DoD Systems Engineering

Mr. Stephen Welby
Director, Systems Engineering
Office of the Director, Defense Research and Engineering
Our Guidance

- **Quadrennial Defense Review Executive Summary, February 2010**
  - Further rebalance the capabilities of America’s Armed Forces to prevail in today’s wars, while building the capabilities needed to deal with future threats
  - Further reform the Department’s institutions and processes to better support the current needs of the warfighter; buy weapons that are usable, affordable and truly needed; and ensure that taxpayer dollars are spent wisely and responsibly
  - Preserve and enhance the All-Volunteer Force
  - Improve how it matches requirements with mature technologies, maintains disciplined systems engineering approaches, institutionalizes rapid acquisition capabilities, and implements more comprehensive testing

- **Quadrennial Defense Review Report Preface**
  - Secretary of Defense Robert M. Gates, February 2010
  - United States needs a broad portfolio of military capabilities with maximum versatility across the widest possible spectrum of conflict
Perspective for the Next Decade


- Cold War
- Vietnam War

National Security Challenges

- Satellite comms
- C4ISR

Defense Capabilities

- ICBM
- LGB’s
- Nuclear propulsion
- GPS
- Stealth
- Precision Strike
- UAV
- Robotics
- Night Vision

Enabling Technologies

- Transistor
- Solid state laser
- Space tracking
- Digital computing
- Composite Materials
- Superconductors
- MEMS
- Superconductors
- VHSIC
- MIMIC
- IR Sensors
- High Performance Computing
- Web protocols
- Advanced Electronics, Photonics Algorithms, MEMS
  - Nano; Meta; & New Materials
  - Cognitive Computing
  - Bio-Revolution

Human Terrain Ubiquitous Observation Contextual Exploitation Scaleable Action

Irregular/Hybrid Warfare

- Collapse of Soviet Union
- Kosovo
- OIF
- OEF
- Desert Storm
- Bosnia


- Cold War
- Vietnam War

DISTRIBUTION STATEMENT A -- Cleared for public release by OSR on Feb 2010 -- SR case number 10-S-1023 refers.
The Timeline has Collapsed!

Conventional Warfare

**USAF Capability**
- High Altitude Aircraft
- Electronic Countermeasures
- Endgame Countermeasures

**Adversary Capability**
- High Altitude SAM
- Monopulse SAM
- SAM with ECCM
- Engage SAM

Response loop measured in years

Counter-Insurgency Warfare

**US Capability**
- Jammers
- Mine Resistant Ambush Protected (MRAP)
- Advanced Technology

**Adversary Capability**

Response loop measured in months or weeks
Support from the Top for Change

Weapon Systems Acquisition Reform Act of 2009
(Public Law 111-23)

- Establishes Director, Systems Engineering (D, SE) and Director, Developmental Test and Evaluation (D, DT&E) as principal advisors to the SECDEF and the USD(AT&L)
- Mandates documented assessment of technological maturity and integration risk of critical technologies for MDAPs during the Technology Development (TD) phase
- Establishes D, DT&E and D, SE Congressional reporting on MDAP achievement of measurable performance criteria
- Mandates competitive prototyping and MDA completion of a formal Post-Preliminary Design Review Assessment for all MDAPs before MS B
- Strengthens technical analysis of cost and schedule breaches during Technology Development (pre-MS B) and Engineering and Manufacturing Development (post-MS B)

Systems Engineering Mission

We execute substantive technical engagement throughout the acquisition life cycle with major and selected acquisition efforts across DoD.

We apply best engineering practices to:

- Help program managers identify and mitigate risks
- Shape technical planning and management
- Support and advocate for DoD Component initiatives
- Provide insight to OSD stakeholders
- Identify systemic issues for resolution above the program level

We are the “E” in DDR&E
Director, Systems Engineering

Steve Welby
Terry Jaggers, Principal Deputy

Systems Analysis
Kristen Baldwin
- System Complexity Analysis
- Red Teaming
- Modeling & Simulation Coordination Office
- Development Planning
- SE for Systems of Systems
- Program Protection/Acquisition Cyber Security
- SE Research Center

