

Guidance for Engineers

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The realization of successful complex systems requires experts from many disciplines to work together. This makes the SEBoK useful to engineers with backgrounds in biomedical, civil, electrical, chemical, civil, materials, mechanical, software, and many other engineering disciplines.

Studying the SEBoK enables engineers from disciplines other than systems engineering (SE) to:

- see why good systems engineering practice must involve multiple disciplines,
- appreciate a broader view of systems beyond their specialties,
- understand how their contributions fit into the larger systems picture, and
- prepare to solve more difficult and encompassing problems.

In many cases, engineers who study systems engineering as a supplement to their area of specialization find their professional value enhanced when they put the new knowledge into practice.

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Use of Topics

For engineers from non-SE backgrounds, each part of the SEBoK contributes something to the experience of learning about systems engineering.

- Part 1: SEBoK Introduction provides an overview both of systems engineering and of the SEBoK itself
- Part 2: Foundations of Systems Engineering highlights the areas of systems knowledge most relevant to systems engineering, providing a foundation for the theory and practice of systems engineering as explained in Parts 3, 4 and 5
- Part 3: Systems Engineering and Management includes the knowledge areas of Life Cycle Models, System Definition, System Realization, and System Deployment and Use, all highly important when approaching the study of SE from another discipline
 - Also in Part 3, Systems Engineering Management includes such relevant topics as risk management, measurement, configuration management, and quality management
- Part 4: Applications of Systems Engineering identifies the SE activities for four kinds of engineered systems, namely products, services, enterprises, and systems of systems (SoS)
 - The primary references and glossary terms — not just the content — for a given type of system are essential reading for an engineer developing or modifying a system of that kind
- Part 5: Enabling Systems Engineering, especially Team Capability, explains how systems engineers and other types of engineers fit into the larger picture of enabling individuals and teams to perform systems engineering activities, and into the larger picture of systems engineering organizational strategies
- Part 6: Systems Engineering and Other Disciplines is key for engineers from non-SE backgrounds
 - Within Part 6, Systems Engineering and Project Management should be of interest to almost all readers, while Systems Engineering and Software Engineering and Systems Engineering and Quality Attributes are naturally most essential for engineers in the respective disciplines
- Part 7: Systems Engineering Implementation

Examples illustrates how systems engineering practices, principles, and concepts are applied in real settings and contain universally useful insights

Engineers may be tempted to skip over knowledge areas or topics that sound more like management than engineering stories, for example Systems Engineering Management in Part 3 or Part 5. This temptation should be resisted, because these topics are actually about how SE orchestrates the efforts of multiple disciplines, not management in the administrative sense.

Finally, the extensive lists of references throughout the SEBoK provide a basis for further readings.

Vignette: Software Engineer

José Wilks is an entrepreneurial software engineer who wants to learn more about systems engineering principles applied to embedded systems for advanced document identification and verification. He wants to implement best practices in developing highly secure systems for real-time image processing and forensic verification of documents. His company provides a rapid, secure and cost-effective solution for verifying the authenticity of identification, travel, and financial documents, with technology that runs on proprietary tablet computers for portable and fixed locations.

José is knowledgeable about computer hardware engineering, low-level interfaces between hardware and software, and the related tradeoffs in embedded devices. His company has developed research prototypes, but without the stringent security requirements for actual field usage linked to government identification databases. The few experimental units which have been sold have fared well in limited testing, but José wants to expand into markets for government agencies, law enforcement departments and the private sector. To make headway into those diverse markets, he will need to confront abundant new constraints and challenges.

José begins his study of SE by skimming the SEBoK Introduction and the Scope and Context of the SEBoK to get an overview of the SEBoK contents. As he reads, he sometimes refers to the *Software Engineering Body of Knowledge (SWEBoK)* (Bourque and Fairley 2014), which José already knows from his many years of experience on software projects. In the SEBoK, José is looking for nuggets of knowledge and pointers that can help his enterprise expand. Here are his notes:

