SEBoK: a guide to the systems engineering body of knowledge

Presented by a panel of contributors to SEBoK

IEEE computer society

IEEE Advancing Technology for Humanity

Panelists

- Rick Adcock, Cranfield University
- Dick Fairley, IEEE Computer Society
- Dave Olwell, Naval Postgraduate School
- Garry Roedler, Lockheed Martin
- Massood Towhidnejad, Embry Riddle Aeronautical University

IEEE Advancing Technology for Humanity

Agenda and goals for this panel session

- Agenda
  - Short presentations by the panelists
  - Q&A with the attendees
- Goals:
  - To indicate the role of SEBoK within the larger context of systems engineering
  - To address your questions and concerns
  - To receive feedback for improvements

IEEE Advancing Technology for Humanity

Presentation topics

- Dick: brief overview of SEBOK wiki and usage statistics
- Rick: editorial board structure; past & planned evolution of SEBoK
- Garry: SEBoK related standards, systems engineering handbook, and certification
- Dave: SEBoK Parts 6 & 7 plus relationship of GRCSE to SEBoK
- Massood: relationships between systems engineering and software engineering
- Dick: moderate Q&A and panelists' comments

IEEE Advancing Technology for Humanity

SEBoK

- SEBoK is a ***guide*** to the systems engineering body of knowledge
- SEBoK has 7 parts
  - Each part has knowledge areas
  - Each knowledge area has topics
  - Each topic provides a summary and references for further reading

The 7 parts of SEBoK

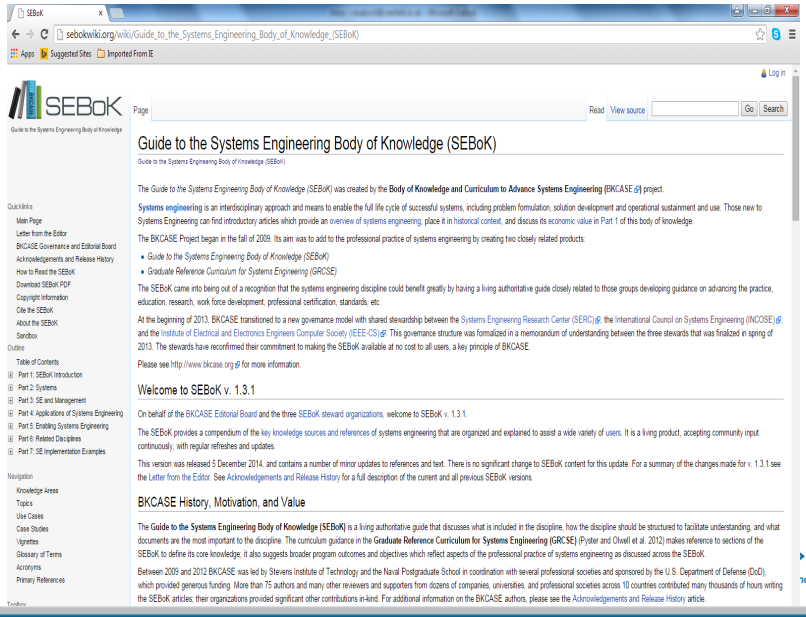
- Part 1: SEBoK Introduction
- Part 2: Systems
- Part 3: SE and Management
- Part 4: Applications of Systems Engineering
- Part 5: Enabling Systems Engineering
- Part 6: Related Disciplines
- Part 7: SE Implementation Examples