Mission Assurance
Nicholas Torelli
- Systems Engineering Policy, Guidance, Standards
- System Safety
- Reliability, Availability, Maintainability
- Quality, Manufacturing, Producibility
- Human Systems Integration (HSI)
- Technical Workforce Development
- Organizational Capability Assessment (WSARA)

Major Program Support
James Thompson
- Program Support Reviews
- Systems Engineering Plans
- Program Technical Auditing
- OIPT/DAB/DSAB Support
- DAES Database Analysis and Support
- Performance Measurement
- Systemic Root Cause Analysis

Responsible to provide technical support, systems engineering oversight, program development and mission assurance certification to USD(AT&L) in support of planned and ongoing acquisition programs.
1. Accelerate delivery of technical capabilities to win the current fight.

2. Prepare for an uncertain future.

3. Reduce the cost, acquisition time and risk of our major defense acquisition programs.

4. Develop world class science, technology, engineering, and mathematics capabilities for the DoD and the Nation.
Systems Engineering Focus for accomplishing DDR&E Imperatives

1. Accelerate delivery of technical capabilities to win the current fight
   – Support the current fight, manage risk with discipline

2. Prepare for an uncertain future
   – Grow engineering capabilities to address emerging challenges

3. Reduce the cost, acquisition time and risk of our Major Defense Acquisition Programs
   – Champion Systems Engineering as a tool to improve acquisition quality

4. Develop World Class Science, Technology, Engineering and Mathematics capabilities for the DoD and the Nation
   – Develop future technical leaders across the acquisition enterprise
DoD 5000.02 and PL 111-23 — the Changed Acquisition Landscape

Renewed Emphasis on Development Planning and Early Engineering Engagement

New 2366a & 2366b Certifications*

MS A

MS B

MS C

CBA

ICD

MDD

Technology Development

CDD

Engineering and Manufacturing Development

CPD

Production and Deployment

O&S

Full Rate Production Decision Review

Development Planning

Materiel Development Decision (MDD)

Mandatory Competitive Prototypes

PDR

PDR, PDR Report to the MDA, and Post-PDR Assessment before MS B

CDR

System-level CDR with an initial product baseline and a Post-CDR Report to the MDA

Post-CDR Assessment by the MDA between EMD sub-phases

Renewed emphasis on manufacturing across the lifecycle

“Knowledge-based” Decision Making . . . making acquisition decisions when you have solid evidence and acceptable risk

* Director, SE supports MDA certifications including PDR Report assessment at MS B
Pre-MS A Technical Engagement and Authority

• Major acquisition programs are being initiated without adequate technical foundation, resulting in cost and schedule growth

• Acquisition policy has been updated to require Pre-MS B systems engineering engagement and technical risk reduction activity (e.g. Preliminary Design Review, prototyping)

• There remains a Gap in pre-MS A and pre-MDD engagement
  – Adequate technical rigor of concepts prior to the AoA and MDD
  – Technical analysis post AoA, in preparation for MS A solution proposal

• WSARA directed the D, SE to oversee Component Development Planning which can address this gap
  – Need clear acquisition policy to address Development Planning responsibilities

• Solution strategy:
  – Clear policy and guidance for Component Development Planning activities
  – Identify resources to perform these activities

• The goal
  – Informed investment decision and engineered alternatives with sufficiently understood technical risk
  – Improved technical planning for post-MS A risk reduction and system solution development activities resulting in more accurate early cost and schedule estimates
## Significant Technical Issues Pre-MS A

<table>
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<tr>
<th>ISSUE</th>
<th>IMPACTS</th>
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| • Lack of technical engagement with the operational user  
  • To make user aware of potential solutions  
  • To ensure technical developer fully understands user performance needs | • Missed solution opportunities  
  • System requirements growth due to lack of understanding of the CONOPS |
| • Program-focused analysis, when solutions will impact broad sets of systems and SoS | • Delivery of capability that will not integrate, or that has reduced benefit because of external system issues |
| • Lack of technical modeling and assessment of concepts that enter into the AoA | • Increased AoA time and cost due to evaluation of solutions that are not feasible |

