Panel Discussion: SERC Research Programs

SERC Sponsor Research Review

November 13, 2012
Response defines 4 thematic areas, each with a specific goal:

**Human Capital Development:** Speed the professional development of highly capable systems engineers and technical leaders in DoD and the defense industrial base

**Trusted Systems:** Develop safe, secure, dependable defense systems that are resilient to cyber & other threats through systemic security approaches that complement current, incomplete perimeter/network

**Systems Engineering Transformation:** Move from engineering approaches for systems designed for optimal performance against a static set of requirements over long procurement cycles to approaches that enhance the productivity of engineers to rapidly develop cost effective, flexible, agile systems that can respond to evolving threats and mission needs

**Enterprise/SoS:** Improved engineering to develop and deliver end-to-end defense capability to the warfighter for operation in complex organizational and operational environments, with fewer unintended consequences and unforeseen risks
• Potential for transformative impact to DoD and IC

• Long-term funding and focus

• Synergy between SERC projects

• Focal point for research communities of interest

• Connection point for channels of impact
Programs & Panelists

- **Enterprise/SoS**
  - System of Systems Modeling – *Dr. Bill Rouse*

- **Trusted Systems**
  - Systemic Security - *Dr. Barry Horowitz*

- **Systems Engineering Transformation**
  - Agile System Engineering - *Ms. Debra Facktor Lepore*
  - Affordability & Value – *Dr. Barry Boehm*
  - Concept Engineering – *Dr. Robert Cloutier*

- **Human Capital**
  - The Evolving Body of Knowledge for Systems Engineering – *Dr. Art Pyster*
  - Systems Engineering and Technical Leadership – *Dr. Mark Ardis*
  - Experience Acceleration – *Dr. Jon Wade*
Multi-Level Modeling of SoS & Enterprises

Dr. Bill Rouse
SERC Research Council Member,
Alexander Crombie Humphreys Chair
in Economics of Engineering,
Stevens Institute of Technology
Multi-Level Modeling of SoS & Enterprises

Hypothesis: Multi-level modeling can provide a powerful means to understanding and improving complex socio-technical systems.

Goals:
1. Provide a rigorous systems science and engineering foundation for multi-level concepts, principles, models, methods and tools
2. Foster a broadly-based academic community pursuing research and applications in this area
3. Develop compelling demonstrations of the benefits of multi-level modeling in a range of DoD-relevant domains

Driving the Future Before You Write the Check
Policy Flight Simulators

How Simulators Work:
1. Problem and stakeholder focused
2. Org. process & demographics tailored
3. Large, interactive displays and controls
4. Computational exploration of “What if?”

Benefits of Simulators:
1. Many alternatives explored
2. Bad ideas identified quickly
3. Good ideas refined for experimentation
4. Stakeholder buy-in due to involvement

Doing More With Less,
While Avoiding Decisions You Will Later Regret
System Aware Cyber Security

Dr. Barry Horowitz
SERC Research Council Member,
Munster Professor of Systems and Information Engineering and Chairman,
University of Virginia
System Aware Cyber Security

• Operates at the system *application-layer*,
  – For *security inside* of the network and perimeter protection provided for the whole system
  – Directly protects the *most critical system functions*
  – Solutions are *embedded within* the protected functions

• Addresses *supply chain* and *insider threats*

• Includes *physical systems* as well as *information systems*

• Solution-space consists of *reusable design patterns*, reducing unnecessary duplications of design and evaluation efforts

• Includes a *scoring framework* for supporting Systems Engineers in evaluating alternative architectures
System Aware Cyber Security

Architecture Design Objective
Reverse cyber security asymmetry from favoring offense to favoring defense

Solution Technology Sources
- Fault Tolerant Systems
- Automatic Control Systems
- Information Assurance

Design Patterns
- Diverse Redundancy
- Diverse Redundancy + Verifiable Voting
- Physical Configuration Hopping
- Virtual Configuration Hopping
- Data Consistency Checking
- Physical Confirmations of Digital Data
- Use of Analog Components

Initial Prototype Application: UAV
- Research Team: UVA/GTRI
- UAV Mission: Surveillance
- Cyber Threat: Supply Chain
- Evaluations: Live Flight, Emulation, Simulation
Agile System Engineering

Ms. Debra Facktor Lepore
SERC Director of Strategic Programs,
Industry Professor,
Stevens Institute of Technology
SERC Research Challenge: Agility in SE

Demands of Expedited SE

- Timelines measured in days/months
- Delivering real solutions to problems, 80/20 as opposed to 100% of the “requirements”
- High understanding of risk management, what processes are needed vs “checklists,” what can be tailored / scaled
- Manage transitions, from lab/prototype to fieldable product, or larger program
- Right team who can make judgment calls

Importance of Agility

- One size doesn’t fit all – many “rapids” and lanes of acquisition, requiring flexible processes
- Enable response to rapidly changing and unknown threats
- Delivering the desired effect, at the right time, at an affordable cost
Leveraging SERC RTs to Increase Agility of Systems and SE Process

**The SE Environment**

**Agile MPTs MPT, RT-9:** What agile methods, processes and tools are currently being used in SE, how can we model agile processes to evaluate their applicability to SE, and how can we describe their dependencies amongst each other?