SEBoK wiki

- SEBoK is implemented as an online, interactive wiki
  - URL: sebokwiki.org

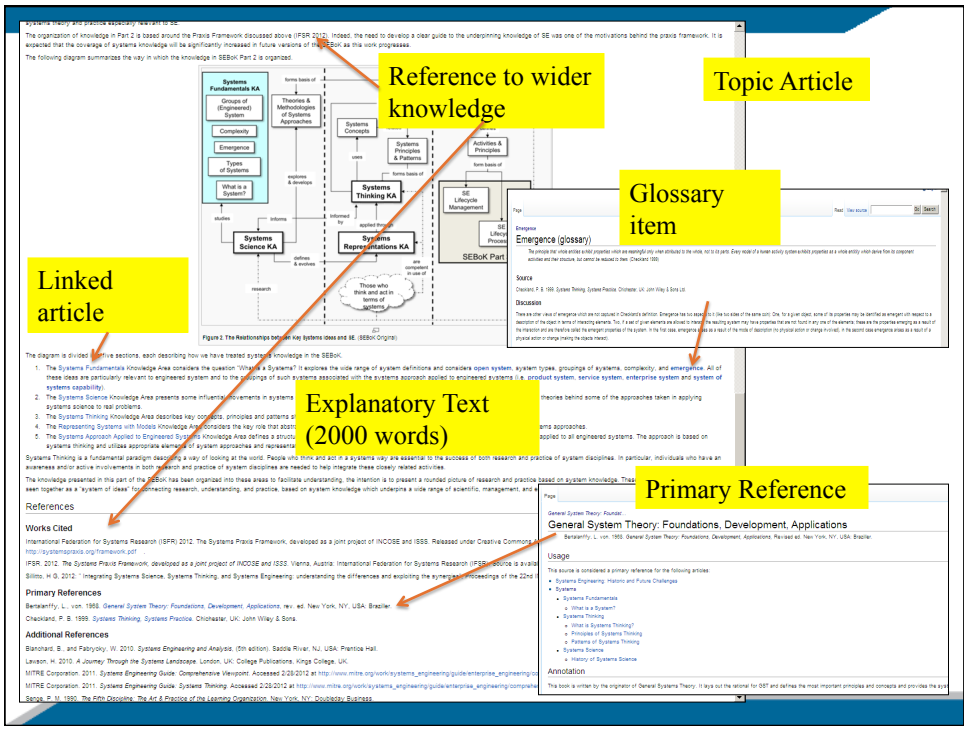
IEEE Advancing Technology for Humanity

www.sebokwiki.org

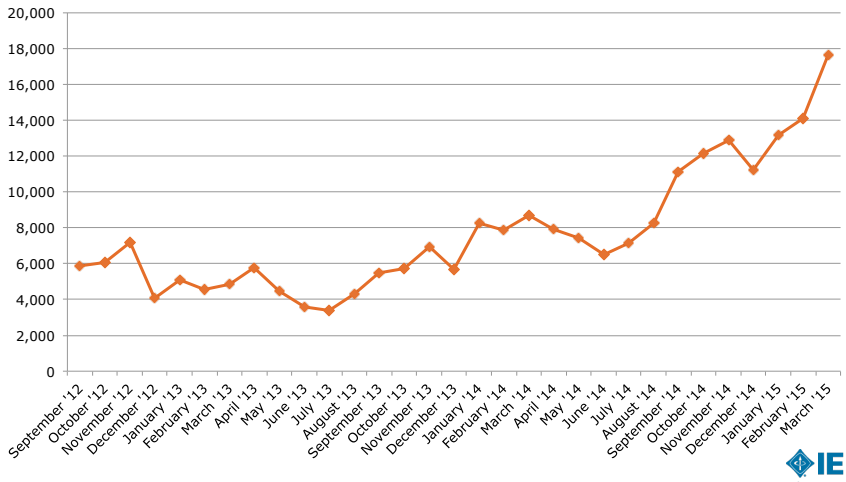


IEEE Advancing Technology for Humanity

www.sebokwiki.org



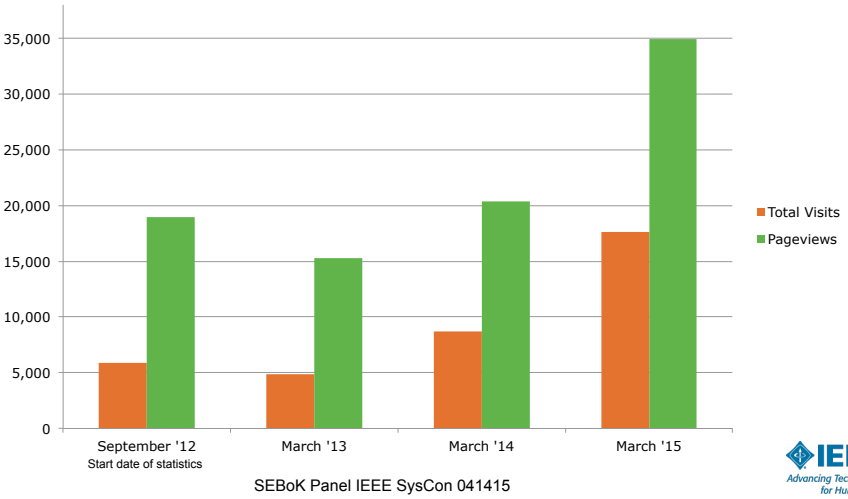
Visits per month



SEBoK Panel IEEE SysCon 041415

IEEE Advancing Technology for Humanity

Snapshot March



SEBoK Panel IEEE SysCon 041415

IEEE Advancing Technology for Humanity

SEBoK stewards and editorial board

- The SEBoK stewards are:
  - INCOSE
  - IEEE Computer Society
  - Systems Engineering Research Center
- SEBoK content is managed by an editorial board

IEEE Advancing Technology for Humanity

Presentation topics

- Dick: brief overview of SEBOK wiki and usage statistics
- Rick: editorial board structure; past & planned evolution of SEBoK
- Garry: SEBoK related standards, systems engineering handbook, and certification
- Dave: SEBoK Parts 6 & 7 plus relationship of GRCSE to SEBoK
- Massood: relationships between systems engineering and software engineering
- Dick: moderate Q&A and panelists' comments

IEEE Advancing Technology for Humanity

Body of Knowledge and Curriculum to Advance Systems Engineering

Guide to the Systems Engineering Body of Knowledge

Graduate Reference Curriculum for Systems Engineering

IEEE Advancing Technology for Humanity

Body of Knowledge and Curriculum to Advance Systems Engineering

Guide to the Systems Engineering Body of Knowledge

- A living authoritative guide to the knowledge most relevant and important to the advancement of Systems Engineering
- Discusses what is included in the discipline,
- how this knowledge can be structured to facilitate understanding,
- what sources are most important to the discipline.

IEEE Advancing Technology for Humanity

Body of Knowledge and Curriculum to Advance Systems Engineering

GRCSE®

Graduate Reference Curriculum for Systems Engineering

- Curriculum guidance for systems engineering master's program.
- Knowledge coverage against the SEBoK
- broader program guidance and advice
- Broad based curriculum framework, tailor-able, advisory and useful
- While setting some agreed minimum baseline of what SE Masters education needs to be

Body of Knowledge and Curriculum to Advance Systems Engineering

- BKCASE is a partnership between three well known organizations
  - International Council on Systems Engineering (INCOSE),
  - Institute of Electrical and Electronics Engineers Computer Society (IEEE-CS),
  - Systems Engineering Research Center (SERC).
- The detailed content and use of SEBoK, GRCSE and any future products are now driven by a **BKCASE Editorial Board**.

Body of Knowledge and Curriculum to Advance Systems Engineering

The BKCASE products continue to provide a living, shared and authoritative guide to the full scope of Systems Engineering Knowledge, becoming the most used reference in the world to guide systems engineering graduate education and systems engineering practice. - BKCASE Vision 2014

- By continuing to work towards aligning technical initiative and research, competency models, certification programs, textbooks, standards and guides, graduate programs, and related workforce development initiatives around the world to BKCASE our sponsors can enhance their ability to
  - Share, use, evolve and co-create value from that knowledge with their stakeholders.
  - Providing a framework for the education, development and recognition of all those involved in the professional practice of Systems Engineering.
  - Better describe the place Systems Engineering holds in complex problem resolution and thus shape and grow that role.