### Strategic Guidance
- CBA
- ICD

### Joint Concepts

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**DoD 5000**
Benefit of Development Planning Engagement

1. Iterative, rapid, anticipatory interface between operational and technical community

2. Mature, valid concepts and technical models from broad set of options to enter and bolster the AoA

3. Engineering analysis that considers strategic direction, operational context, SoS and legacy integration

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**IMPACTS**

- Lack of technical engagement with the operational user
- To make user aware of potential solutions
- To ensure technical developer fully understands user performance needs
- Missed solution opportunities
- System requirements growth due to lack of understanding of CONOPS
- Program-focused analysis, when solutions will impact broad sets of systems and SoS
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**Technology**

- Development

**Materiel Solution**

- Analysis

**Engineering Analysis**

- ASR

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**Strategic Guidance**

- Joint Concepts

**CBA**  **ICD**

**DoD 5000**
Development Planning

Translating User Needs and Opportunities Into Viable Solutions

Concept Development and Engineering

Development Planning

Concept Evaluation

Concept Evaluation and Refinement

MDD

Analysis of Alternatives

Engineering Analysis

ASR

Materiel Solution Analysis

Technology Development

DoD 5000

Strategic Guidance

Joint Concepts

CBA

ICD
Development Planning

- OSD Development Planning leadership is required by WSARA
  - The D, SE shall oversee Development Planning activities of major defense acquisition programs, and periodically assess Component Development Planning capabilities

Analysis of future user needs and engineering of new system concepts in a System of Systems (SoS) operational environment

Multiple sufficiently robust, material options to address gap

Defined costs and benefits of the options

Preferred solution with clear evidence & understanding of risk

Sufficiently robust, material solution and a solid TD Plan

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Development Planning

Development Planning is the upfront technical preparation to ensure successful selection and development of a materiel solution
Effective and efficient execution of Systems Life Cycle Management requires a highly skilled and dedicated workforce.
DoD Technical Workforce: Strategy

- Workforce Size
- Workforce Age

**Develop / Train and Retain**

- Recruit: “Interns”
- Recruit: “Journeymen”
- Retired Military

**Develop / Train:**
- Mentors

**Recruit:**
- “Highly Qualified Experts”
- “Highly Qualified Experts”
The SE Workforce Challenge

How can the DoD accelerate the experiential learning cycle to more rapidly develop “scar tissue” for systems engineers?

• **Resource and Support Rotational Training Assignments**
  – More Engineers in Development Labs
  – More Education with Industry
  – More Cross-Service Training Opportunities on New Programs

• **Provide Better Education and Training Alignment with Academia**

• **Provide Experiential Learning Opportunities to both Industry and DoD Workforces**
  – Can we create a “good” revolving door?

*Developing and Accelerating World-class Workforce Capabilities*
Over 20 technical workforce development initiatives across government, industry and academia are in progress:

- Competency Assessments for technical management career fields (“first look” in Q2 2010)
- Competency-based certification standards to enable “raising the bar” for workforce performance at all levels
- Flexible certification framework to encourage and accelerate professional growth and provide the opportunity for subsequent progression to Program Management
- Expanded collaboration with civilian universities and industry associations

We Serve as the Technical Workforce Functional Leader for 44,000 Uniformed and Civilian Acquisition Personnel
Workforce Development Initiatives: Government

- WSARA Workforce Development and Human Capital Activities and Service Assessments for Systems Engineering
- Developing Organization and Capability Assessment Functions
- New Executive Level Certification Standards for Systems Engineering Career Field – Key Leader Profession Development
- Developing Systems Engineering Technical Leaders (with SERC)
- Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE) (with SERC)
- Support to AT&L Workforce Management Group
  - Acquisition Occupational Career Code Subgroup
  - Workforce Data Metrics and Standards Subgroup
- DDR&E Systems Engineering Capstone Courses Initiative
- Mentoring Workshops and Tutorials, Mentoring Programs
Workforce Development Initiatives: Academic

