

Systems Engineering and Management

From SEBoK

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Part 3 of the Guide to the SE Body of Knowledge (SEBoK) focuses on the general knowledge of *how* systems are engineered.

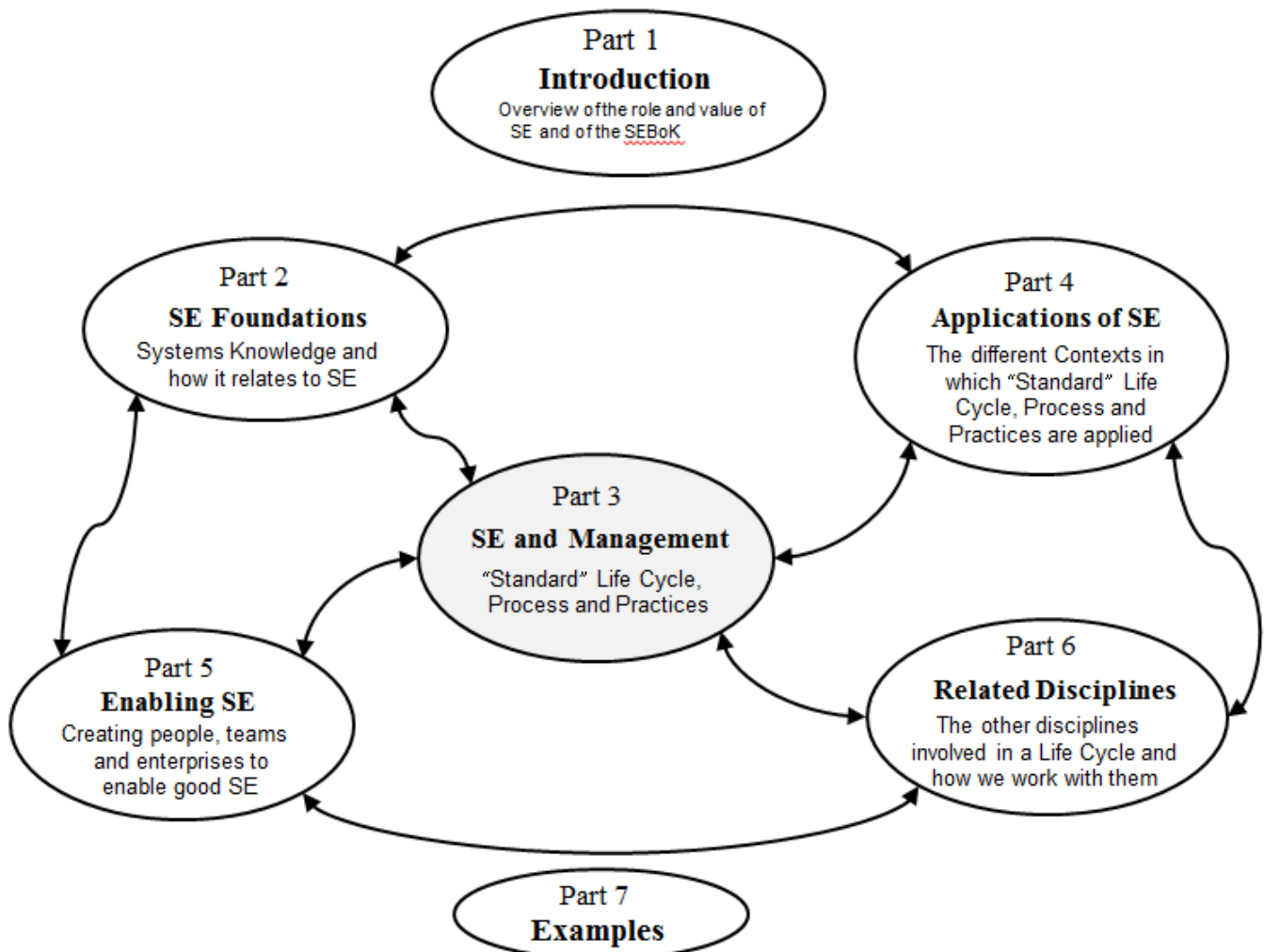


Figure 1 SEBoK Part 3 in context (SEBoK Original). For more detail see Structure of the SEBoK

This part builds upon Part 2: Foundations of Systems Engineering, which discusses the need for a systems approach applied to one or more engineered system contexts as a part of managed interventions into complex real world problems. Part 3 provides an overview of the common uses of life cycle models to organize the technical and none technical aspects of SE and discusses Systems Engineering Management activities. Part 3 also discusses the most commonly-used SE technical processes; provides additional references to the common methods, tools, and techniques used in these processes

The commonly recognized definition of systems engineering (SE) used across the SEBoK (INCOSE 2015) defines SE as an interdisciplinary approach which applies across the complete life cycle of an identified System-of-Interest. The definition states that systems engineering **"integrates all the disciplines and speciality groups into a team effort forming a structured development process that proceeds from concept to production to operation"**. Thus, SE is an engineering

discipline concerned with all aspects of an engineered systems life, including how we organize to do the engineering, what is produced by that engineering and how the resulting systems are used and sustained to meet stakeholder needs.