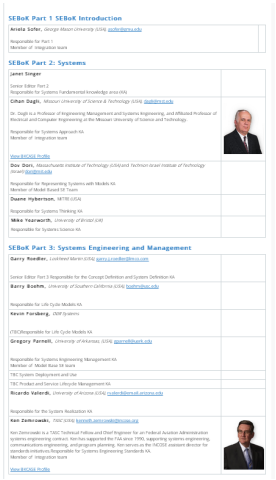
www.BKCASE.org

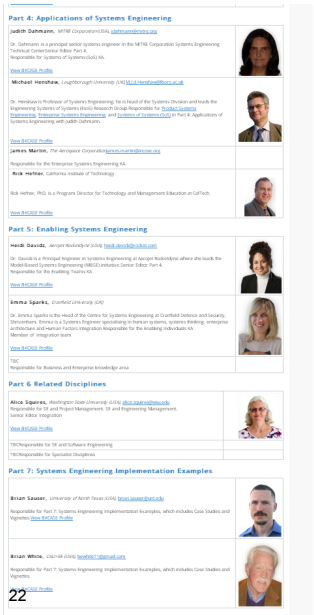
www.BKCASE.org

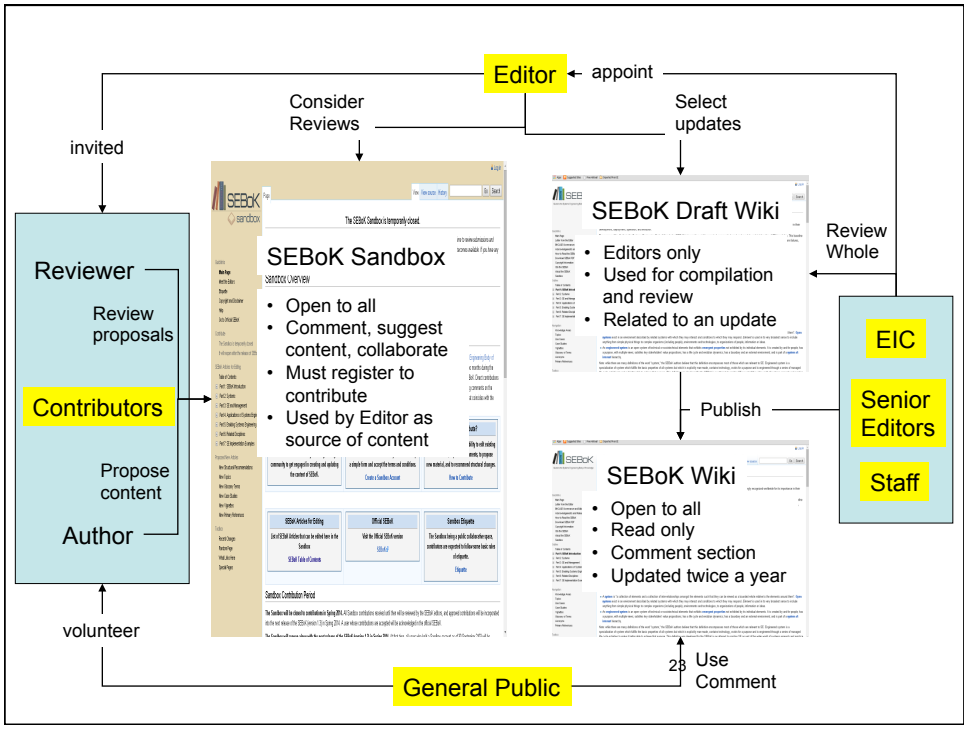
- The website is the first place to visit for information on the BKCASE project:
  - History, Governance and Editorial Board
  - News items
  - Explanatory Slide Casts giving details of:
    - Governance
    - Update process
    - SEBoK Overview
    - SEBoK plans and evolution

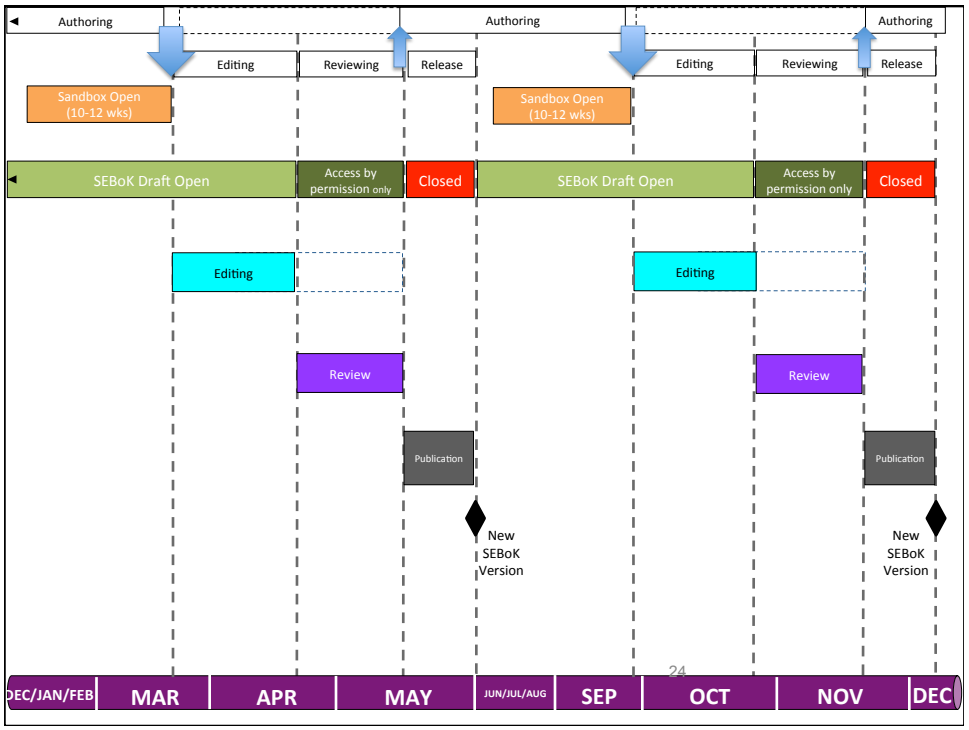
IEEE Advancing Technology for Humanity

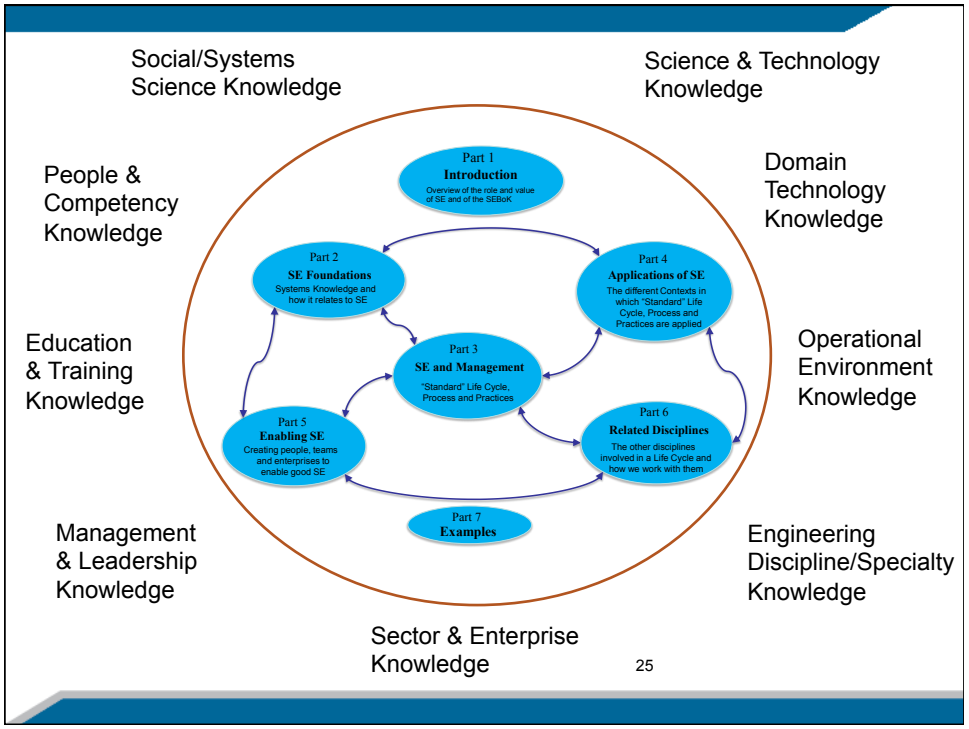
BKCASE Editorial Board






Editor
appoint
Consider Reviews
Select updates
invited
Reviewer
Review proposals
Contributors
Propose content
Author
volunteer
SEBoK Sandbox
• Open to all
• Comment, suggest content, collaborate
• Must register to contribute
• Used by Editor as source of content
SEBoK Draft Wiki
• Editors only
• Used for compilation and review
• Related to an update
Review Whole
EIC
Senior Editors
Staff
Publish
SEBoK Wiki
• Open to all
• Read only
• Comment section
• Updated twice a year
Use
Comment
General Public

