance goals in the earliest phases of development. Enable composition of assurance judgments for components into overall judgments for systems.
- **Direct analysis:** Use semantics-based techniques to enhance confidence and scalability, focusing on challenges significant for modern systems, such as: framework protocol compliance, highly versioned systems, automatic defect repair, and safe concurrency.
- **Combined methods:** Integrate multiple methods to evaluate quality attribute requirements for heterogeneous systems, combining informal and formal, static and dynamic, and development and operational monitoring.

The project builds on a baseline examination of a sample of existing practices for acceptance evaluation. DO-178C, for example, which is used by the FAA and other authorities, potentially supports traceability, model-based techniques, formal methods to complement testing, and object oriented technology. The NIAP Common Criteria, another example, evaluates security attributes of designs against intended mission security needs.

We are identifying meta-criteria for both the baselining and the advanced assurance techniques being developed by the team. Candidate criteria include:

- Specific technical quality attributes addressed and overall level of quality attainable and assurable for each
- Reliability/validity of results – from sound verification to heuristic correlates
- Phases where evaluation activities are undertaken – ranging from early (requirements and architecture) to after-the-fact
- Access required by evaluators to supplier intellectual property and artifacts
- Role of evaluation considerations in architectural decisions and implementation choices
- Role of process indicators versus direct examination of development artifacts
- Reusability of evidence from prior evaluations for incremental re-evaluation and recertification
- Diversity of evidence to support judgments
- Up-front investment (tooling, training) and ongoing cost (based on complexity and scale)
- Benefits to cost and schedule; enhancements to engineer productivity and risk management
- Composability of results for components, libraries, and frameworks in evaluating aggregates
- Support for ecosystems (mobile devices, big-data analytics, graphical interaction, etc.)

SYSTEMS ENGINEERING AND SYSTEMS MANAGEMENT TRANSFORMATION

RISK EARLY WARNING: Practical Approaches to Identify and Quantify Early Sources of Acquisition Program Technical Risk

SE AND SM TRANSFORMATION

PI: Gary Witus (Wayne State University)

Sponsor: DASD(SE)

Collaborator: Stevens Institute of Technology

Partners: PEO Ground Systems, U.S. Army TARDEC

This research develops, prototypes, and pilots practical and relevant risk early warning methods, procedures, and tools for acquisition programs. Focusing on the Technology Development and Engineering and Manufacturing Development stages, evidence extracted from standard program and system development contract data and reports will form the basis for analysis. Risk early warning combines cost, schedule, and system development data to assess integrated risk exposure. Risk exposure defines the degree to which unforeseen future events, unrecognized past events, and normal variances due to uncertainty have amplified adverse consequences. Risk exposure warning is based on understanding the causal chains from root causes to adverse outcomes, and how evidence of problems manifested in standard program and system development data and reports. Secondary objectives are to identify sources of risk injected prior to contract award, and evidence-based indicators of risk exposure.

A review of the literature on system development leading indicators, causal mechanisms from root causes to adverse outcomes, risk leading indicators, and root causes of adverse acquisition outcomes provides the basic groundwork for this research. At the same time, we examine in depth the Request for Proposal packages original source material across several major ground vehicle acquisition programs to answer the following questions:

- What risks are considered, how risks are considered, and what risk indicators are used in proposal evaluation, program execution, and in making cost, schedule, and technical performance tradeoffs?
- What program management and system development data and deliverables could provide evidence to compute risk leading indicators and calibrate risk estimating relationships?

Integrating the results of these studies will support developing a set of practical and relevant risk leading indicators that can be computed from standard proposal and contract artifacts. Additionally, guidelines and recommendations will be developed for the specification of Integrated Master Plan events, and other contract reporting requirements. These will aid the collection of standard reporting artifacts that represent incremental technical progress and can be tracked and correlated to identify integrated time, cost, and technical performance outcome risks, with timing and resolution suitable for risk exposure early warning.

The research will identify potential risk sources, causal mechanisms and leading indicators addressing risks injected into the program prior to contract award in the concept development work and the development of the Request for Proposal package.

We will review and coordinate the findings with the TARDEC SE risk team for practicality and relevance, and for transition to the Integrated Systems Engineering Framework suite of tools. Additionally, in collaboration with TARDEC SE and PEO Ground Systems, a pilot study will be conducted on a ground vehicle acquisition program. This will "stress test" the methods, processes, and tools, demonstrate value, and identify candidate outlier detection and regression modeling approaches suitable for risk estimating relationships.

The results of this research will be applied initially by US Army TARDEC in coordination with PEO Ground Systems. For more information, see Gary Witus et al., "Risk Leading Indicators For DoD Acquisition Programs," Proceedings of the NDIA Ground Vehicle Systems Engineering and Technology Symposium, Livonia, MI, Aug 12-14 2014.

iTAP: ilities Tradespace and Affordability

SE AND SM TRANSFORMATION

PI: Barry Boehm (University of Southern California)

Sponsors: DASD(SE), USAF/SMC, US Navy

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

iTAP continued its 2013 role as a major source of complementary funding to its SERC core funds, with significant support to Georgia Tech from the Navy for extensions of its FACT and modeling infrastructure capabilities, and to USC and the UVa for extensions of their formal approaches to the definitions of and relations among a system's various ilities. The USC, MIT, and UVa Foundations efforts are coalescing into a much-needed ontology for the currently-chaotic state of ility definitions and relationships, which are frequently the source of major DoD system acquisition and life-cycle overruns and performance shortfalls.

The Wayne State, Penn State, NPS, and GT approaches to set-based design are progressing in concert with NAVSEA and TARDEC. AFIT and NPS are collaborating with their Air Force and Navy counterparts in applying architecture frameworks such as Monterey Phoenix to the design and evaluation of the ility aspects of ISR drones. In partnership with USAF-SMC, Aerospace Corp., and the INCOSE Affordability working group, USC and NPS are developing next-generation versions of their systems and software engineering cost models, which will then be used to extend the USC-GT collaborative effort to integrate the cost models with SysML-based architecture models. The resulting capability addresses several of the Better Buying Power objectives, including setting realistic affordability constraints and should-cost targets, providing the basis for formulaic incentives, and supporting better cost-value-risk tradespace analyses.

AGILE SE MANAGEMENT: Identifying, Validating, and Transitioning Adaptive SE, SwE, and SM Concepts

SE AND SM TRANSFORMATION

PI: Richard Turner (Stevens Institute of Technology)

Sponsors: DASD(SE), IC

Collaborators: Auburn University, University of Southern California, Carnegie Mellon University

In 2011, SERC sponsors identified four critical problems in SE management:

1. Failure of complicated integrated master schedules and plans to provide effective management within a large, evolving operational SoSs
2. Inability of scarce SE resources to support schedule-driven projects.
3. Decisions made late or at a level removed from the context
4. Lack of status visibility at the scale of SoS capability developments where multiple organizations are developing individual projects without close inter-project communication

The SERC postulated that on-demand scheduling techniques successfully adapted in software development could mitigate some of these issues, resulting in a two-year investigation into value-based scheduling, new ways of providing SE services, and shared knowledge concerning the value of work.