- Competency Assessments/Surveys for Technical Management Career Fields – SPRDE-SE/PSE and PQM (with DAU and CNA)
- SE Education Symposium April 2010 (with USAF Academy)
- STEM Strategic Plan and Implementation Plan Working Group
- Equivalency with Air Force Institute of Technology and Air Force Academy for DAU Technical Courses
- Air Force Academy Preparation Course for INCOSE Associate SE Professional (ASEP) Certification
- Acquisition Qualifications Standards (with DSMC at DAU)
- Specialty Engineering Competencies for Education, Training, and Experience (with DAU and O-FIPT)
- Collaboration with Civilian Universities (with DAU and SERC)
- Workshops with Singapore on SE Competency Models
Workforce Development Initiatives: Industry

• **International Council on Systems Engineering (INCOSE)**
  – Certified Systems Engineering Professional – Acquisition (CSEP-Acq)
  – Future Extensions: Associate Systems Engineering Professional – Acquisition (ASEP-Acq)
  – International Workshops, Symposia, and Working Group Co-Leads
  – Corporate Advisory Board

• **National Defense Industrial Association (NDIA) SE Division Education and Training Committee**
  – Identify Industrial Base Workforce Challenges
  – Determine How to Best Attract, Foster and Develop Future Engineering Leaders
Benefits

• All of these initiatives directly contribute to “raising the bar” for Systems Engineering across the board by:
  – Enabling us to assess the entire DoD Systems Engineering workforce across critical competencies
  – Enabling us to better determine shortfalls in both competencies and workforce size at all levels
  – Enabling us to better manage workforce development requirements and certification standards
  – Enabling us to make better decisions about human capital strategy and initiatives for the Systems Engineering workforce
  – Enabling us to provide acquisition programs with the quantity and quality of Systems Engineers they need to be successful
Opportunities

- Acquisition reform efforts have recognized criticality of strong Systems Engineering focus for program success
  - *Systems Engineering toolkit focused on identifying and managing risk* – development risk, production risk and life-cycle

- Growing focus on addressing “early-acquisition” phases - requirements definition, development planning, and early acquisition system engineering support
  - *Leading to more informed decisions at MS B*

- Our development processes need to evolve to provide faster product cycles, more adaptable products and address emerging challenges

- Future US Defense capabilities depend on a capable US engineering workforce in and out of government
  - *Need to create opportunities to grow future “Engineering Heroes”*
Systems Engineering: Critical to Program Success

Innovation, Speed and Agility
Background

- **National Academies of Sciences Study**
  - All programs destined to fail without early [pre-MS A] systems engineering
  - Development Planning should be used to implement pre-MS A early systems engineering

- **DoD Acquisition Regulations (DoDI 5000.02) Update**
  - Increased focus on early pre-acquisition phases
  - Implication for added early systems engineering

- **Weapon Systems Acquisition Reform Act of 2009 (WSARA)**
  - Directs SE responsibilities to reinvigorate Development Planning
## Systems Engineering Directorate

### Focus Areas/Deliverables

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<tbody>
<tr>
<td>- DoDI 5000.02 Enclosure 12</td>
<td>- Program Protection</td>
<td>- Program Support Reviews (PSRs)</td>
<td>- APPROVE</td>
<td>- Early PSRs</td>
<td>- Defense Support Teams (DSTs)</td>
<td>- Chair SES SA Council</td>
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<tr>
<td>- SE for Adaptability</td>
<td>- Reliability</td>
<td>- Engagement</td>
<td>- TEMP</td>
<td>- SE IPTs, WIPTs</td>
<td>- Independent</td>
<td>- System Assurance</td>
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### Workforce
- Lead for SPRDE, PQM,
- Assess Service capabilities
- Chair Functional IPTs
- SE and DP on MDAPS
- Waivers & Deviation
- Lead for SEPs
- Program Protection
- Mission Assurance
- Config Mgt
- Quality
- Reliability
- Risk Mgt
- Specs and Standards

### Joint Congressional Report w/ DT&E
- Assess Service capabilities
- Lead for SEPs
- Program Protection
- Mission Assurance
- Config Mgt
- Quality
- Reliability
- Risk Mgt
- Specs and Standards

