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The Systems Engineering Body of Knowledge and Graduate Reference Curriculum - BKCASE

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The Systems Engineering Body of Knowledge and Graduate Reference Curriculum

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Abstract. BKCASE is the acronym for the Body of Knowledge and Curriculum to Advance Systems Engineering. The BKCASE project is led by the Stevens Institute of Technology and the Naval Postgraduate School. The project scope is to define a Systems Engineering Body of Knowledge (SEBoK) and to use the SEBoK to develop an advanced Graduate Reference Curriculum for Systems Engineering (GRCSE).

The planned outcome is that the SEBoK will be supported worldwide by the Systems Engineering community as the authoritative SEBoK for the SE discipline; and that the GRCSE will receive the same global recognition and serve as the authoritative guidance for graduate degree programs in SE.

A distinguished group of systems engineers from across the world is volunteering as authors and reviewers on the project, to collaborate over a three year period, and to deliver the products, the SEBoK and GRCSE, to the public incrementally through 2012.

This paper presents the results of the first two project workshops, and outlines the content of SEBoK version 0.25, which will be released in July, 2010, and GRCSE version 0.25 which will be released in October, 2010.

Introduction: Why BKCASE?

In the opinion of the authors, there is no authoritative source that defines and organizes the knowledge of the systems engineering (SE) discipline, including its methods, processes, practices, and tools. The resulting knowledge gap creates unnecessary inconsistency and confusion in understanding the role of SE in projects and programs; and in defining SE products and processes. There are standards and handbooks, but what is missing is an integrated treatment of the whole body. Others have held this opinion (Kasser-Massie, 2001) (Kasser -Adelaide, 2007).

There is also a great variance in the admissions standards, content, and outcomes of graduate systems engineering programs (Jain-Verma 2007). As a result, employers have difficulty knowing what to expect from a graduate of one of these programs.

The field of software engineering similarly lacked an agreed body of knowledge and consistent curricula (Pyster, et al. 2009, 94-101) and (Fabrycky-McCrae 2005). A three year project funded by the United States Office of the Secretary of Defense (OSD) developed a graduate reference curriculum for software engineering (Pyster-Turner 2008, 18-22). This project involved 42 authors and 115 reviewers. The curriculum was developed in less than three years, with three iterations for comment and review, and the final iteration ("GSwE2009") was published in September 2009 (Pyster 2009). The associated professional societies (ACM, IEEE Computer Society, and INCOSE) endorsed the effort and the ACM and IEEE Computer Society agreed to sustain and update the reference curriculum over time.

Inspired by this model and recognizing the need, the OSD funded another three year project to define the systems engineering body of knowledge (SEBOK) and to define an accompanying graduate reference curriculum in systems engineering (GRCSE). The project began in September 2009 with Art Pyster as principal investigator and Dave Olwell as co-principal investigator. The combined effort was titled "Body of Knowledge and Curriculum to Advance Systems Engineering," or BKCASE.

Project Members, Partners, and Structure

The success of the GSwE2009 project was due to the quality of the authors and reviewers who volunteered their services. BKCASE has attracted a similar set of high quality of authors and reviewers, including several who participated in GSwE2009. The list of authors as of April 2010 with their affiliations is in Table 1. These authors represent the world-wide scope of the project, spanning ten nations to date, academia, government, and industry. There is extensive representation from European industry and academia.

Table 1. BKCASE Authors as of April 2010

Rick Adcock, Cranfield University and INCOSE, UK	*Bud Lawson, Lawson Konsult AB, Sweden*
Johann Amsenga, Eclipse RDC, South Africa	*Alex Lee, Defence Science and Technology Agency, Singapore*
Erik Aslaksen, Sinclair Knight Merz, Australia	*Ray Madachy, Naval Postgraduate School, US*
John Baras, IEEE Systems Council and University of Maryland, US	*Andrew McGettrick, Association for Computing Machinery (ACM) Education Board and Education Council*
Barry Boehm, University of Southern California, US	*Ken Nidiffer, Software Engineering Institute and IEEE Systems Council, US*
Cihan Dagli, Missouri University of Science and Technology, US	*Dave Olwell, Naval Postgraduate School and BKCASE Co-Principal Investigator, US*
J. Ekstrom, Brigham Young University, US	*Art Pyster, Stevens Institute of Technology and BKCASE Principal Investigator, US*
Alain Faisandier, Map Systeme, France	*Garry Roedler, Lockheed Martin and National Defense Industrial Association Systems Engineering Division, US*
Tim Ferris, University of South Australia and INCOSE, Australia	*Jean-Claude Roussel, EADS, France*
Kevin Forsberg, Center for Systems Management and INCOSE, US	*Sven-Olaf Schulze, Berner & Mattner Systemtechnik GmbH, Germany*
Richard Freeman, Air Force Center for Systems Engineering, US	*Jon Gye Shin, Seoul National University, South Korea*
Sandy Friedenthal, Lockheed Martin, US	*Hillary Sillitto, Thales Group and INCOSE, UK*
Richard Frost, General Motors, US	*John Snoderly, Defense Acquisition University, US*
Edward Ghafari, ICES Corporation and Defense Information Systems Agency, US	*Alice Squires, Stevens Institute of Technology, US*
Richard Grzybowski, Corning Incorporated, US	*Massood Towhidnejad, Embry-Riddle University, US*
Tom Hilburn, IEEE Computer Society and Embry-Riddle University, US	*Guilherme Travassos, Federal University of Rio de Janeiro, Brazil*
Scott Jackson, University of Southern California, US	*Mary VanLeer, Arkansas Scholarship Lottery, US*
Michael Krueger, ASE Consulting, US	*Brian Wells, Raytheon, US*