** Expedited SE RT-34:** How are expedited SE teams achieving success and what are the common factors among them, if any?

**SE Transformation Roadmap RT-10:** Analysis and definition of SE concerns and definition of a set of enabling technologies for change.

**Systems 2020 RT-20/20a:** Approach to evolving SE to meet defense challenges based on RT-10

**Evolutionary Acquisition RT-5:** Identify next-generation DoD life cycle systems engineering process needs programs that are more cost-effective and rapidly adaptable to changing mission needs.

**Agile/Lean SE RT-35/35a:** Redefining the way SE is scheduled to provide more effective integration and better visibility in large system evolution.

**Reconfigurable Architecture RT-2:** Enabling data-driven documentation for more agile management of SE artifacts.

**VV&A Modeling RT-21:** Methods, languages and tools for effective M&S of complex systems as a means for Verification, Validation and Accreditation.

**Major Modeling and Simulation Change in Accreditation RT-38:** Redefinition of "major change" to accelerate SE by eliminating unnecessary model accreditation.

**Integrating DoDAF with other artifacts RT-24:** Closer integration of DoDAF into architecture, M&S, SW design activities to reduce rework and improve resource efficiency.

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**Plus ... Concept Engineering, Affordability & Flexibility, Workforce, etc**
SERC Ilities Tradespace and Affordability Program (ITAP)

Dr. Barry Boehm
SERC Research Council Member,
TRW Professor of Software Engineering,
University of Southern California
SERC Ilities Tradespace and Affordability Program (ITAP)

PROJECT DESCRIPTION:
• Build on previous SERC research, other research from Collaborators, and ERS to create MPTs to better analyze tradespace in complex systems

VALUE:
• Being able to quickly and rigorously analyze the tradespace of complex systems, especially with regard to “ilities” such as safety, resilience, and availability, will aid decision makers early in the life cycle in a project when alternative requirements, architectures, and implementation technologies are all under consideration.

STATUS:
• A workshop was held on July 18-19 to shape the specific research
• Project expected to begin in November
• There are several current SERC projects that informed the workshop, including Valuing Flexibility (RT-18), Flexible Vehicle Requirements (RT-26), and Software-Intensive System Cost Models (RT-6). Projects outside the SERC with which the SERC could collaborate were also identified

TEAM:
• USC, MIT, Stevens, Georgia Tech, UVA, Wayne State, AFIT, NPS

PAST AND CURRENT EFFORT:
• Almost $2.5M has been awarded on other SERC projects that informed the July 18-19 workshop that developed the project approach
• $345K from FY12 RDTE funds for first phase of research

FUTURE EFFORT AND TRANSITION:
• Approximately $700K in FY13 RDTE funding requested for second phase of research. Primary focus will be on maturing and piloting strongest existing toolsets.
• Projects outside the SERC with which the SERC may coordinate would provide overall funding several times OSD immediate investment

IMPLEMENTS:
• Thematic Area: Systems Engineering Transformation
• Strategies: Make Smart Trades Quickly

PHASE 1 PRODUCTS:
• Tech report on DoD priorities for ilities and their tradeoffs
• Tailoring and demonstration of current SERC tradespace and affordability toolsets at INCOSE IW, Jacksonville FL, Jan 28, 2013 and CSER, Atlanta GA, March 18, 2013
• Technical report on various frameworks for tradespace and affordability; e.g., value-based, means-ends based, process-based, and architecture-based
• New MPTs on tradespace and affordability

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Importance of Ility Tradeoffs
Major source of DoD system overruns

- System ilities have systemwide impact
  - System elements generally just have local impact

- Ilities often exhibit asymptotic behavior
  - Watch out for the knee of the curve

- Best architecture is a discontinuous function of ility level
  - Large system example below
  - Highly risky to “Build it quickly, tune or fix it later”
    - Complementary RT-40 addresses quantitative risk assessment
Concept Engineering

Dr. Robert Cloutier
Associate Professor of Systems Engineering,
Stevens Institute of Technology
How do you develop a system if you do not know what it is supposed to do?