- Part 3: Systems Engineering and Management has concepts that are new to us and that may work. Extra system-level verification and validation (V&V) gates identified in Life Cycle Models can be incorporated in company processes, and the references can help with implementation details. There is also material about system-wide procedures beyond software V&V, and about where to find testing and regulation standards used by various government entities. Together with the traditional software testing already in place, these processes could ensure conformity to the regulations and expedite the product's approval for use.
- Though the system concept is proven, the company must still convince potential buyers of the system's financial benefits while demonstrating that all security criteria are satisfied. To do that, we must better understand the needs of the stakeholders. In expressing system requirements and benefits, we need to start using the terminology of users, corporate/government purchasers, and regulatory agencies. Stakeholder Needs Definition is relevant here. The company needs to quantify expected return on investment (ROI) for its products.
- System Realization addresses our broader V&V concerns. We need to demonstrate the measures we are taking to boost reliability of system performance. The standard models and measures for system reliability described in the SEBoK are new to us — now staff must develop tests to quantify important attributes. We may want to model reliability and system adherence to regulations using a form of model-based systems engineering (MBSE). We can learn more about this from the references.
- Systems Engineering Management makes it clear that new configuration management (CM) and information management (IM) procedures need to be adopted for federal database controls and integrity. We can use the references in Systems Engineering Standards to learn how to define processes and develop test cases.
- Part 5: Enabling Systems Engineering makes a convincing case that having the right people for a new systems engineering culture is critical. We should probably hire a systems engineer or two to augment our engineering department expertise.
- Our application must deal with private data concerns, and Part 7: Systems Engineering Implementation

Examples, particularly the FBI Virtual Case File System Case Study, could help us avoid pitfalls that have hurt others in similar situations. We can put this in context based on Security Engineering in Part 6: Related Disciplines, and then follow up with further study based on the references.

Now José feels that he is better prepared to adapt his processes for new system lifecycles and environments, and that he can see a clear path through the morass of agencies and regulations. His priorities are to quantify the value proposition for his technology innovations, make inroads into new markets, and strengthen his staff for the long-term enterprise.

Vignette: Mechanical Engineer

Cindy Glass is a mechanical engineer whose experience in the petroleum industry has focused on large-scale oil extraction equipment in the field. Now Cindy is tasked with helping to manage the development of new offshore oil platforms featuring robotic technology and computer networks. This calls for incorporating SE principles from day one to cope with the systems considerations, which are broader than anything in Cindy's previous experience.

Some of the drilling is to be done with remote-controlled, unmanned underwater vehicles (UUVs). Along with safety, which was always a major concern, cybersecurity now takes center stage. Hostile state actors, "hacktivists," or others could cause havoc if they succeed in taking control of the remote vehicles or other infrastructure. Unfortunately, software system implementation is completely new to Cindy, who realizes that this entails dealing with many more engineering disciplines and dimensions of system constraints than she previously encountered.

Cindy is accustomed to implementing minor design changes in existing equipment, with automation and safety guidelines already in place. Now she is starting from scratch with the earliest stages of the platform lifecycle. While Cindy understands tradeoffs involving mechanical sub-systems like rigs and drilling materials, she must now broaden her system analysis to include new environmental constraints and system security.

Cindy consults the SEBoK and discovers that for her effort to understand system design with many "-ilities," System Realization is a good starting point and its

references should provide the in-depth information she needs.

The project lifecycle requires pursuing several major activities concurrently:

- engineering platform sub-components
- evaluating technology opportunities
- understanding the needs of all stakeholders inside and outside the company
- progressing through increasingly detailed prototypes, working slices of software, system specifications, designs, plans, business cases, and security and safety analyses of the platform architecture and its operations.

To understand how to manage such a project lifecycle, Cindy turns to Part 3: Systems Engineering and Management. The planning section provides detailed advice for starting out. Cindy expects to conduct her management activities on a rigorous basis, to consider the interfaces between the engineering specialties, and to produce a project plan that calls for a broad set of integrated management and technical plans.

Being new to the software development world, Cindy reads *The Nature of Software and Key Points a Systems Engineer Needs to Know about Software Engineering*, and consults the SWEBoK for references on software engineering.

These readings show Cindy how closely systems engineering and software engineering are intertwined. For example, they remind her to include security specialists at both the software level and the systems level from the beginning.

From her initial plunge into study of the SEBoK, Cindy has gained an appreciation of the wide range of system constraints for which she must account, and the many engineering disciplines she must work with as a result. She plans to consult the references in the SEBoK on each unfamiliar subject that she encounters throughout the architecting, design, development and deployment of the new platforms.

Summary

Engineers from disciplines other than systems engineering benefit from the insights about SE

principles that the SEBoK provides. Studying the knowledge areas highlighted in this use case and the sources to which their references point can help such engineers become more interdisciplinary. Ultimately, they can consider broadening their work responsibilities, rendering them more valuable to their employers and society.

References

Works Cited

Bourque, P. and R.E. Fairley. Eds. 2014. *Guide to the Software Engineering Body of Knowledge (SWEBOK)*. Los Alamitos, CA, USA: IEEE Computer Society. Available at: <http://www.swebok.org>

Primary References

None.

Additional References

None.

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