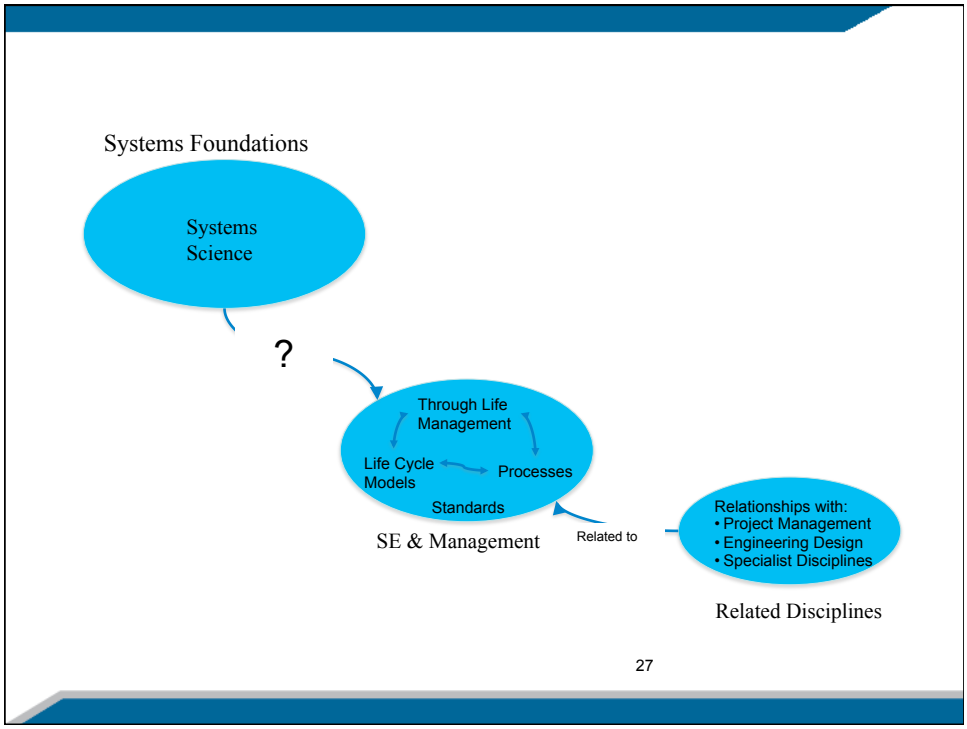

Authoring
Editing
Reviewing
Release
Sandbox Open (10-12 wks)
SEBoK Draft Open
Access by permission only
Closed
Review
Publication
New SEBoK Version
DEC/JAN/FEB
MAR
APR
MAY
JUN/JUL/AUG
SEP
OCT
NOV
DEC



SEBoK Content

- SEBoK cover knowledge created by or directly relevant to SE education and practice
- This includes:
  - Key SE Standards on Life Cycle and Process
  - Application of Life Cycle and Process in different contexts
  - Related Systems Foundations
  - Knowledge on how to enable SE in organisations
  - Relationships with related disciplines
- This SE knowledge sits within a context of related Systems, Management and Engineering Bodies of KNowledge

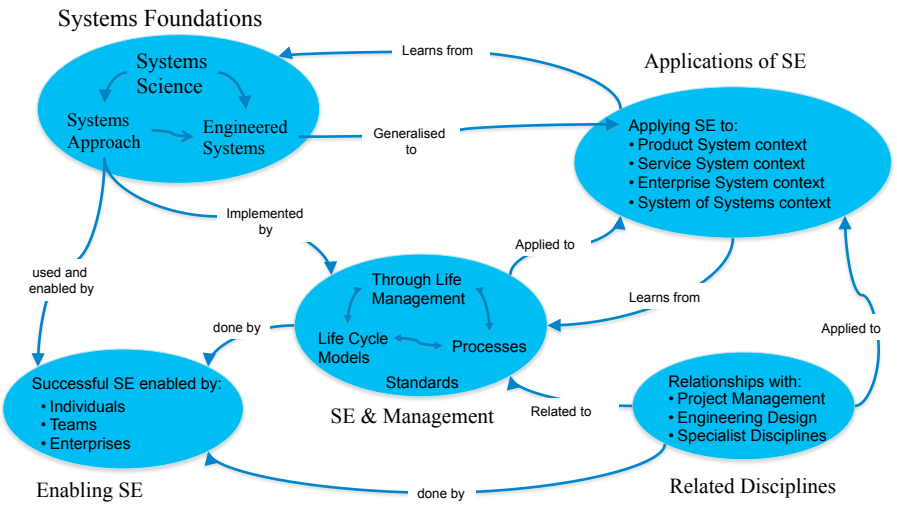
IEEE Advancing Technology for Humanity



SEBoK starting point

- The SEBoK start form previous work, building out from SE standards:
  - ISO/IEC/IEEE 15288 & INCOSE Handbook
- And existing links to other disciplines and BoK
  - Including both PMIBoK and SWEBoK
- Part of the initial aspiration was to include stronger links to foundational systems science knowledge

