Status of the Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE™) Project

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ABSTRACT

The Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE™) project has been established to develop a guide to the Body of Knowledge for Systems Engineering (SEBoK) and a Graduate Reference Curriculum for Systems Engineering (GRCSE™).
The project, primarily funded by the U.S. Department of Defense, is led by a university partnership between the Stevens Institute of Technology and the U.S. Naval Postgraduate School (NPS) with support from various professional societies, especially the International Council on Systems Engineering (INCOSE) and the Institute of Electrical and Electronics Engineers (IEEE), Universities and Industries, all supporting the core authors from across the globe.
The project was initiated in September 2009 and had its inaugural workshop at NPS in Monterey, CA where a team of international authors first gathered to initiate collaborative efforts. It is anticipated that the effort will take three years during which SEBoK and GRCSE products will be delivered incrementally to the public though 2012. Industry and academia are equally represented with approximately 1/3 of the authors based outside the U.S. with representation primarily from Europe, Asia and Australia. This paper will focus on the progress of each document (SEBoK and GRCSE) about one year before their final scheduled delivery to the public in fall 2012.

KEYWORDS: Systems; Body of Knowledge; Engineering; Reference Curriculum; Graduate.

1. INTRODUCTION - BKCASE Project Background & Overview

The BKCASE project was previously introduced in [5] and [6].

1.1 History

The BKCASE project was born from a need to develop an internationally accepted authoritative guide to both the knowledge of the systems engineering discipline and the curriculum needed to teach the discipline at the Masters (professional) level. Historical efforts to create a body of knowledge for systems engineering were supported primarily through the International Council on Systems Engineering (INCOSE) [7, 9]. These efforts included the evolution of the INCOSE Systems Engineering Handbook (see INCOSE 2011 Version 3.2.1 [7] for the latest version) as well as a guide to the systems engineering body of knowledge that was published online and described in the April, 2002 edition of INCOSE INSIGHT which remains available to INCOSE members. Systems engineering knowledge has also been documented through the standards bodies, most notably :

- *ISO/IEC/IEEE 15288, Systems Engineering-System Life Cycle Processes, 2008* (see [10]).
- *ANSI/EIA 632, Processes for Engineering a System, (1998)*
- *IEEE 1220, ISO/IEC 26702 Application and Management of the Systems Engineering Process*[1]
- *EIA 731, Systems Engineering Capability Model*[2]
- *CMMI, Capability Maturity Model Integration*
- *United States Defense Acquisition Guidebook, Chapter 4, June 27, 2011*
- *IEEE/EIA 12207, Software Life Cycle Processes, 2008*
- *United States Air Force Weapon System Software Management Guidebook*
- *U. S. Dept of Defense Manual for the Service Development and Delivery Process (SDDP), Version 1.00, 28 Jan 2011*

These efforts were supported by the need to develop a coherent foundation of community accepted systems engineering knowledge as a basis for future workforce development initiatives and advancement of the ability to more effectively horizontally integrate independent functions and activities within an enterprise.

1.2 Project Members, Partners, Stakeholders

The desire to create a foundational guide to systems engineering knowledge is a shared vision across the wider international community of systems engineers. To this end, the project consists of a core team with a half a dozen members from the lead universities and the funding agency; and a broader author team with over five dozen sponsored and volunteer authors from around the world and across multiple domains. The core team manages the project and members of the core team also serve as co-editors and co-authors on the project.

Two professional societies, INCOSE and IEEE have agreed to become joint stewards of the BKCASE products once they are released in 2012. To this end, both INCOSE and the IEEE are partners in the current project and have provided both observers and authors to the BKCASE team. Other partners and sponsoring organizations include the Association for Computing Machinery (ACM) and the Systems Engineering Division (SED) of the National Defense Industrial Organization. Stakeholders in the development and success of the BKCASE project include many institutions too numerous to mention here, that are spread across government, industry and academia, and around the world.

1.3 BKCASE Project Overview

The project, initiated in September of 2009, has completed, at the time of this writing, seven of twelve planned workshops. The initial three workshops preceded the release of the 0.25 version of the guide to the SEBoK (Pyster, et. al, September, 2010) and the fourth workshop was followed by the release of the 0.25 version of GRCSE (Pyster, et. al, December, 2010). Similarly, SEBoK version 0.5 will be released in the fall of 2011 following the seventh workshop (already completed). However, one major difference between version 0.25 and version 0.5 of the SEBoK will be the format in which the guide is presented. Version 0.25 of the guide to the SEBoK was a document of over 650 pages in length including the front matter as well as

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[1] IEEE 1220 underwent a minor update that enabled concurrent usage with IEEE 15288. It was then fast-tracked into ISO/IEC as ISO/IEC 26702 and now contains a new project element to enable increased focus on SE management planning.