RESEARCH NEED: There is a need to quickly and graphically articulate a concept of operations (CONOPS) for new missions, business processes, and feature sets to realize a shared mental model and understanding of the mission, and potential solutions across a set of diverse stakeholders.

Leveraging 3D Gaming Technologies To Help Visualize Operational Concepts of New Products
A Concept Engineering Framework for the Future

Improving the Fidelity of Graphical CONOPS

Development Process and Tools
- Adopting a modified Scrum process
  - 30 Day Sprints
  - Weekly telecons with all parties invited
- Using an Internet tool—Trello to track Day-to-day work assignments
- Use Unity Asset Server to manage/share codebase
- Releases will be first Monday of each Month.

SERC/Govt Funding?
Open Source? Spin-off?
Corp Partner?

From Agile Development Approaches to Integration with COTS Tools
The Evolving Body of Knowledge for Systems Engineering

Dr. Art Pyster
SERC Deputy Director,
Distinguished Research Professor,
Stevens Institute of Technology
Anticipated Early Applications: INCOSE SE Handbook 4.0 and Certified SE Professional – IEEE-CS Software Systems Engineer Certification
Professional Masters in SE with Flexibility for Diverse Programs

GRCSE Elements in the Context of Curriculum Design

Education Pathways Accommodated in GRCSE

GRCSE Curriculum Architecture and Course Alignment

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Systems Engineering Technical Leadership

Dr. Mark Ardis

Distinguished Service Professor,
Stevens Institute of Technology
SETL Research Impacts Students to Most Senior Technical Leaders

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**SE Career Lifecycle**

- **SE Technical Leadership Competencies** framed
  - Three 5-day Experiential DAU Leadership Course Prototypes
    - SYS 350A Systems: Leading in the face of Uncertainty & Change
    - SYS 350B Business: Enhancing Technical Buying Power
    - SYS 350C Enterprise: Understanding & Adapting a Technical Enterprise

- Over 3,000 Faculty-Student Leadership Course contact hrs gained from prototype pilots with SPDRE engineers from
  - US Army Aberdeen Proving Ground
  - MDA Huntsville, AL

- **Next Steps**
  - Assess Student & Instructor feedback & findings
  - Recommend course content & efficient delivery modes

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**DAU Technical Leadership Pilot:** Approx 4,500 student-faculty contact hours, 7 pilots, and over 60 class segments
Impacting the Next Generation of SE

Multidisciplinary Systems Engineering Capstone Projects

First year: Individual projects revealed 9 promising practices

Second year: Partnerships with non-SERC schools to test scale-up

Capstone Project Registry: Pilot 2012-2013 Academic Year

Stakeholders propose challenging projects
Students volunteer to participate
Faculty provide guidance, academic assessment

1. Humanitarian assistance and disaster recovery kit and Dual use ferry
   — Stevens, UAH

2. Satellite radiometer
   — SMU, UH at Manoa

3. Immersive training system
   — Missouri S&T, UH at Manoa

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Experience Acceleration

Dr. Jon Wade
SERC Research Council Member,
Associate Dean of Research & Professor,
Stevens Institute of Technology
Experience Acceleration

**Hypothesis:** By using technology we can create a simulation that will put the learner in an experiential, emotional state and effectively compress time and greatly accelerate the learning of a systems engineer faster than would occur naturally on the job.

**Goals:** To build insights and “wisdom” and hone decision making skills by:
- Creating a “safe”, but realistic environment for decision making where decisions have programmatic and technical consequences
- Exposing the participants to job-relevant scenarios and problems
- Providing rapid feedback by accelerating time and experiencing the downstream consequences of the decisions made

**Using simulation technology and expert knowledge to safely and effectively build scar tissue in the new workforce**
Relevant, Authentic Experiences

- Experiential focused...incorporates experience base of remaining DoD Chief Engineers
- High-fidelity simulations of complex system development through entire life cycle
- Supports entire learning cycle,
- Dynamic skill adjustment, kill level adjustment, initial focus on expert level

Cost Effective, Available and Open

- Approximately 1 hour time limit for each session
- Low Server utilization per client user...highly scaleable
- No special client hardware or administrative needs
- Open architecture + Open Source Software with no-cost licensing
- User-friendly tool-set in parallel development

Supporting a complete learning experience over the lifecycle by leveraging Open Source technology and community development
Backup Slides
For each thematic area goal, there is a multi-year strategy to realize it.

The strategy aligns with other DoD priorities and efforts; e.g.