### Performance Measurement
- Performance criteria in SEP & TEMP
- Systemic Root Cause Analysis
- Leading Indicators

### SE Research
- Modeling & Sim
- RAND Strategic Planning Panel
- Reliability Investment Model
- SE
- SEI-CMMI
- SERC

### Direct Program Management
- RTOC
- -- Project Selection
- -- Funds Mgt
- -- VE Advisory Group

### Modeling & Simulation (MSCO)
- Policy & Guidance
- Coordination
- Strategic Plan
- Acq Modeling & Simulation Master Plan
- M&S EXCIMS
- Overseer Service M&S

### International Engagement
- NATO AC/327
- NDIA SE & Logistics Divisions
- US-UK-CA Tri Working Group
- Technical Cooperation Program

### Institutionalize SE
- INCOSE
- JRC1/SC7 – ISO Life Cycle Management
- NDIA SE Division
- -- Software Comm
- -- SoS
- -- System Assurance
- NDIA Logistics Division

### Management/Personnel
- Leadership
- NSPS/SES
- Hiring
- Budget Plan & Execution
- Contracting Support
- Admin

### Service Capability Review
- Develop Methodology
- Establish standards

### Technical Support
- Capabilities Portfolio Management
- GIG Guidance & Policy
- Interoperability Senior Review Panel
- IT Standards
- Spectrum Management
Core SE Mission only

Does not include

- MSCO
- Cyber
- JIAMD
- RTOC
- Part-time & Consultants
Scope of DDR&E Acquisition Program Oversight Efforts*

<table>
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<tr>
<th>Program Category</th>
<th>Increasing cost/risk</th>
<th># of Progs</th>
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<tr>
<td>ACAT ID**</td>
<td>$$$ MDA = AT&amp;L</td>
<td>93</td>
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<tr>
<td>ACAT IC**</td>
<td>$$$ MDA = CAE</td>
<td>52</td>
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<tr>
<td>Special Interest**</td>
<td>Any $s Risk</td>
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<tr>
<td>MAIS, ACAT IA</td>
<td>$$-$$$, AIS</td>
<td>30</td>
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<tr>
<td>Pre-MDAP</td>
<td>$$$ pre-MS B</td>
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<td>Pre-MAIS</td>
<td>$$-$$$, AIS pre-MS B</td>
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<td>ACAT II</td>
<td>$$ &lt; ACAT I</td>
<td>8</td>
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<tr>
<td>ACAT III</td>
<td>$ &lt; ACAT II</td>
<td>9</td>
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<td>Total</td>
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<td>274</td>
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*Based on 2009 T&E Oversight List (Jan 5, 2009)
**Major Defense Acquisition Program (MDAP) +Major Automated Information System (MAIS)

% Distribution of MDAPs by Domain

- Land, 11%
- C2-ISR, 14%
- Unmanned, 4%
- Ships, 9%
- Munitions, 3%
- Rotary Wing, 15%
- Missiles, 8%
- Business, 2%
- Space, 6%
- Comms, 6%
- Fixed Wing, 20%
- Other, 2%
Threats to DoD Acquisition

**Threats:** Nation-state, terrorist, criminal, rogue developer who:
- Gain control of systems through **supply chain opportunities**
- Exploit vulnerabilities remotely

**Vulnerabilities:** All systems, networks, applications
- Intentionally implanted logic (e.g., back doors, logic bombs, spyware)
- Unintentional vulnerabilities maliciously exploited (e.g., poor quality or fragile code)

**Consequences:** Stolen critical technology; corruption, denial of critical warfighting functionality, or loss of information

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**Today’s acquisition environment drives the increased emphasis on Program Protection:**

<table>
<thead>
<tr>
<th>Then</th>
<th>Now</th>
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<tr>
<td>Standalone systems</td>
<td>Networked systems</td>
</tr>
<tr>
<td>Some software functions</td>
<td>Software-intensive</td>
</tr>
<tr>
<td>Known supply base</td>
<td>Prime Integrator, hundreds of suppliers</td>
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Program Protection
Major Efforts

• Implementing 5200.39 and 5000.02 Program Protection Policy
  – DoD 5200.39 Manual (draft SD106)
  – DoD 5000 procedures for Review/Approval of PPPs (PPP Guide)
  – Guidance and best practice countermeasures, education and training, industry outreach, to assist PMs with CPI protection