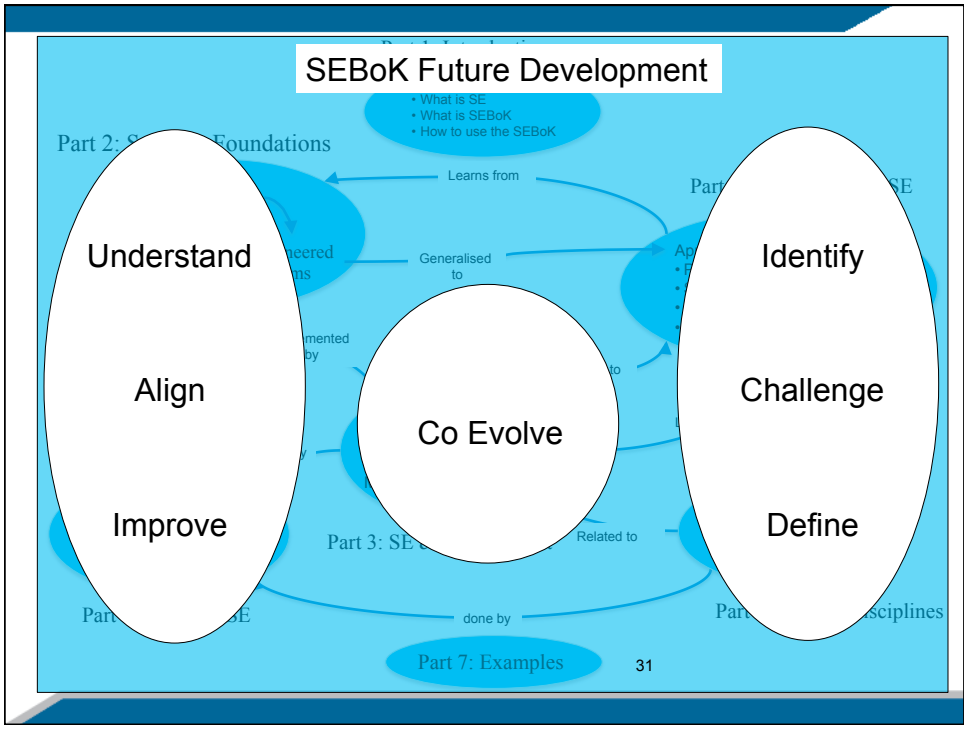
IEEE Advancing Technology for Humanity



29

SEBoK development

- There is a very wide range of systems science knowledge, not all relevant to SE, from this we identified:
- **Systems Approach** to complex problems:
  - Implement within SE standards
  - And applied by people, team and organisations
  - Also gives another link to related disciplines
- **Engineered Systems**:
  - Contain technology (HW, SW and People), often in social, public or business context
  - Generically organised into Product, Service, Enterprise and SOS contexts
  - To which standards SE Life Cycle and Process can be applied
  - Again, this application is shared with related disciplines
- We recognise that much of our new knowledge comes out of these applications



Future Evolution

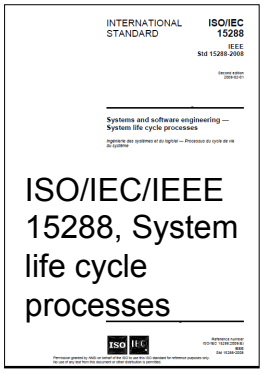
- Understand, Align and Improve:
  - Systems Science foundations
  - Available systems methods, tools, patterns, etc.
  - Competency, roles, people, etc.
- Co Evolve:
  - Life Cycle and Process standards
  - Relationships (in particular SW and HW design)
- Identify, Challenge, Define:
  - Product and Service in different domains
  - Enterprise and Systems of Systems scope
  - Model Based SE transformation
  - Life Cycle scope and tailoring

Presentation topics

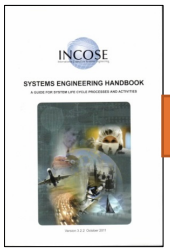
- Dick: brief overview of SEBOK wiki and usage statistics
- Rick: editorial board structure; past & planned evolution of SEBoK
- Garry: SEBoK related standards, systems engineering handbook, and certification
- Dave: SEBoK Parts 6 & 7 plus relationship of GRCSE to SEBoK
- Massood: relationships between systems engineering and software engineering
- Dick: moderate Q&A and panelists' comments

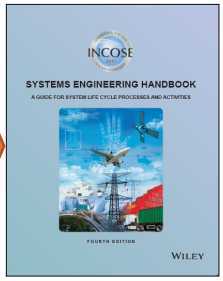
IEEE Advancing Technology for Humanity

Systems Engineering Landscape



ISO/IEC/IEEE 15288, System life cycle processes



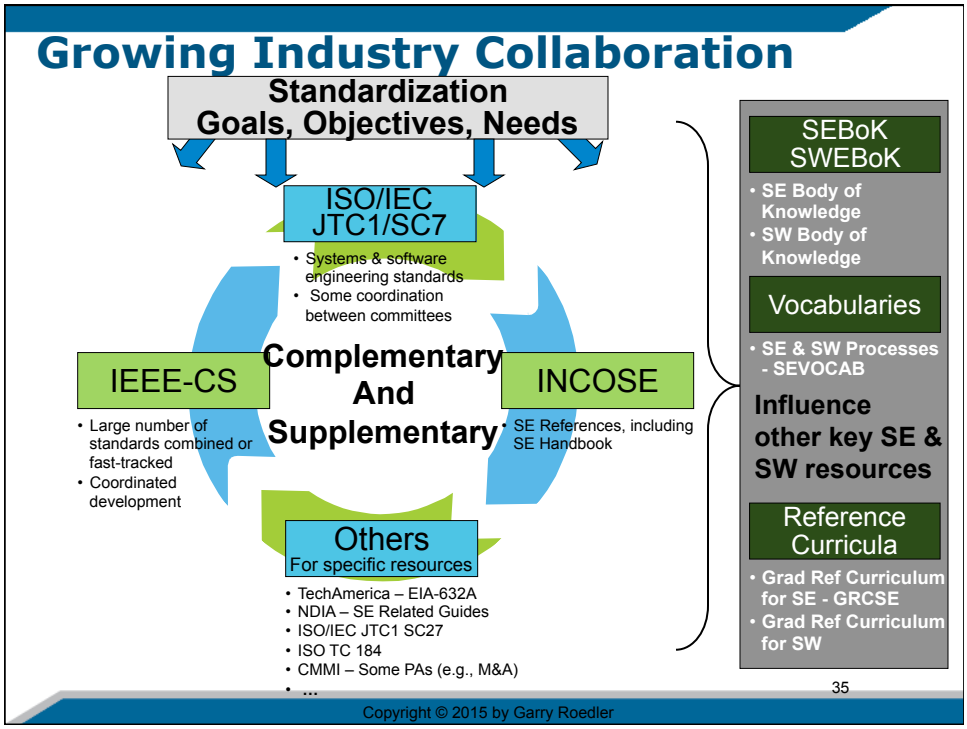


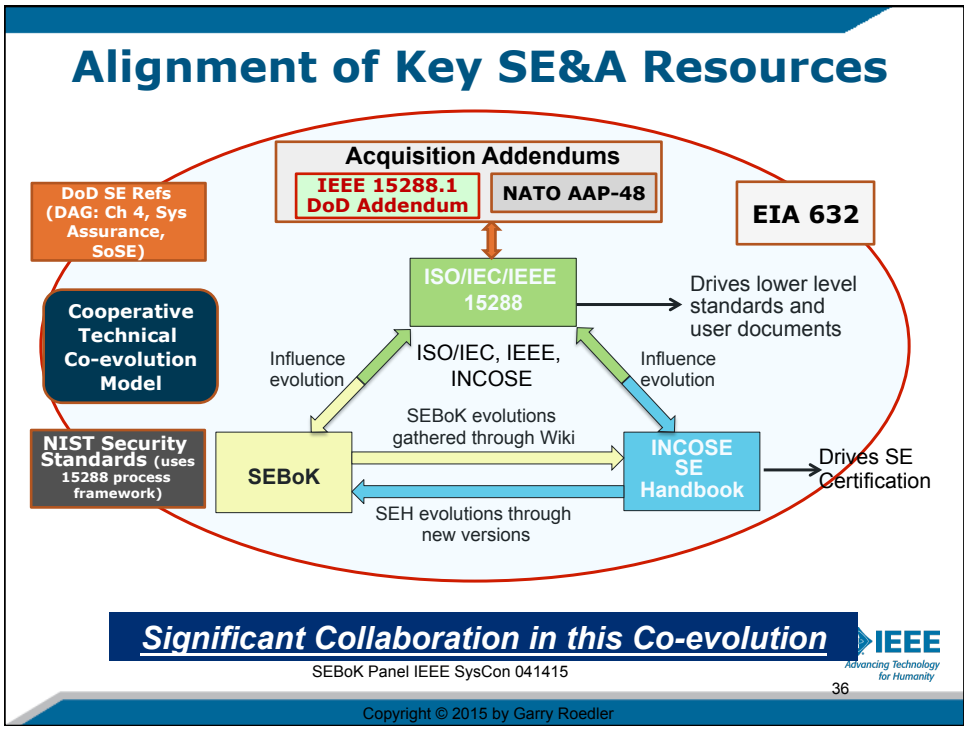
SEBoK
Guide to the Systems Engineering Body of Knowledge