- The *Systems Engineering Transformation* strategy aligns with the DoD Science and Technology priority Engineered Resilient Systems (ERS)

- The *Human Capital Development* strategy aligns with DoD efforts to implement the Weapons Systems Acquisition Reform Act, the AT&L Priority *Strengthening the Acquisition Workforce*, and the Assistant Secretary of Defense (Research and Engineering) Imperative *Develop World Class Science, Technology, Engineering, and Mathematics Capabilities*

Each research project execution strategy identifies and leverages (a) the best research teams from across the Collaboration of universities that constitute the SERC, (b) transition partners from DoD labs, federally funded research and development centers, and elsewhere, (c) multiple pilots to validate and guide research and provide early impact, and (d) broad research result dissemination in journals, conferences, and classrooms.
**Human Capital Research Strategy**

**Goal:** Speed the professional development of highly capable systems engineers and technical leaders in DoD and the defense industrial base

1. *Educate and Train Faster:* Develop innovative approaches to educate and train systems engineers at all levels much more rapidly than classical means to address the shortage of qualified systems engineers

2. *Make Effective Technical Leaders:* Develop innovative approaches to educate DoD technical leaders with the right mix of technical, business, and enterprise skills

3. *Improve SE Education:* Develop recommendations on what to teach the next generation of engineers about systems engineering as well as recommendations to educate the next generation of systems engineers. Encourage and enable their wide adoption so DoD and the DIB can hire better educated systems engineers

4. *Access Knowledge Easily:* Make it easy for systems engineers to understand the SE discipline and to access the information needed to perform systems engineering well so the workforce can master the most important competencies

5. *Track Progress:* Track the changes in SE workforce demographics and performance over time to understand how well the workforce is improving and how well improvement programs are working
Trusted System Research Strategy

**Goal:** Develop safe, secure, dependable defense systems that are resilient to cyber & other threats through systemic security approaches that complement current, incomplete perimeter/network

1. *Design for System Security:* Develop design patterns and security architectures, with corresponding systems engineering principles guiding application, that enable security to be based on the specific properties of the system and its implementation rather than on traditional perimeter strategies

2. *Understand the Cost of Security:* Develop MPTs that enable understanding and predicting the cost of implementing specific security policies and requirements, especially on complex systems and complex systems of systems

3. *Tradeoff Security with Other “Ilities”:* Develop MPTs that enable understanding and predicting the relationship between specific security policies/requirements and other “ilities”, such as reliability, safety, and maintainability

4. *Measure System Security:* Develop MPTs that allow measuring “how much” security a system has and that permits comparison of the relative security between two alternative systems
SE Transformation Research Strategy

**Goal:** Move from engineering approaches for systems designed for optimal performance against a static set of requirements over long procurement cycles to approaches that enhance the productivity of engineers to rapidly develop cost effective, flexible, agile systems that can respond to evolving threats and mission needs.

1. **Make Smart Trades Quickly:** Develop MPTs to enable stakeholders to be able to understand and visualize the tradespace and make smart decisions quickly that take into account how the many characteristics and functions of systems impact each other.

2. **Rapidly Conceive of Systems:** Develop MPTs that allow stakeholders to quickly develop alternative system concepts and evaluate them for their effectiveness and practicality.

3. **Be Agile:** Develop SE MPTs that work well in the face of high uncertainty and rapid change in mission, requirements, technology, and other factors to allow a system to be rapidly acquired and responsive to both anticipated and unanticipated changes in the field.

4. **Align with ERS:** Align research to leverage ERS and contribute to it; e.g., ERS efforts to define new approaches to tradespace.
**Enterprise/SoS Research Strategy**

**Goal:** Improved engineering to develop and deliver end-to-end defense capability to the warfighter for operation in complex organizational and operational environments, with fewer unintended consequences and unforeseen risks

1. **Model:** Develop MPTs that allow quick and insightful modeling of enterprises/SoSs so that the effects of changes in policies, practices, components, interfaces, and technologies can be anticipated and understood in advance of their implementation

2. **Acquire:** Develop MPTs that allow insight into enterprise/SoS acquisition approaches in the face of significant uncertainty and change to minimize unintended consequences and unforeseen risks

3. **Evolve:** Develop MPTs that facilitate evolving and growing an enterprise/SoS, including insight into different architectural and integration approaches that facilitate evolution in the face of uncertainty and change in how an enterprise/SoS is used, the technologies available to implement it, and the environment in which it exists