• Supply Chain Risk Management
  – Procedures, capability to utilize threat assessments in acquisition
  – Vulnerability assessment methodology, pilots, Centers of Excellence
  – Commercial standards for secure components

• Horizontal Protection Procedures
  – Acquisition Security Database (ASDB) adoption and implementation

• System Security Engineering
  – NDIA System Assurance Guidance, adopted by NATO, foundation for ISO 15026
  – INCOSE Working Group
  – Criticality Analysis Working Group (Program Protection WG#9)

• DoD Anti-Tamper Executive Agent
  – Anti-Tamper IPT, AT policy, guidance advocate
  – Legislative Proposal – Defense Exportability Fund
The Current Systems Engineering Environment

5 C’s

Compatibility
Criticality
Compression
Competency
Complexity

Systems Engineers confront a spectrum of issues that challenge “traditional” systems engineering
Multi-Level Engagement

System Engineering

Policy & Guidance
- Systems Engineering
- Software Engineering

Program Support
- Program Support Reviews
- OIPT and SE WIPTs
- AOTR, Post-PDR/CDR Review & Assessment

Workforce Planning
- Competency Models
- Certification Requirements
- Education & Training

Emerging Concepts
- Systems of Systems
- SE Research

Outreach
- SE Forum
- Engagement Strategy

Congress

OSD

Requirement Developers

Service Acquisition Executives

PEOs/Program Offices

Engineering Centers and Evaluation Commands

Prime Contractors and Supply Chain

Education & Collaboration Infrastructure

Professional/Industry Associations

DAU, Academic Institutions, SERC, International Partners

Statutory Direction

Policy and Guidance

ICD, CDD, CPD

DAB, ITAB, DSAB, OIPT, PSR, SEP, PPP, Technical Reviews, SE WIPT

Improved SE Methods, Processes, and Tools, International and National Standards
• Systems engineering, as currently practiced, is less capable of handling the complexity, criticality and pace required of today’s systems
  – Increasingly considered a barrier to success rather than an enabler
• SERC provides a critical mass of researchers from 20 universities to address these challenges
  – Provide methods, processes and tool to advance the state of the practice
  – Grow our nation’s engineering competencies
  – Provide robust and agile solutions to urgent and changing needs
• BKCASE is creating the definitive body of knowledge for SE (SEBoK) and graduate reference curriculum for a professional master’s degree in SE (GRCSE). Incremental releases with Version 1.0 in 2012. [www.bkcase.org]

• BKCASE is led by Stevens Institute and Naval Postgraduate School with support from DoD, SERC, INCOSE, IEEE Systems Council, and NDIA SE Division and volunteer authors from many organizations world-wide.

• Vision is for Systems Engineering competency models, certification programs, textbooks, graduate programs, and related workforce development initiatives around the world to align with BKCASE.

• SEBoK will organize domain independent SE knowledge and provide examples of how to organize domain dependent SE knowledge for some domains. It will structure SE knowledge, define important terms, summarize important topics, selectively help users choose among popular alternative methods, and identify references which elaborate more fully on all topics.

• GRCSE will build on SEBoK and provide recommended student outcomes, entrance expectations and curriculum architecture with sufficient flexibility to accommodate academic programs world-wide.
• GSwe2009 is a set of curriculum guidelines for graduate degree programs in software engineering - published in September 2009. [www.gswe2009.org]

• GSwe2009 project was led by Stevens Institute with support from DoD, INCOSE, IEEE Computer Society, ACM, Brazilian Computer Society, and NDIA SE Division and 40 volunteer authors from around the world.

• Vision is for master’s degree programs in software engineering around the world to align with GSwe2009.

• IEEE Computer Society and ACM have agreed to take over responsibility to maintain GSwe2009. Stevens will continue to lead efforts to encourage and enable world-wide adoption.

• GSwe2009 provides recommended student outcomes, entrance expectations and curriculum architecture with sufficient flexibility to accommodate academic programs world-wide. Companion information compares existing master’s programs to GSwe2009 recommendations and provides FAQs to aid faculty who are implementing GSwe2009.