INCOSE SEP
SYSTEMS ENGINEERING PROFESSIONAL

. . . and several others

IEEE Advancing Technology for Humanity


Growing Industry Collaboration
Standardization
Goals, Objectives, Needs
ISO/IEC JTC1/SC7
• Systems & software engineering standards
• Some coordination between committees
IEEE-CS
• Large number of standards combined or fast-tracked
• Coordinated development
Complementary And Supplementary
INCOSE
SE References, including SE Handbook
Others
For specific resources
• TechAmerica – EIA-632A
• NDIA – SE Related Guides
• ISO/IEC JTC1 SC27
• ISO TC 184
• CMMI – Some PAs (e.g., M&A)
• ...
SEBoK
SWEBoK
• SE Body of Knowledge
• SW Body of Knowledge
Vocabularies
• SE & SW Processes - SEVOCAB
Influence other key SE & SW resources
Reference Curricula
• Grad Ref Curriculum for SE - GRCSE
• Grad Ref Curriculum for SW
35
Copyright © 2015 by Garry Roedler


Alignment of Key SE&A Resources
Acquisition Addendums
IEEE 15288.1 DoD Addendum
NATO AAP-48
DoD SE Refs (DAG: Ch 4, Sys Assurance, SoSE)
EIA 632
ISO/IEC/IEEE 15288
Drives lower level standards and user documents
Cooperative Technical Co-evolution Model
Influence evolution
ISO/IEC, IEEE, INCOSE
Influence evolution
SEBoK evolutions gathered through Wiki
NIST Security Standards (uses 15288 process framework)
SEBoK
INCOSE SE Handbook
Drives SE Certification
SEH evolutions through new versions
Significant Collaboration in this Co-evolution
IEEE
Advancing Technology for Humanity
SEBoK Panel IEEE SysCon 041415
36
Copyright © 2015 by Garry Roedler

ISO/IEC/IEEE 15288 scope and focus

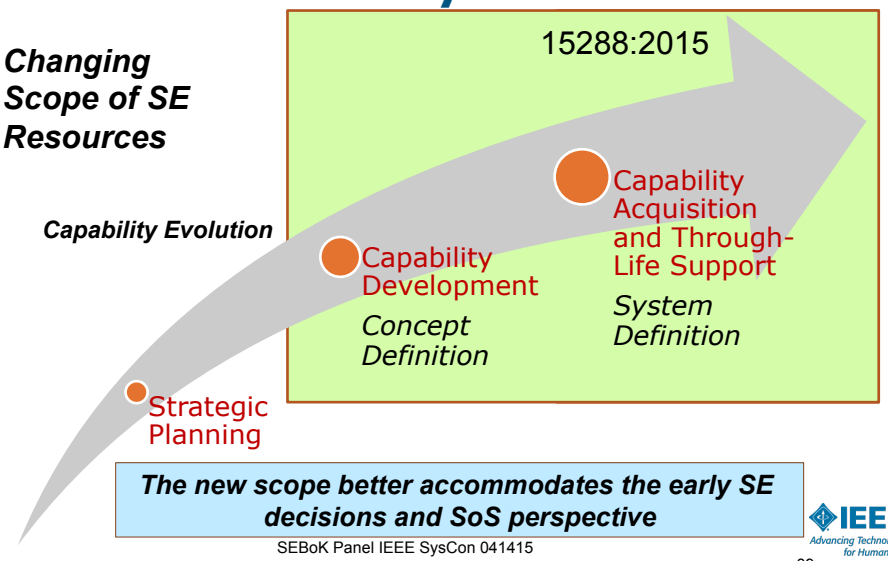
- Provides a common, comprehensive & integrated framework for describing and managing the full life cycle of systems for:
  - Small, medium and large organizations
  - Internal self-imposed use, as well as providing a basis for contractual arrangements (i.e., any agreement)
  - Applicable to most domains
  - Applicable to any life cycle model
- Defines a set of processes, concepts, and associated terminology
  - Can be applied at any level in system structure across its life cycle
  - Not sequential or one-way to apply
  - Allows for concurrent process application and concurrent stages

Source: Adapted from ISO/IEC JTCI/SC7/WG7 presentation on ISO/IEC 15288.

ISO/IEC/IEEE 15288 scope and focus (2)

- Applies to man-made systems configured with one or more of the following:
  - Hardware, software, humans, or processes
- Focuses on "what", not "how"
- Includes tailoring process
- Includes guidance for application to System of Systems (SoS)

Expanded Scope to Better Address Full Life Cycle



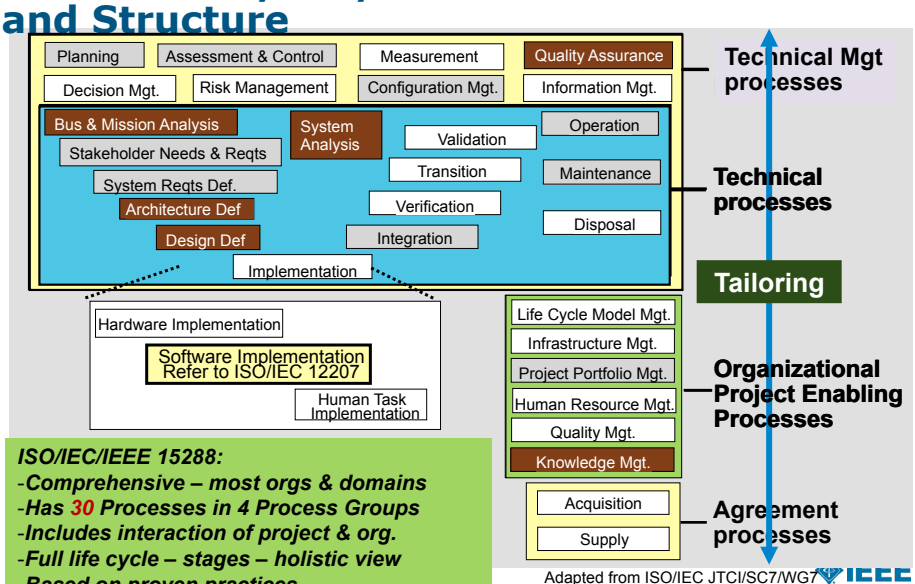
The new scope better accommodates the early SE decisions and SoS perspective

SEBoK Panel IEEE SysCon 041415

39

Copyright © 2015 by Garry Roedler

Revised ISO/IEC/IEEE 15288 Processes and Structure



ISO/IEC/IEEE 15288:
-Comprehensive – most orgs & domains
-Has 30 Processes in 4 Process Groups
-Includes interaction of project & org.
-Full life cycle – stages – holistic view
-Based on proven practices

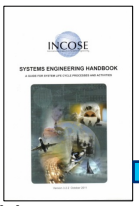
Adapted from ISO/IEC JTCI/SC7/WG7 presentation on ISO/IEC 15288. Author – Roedler.