Our ongoing work seeks validation of those concepts and effective transition of successful approaches to government and industry. The team intends to demonstrate that scheduling and flow mechanisms successful in software, product development, and manufacturing, could be similarly effective in large systems of systems. To discover and compare effectiveness, the team will independently experiment with various combinations of organizational structure and dynamics; work flow in terms of content, resources required, value and variation of arrival rate; and governance mechanisms at all levels that implement flow management and value sharing strategies.

Two integrated tasks are working to achieve this goal.

- **Agile/Lean Enablers for SE:** The team is continuing to research and refine its understanding of enablers identified in earlier work. The team is also intentionally seeking other adaptive methods, processes, and tools to triage their potential value to SE, and where appropriate, define them sufficiently to simulate them.
- **Demonstration and Analysis Tool for Agile SE Management (DATASEM):** The centerpiece and persistent result of this work is a web-available, simulation-based sandbox tool to validate, study, and demonstrate to decision makers the benefits and risks of these adaptive management approaches. With it, the team can show if the new approaches work, where they work, why they work, and how they interact. The team wants to investigate the human and organizational factors involved when applying the approaches. Most importantly, the team wants to provide many types of organizations the ability to "try before they buy." Initial work will address value-driven, flow-based management and Systems Engineering as a service across a set of differing organizational structures. The current DATASEM architecture uses domain-specific language, coupled with implementation software, to describe organizational, flow, and governance models. Both discrete event and agent-based simulation environments will be used. Additional tools will be developed to allow organizations to define organizational-specific experiments.

PMAT: Portfolio Management and Analysis Tool

SE AND SM TRANSFORMATION

PI: Daniel C. Browne (Georgia Institute of Technology)
Sponsor: Marine Corps Systems Command
Collaborator: None

Management of a portfolio of capabilities, generally realized in a suite of physical systems, is a common problem faced by the agencies and programs within the DoD. Standardized methods of tackling these problems have been developed through a focus on sound SE principles and tools. However, no tool exists to support the standard process. Separate tools are often developed for each SE effort; these tools may or not be reused by future teams.

This limited reuse of tools is a primary motivator of this research. The goal is to capture the standard SE process and develop a toolset that allows the team to focus on the analysis, instead of the management of tools and processes. The result is the Portfolio Management and Analysis Tool (PMAT) that leverages SE standards, a browser-based front end, and open-source software to create a framework for portfolio development and analysis. The PMAT separates the portfolio management process into modules; this allows the user and a SE facilitator to work together to accomplish the following:

- State the problem and define requirements
- Manage data
- Analyze and explore options

Requirements. The Requirements Development and Analysis module specifies the problem statement, creates high-level capabilities, and produces a set of well-defined requirements. The module keeps a complete history of the drafts and revisions of the problem statement. Additionally, the user may make notes, refer to external documents, add important terms to a glossary, and assign responsibilities.

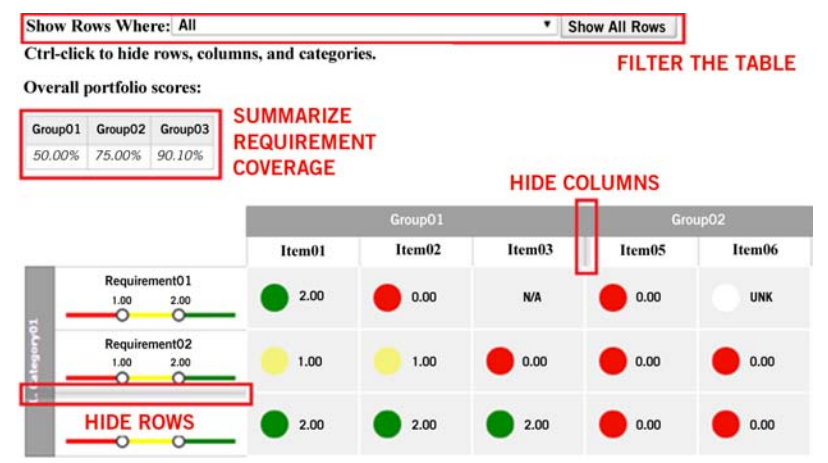
Ultimately, the product of this module is a set of well-defined requirements. This means that requirements are traceable, current, unambiguous, prioritized, and verifiable. The module assists the user wherever possible in creating these. For example, the notes and revision history help to trace the origins of each requirement. Requirements are prioritized according to a user-defined scale (e.g. blocker, critical, major, minor, or trivial). The module captures the verification method and a detailed description of the verification plan.

Data. The flexibility of the software allows external data to be considered in the analysis, even when the format is complex. This includes custom spreadsheet data and complicated text files. A parser processes the data into a usable format and outputs basic checks. The automation allows the user to better focus on data quality.

Analysis. The PMAT analyzes and compares portfolios. The analysis is limited only by the available data sources. For example, a stoplight visualization displays the requirements coverage of each portfolio (see image).

Future extensions to the PMAT capabilities include:

- The Survey Builder converts well-defined requirements into a market survey form. Forms are distributed to subject matter experts to be completed in a web interface and results catalogued.
- The Integration Risk Assessment measures the risk inherent in combining a set of systems into a portfolio.
- The Metrics Analysis module calculates a portfolio score using the metrics for each system.
- The Document Library allows for the storage, sharing, and versioning of reference material.
- The Data Citation module provides a means to associate application data to its authoritative source.



IMCSE: Interactive Model-Centric Systems Engineering Project

SE AND SM TRANSFORMATION

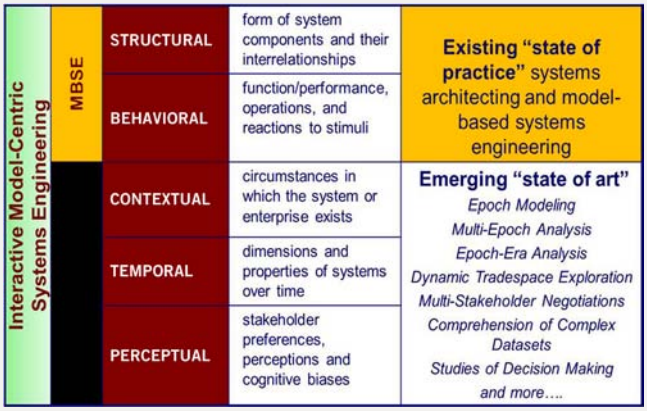
PI: Donna H. Rhodes (Massachusetts Institute of Technology)
Sponsor: DASD(SE)
Collaborator: None

This new research project, initiated in May 2014, and led by a team of researchers and graduate students at the Massachusetts Institute of Technology, fills a critical gap in ongoing model-based engineering research and practice. Progress has been made on standards, methods and techniques for model-based systems engineering, yet little attention has been given to human-model interaction. Similarly, a science of human-systems interaction has emerged, but focuses on operational systems. The research team believes there are unique factors, considerations, and needs for human interaction with models, as abstractions of reality. Models are increasingly used to drive major acquisition and design decisions, yet the diverse set of model developers, analysts, and decision makers are faced with many challenges in transitioning to model-centric engineering. For instance, there are issues with perceived truthfulness of models and trust in the models that impact the timeliness, quality, and confidence in model-based decisions.