Part 3 provides only an overview of how systems are engineered in a generic sense. Part 4 provides more specific information as to how the principles discussed in Part 3 are applied differently in consideration of product systems, service systems, enterprise systems, and systems of systems (SoS) contexts. Part 5 explains how people and organizations may approach utilizing these principles as part of a holistic systems approach. Part 6 contains references to other engineering and management disciplines, which work with the SE processes within a systems life cycle, but do not fall under the umbrella of SE.

Systems engineering is transitioning to a model-based approach, model-based systems engineering (MBSE), like many other engineering disciplines. The aim is to enhance productivity and quality, and to cope with the design of increasingly complex systems. Although, models have always been used by systems engineering to create information about engineered systems, that information has been translated and managed through document based artifacts. In a model-based approach, the information about the system is captured in a shared system model, made up of a set of integrated models appropriate to the life cycle stages. This model is managed and controlled throughout the system life cycle as noted in Part 2 under Representing Systems with Models. This provides the ability to maintain more consistent, precise, and traceable information about the system. The system model provides an authoritative source of information that can be communicated across the development team and other stakeholders, can be used to generate views of the system relevant to particular stakeholders, and be used to generate documentation about the system similar to more traditional systems engineering documentation. The model can also be analyzed to assess the integrity of the system specification and design. A model also captures knowledge in a way that can be more readily reused than traditional document based approaches. In a model-based systems engineering approach, the processes referred to in this and other Parts of the SEBoK remain fundamentally the same, but the artifacts produced are model-based. Some examples of MBSE methods are highlighted in A Survey of Model-Based Systems Engineering (MBSE) Methodologies (Estefan 2008). It is anticipated that as the transition to model-based practices occurs, the SEBoK will be updated to reflect the body of current and emerging practice.

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Knowledge Areas in Part 3

Each part of the SEBoK is divided into knowledge areas (KAs), which are groupings of information with a related theme. Part 3 contains the following knowledge areas:

- Introduction to Life Cycle Processes
- Life Cycle Models
- Concept Definition
- System Definition
- System Realization

- System Deployment and Use
- Systems Engineering Management
- Product and Service Life Management
- Systems Engineering Standards

See the article Matrix of Implementation Examples for a mapping of case studies and vignettes included in Part 7 to topics covered in Part 3.

Value of Ontology Concepts for Systems Engineering

Ontology is the set of entities presupposed by a theory (Collins English Dictionary 2011). Systems engineering, and system development in particular, is based on concepts related to mathematics and proven practices. A SE ontology can be defined considering the following path.

SE provides engineers with an approach based on a set of concepts (i.e., stakeholder, requirement, function, scenario, system element, etc.) and generic processes. Each process is composed of a set of activities and tasks gathered logically around a theme or a purpose. A process describes “what to do” using the applied concepts. The implementation of the activities and tasks is supported by methods and modeling techniques, which are composed themselves of elementary tasks; they describe the “how to do” of SE. The activities and tasks of SE are transformations of generic data using predefined concepts. Those generic data are called entities, classes, or types. Each *entity* is characterized by specific *attributes*, and each attribute may have a different value. All along their execution, the activities and tasks of processes, methods, and modeling techniques exchange instances of generic entities according to logical *relationships*. These relationships allow the engineer to link the entities between themselves (traceability) and to follow a logical sequence of the activities and the global progression (engineering management). Cardinality is associated with every relationship, expressing the minimum and maximum number of entities that are required in order to make the relationship valid. Additional information on this subject may be found in *Engineering Complex Systems with Models and Objects* (Oliver, Kelliher, and Keegan 1997).

The set of SE entities and their relationships form an ontology, which is also referred to as an “engineering meta-model”. Such an approach is used and defined in the ISO 10303 standard (ISO 2007). There are many benefits to using an ontology. The ontology allows or forces:

- the use of a standardized vocabulary, with carefully chosen names, which helps to avoid the use of synonyms in the processes, methods, and modeling techniques
- the reconciliation of the vocabulary used in different modeling techniques and methods
- the automatic appearance of the traceability requirements when implemented in databases, SE tools or workbenches, and the quick identification of the impacts of modifications in the engineering data set
- the continual observation of the consistency and completeness of engineering data; etc.