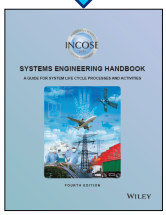
SEBoK Panel IEEE SysCon 041415

40

Copyright © 2015 by Garry Roedler

INCOSE SE Handbook





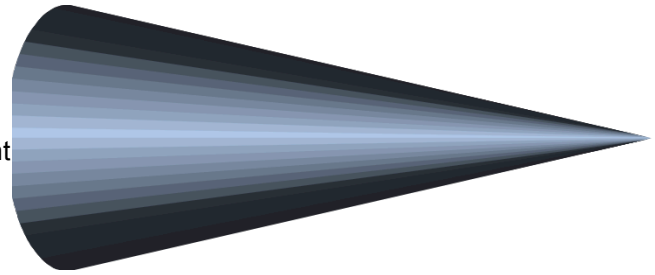
- INCOSE SE Handbook (SEH)
  - Reflects the state-of-the-practice of Systems Engineering (SE)
  - Based on ISO/IEC/IEEE 15288
    - Further elaborates the processes and activities to execute the processes
  - Aligns well with the SEBoK – which reflects state-of-the-art
  - Inputs from the entire INCOSE Technical Community
  - Serves as a reference to practices and methods that have proven beneficial to the SE community at large
- Version 4 planned to be published soon
- Purpose
  - Defines the discipline and practice of SE
  - Provides an authoritative reference

SEH serves as the basis for the CSEP & ASEP exams

SEHv4 Drivers for Change

- Alignment with the **ISO/IEC/IEEE 15288:2015** updates
- Refresh the Technical content based on SE state-of-the-practice with the latest inputs from the **INCOSE technical Working Groups (WGs)**
- Add new content consistent with the **SE state-of-the-practice**
- Be consistent with the **Guide to the Systems Engineering Body of Knowledge (SEBoK) version 1.3** to the maximum extent practicable (www.sebokwiki.org)

Convergence of 15288 and SEH - History



2006 → **2015**

Version 3.0
- Adopted terminology
- General alignment of process structure

Version 3.2
- Adopted processes
- Same purposes and activities

Version 4.0
- Full alignment
- Terms & definitions
- Concepts
- Processes

Multi-Level SE Certification Concept

Senior Level
- *Significant Experience*
- *Demonstrated Accomplishments*
- *References*
- *Education*
- *Panel Interview*
- *INCOSE Member*

20 yrs SE experience
Technical Bachelor's*

INCOSE ESEP
No Exam
Professional Development
Oral Interviews

25 yrs SE experience
Technical Bachelor's*

Foundation Level
- *Experience*
- *References*
- *Education*
- *Knowledge*

INCOSE CSEP
ASEP/CSEP Exam
5 yrs SE experience
Technical Bachelor's*

Entry Level
- *Knowledge*
- *INCOSE Member*

INCOSE ASEP
ASEP/CSEP Exam

** or Non-Tech Bachelor's & additional 5 yrs experience or No Bachelor's & additional 10 yrs experience*

Certification Candidates

ESEP Expert Systems Engineering Professional
CSEP Certified Systems Engineering Professional
ASEP Associate Systems Engineering Professional

Adapted from: INCOSE Certification Overview

14 Functional Areas Recognized for Systems Engineering Experience

- CSEP needs at least 1 year in each of 3 or more areas
- ESEP needs at least 2 years in each of 6 or more areas

- SE Technical Areas
  - Requirements Engineering
  - Design Development
  - System Integration
  - Qualification, Verification, and Validation
- SE Management Areas
  - Technical Planning
  - Technical Effort Assessment
  - Risk and Opportunity Management
  - Baseline Control
- SE Support Areas
  - Specialty Engineering
  - Process Definition
  - Training
  - Tool Support
  - Quality Assurance
- Other SE Areas
  - To allow for the variety of SE across domains

Successful candidates must have balanced experience across multiple areas

IEEE Advancing Technology for Humanity

45

Adapted from: INCOSE Certification Overview

Presentation topics

- Dick: brief overview of SEBOK wiki and usage statistics
- Rick: editorial board structure; past & planned evolution of SEBoK
- Garry: SEBoK related standards, systems engineering handbook, and certification
- Dave: SEBoK Parts 6 & 7 plus relationship of GRCSE to SEBoK
- Massood: relationships between systems engineering and software engineering
- Dick: moderate Q&A and panelists' comments

IEEE Advancing Technology for Humanity

Part 6: Related Disciplines

- Systems Engineering and Software Engineering
- Systems Engineering and Project Management
- Systems Engineering and Industrial Engineering
- Systems Engineering and Procurement/Acquisition
- Systems Engineering and Specialty Engineering

Specialty engineering

- Integration of Specialty Engineering
- Reliability, Availability, and Maintainability
- Human Systems Integration
- Safety Engineering
- Security Engineering
- System Assurance
- Electromagnetic Interference/ Electromagnetic Compatibility
- Resilience Engineering
- Manufacturability and Producibility
- Affordability
- Environmental Engineering

Part 7:Implementation examples

Case Studies	
HST	Hubble Space Telescope
GPS	Global Positioning System
Radiation	Medical Radiation
FBI VCF	FBI Virtual Case File System
MSTI	Miniature Seeker Technology Integration
Infusion Pump	Next Generation Medical Infusion Pump

Vignettes	
Bag Handling	Denver Airport Baggage Handling System
VA Sub	Virginia Class Submarine
Route Mod	UK West Coast Route Modernisation Project
Water Mgmt	Singapore Water Management
FAA AAS	FAA Advanced Automation System
Light Rail	Standard Korean Light Transit System

Graduate Reference Curriculum for Systems Engineering

- GRCSE describes a process for curricular design
- GRCSE suggests content to be included in SE curricula
- GRCSE suggests an architecture
- GRCSE describes how to implement itself
- GRCSE discusses program assessment

GRCSE

- Influencing curricular discussions across the world
- Influential in the design of new curricula in the US and in Italy
- Influencing curricular reviews of existing curricula across US and the world
  - Content checklist and weighting
  - Especially the addition of systems science to SE curricula.
- Informing the discussion of program criteria for graduate systems engineering accreditation
  - Used in the UK for the review of the Cranfield program by the UK Council on Engineering