The IMCSE research project aims to develop transformative results through enabling intense human-model interaction, to rapidly conceive of systems and interact with models in order to make rapid trades to decide on what is most effective given present knowledge and future uncertainties, as well as what is practical given resources and constraints. IMCSE focuses at the intersection of four pillars: visual analytics, big data science, model-based systems engineering, and the complex systems domain. The team has discovered key challenges for further investigation, including visual analytics of artificial (model-generated) data; trade-off and choice of models; and cognitive and perceptual considerations in human-model interaction.

A pathfinder workshop was conducted in January 2015 to bring together interested stakeholders for an initial dialogue on human-model interaction, identifying research needs from both a model-centric perspective and an interactive perspective. A report will be available to SERC members and the broader community. The workshop will be followed by a process that will include input from SERC members and the broader systems community to help craft the collaboratively defined research agenda for IMCSE. The ultimate goal is to establish a shared set of research priorities and roadmap for IMCSE, excite the research community around the topic, and build partnerships for research collaboration and for transition to practice.

Several proof-of-concept prototypes are under development and will be made publicly available. These will showcase specific strategies and implementation possibilities for enhancing the human-model interaction for several model-based activities, leveraging prior research prototypes as a foundation in order to accelerate development and transition of the prototypes.



The research will produce:

1. A compilation of knowledge drawing from literature and subject matter experts across four pillars and several challenge areas
2. Methods, processes and techniques for enhanced human-model interaction and model-based decision making
3. Prototypes to demonstrate innovations in providing enhanced human-model interaction
4. A self-identified research community rallying around IMCSE as a viable research area
5. Technical reports, workshop reports, published papers, and guidance materials to enable knowledge transfer, foster collaborative research and accelerate transition to practice

HUMAN CAPITAL DEVELOPMENT

SEEA: Systems Engineering Experience Accelerator

HUMAN CAPITAL DEVELOPMENT

PI: Jon Wade (Stevens Institute of Technology)

Sponsors: DASD(SE), Defense Acquisition University

Collaborators: Georgia Institute of Technology, Purdue University

The SEEA project team has created a new approach to developing the systems engineering workforce. Traditional, in class education methods are augmented with technologies that accelerate gaining skills, experience, and "scar-tissue" through immersive simulated learning situations. The SEEA technology provides a graphical user interface, allowing the learner to see the program status, interact with non-player characters to gain additional program information, and make technical decisions to correct problems. It also provides capability to simulate the program into the future-based on these learner decisions, so that outcomes can be shown to the learner. In particular, this approach illustrates the effect of upstream decisions on downstream outcomes in the system lifecycle.

SEEA research consists of two interdependent tasks:

1. **Enhance SEEA Capabilities for Defense Acquisition University Classes:** Several enhancements were needed to address the specific classroom environment. A stable multi-player capability was developed to allow live player support for team-based learning, as well as for a mentor to provide advice and feedback. Dialog was enhanced to include responses based on students' past recommendations. Support will be provided for instructor and student pilots of the SEEA, to include the SEEA application and associated training materials. Alternatives for hosting the SEEA will be identified, and a study on transitioning maintenance to a 3rd party after the SERC completes its research support will be performed.

2. **Experience Development Tools:** Although developed with a goal of transitioning to an open-source sustainment model providing long-term support for a community of educators and learners in creating learning exercises to address their specific needs, the existing prototype SEEA technical infrastructure has limited ability to support such a community. This task, led by PI Doug Bodner (Georgia Tech), will develop a set of tools specifically to support educators and developers outside of the SEEA research and development team to design and develop learning modules for their use. The table provides a short description of each tool.

Simulation: These tools work interactively to allow construction, testing and tuning of systems dynamic models.	
Sim Builder	enables non-technical staff to graphically build systems dynamics models based on templates.
Sim Tuner	provides the ability to analyze the model, determine the sensitivity of various parameters, and support tuning the system to achieve desired learning objectives.
Experience Building: These tools, used with ChatMapper (a commercially available dialog builder), enable non-technical staff to build and modify EA experiences without any programming. All of this is accomplished through an integrated graphical interface.	
Phase Editor	changes the finite state machine that defines EA experience phase transitions to allow customization to new domains and environments.
Event Editor	creates and edits experience events and the activities that may trigger them.
Artifact Integrator	allows quick upload of SEEA artifacts such as dialogs, or recommendation forms.
Learning Analysis: This tool can support learning in a number of experiential environments	
Learning Assessor	supports the determination of the learning level achieved by collecting and analyzing the necessary information, such as the subject's activities, decisions, project performance and self-assessments

The tools noted above are a prioritized subset of possible tools identified by the team. Others include:

- Experience concept tools (storyboarding, learner profile creation)
- Context tools (project specification linked to learning outcomes, NPC roles-motivations-personalities)
- Experience module events-flows (automated linkages between challenges, land mines, epiphanies, competencies, and mitigating actions and their effects)

SEEK: Systems Engineering Expert Knowledge Case Studies

HUMAN CAPITAL DEVELOPMENT

PI: David Olwell (Naval Postgraduate School)

Sponsor: Defense Acquisition University

Collaborators: Stevens Institute of Technology, Carnegie Mellon University

One of the ongoing themes of SERC research has been providing products that help preserve and extend systems engineering knowledge among the DoD workforce, especially to address the uneven distribution of the engineering workforce by age. The SEEK project is building a library of case studies to capture key lessons learned and to integrate them with the Defense Acquisition University and Naval Postgraduate School coursework. Two versions of each case study will be prepared, one with distribution limited to DoD. The restricted distribution version will include more detailed supporting technical information to allow the reader to explore the case in depth.

The project team includes Dr. Jon Wade from Stevens Institute, Dr. Dave Olwell from NPS, and Dr. Forrest Shull from Carnegie Mellon University. Dr. Wade is supported by doctoral student, James Mason.