Several professional societies have affiliated with the BKCASE project. They include INCOSE, ACM, NDIA Systems Engineering Division, the IEEE Systems Council, and the IEEE Computer Society. With the financial sponsor, OSD, collectively they are referred to as the project partners. The professional societies have nominated authors as identified in Table 1, and they provide financial support for their author's participation.

The project is organized with a core management and administrative team. The core team provides management and logistical services. The authors are task-organized into several teams to write and internally review materials. The composition of these teams is fluid as the structure of the SEBOK and GRCSE evolve.

The materials will proceed through three versions, labeled 0.25, 0.50, and 1.0, and delivered in 2010, 2011, and 2012. Each of versions 0.25 and 0.50 will be circulated to a wider audience for review and comment. It is expected that the copyright for version 1.0 will be passed to INCOSE and the IEEE for maintenance, sustainment, and further revision of the materials.

Workshops are held quarterly for authors. The first was in Monterey in December 2009, and the second was in Daytona Beach in March 2010. The workshops allow the authors to collectively set the overall course of the project, to share updates, and to plan the work between workshops. Authors meet electronically in their teams as necessary.

SEBoK Overview and Status

The SEBoK claims the following value proposition:

a. There is no authoritative source that defines and organizes the knowledge of the SE discipline, including its methods, processes, practices, and tools. The resulting knowledge gap creates unnecessary inconsistency and confusion in understanding the role of SE in projects and programs; and in defining SE products and

processes. SEBOK will fill that gap, becoming the "go to" SE reference.

b. The process of creating the SEBoK will help to build community consensus on the boundaries and context of SE thinking and to use this to help understand and improve the ability of management, science and engineering disciplines to work together.

c. Having a common way to refer to SE knowledge will facilitate communication among systems engineers and provide a baseline for competency models, certification programs, educational programs, and other workforce development initiatives around the world. Having common ways to identify metadata about SE knowledge will facilitate search and other automated actions on SE knowledge.

The initial structure of the SEBOK followed the processes outlined in ISO 15288. At the second workshop, the authors adopted an expanded table of contents. That table of contents is listed in Table 2. Authors are currently writing content against that table of contents for the July 2010 release of version 0.25.

Table 2. Table of contents for the SEBoK as of April 2010.

1. Executive Summary
2. Introduction (Overview)
    - Purpose of BoK
    - Scope
3. System Concepts
    - System Definition – what is a system
    - Systems Thinking
4. Fundamentals
    - Value/Quality
    - Principles of SE
    - Integration of other disciplines such as software engineering and project management
    - Socio-technical Issues (Context)
    - SE Standards
    - Application domains (describes each)
5. SE Approach and Practices
    - Life Cycles
    - Organization
    - Management
    - Technical
    - Agreement
    - Specialty Engineering/Design Considerations
6. SE Artifacts
7. SE Applications/Case Studies
8. SE Competency (ethics, statistical modeling, …)
9. Glossary
10. Other Closing Matter

Primary direct SEBoK users will be (a) practicing systems engineers ranging from novices up through senior experts, (b) those responsible for defining and implementing SE processes within organizations, projects, and programs; (c) those responsible for certifying systems engineers and developing certification programs; (d) customers of SE organizations to help them better select and evaluate those organizations; (e) any project manager, engineer, technologist, researcher, or scientist who needs to know about SE; (f) those who educate and train systems engineers; and (g) the GRCSE author team. The SEBoK will facilitate easy access and use by these different types of users.Styles

GRCSE Overview and Status

The GRCSE value proposition claims:

a. There is no authoritative source to guide universities in establishing the outcomes graduating students should achieve with a master's degree in SE, nor a guidance source on reasonable entrance expectations, curriculum architecture, or curriculum content.

b. This gap in guidance creates unnecessary inconsistency in student proficiency at graduation, makes it harder for students to select where to attend, and makes it harder for employers to evaluate prospective new graduates.

c. GRCSE will fill that gap, becoming the "go to" reference to develop, modify, and evaluate graduate programs in SE. The initial focus is on systems engineering centric programs. The approach to domain centric programs is still under discussion.

GRCSE necessarily lags the SEBoK, since the SEBoK will be the basis of the core body of knowledge (CBOK) for the curriculum. The release of GRCSE version 0.25 is scheduled for October 2010.

At the March 2010 workshop, the structure outlined in Table 3 was adopted for GRCSE.

Table 3. Structure of GRCSE as of April 2010.