[2] Although still in use and available, EIA 731 is not considered “current” by many and is viewed as being replaced by CMMI

references and a glossary. This version was comprised of sixteen chapters. The newer version 0.5 will be released in a wiki format and will be comprised of over 170 wiki articles ranging up to 2000 words each. These articles are comprised of seven main part introductions, about a dozen introductory sections in the initial part (Part 1), 26 knowledge areas, 107 topics, and over a dozen case studies and vignettes. For GRCSE, both the version 0.25 and 0.5 will be released in document form with the second release being more international in flavor and more mature in the recommendations for developing graduate programs in systems engineering. More detail on both the SEBoK and GRCSE products are outlined in the next two sections.

2. SEBoK Overview and Status

2.1 SEBoK Purpose

According to the BKCASE Project Charter as defined when the project was launched in Dec 2009 [4] , 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.

2.2 SEBoK Structure

The initial structure of the SEBoK at the project launch was based on the ISO 15288 processes [10]. Then, the authors adopted an expanded table of contents which was used for the SEBoK 0.25 issued in Sep 2010 [8]. Many SEBoK 0.25 reviewers recommended changing the overarching structure of the document and provided suggestions. In line with these proposals/comments and following discussions with authors held in the 3 last workshops (Phoenix in Jan 2011, Los Angeles in April 2011 and Denver in June 2011), the structure of SEBoK version 0.5 has finally been decomposed in 7 main “parts”. Those main parts:

1. **Part 1 : Introduction**
   This will cover the context, purpose and scope of the SEBoK, its relationship to overlapping communities of interest, the current status of Version 0.5 , and the guidance and plans for progressing to Version 1.0
2. **Part 2 : Systems**
   This part will discuss the basic characteristics of engineered systems and the languages for describing them. This is the “what” of Systems Engineering : What is engineered ?
3. **Part 3 : Systems Engineering and Management**
   This part will cover the actual engineering of systems, how engineering may be performed, how engineering is managed, and the implications of engineering activities throughout a systems life. This will also discuss the different common lifecycle models. This is the “how” and “when “ of systems engineering: How are systems engineered ? When does this take place ?
4. **Part 4 : Applications of Systems Engineering.**
   This part will cover the organizational aspects of systems engineering, who manages and performs systems engineering, as well as organizational considerations such as where systems engineering is housed and competency models for systems engineers. This is the “who” and the “where” of systems engineering : Who is responsible for performing and overseeing systems engineering? Where do systems engineering activities reside within an organization ?

5. **Part 5 : Enabling Systems Engineering**
   This part will cover the analysis of existing systems engineering case studies in relation to the SEBoK and how well they address specific aspects of the SEBoK. When possible, a discussion will also be provided on any domain-specific implications. For example, does the domain relevant to the case study use different terminology from that found in the SEBoK? Do they have specific focus areas that are different from those discussed in the SEBoK?
6. **Part 6 : Related Disciplines**
   This part will cover how some related disciplines are interfering with Systems Engineering. These related disciplines are:
   - Software Engineering
   - Project Management
   - Procurement / Acquisition
   - Marketing / Sales
   - Specialty Engineering :
     - Reliability, Availability and Maintainability
     - Human System Integration
     - Safety
     - Security
     - System Assurance
     - Electromagnetic Interference/ Electromagnetic Compatibility
     - Resilience
     - Manufacturability and Reparability
     - Sustainability
7. **Part 7: Systems Engineering Implementation Examples.**
   Part 7 is a collection of implementation examples to illustrate the principles described in the SEBoK. These examples describe the application of systems engineering practices, principles, and concepts in real-life settings. The intent is to provide real examples of the application of SE, in the hope that others will learn from these experiences. These systems engineering examples can be used to to improve the practice of systems engineering by illustrating to students or practitioners the benefits of effective practice and the risks and liabilities of poor practice.

   A matrix of Implementation Examples is used to map the implementation examples to topics in the SEBoK. To provide a broader set of domains, both formal case studies and shorter vignettes are used as examples. For the case studies, an introduction and analysis of the case is given, with references to the external case study. For the vignettes, the implementation example is described directly. In the literature, a wide variety of examples and formats are considered "case studies." Here, the distinction between a case study and a vignette is that a vignette is a short wiki article written for the BKCASE project and a case study exists externally in the literature. An initial set of examples is included, anticipating that other examples will be added over time to highlight the different aspects and applications of systems engineering.

   Present Case Studies are : HST (Hubble Space Telescope), GPS (Global Positioning Systems), FBI Virtual Case File, ISS (International Space Station), Space Shuttle, Korean Rail.

   Present Vignettes are : Denver Airport baggage Handling System, GE Birth of IDEF, Virginia Class Submarine, UK West Coast Route Modernisation Project, Singapore Water Management System

3. GRCSE Overview and Status

The Graduate Reference Curriculum for Systems Engineering (GRCSE), product of the BKCASE project was commenced in March 2010.

3.1 GRCSE Purpose

GRCSE addresses the general concern that there are a wide diversity of Masters level education programs using the name “systems engineering” in their title with such great differences between the programs that prospective students and employers have difficulty understanding what kind of systems engineering education is provided across the range. The purpose of GRCSE is to describe the systems engineering education space in a way which provides a common vocabulary for all stakeholders and which provides a framework for stakeholders to understand what they would receive from particular programs. The first, limited release, review version was provided to about 200 reviewers on 15 December 2010, and resulted in well over 100 reviewers submitting in excess of 1300 distinct review comments by 15 March 2011.