(U.S. Navy photo by Seaman Benjamin Crossley/Released)

Two case studies focused on reliability engineering throughout the life cycle are planned for delivery late in the summer of 2015. The first case study involves the successful upgrade of an existing system, the missile guidance system for the Trident D5 missile. The second looks at the early reliability engineering of the expeditionary fighting vehicle and traces the effects of that engineering through the remainder of the program life. Data collection on both cases is underway.

ASE-CDM: Army SE Career Development Model: Driving Engineering Professional Development Through the Use of Value Propositions

HUMAN CAPITAL DEVELOPMENT

PI: Val Gavito (Stevens Institute of Technology)

Sponsor: US Army

Collaborator: None

The Office of the Assistant Secretary of the Army (Acquisition, Logistics, & Technology) Systems of Systems Engineering & Integration (ASA (ALT) SOSE&I) requires a deliberate, continuous, and progressive SE career development model that provides engineers with the experience, education, and training to effectively support the acquisition community. The SERC previously conducted SE Career Development Model research that evolved to a recommended Army SE Career Development System (CDS) as documented in SERC Technical Report SERC-2014-TR-042-1, March 31, 2014.

In April 2014, ASA (ALT) SOSE&I requested the SERC perform additional research to expand on the education, experience, tenure, currency, and cross-functional competency components of the earlier task CDS as well as the Continuous Learning Modules (CLM) currently required for Key Leadership Positions (KLP). This task expanded upon the CDS components and the CLMs through four specific subtasks. A review of the subtask level recommendations was then conducted to synthesize a holistic set of three recommendations that represented the significant themes of the team's findings:

1. Value Propositions as Primary Acquisition Professional Development Drivers: Consider a cultural shift to the use of value propositions as certification criteria as a more explicit way of demonstrating individual capabilities for the career development enterprise.

2. Level I/II/III/KLP Progression Continuity: Improve engineering certification processes to enhance the transition of Level III-to-KLP.

3. Integrated Professional Development Planning & Measurement: Implement a CDS Decision Support System to expand the utility of the current career management information system.

As a summary recommendation, the research team proposed an approach to synthesize an integrated individual development plan through the use of a responsibilities-value proposition scorecard. Individual, organizational, and enterprise tailoring would result through the convergence of progressive, explicit objective value propositions that not only comprise the goals and objectives of the engineering professional, but provides a framework for enhancing the effectiveness of a professional acquisition engineering workforce.

SERC Research Bears Fruit

The value of systems engineering research is only realized when it is applied. This section provides examples of how SERC research projects have influenced the SE community, provided guidance in critical operational areas, and continue to lead in shaping SE education and workforce development.

SEEA: The Systems Engineering Experience Accelerator

HUMAN CAPITAL DEVELOPMENT

PI: Jon Wade (Stevens Institute of Technology)

Sponsors: DASD(SE), Defense Acquisition University

Collaborators: Georgia Institute of Technology, Purdue University

The objective of the experience acceleration program is to transform the education of systems engineers and technical leaders by creating a new paradigm capable of accelerating the time to maturity while providing the skills necessary to address emerging system's challenges. We are piloting and transitioning the use of SEAA technology at DAU and developing a set of tools to decrease the time and effort necessary to create new experiences and customize existing ones. Simply evolving the technology, however, is insufficient to reach our goals. We must create a self-sustaining open-source community to create experiences and apply them to shape the next generation of system engineers.

A number of potential SEEA users and developers have been identified and are engaging in an Experience Accelerator User Group community. Interested organizations include: Defense Acquisition University, Office of Naval Research, National Reconnaissance Office, Army Armaments Research, Development and Engineering Center, Lockheed Martin, Sandia Labs, MITRE, and Si Corporation. The response to the kickoff meeting, held on November 25, 2014, was quite positive and identified a number of piloting efforts. We are currently creating an Evaluation Terms of Agreement to facilitate these engagements, establishing a website for SEEA communications, and hope to leverage INCOSE and other SE-related organizations to evaluate and communicate the SEEA message.

SETL: SE Technical Leadership

HUMAN CAPITAL DEVELOPMENT

PI: Val Gavito (Stevens Institute of Technology)

Sponsor: Defense Acquisition University

Collaborator: Wayne State University

The research objective of Systems Engineering Technical Leadership was to explore ways in which education might support the acceleration of the technical leadership capabilities of senior DoD systems engineers and technologists. The task required defining the required leadership capabilities, researching candidate curricula architectures, developing a series of pilot courses, and testing the pilots with government systems engineers, technical functional specialists, program managers, supporting functional specialists, and Defense Acquisition University faculty. The research, conducted over a four year period, developed and tested a syllabus comprised of three 5-day courses: SYS 350A Systems, SYS 350B Business, and SYS 350C Enterprise. The team then developed and facilitated nine SYS 350 Series instructor and DoD system engineer pilots. Over 100 lecture, case study, exercise, simulations, and group project classroom segments were developed and tested. The highly positive feedback generated from over 5,200 faculty-student pilot contact hours strongly suggests the project met the need for engineering technical leadership education.

Impact: The research provided the DAU with a set of opportunities for engineering education portfolio enhancements and expansion in the areas of Research, Curriculum, Scope, and Simulations.

Research: The hypothesis that technical leadership preparation of systems engineers can be accelerated through an educational program in technical leadership was successfully tested.

Curriculum: The SETL curriculum was expanded to include the people, process, and tool elements of system development, business strategy and operations, and enterprise behavior and modification.

Scope: SETL education was broadened from system engineering and communication processes to address the spectrum of technical and behavioral responses required by the emergent and disruptive strategic, financial, and technology elements of engineering development programs.

Simulations: Dynamic simulations demonstrated their effectiveness by illustrating the uncertainty and ambiguities that arise during the course of engineering development and providing a stimulus for individual and group synthesis of technical leadership decisions.

Transition: SYS 350A is in the process of transition to the Defense Acquisition University. SYS 350B and SYS 350C are scheduled for transition to the Defense Systems Management College during FY16 and FY17.

BKCASE: Body of Knowledge and Curriculum to Advance Systems Engineering

HUMAN CAPITAL DEVELOPMENT

PI(s): Art Pyster (Stevens Institute of Technology)

Sponsor: DASD(SE)

Collaborator: Naval Postgraduate School

Partners: INCOSE, IEEE Computer Society

BKCASE®, which stands for the Body of Knowledge and Curriculum to Advance Systems Engineering was started in 2009 as one of the earliest SERC projects; it is one of the best examples the SERC has of successful transition to broad community use. Led by Dr. Art Pyster from Stevens Institute of Technology and Dr. David Olwell from the Naval Postgraduate School, BKCASE created two products that were first released for general use in late 2012—the Systems Engineering Body of Knowledge (SEBoK) and the Graduate Reference Curriculum for Systems Engineering (GRCSE®). The SEBoK is a wiki, accessed at *http://www.sebokwiki.org*, while GRCSE is a PDF document found at *http://www.bkcase.org*.