1. Introduction/front matter
2. Curricular objectives
3. Curricular outcomes
4. Entrance expectations
5. Curriculum architecture
6. Core Body Of Knowledge (CBOK)
7. Assessment
8. Maintenance / refresh strategy
9. Closing matter
10. Appendix: catalog of programs / benchmarks

The emphasis on objectives and outcomes parallels the increasing emphasis for these from the regional and professional accrediting bodies. While GRCSE is not tied to any accrediting body, the approach seemed consistent with requirements flow-down and was adopted.

The GRCSE author team will propose a set of curriculum objectives that will span the majority of program stakeholder needs. These curricular objectives describe what a graduate is expected to achieve three to five years after graduation. In turn, these objectives drive the curricular outcomes that describe the capabilities of a student upon graduation. These outcomes then drive the selection of the core body of knowledge. The core body of knowledge is anticipated to constitute less than half of the credit hours for the graduate reference curriculum.

There is a wide range of existing entrance requirements for graduate systems engineering programs. The authors will attempt to see if a consensus can be reached on the expected admissions qualifications. In particular, what undergraduate engineering content will be assumed?

Way Forward

BKCASE is continuing to recruit reviewers. GSwE2009 had over a hundred, and BKCASE anticipates even more. Authors who expand the diversity of the author team or who fill expertise gaps are also being recruited.

Quarterly workshops will continue through 2012. Version 0.25 of SEBOK will be released in July 2010 and of GRCSE in October 2010. Version 0.50 will follow a year later, with the release version 1.0 set for publication in 2012.

The project web page is publicly available at http://www.bkcase.org. Materials will be available there as they are released.

The project team will continue to "build community consensus" about the SEBoK by actively presenting the project plan and intermediate products to a wide sets of conferences and audiences.

Conclusion

The BKCASE project is very much a work in progress, building on the successful approach of the GSwe2009 project. An international team of volunteers is shaping the project; and there is room for others to help. Thus far, the team has written a draft portion of the SEBoK version 0.25 that covers the life-cycle processes of 15288 and this draft is currently being expanded to include systems concepts, fundamentals, competencies, artifacts and companion case studies. A team has also been put together and is addressing the strategy and development of the follow-on product GRCSE. The primary products, the guide to the systems engineering body of knowledge and the graduate reference curriculum, will undergo an annual release and review cycle over the next two years with the final version 1.0 release in 2012. The vision of the authors, reviewers, sponsors, and partners is that the products will positively influence systems engineering practice and education throughout the world.

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BIOGRAPHIES

David. H. Olwell is Professor of Systems Engineering at the Naval Postgraduate School, where he recently completed a five-year term as department chair. His research interests are reliability engineering and statistical quality control. He previously was on the faculty of the United States Military Academy.

Art Pyster is a Distinguished Research Professor in the School of Systems and Enterprises at Stevens Institute of Technology and the Deputy Executive Director of the Systems Engineering Research Center, a Department of Defense's University Affiliated Research Center. Previously, he served in leadership roles for SAIC, the Federal Aviation Administration, the Software Productivity Consortium, Digital Sound Corporation and TRW. During his career, Art directed the creation of three Capability Maturity Models, oversaw more than $10 billion in investments and has authored many papers and one textbook – Compiler Design and Construction. He is an INCOSE Fellow.

Alice Squires is a PhD candidate and faculty in Systems Engineering in the School of Systems and Enterprises at Stevens Institute of Technology with over 28 years of experience. After completing her Electrical Engineering bachelor's degree at the University of Maryland, she served as a technical lead for IBM, completed her MBA from George Mason, served as a senior systems engineering manager for both Lockheed Martin and General Dynamics (GD). Next, she served as a Senior Systems Engineer consultant to Lockheed Martin, IBM, and EDO Ceramics, for ASSETT. Alice holds INCOSE CSEP, CSEP-Acquisition certifications.

Don Gelosh is the Deputy Director for Workforce Development in the OSD Directorate of Systems Engineering. He provides expertise in workforce development, competency, and knowledge management and has over 33 years of combined experience from the US Air Force, government, industry, and academia. Don received a PhD in Electrical Engineering from the

University of Pittsburgh in 1994, a MS in Computer System Design from the University of Houston at Clear Lake in 1989, and a BS in Electrical Engineering from the Ohio State University in 1981. He also holds an INCOSE CSEP-Acquisition certification.

Stephanie Enck is a research assistant at the Naval Postgraduate School's Systems Engineering Department. She has a Bachelor of Science in Communication, sales and marketing management experience, and volunteered to assist Army families for several years before joining the SE department at NPS. Her research interests and project coordination efforts include M&S education, project management, and SE education.

Jim Anthony is a Senior System Engineer supporting the Department of Defense Systems Engineering Directorate. He has 27 years engineering experience with the U.S. Air Force, U.S. Navy, Defense Threat Reduction Agency, and DoD Modeling and Simulation Coordination Office. He is "Qualified in Submarines" and a retired U.S. Navy Commander. He has a B.S. in Chemical Engineering, *Magna cum Laude,* (1981) from Christian Brothers University and a M.S. in Systems Engineering from George Mason University (2006).