IEEE Advancing Technology for Humanity

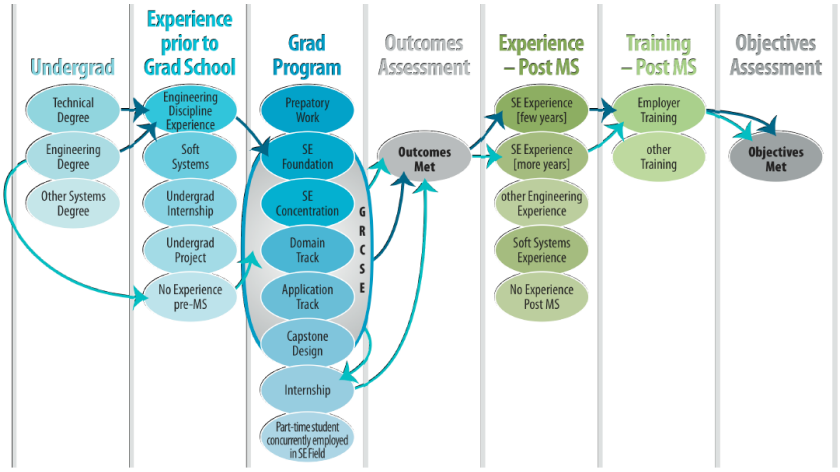


Figure 1. The Diversity of Education Pathways Accommodated in GRCSE. (GRCSE Original)

IEEE Advancing Technology for Humanity

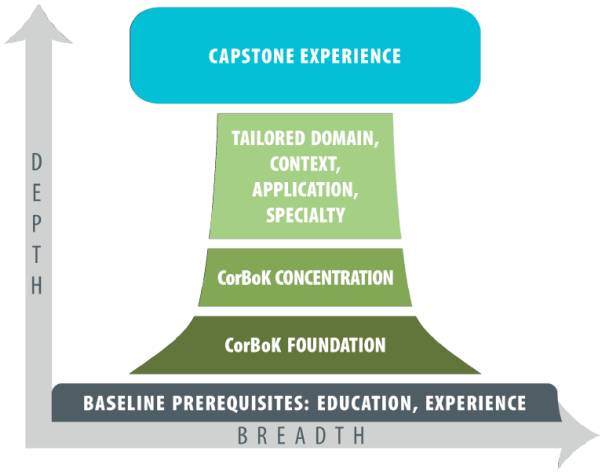


Figure 4. Architectural Structure of Topics in a GRCSE Master's Program. (GRCSE Original)

Presentation topics

- Dick: brief overview of SEBOK wiki and usage statistics
- Rick: editorial board structure; past & planned evolution of SEBoK
- Garry: SEBoK related standards, systems engineering handbook, and certification
- Dave: SEBoK Parts 6 & 7 plus relationship of GRCSE to SEBoK
- Massood: relationships between systems engineering and software engineering
- Dick: moderate Q&A and panelists' comments

Software and System Engineering History

- First System Engineering text book appeared around 1960
- Software Engineering term was first introduced at NATO conference in 1968
- First SE Body of Knowledge 2012
- First SwE Body of Knowledge 2004
- SE graduate curriculum recommendation - GRCSE 2012
- SwE graduate curriculum recommendation – GSwE 2009

IEEE Advancing Technology for Humanity

Why SEs should be interested in Software

- Most systems have some software component
- Software plays a dominant role in operation of some systems (Software Intensive Systems)
  - The software development and maintenance cost almost equals all other costs for development of jet fighter
  - "We no longer build aircraft, we build flying computers" President of Boeing

IEEE Advancing Technology for Humanity

SwE in the SEBoK

- SEBoK Part 6: Related Disciplines, includes a SwE Knowledge Area
- Includes the following Articles
  - The Nature of Software
  - An Overview of the SWEBOK Guide
  - Key Points a Systems Engineer Needs to Know about Software Engineering
  - Key Points a Systems Engineer Needs to Know about Managing a Software Team
- The aim is not to reproduce the SWEBOK, but to give Systems Engineers an insight into Software and Software Engineering

IEEE Advancing Technology for Humanity

Common Myth: SwE is a specialized SE

- Artifacts: SE deals with physical entity BUT SwE deals with invisible entity
- Scope/Domain: SE deals with Broad range of domains BUT SwE mainly deals with software
  - Therefore SE must have breadth of knowledge, and SwE must have depth
- Education: Typical SE has background in EE and ME, BUT typical SwE has CS

IEEE Advancing Technology for Humanity

SE and SwE Commonalities (10,000 feet view)

- Similar Development Phases
  - Acquisition, Requirement, Design, Construction, Testing, Maintenance
- Similar Development Life Cycle
  - Waterfall, V, Iterative, Agile, etc.
- Similar Development Methods/Techniques
  - Component Base, Model Based, Reuse, etc.
- Similar Management Techniques
  - Project, Quality, Configuration, etc.

IEEE Advancing Technology for Humanity

SE and SwE Learning from each other

Systems Engineering Methods Adapted to Software Engineering	Software Engineering Methods Adapted to Systems Engineering
•Stakeholder Analysis •Requirements Engineering •Functional Decomposition •Design Constraints •Architectural Design •Design Criteria •Design Tradeoffs •Interface Specification •Traceability •Configuration Management •Systematic Verification And Validation	•Model-Driven Development •UML-SysML •Use Cases •Object-Oriented Design •Iterative Development •Agile Methods •Continuous Integration •Process Modeling •Process Improvement •Incremental V&V

IEEE Advancing Technology for Humanity

Things that SEs need to know about SW & SwEs (1)

- Project Management
  - Software Estimation is typically inaccurate
  - Increasing # of SwEs may result in project delay
    - Communication plays a major role
    - Cohesive teams are very successful
  - SwEs are not interchangeable
  - Software Metrics include product and process data
    - Both are necessary for SW project management
  - Software Development (trends)
    - More Iterative and More Agile

IEEE Advancing Technology for Humanity

Things that SEs need to know about SW & SwEs (2)

- Seemingly minor change may require major work
- Minor change may introduce major defect/side effect
- Some quality attributes may be evaluated subjectively
- Almost every software product is unique
- Software Testing is at best a sampling process
- Software requirements is more prone to change
  - Be wary of requirement creep
- Software typically serves as a glue between components

IEEE Advancing Technology for Humanity

SE and SWE: present and future challenges

- SE and SWE have long common history and share many things
- Some problems in SE are due to lack of understanding of nature of SW and SWE
- As we move to Cyber Physical systems both SE and SWE will need to change:
  - Become more closely integrated
  - But develop key specialist skills
  - As part of a general move to integrated through life Management & Engineering

IEEE Advancing Technology for Humanity

Presentation topics

- Dick: brief overview of SEBOK wiki and usage statistics
- Rick: editorial board structure; past & planned evolution of SEBoK
- Garry: SEBoK related standards, systems engineering handbook, and certification
- Dave: SEBoK Parts 6 & 7 plus relationship of GRCSE to SEBoK
- Massood: relationships between systems engineering and software engineering
- Q&A and panelists' comments

IEEE Advancing Technology for Humanity