Throughout Part 3, there are discussions of the ontological elements specifically relevant to a given topic.

Mapping of Topics to ISO/IEC 15288, System Life Cycle Processes

Figure 2, below, shows the relative position of the KA's of the SEBoK with respect to the processes outlined in the ISO/IEC/IEEE 15288 (ISO 2015) standard.

As shown, all of the major processes described in ISO/IEC/IEE 15288:2015 are discussed within the SEBoK.

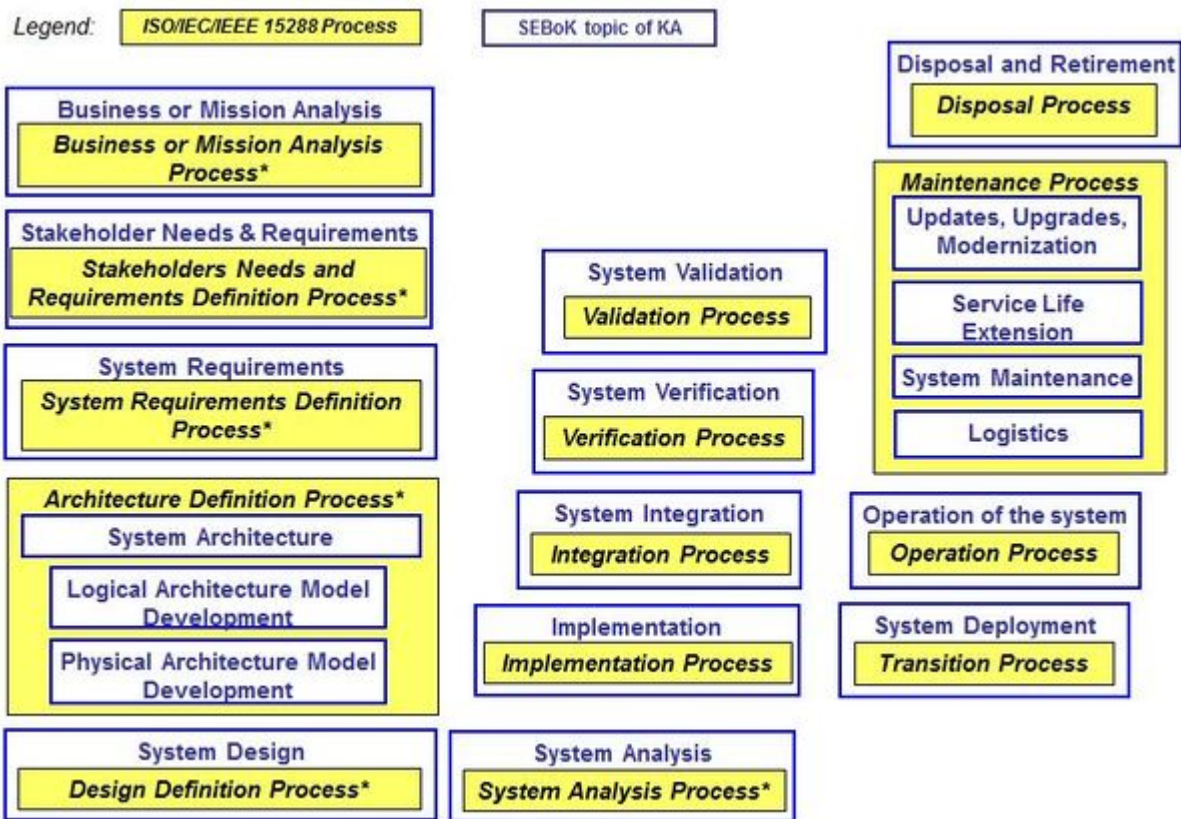


Figure 2. Mapping of Technical Topics of Knowledge Areas of SEBoK with ISO/IEC/IEEE 15288 Technical Processes. (SEBoK Original)

The ISO/IEC/IEEE 15288:2015 marked with an * are new or have been renamed and modified in scope for this revision of the standard.

These changes and associated changes to the SEBoK now mean that the two are significantly more closely aligned than before. It should also be noted that the latest update of the INCOSE SE Handbook (INCOSE 2015) is now fully aligned with the 2015 revision of the standard.

Any future evolution of Life Cycle Process knowledge in the SEBoK will be complementary to these standard descriptions of the generic SE process set.

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