The transition strategy for BKCASE was developed at the beginning of the project and successfully executed. The five primary tenants of the strategy were:

1. SERC sponsor, the Deputy Assistant Secretary of Defense for Systems Engineering, would fund BKCASE until version 1.0 of both the SEBoK and GRCSE were published and then for a short while afterwards to facilitate successful transition.
2. The International Council on Systems Engineering (INCOSE – *http://www.incose.org*) and the Institute of Electrical and Electronics Engineers Computer Society (IEEE-CS – *http://www.computer.org*) were recruited as early co-sponsors of BKCASE with the intent of having them join the SERC in managing the evolution and dissemination of SEBoK and GRCSE after DoD funding ended. Those organizations, especially INCOSE, provided tens of thousands of volunteer labor hours to build SEBoK and GRCSE, leveraging DoD's substantial funding.
3. Both the SEBoK and GRCSE would be freely available to facilitate their broad adoption.
4. SERC, INCOSE, and IEEE-CS would hold workshops, give presentations, advertise on their websites, and take other steps to encourage widespread adoption by both the defense community and the broader research, academic, and practitioner communities around the world.
5. SERC, INCOSE, and IEEE-CS established a robust infrastructure of an editor-in-chief, associate editors, and support staff to oversee the evolution of both SEBoK and GRCSE to maintain their currency as the field changes and to respond to user feedback. Updates to the SEBoK are published every few months (the latest version is 1.3.1) and a new release of GRCSE is planned for 2016.

The transition results have been as hoped. The global community has accessed SEBoK articles more than 500,000 times since version 1.0 was launched in September 2012 with usage rising steadily as the SEBoK becomes increasingly visible. For example, a Google search for the term "systems engineering" routinely returns the SEBoK in the top 10 responses. Thousands of free copies of the complete SEBoK have been downloaded for use by individuals and organizations. INCOSE considers the SEBoK and GRCSE as critical assets in its 5-year strategy and the SEBoK strongly influences the content of the soon-to-be-published version 4.0 of INCOSE's Systems Engineering Handbook. The IEEE-CS relied in part on the SEBoK when building its software engineering competency model (see *http://www.computer.org/web/peb/swecom-download*). Moreover, GRCSE has influenced a number of graduate systems engineering curricula, including those in universities in the US, Europe, and Australia. BKCASE impact is expected to expand indefinitely.

iTAP: ilities Tradespace and Affordability

SE AND SM TRANSFORMATION

PI: 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

iTAP has had considerable success transitioning its findings to the larger SE community. The *DoD Systems Engineering Guide for Systems of Systems*, co-authored by Jo Ann Lane (USC) and George Rebovich (MITRE) under the leadership of Judith Dahmann (MITRE), has been applied to the development and evolution of numerous DoD systems of systems.

The Georgia Institute of Technology Framework for Assessing Cost and Technology (FACT) extensions and infrastructure development led by Tommer Ender have led to several Service-sponsored applications and follow ons, including the Army Armament Research, and Development and Engineering Center, a FACT portfolio management capability, and an application to support the amphibious combat vehicle design.

NGCEM: Next-Generation Cost Estimation and Metrics for Software-Intensive Systems

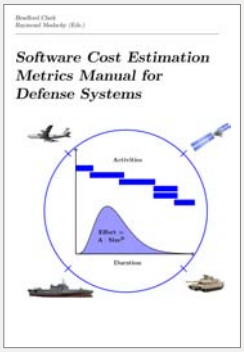
SE AND SM TRANSFORMATION

PI: Barry Boehm (University of Southern California)

Sponsor: Air Force Cost Analysis Agency

Collaborator: Naval Postgraduate School

This research, completed in 2012, became the basis for the *Air Force Cost Analysis Agency's Software Cost Metrics Manual*, and developed improvements to the revised DoD Software Resources Data Report definitions document. USC (Brad Clark and Barry Boehm) and NPS (Ray Madachy) collaborated with the Air Force Cost Analysis Agency sponsor in developing *AFCAA's Software Cost Metrics Manual*, which has been applied to numerous AFCAA cost estimates and evaluations. Related experience in analyzing data from the DoD Software Resources Data Report (SRDR) led to improvements to the revised SRDR definitions document and to more accurate data reporting. Analysis of SRDR data led to the expansion of the Air Force Cost Analysis Agency manual into the *Software Cost Estimation Metrics Manual for Defense Systems*, currently also being used by the Naval Center for Cost Analysis for early phase software cost estimation.



The following sponsor testimonial speaks to the impact of this work.

"The Software Cost Estimation Metrics Manual for Defense Systems far exceeds our expectations for transferring research to practitioners. As a previous SERC sponsor of RT-6: Software Intensive Systems Data Quality and Estimation Research In Support of Future Defense Cost Analysis, I wanted to create cost estimation models based on consistent metrics definitions. The editors have substantially furthered our results into a high quality manual with practical guidance.

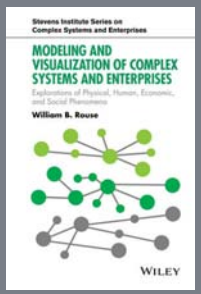
This transition product will help DoD analysts and decision makers develop more accurate early software cost estimates for different classes of defense system applications and operating environments. The manual is fully comprehensive and detailed for providing relevant and practical Cost Estimating Relationships.

I'm certain it will immediately be used by software cost analysts in DoD agencies for all the services, in program offices and by contractors. I expect it will be adopted in DoD training curricula and universities. Cost analysts and program management in related and similar application domains will also find it useful."

Dr. Wilson Rosa,
AIS/C4ISR Branch Head, Naval Center for Cost Analysis

Multi-Level Socio-Technical Modeling and Enterprise Systems Analysis

SERC researcher William Rouse has written a new book *Modeling and Visualization of Complex Systems and Enterprises*, due to be released in May 2015. The book presents a ten-step modeling methodology for addressing questions related to the design and operation of enterprises. The book considers six enterprise problems from multiple domains including healthcare, urban systems, financial systems, and defense systems. The methodology presented in this book was used in the SERC Policy "Flight Simulator" research task. Dr. Rouse has developed a graduate level course based on the book.