GRCSE addresses the Masters level education of people seeking to advance into systems engineering from other areas with a view to providing holistic perspectives on the engineering work. GRCSE has taken the perspective that curriculum should be broadly interpreted to mean the combination of all the teaching and learning experience and the context in which they are provided with a view to creating the educational results of the program [1-3].

The goal of GRCSE is to provide useful guidance to several groups of stakeholders, as follow:

1. University program developers, to assist the development of professionally oriented systems-centric masters level programs in systems engineering. The guidance provided includes characteristics of the people who progress through the program in the form of objectives, the capabilities that graduates are expected to demonstrate 3 to 5 years after graduation, outcomes, the knowledge and capabilities graduates are expected to have at the time of graduation, entrance expectations which enable a program to expect to achieve the desired objectives and outcomes.
2. University program maintainers, who can use GRCSE to compare their program with the considered view of the systems engineering community as to what masters level systems engineering education should be like.
3. Prospective students, who will better understand the program options available to them through having access to a general discussion of the various kinds of programs available, and the expected outcomes of those programs, written without the vested interest of promoting any particular program.
4. Employers of systems engineers, who benefit in the same way as prospective students, by having a basis to determine the match between particular programs and their specific needs.

3.2 GRCSE Structure

The author team divided GRCSE into sections describing the development of people achieved through the program, an architecture for organizing the teaching, areas of knowledge content to be learned, and methods for assessment of student and program attainment. GRCSE contains other materials which are included to assist the reader in understanding the main content of GRCSE described above.

GRCSE provides a description of a curriculum architecture which conveys the concept of the intended curriculum, which has about 50% of the time required to teach core topics and capabilities which all systems engineers should have and the additional capabilities which are needed by systems engineers in particular sub-areas or practice. The remaining 50% of the program time is available for universities to develop distinctive kinds or levels of attainment in their graduates. Associated with the curriculum architecture GRCSE has a list of knowledge areas from the SEBOK which present the substance of what should be learned in the core section of the program, and in programs targeted at one of several focus fields of practice within systems engineering. The expected levels of attainment by students are described using Bloom's taxonomy of educational outcomes. GRCSE describes what should be achieved by a masters program, but does not attempt to instruct how the education will be delivered. This perspective is deliberate, to ensure that GRCSE is useful globally, in widely divergent education systems, regulatory environments, and with a wide diversity of other local contextual factors.

This approach enables universities to distinguish themselves through the manner in which they design their programs to achieve desired results, and will also prevent GRCSE being used directly as an accreditation specification.

The GRCSE v0.5, public review, version is scheduled for release by any interested person in mid-December 2011, again for a three month review period. This is working towards the later 2012 final release date.

4. CONCLUSION - Practitioners' Needs to fill the gap with Academia

When examined through the eyes of those who design, develop, field and sustain systems, that must increasingly rely on each systems ability to integrate with other systems to operate effectively, the BKCASE initiative is long overdue.

In the mid 1990's pressure was mounting on major enterprises to dramatically change the way they developed, acquired, fielded, and sustained systems. It was widely believed at the time that this unbridling of the contractor would reduce costs while simultaneously fostering innovation. Contractors were strongly advocating that if they were free of these inhibitors, they could deliver better products at lower costs. This dual onslaught from the media who highlighted cost overruns on major projects, and contractor's advocacy, resulted in sweeping changes that included the rescinding of a large number of the military specifications and standards, slashing program documentation requirements, and greatly reducing the size of acquisition program offices.

The language of contracts was changed to specify the desired "capability" and allowed contractors the freedom to determine "how" to best deliver this capability. This action effectively transferred systems engineering to the sole purview of the contractors. The contractors were being relied upon to deliver, while the responsibility for the delivery of viable solutions remained squarely with the buyer. This situation was further exasperated as various procurement operations moved away from the application of published specifications, standards, methods, and rules, to a more hands-off approach.

What resulted was a vacuum in which neither the buyer nor the contractors accomplished the necessary systems engineering. Over the following decade, the externally focused integration SE capabilities within many large entities virtually disappeared. This absence of SE capability became increasingly apparent on multiple-system (systems-of-systems) programs in which more than one contractor was involved where the lack of a standard language, which supported standard common methods models and tools, was most apparent.

Faced with increasingly complex systems that relied on other complex systems and a barrage of failures and miss-starts, companies/governments began re-focusing their attention on external integration requirements. This re-focusing demand mutually agreed upon standards that are based on a common language. As was highlighted earlier in this paper numerous different entities initiated efforts to develop such SE process standards, however, after almost 20 years no single common language yet exists, hence the critical importance of the recently initiated BKCASE project. The practitioner community must increasingly assure that their products/services effectively integrate with those products and services provided by others to deliver the outcome desired by the customer. To effectively achieve this, companies and governments are increasingly seeking systems engineers who can communicate across horizontally beyond traditional boundaries. To do so, these engineers must be educated in a manner that instills a common set of knowledge.

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