4. **Verify:** Develop MPTs that allow the properties of an enterprise/SoS to be confirmed during development and evolution, including for an enterprise/SoS which includes legacy systems that are in operation while development and evolution are underway
## Selected Projects from the SERC Research Portfolio

<table>
<thead>
<tr>
<th>Thematic Area</th>
<th>Project</th>
<th>Multi-Year Project Description</th>
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<tbody>
<tr>
<td>Human Capital Development</td>
<td>BKCASE</td>
<td>Develop and transition into use the SE Body of Knowledge and Graduate Reference Curriculum in SE</td>
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<td>SE Capstone Registry</td>
<td>Pilot innovative approach to national scale up of capstone experience in undergraduate and graduate engineering programs that integrates SE</td>
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<td>Workforce Evolution</td>
<td>Begin longitudinal multi-year study of systems engineers in defense acquisition workforce, looking at education, experiences, competencies, and past performance</td>
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<td>Experience Accelerator</td>
<td>Develop virtual environments to accelerate the rate at which systems engineers are exposed to complex situations, make decisions associated with those situations, and see the consequences of their decisions</td>
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<td>System-Aware Security</td>
<td>Mature new system-aware security MPTs and pilot them on UAVs and perhaps other systems</td>
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<td>Tradespace and Affordability</td>
<td>Build on previous SERC research, other research from Collaborators, and ERS to create MPTs to better analyze tradespace in complex systems</td>
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<tr>
<td>SE Transformation</td>
<td>Expedited Systems Engineering</td>
<td>Develop a framework by which SE can be tailored for application in programs that have short timelines</td>
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<tr>
<td>Enterprises/SoS</td>
<td>Multi-Level Modeling of Socio-Technical systems</td>
<td>Build toolset, techniques, and reusable datasets to rapidly perform “what if” analysis on the effect of enterprise/SoS policies and practices across many domains of interest to DoD, beginning with counterfeit parts</td>
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<td>SoS Analytic Workbench</td>
<td>Develop, validate, and pilot a collection of methods and tools to understand the behavior of SoSs under a variety of different assumptions that reflect the uncertainties early in the acquisition life cycle – create a “workbench” for such tools</td>
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<td>SoS Agent-Based Models</td>
<td>Develop, validate, and pilot agent-based methods and tools to understand the behavior of SoSs under a variety of different assumptions that reflect the inherent uncertainties, especially early in the life cycle</td>
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SERC Vision & Strategy

**Vision**

The networked national resource to further systems research and its impact on issues of national & global significance.

**Mission**

Harness community of research talent through collaboration
Build tomorrow's community through research & education
Transition systems research to people, practice and impact
Influence affordable timely solutions through systems thinking
Enhance security and prosperity in the whole of the nation

**Leverage Factors**

- Collaborators' Standing
- Collaborators' Faculty, Students & Facilities
- Collaborator Network
- Relationship Network (Ind., Gov't & Acad.)
- NAE & CESUN, INCOSE and others
- Publications, Presentations and other outreach
- Community Leadership

**Strategies**

- Create Research Ecosystem
- Develop Critical Sponsor Relationships
- Conduct Transformational Research
- Transition Results Into Impact

**Key Initiatives/Activities**

1. Catalyze Community Growth
   - a) Build Partnerships
     - Federal Agencies (DoD, FAA, DHS, etc.)
     - Collaborator Network
     - Other UARCs and FFRDCs entities
     - Industries and Associations
   - b) Incentivize Involvement
     - Fellowships, internships and mentoring
     - Professional networking
     - Community leadership

2. Accelerate SE Competency Development
   - Communication
     - Strategic communications and branding
     - Articles, papers, chapters & books
     - Conferences, seminars & workshops
     - SERC Journal, website & blogs
     - Translation of research to curriculum and training
     - Publication and usage of MPTs, case studies and lessons learned

3. Transform SE practice throughout the government
   - a) Invest in Infrastructure
     - Modeling and simulation
     - Enterprise Technologies
     - Data sets and tools
     - Visualization
     - Collaboration venues
     - Strategic communications
   - b) Create Transformation Capabilities
     - Domain knowledge
     - Enterprise architectures
     - Methods and tools
     - Best practices & education

Inspired by Tennebaum Institute, Georgia Tech (Bill Rosell)
The Evolving Body of Knowledge

- The Body of Knowledge and Curriculum to Advance Systems Engineering project was initiated in 2009 to produce:
  - Graduate Reference Curriculum for Systems Engineering (GRCSE™) – Version 1.0 will be released December 2012
- 70 authors worldwide; hundreds of reviewers; thousands of adjudicated review comments
- INCOSE, IEEE-CS, and SERC become joint stewards starting 2013