PROGRAM	PROJECT
RESEARCH CATEGORY	**HUMAN CAPITAL DEVELOPMENT**
Evolving Body of Knowledge	HELIX: What Makes Systems Engineers Effective? SEEK: Systems Engineering Expert Knowledge Case Studies
SE Technical Leadership Education	SETL: Developing SE Technical Leadership CAPSTONE: A Marketplace to Infuse SE into Capstone Projects ASE-CDM: Army SE Career Development Model S&T-PORT: Strategic Planning Science & Technology Portfolio Development
Experience Acceleration	SEEA: SE Experience Accelerator Evolution SEEA: SE Experience Accelerator Tools
RESEARCH CATEGORY	**ENTERPRISES AND SYSTEMS OF SYSTEMS**
System of Systems Modeling and Analysis	AOA-SOS: Impact of Development Disruptions and Dependencies in Analysis of Alternative SoS FILA-SOS: Flexible Intelligent Learning Architectures For Systems Of Systems
Enterprise Modeling	POLICY "FLIGHT SIMULATOR": Methods and Tools for Dynamic Enterprise Systems Analysis
RESEARCH CATEGORY	**SE AND SM TRANSFORMATION**
Affordability and Value in Systems	iTAP: Tradespace and Affordability Methods and Tools IRiS: Investigating Resilience in Systems EATA: Enterprise Architecture Tradespace Analysis VCE-DT: Virtual Collaborative Environment for Conducting Project Design and Tests PMAT: Portfolio Management and Analysis Tool
Quantitative Risk	RISK EARLY WARNING: Practical Approaches to Identify and Quantify Early Sources of Acquisition Program Technical Risk
Interactive Model-Centric Systems Engineering (IMCSE)	ADOPTING MBSE: Transforming Systems Engineering through Model Centric Engineering IMCSE: Interactive Model-Centric Systems Engineering Project
Agile Systems Engineering	Agile SE MANAGEMENT SANDBOX: Demonstration and Analysis Tool for Agile SE Management (DATASEM) Agile SE MANAGEMENT EXPLORATION: Agile SE Enablers and Quantification Project
RESEARCH CATEGORY	**TRUSTED SYSTEMS**
Systemic Security	SYSTEM-AWARE SECURITY: A Cybersecurity Prototype for A Cyber-Physical System
Systemic Assurance	SYSTEMIC ASSURANCE: Achieving More Assurance Cost-Effectively
RESEARCH CATEGORY	**OTHER**
Other	INCUBATOR: Exploring new research ideas

RESEARCH PARTNERSHIPS

The SERC maintains close working relationships with systems-related professional societies by filling leadership roles (INCOSE), providing conference support (INCOSE, NDIA, and AFEI), participating in working groups (INCOSE, IEEE), and joint research (e.g. BKCASE and Agile SE). The SERC also has research partnerships with Federally Funded Research and Development Centers (FFRDCs) and other University Affiliated Research Centers (UARCs). MITRE, a private, not-for-profit corporation that operates FFRDCs, and SERC have a memorandum of understanding (MOU) in place and are currently working together on two research tasks. The MOU encourages transition opportunities, and MITRE has contributed its own internal research and development funds to one of the System-Aware Security research. The Aerospace Corporation FFRDC is working with the SERC on the Tradespace and Affordability (iTAP) research task, including a workshop on satellite ground system total cost of ownership at their 2014 and 2015 Ground Systems Architecture Workshops. In addition, the SERC is working with the Software Engineering Institute FFRDC on two tasks, including the Practical Agile SE Management and Next-Generation Cost Estimation and Metrics for Software-Intensive Systems.

The Applied Physics Laboratory at Johns Hopkins University is reviewing the SERC research portfolio to explore transition opportunities within the Intelligence Community. The Penn State University Applied Research Lab UARC is pursuing research in set-based design under both its UARC and the SERC iTAP.

ANNUAL EVENTS

Each year, the SERC holds annual events and reviews to showcase the research conducted by its collaborators and doctoral fellows. These annual events present the opportunity to learn first-hand about current and planned SERC projects, about the many research interests of the SERC collaborators and doctoral fellows, and to meet dozens of faculty and students who are conducting SERC-funded research. Through such interaction, we hope to better understand the sponsor needs, and to strengthen and focus the community of systems engineering researchers on projects and research that provide practical value.

The SERC Sponsor Research Review (SSRR) is a one-day, sponsor-focused event held in Washington, DC. This event unites the government, industry, and university systems engineering research community in order to share research progress and discuss the most challenging systems engineering issues facing the DoD as well as other federal departments and agencies. The SSRR program and sessions focus on the research results that we have achieved in each of these key areas.

The SERC Doctoral Fellows Program Forum (DFF) is a half-day event that precedes the SSRR. This event allows the SERC doctoral fellows to present their research progress and results to the broader SE community.

The SERC plays a prominent role in the annual Conference on Systems Engineering Research. This preeminent academic conference on systems engineering research provides a key mechanism for publishing SERC research.

For more information about the annual SSRR and DFF events, please see the SERC website (*www.sercuarc.org*) or contact a member of the SERC Leadership Team.

SERC LEADERSHIP

Barry Boehm
Chief Scientist, SERC

Dr. Boehm is the USC Distinguished Professor of Computer Sciences, Industrial and Systems Engineering, and Astronautics, and the founding Director of the USC Center for Systems and Software Engineering. He was director of DARPA-ISTO for 1989–1992, at TRW for 1973–1989, at Rand Corporation for 1959–1973, and at General Dynamics for 1955–1959. Known primarily for the creation of the spiral model for software development and the COCOMO software estimation tool, his contributions in value-based engineering, risk management, software pedagogy, and software economics form the basis of modern software engineering. Dr. Boehm is a Fellow of the primary professional societies in computing (ACM), aerospace (AIAA), electronics (IEEE), systems engineering (INCOSE), and lean and agile development (LSS); he is also a member of the U.S. National Academy of Engineering.

Mitchell Kerman
Director of Program Development and Transition, SERC

Dr. Kerman has a diverse background with experience in both the military and industry. He oversees strategic communications and outreach to develop and nurture sponsorships, collaborative relationships and key external alliances with industry, government and academic institutions. He also promotes and expands the awareness of SERC programs and initiatives, such as the SERC Doctoral Fellows Program.

Art Pyster
Chief Operating Officer, SERC

Dr. Pyster is a Distinguished Research Professor at Stevens Institute of Technology and the Director for Academic Matters for INCOSE. He has more than thirty-five years of experience as a successful researcher, engineer, educator, executive, and manager in government, industry, and academia. He has created, delivered, acquired, overseen, taught, or operated numerous leading edge systems and technologies in telecommunications, aerospace, defense, air traffic control, and information technology domains and led software and systems engineering workforce development efforts in both industry and government. Before joining Stevens, he was Senior Vice President and Director of Systems Engineering and Integration for SAIC, and Deputy Chief Information Officer and Chief Scientist for Software Engineering at the US Federal Aviation Administration.

Doris Schultz
Director of Operations, SERC

Ms. Schultz developed the SERC's overall business structure, process and staffing approaches. She is responsible for all sponsored research activities, budget, financial analysis, procurement, reporting, staff development and team building, customer relations, and government regulation interpretation and application (DFAR, FAR, Circulars).

Ms. Schultz combines her 20 years of experience in Fortune 500 organization experience in business management to create efficient business operations. As Vice-President, Noranda Leasing Limited, she leveraged intrapreneurial opportunities to develop a service organization from start up to a mature organization, which she led for 10 years.

Dinesh Verma
Executive Director, SERC

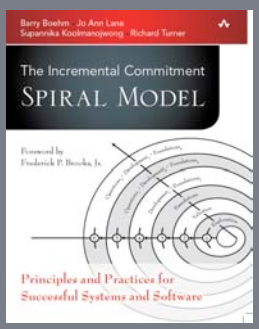
Dr. Verma is Dean of the School of Systems and Enterprises and Professor in Systems Engineering at Stevens Institute of Technology. He also serves as the Scientific Advisor to the Director of the Embedded Systems Institute in Eindhoven, Holland. Prior to this role, he served as Technical Director at Lockheed Martin Undersea Systems, in Manassas, Virginia, in the area of adapted systems and supportability engineering processes, methods and tools for complex system development and integration. His professional and research activities emphasize systems engineering and design with a focus on conceptual design evaluation, preliminary design and system architecture, design decision-making, life cycle costing, and supportability engineering. In addition to his publications, Verma has received one patent and has two pending in the areas of life-cycle costing and fuzzy logic techniques for evaluating design concepts.

Jon Wade
Chief Technology Officer, SERC

Dr. Wade is a Distinguished Research Professor in the School of Systems and Enterprises at the Stevens Institute of Technology, and is the Director of the new Cyber-Physical Systems Engineering program. He conducts research in the areas of systems thinking, complex systems and the use of technology in systems engineering education. Dr. Wade has an extensive background in leading research and development organizations and managing the development of Enterprise systems.

New Systems Engineering Life Cycle Book Draws on SERC Research.

In June of 2014, Barry Boehm, Jo Ann Lane, Supannika Koolmanojwong, and Richard Turner released a new book *The Incremental Commitment Spiral Model: Principles and Practices for Successful Systems and Software*, presenting the latest incarnation of Prof. Boehm's spiral model. Incorporating nearly 30 years of experience and evolution of the concept, ICSM is particularly suited for today's evolving system acquisition and development environment. The core of the book was developed under work sponsored by DoD to extend the spiral model for software to include the complete systems life cycle. Evidence and risk-based decision concepts were refined in the "SE Effectiveness Measurement" research (one of the SERC's first two research projects). Other ICSM-related SERC research includes "Life Cycle SE Needs for Evolutionary Acquisition", "SE and Management Implications for Evolutionary Acquisition of Major Defense Systems", and the collaborative development of BKCASE.



ENTERPRISES AND SYSTEMS OF SYSTEMS

William B Rouse

Alexander Crombie Humphreys Chair in Economics of Engineering, Stevens Institute of Technology

Dr. Bill Rouse is the Alexander Crombie Humphreys Chair within the School of Systems and Enterprises at Stevens Institute of Technology and Director of the Center for Complex Systems and Enterprises. He is also Professor Emeritus, and former Chair, of the School of Industrial and Systems Engineering at the Georgia Institute of Technology. His research focuses on understanding and managing complex public-private systems such as healthcare delivery, urban systems and national security, with emphasis on mathematical and computational modeling of these systems for the purpose of policy design and analysis.

Daniel A. DeLaurentis

Associate Professor, School of Aeronautics & Astronautics, Purdue University

Dr. DeLaurentis leads Purdue's Center for Integrated Systems in Aerospace (CISA), which is home to 20 faculty affiliates, three research staff, and numerous dedicated graduate students. He also leads CISA's largest recent project with the Missile Defense Agency's Enhanced C2BMC program developing agent-based modeling and simulation for development of advanced battle management architectures.

Jo Ann Lane

Co-Director of the Center for Systems and Software Engineering at the University of Southern California

Dr. Jo Ann Lane is currently leading research in the area of systems engineering and system of systems (SoS), including SoS engineering cost models, SoS affordability engineering, lean SoS engineering process models, SoS test and evaluation, and innovation in SoS engineering. Several of her over 50 papers are widely referenced in the SoS literature. She recently co-authored *The Incremental Commitment Spiral Model: Principles and Practices for Successful Systems*. Prior to her work in academia, she was a key technical member of SAIC's Software and Systems Integration Group, responsible for the development and integration of software-intensive systems and systems of systems.

TRUSTED SYSTEMS

Barry Horowitz

Munster Professor of Systems and Information Engineering and Chair, University of Virginia

Dr. Horowitz is the director for the UVa research site of the National Science Foundation sponsored Industry/University Cooperative Research Center called WICAT (Wireless Internet Center for Advanced Technology). Prior to UVa, he was president and CEO of the MITRE Corporation. He received the Air Force's highest award for a civilian, is a member of the National Academy of Engineering, Tau Beta Pi and Eta Kappa Nu honor societies, and was awarded the AFCEA Gold Medal of Engineering in 1990.

William Scherlis

Professor and Director, Institute for Software Research, Carnegie Mellon University

William L. Scherlis is a full Professor in the School of Computer Science at Carnegie Mellon. He is director of CMU's Institute for Software Research (ISR), one of seven academic departments in the School of Computer Science. ISR research and educational programs relate to software engineering, cybersecurity, privacy engineering, network analysis, mobility, and other topics. During 2012 and early 2013 he was the Acting CTO for the Software Engineering Institute, a DoD FFRDC at CMU.

HUMAN CAPITAL DEVELOPMENT

David Olwell

Professor, Department of Systems Engineering, Naval Postgraduate School

Dr. Olwell is Professor and immediate past chair of the Department of Systems Engineering at the Naval Postgraduate School. He is the elected Chair of the NPS Faculty. He is a Fellow of the American Council on Education, a WASC evaluator, an ABET program evaluator, and a member of the Engineering Accreditation Commission. He has extensive knowledge of regional and programmatic accreditation, data driven decision making, curricular design, and distance education best practices.

Jon Wade

Distinguished Research Professor, Stevens Institute of Technology

See bio on previous page.

SE AND SM TRANSFORMATION

Barry Boehm

Distinguished Professor of Computer Sciences, Industrial and Systems Engineering, and Astronautics, and Director of the Center for Systems and Software Engineering, University of Southern California.

See bio on previous page.

Tom McDermott

Director of Technology Policy Initiative. Sam Nunn School of International Affairs, Georgia Institute of Technology

As a leader, educator, and innovator in multiple technology fields, his role is to create bridges between the disciplines of leadership, policy, and social sciences, and the disciplines of science, technology, and engineering. He previously held positions within Georgia Tech Research Institute as interim Director, Director of Research, Lab Director, and Principal Research Engineer.

Paul Collopy

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

Dr. Collopy formerly was Program Director for Systems Science at the National Science Foundation. Prior to NSF, he served as Michael Griffin's deputy at the Center for System Studies at the University of Alabama in Huntsville. Paul founded and led the Value-Driven Design Institute in Urbana, Illinois, and DFM Consulting in Hanover, New Hampshire. He began his career as a manufacturing engineer with Procter & Gamble and Morton Thiokol. Paul managed design engineering groups and programs at GE Aircraft Engines from 1983 through 1995.

Paul is co-inventor on two patents and author of fifty papers. He is an associate fellow of the American Institute for Aeronautics and Astronautics and former chair of the AIAA Value-Driven Design Program Committee and Economics Technical Committee.

SERC ADVISORY BOARD

Major General Curtis M. Bedke
US Air Force (Retired)
Major General Bedke is a defense aerospace and federal science and technology consultant, providing insights and solutions to both government and commercial organizations. He retired from the Air Force in 2010 with 32 years of experience in defense weapon systems science and technology, program acquisition, experimental flight test, operations, and command and control. From 2007 until his retirement, General Bedke was the Commander of the Air Force Research Laboratory at Wright-Patterson Air Force Base, responsible for the Air Force's $2.2 billion S&T program. Prior to his assignment at AFRL, he was Director of the National Security Operations Center at the National Security Agency, where he directed the daily operations of the NSA's quick-response crisis nerve center.

After retiring from the Air Force, General Bedke served as Vice President and General Manager for Science & Technology with High Performance Technologies, Inc. (HPTi), Dynamics Research Corporation (DRC), and Engility.

Lieutenant General Ted Bowlds
US Air Force (Retired)
Lieutenant General Ted F. Bowlds' last assignment in the Air Force was as Commander of the Electronic System Center and Program Executive Office for Command and Control at Hanscom AFB, MA. The center's mission is to acquire command and control systems for the Air Force 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.

Victoria Cox
Assistant Administrator for NextGen at the Federal Aviation Administration (Retired)
As the Federal Aviation Administration's Assistant Administrator for NextGen, Victoria Cox led the transformation of the nation's air traffic control system with responsibility for the multi-billion dollar NextGen portfolio. A results-driven strategic thinker and planner, she has a proven record as an innovator who develops solutions and delivers change. Since retiring from the FAA in 2013, she has served on various technical committees and has recently initiated a consulting practice.

Dr. Ruth David
President and CEO of Analytic Services Inc.
Prior to 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, and is a member of the Standing Committee on Science, Engineering, and Public Policy.

Alfred Grasso
President and CEO, The MITRE Corporation
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 a member of MITRE's Board of Trustees, the Defense Science Board, and vice chair of the Armed Forces Communications and Electronics Association (AFCEA) International Board of Directors, and is a special advisor to the STRATCOM CYBER Strategic Advisory Group. Mr. Grasso is 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.

Dr. Michael D. Griffin
Chairman and CEO of Schafer Corporation; Chairman, SERC Advisory Board
Prior to his position at Schafer, Dr. Griffin was the King-McDonald Eminent Scholar and Professor of Mechanical and Aerospace Engineering, and Director of the Center for System Studies at The University of Alabama in Huntsville. From 2005-09 he was the 11th Administrator of NASA. He was Space Department Head at the Johns Hopkins University Applied Physics Laboratory, and has held numerous executive positions with industry, including President and COO of In-Q-Tel, Chief Executive Officer of Magellan Systems, General Manager of Orbital Science Corporation's Space Systems Group, and Executive Vice President and Chief Technical Officer at Orbital.

Major General Nick Justice
US Army (Retired)
Major General Nick 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 Command and Control Systems to American and Allied Forces during Operation Iraqi Freedom; Program Executive Officer for Tactical Command and Control Systems

and the Commanding General of Research, Development, and Engineering Command and Aberdeen Proving Ground.

David Long

President, INCOSE

David Long is the 2014/2015 President of INCOSE. Mr. Long has served INCOSE since 1997 including a term as the Washington Metropolitan Area chapter president and international roles including Member Board Chair, Director for Communications, and Director for Strategy. He is a frequent presenter at industry events worldwide delivering keynotes and tutorials spanning introductory systems engineering, the advanced application of model-based systems engineering (MBSE), and the future of systems engineering. In 2006, Mr. Long received the prestigious INCOSE Founders Award in recognition of his many contributions to the organization.

Mr. Long is the founder and president of Vitech Corporation where he developed and commercialized CORE, a leading systems engineering software environment used around the world. His experiences and efforts led him to co-author the book *A Primer for Model-Based Systems Engineering* to help spread the fundamental concepts of this key approach to modern challenges.

Dr. Steve Rottler

Vice President, California Laboratory & Energy, Climate and Infrastructure Security Sandia National Laboratories

Dr. Rottler is Vice President of Sandia's California laboratory and serves as lead for the Laboratories' Energy, Climate, and Infrastructure Security business unit. The California laboratory's principal programs include nuclear weapons stewardship; homeland security with a focus on defending against weapons of mass destruction; combustion, transportation and hydrogen energy research; biology; and advanced computational and information systems.

CAPT William M. Shepherd

US Navy (Retired), NASA Astronaut (Retired), Science Advisor, US Special Operations Command (Former)

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. In1993, Capt Shepherd was assigned as the Program Manager for the International Space Station. He retired from active duty in 2002, and served 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 Metal, 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.

The Honorable Michael Wynne

21st Secretary of the Air Force (Retired), Emeritus member and former Chairman of the SERC Advisory Board

Mr. Wynne currently serves as a senior advisor to the President of The Stevens Institute, and is an emeritus member and former Chairman 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.

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 Ph.D. students with a focus on systems-related research consistent with the SERC's charter.

The SERC Doctoral Fellows Program is not a scholarship program. Rather, participating organizations sponsor a specific number of doctoral fellows each year based upon their size and annual revenue. Fellows receive tuition reimbursement from their sponsoring organizations and are allocated one work day per week to dedicate toward their doctoral studies and research. The program is now in its third year of operation and already has its first graduate. Currently, there are three actively participating organizations – The Boeing Company, the US Army Armament Research, Development and Engineering Center (ARDEC) at Picatinny Arsenal; and the MITRE Corporation. The list of interested and soon to be participating organizations is growing. If you are interested in having your organization participate in this exceptional program, please contact the SERC at your earliest convenience.

CONTACT

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Director of Program Development and Transition
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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 page 23).

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 500 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, 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.

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

SYSTEMS ENGINEERING
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www.SERCuarc.org